Introductory physics students connecting their physics experiences and personal perspectives

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Physics students often experience a disconnect between their social identities and their learning of physics. To explore this, we analyzed 669 written survey responses from students in calculus-based introductory physics courses, where they were asked how their personal experiences and perspectives shaped their understanding of physics. Using the Critical Physics Identity framework, we categorized the types of experiences students identified as influential. While most students acknowledged that their perspectives affected their learning, they primarily referenced aspects related to Personal Characteristics within the Ideational Resource construct. Only a small portion mentioned perspectives linked to their social identities as in the Positioning in Physics and Perception of Physicists codes, despite having previously provided demographic information. We argue that this pattern reflects a dominant physics learning culture that presents the discipline as neutral and objective, often ignoring the role of broader social structures—particularly in the experiences of marginalized students.

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I. INTRODUCTION

In recent decades, physics education has broadened its focus beyond conceptual understanding and mathematic and laboratory skills to include the development of students' physics identity. This shift is grounded in a growing body of research showing that students' physics identity plays a crucial role in their persistence and pursuit of physics-related academic and career pathways [1]. Hazari et al. [2] identified three primary components of physics identity: Recognition (how students see themselves and are seen by others as physics people), Competence/Performance (students' perceived ability to perform physics tasks), and Interest. Physics identity is influenced by multiple factors—including curriculum design, classroom environment, teacher and student characteristics, relationships and interactions with peers and significant adults, and informal learning experiences [2]—and can be strengthened further through participation in Learning Assistant programs [3], authentic research [4,5], real-world curricular connections [2], and discussions about underrepresentation [6].

Physics identity is not merely an individual attribute but a dynamic, socially constructed process in which students come to understand and navigate their own positioning and sense of belonging within the discipline [5]. This process is both personal and institutional as it entails marginalized students reconciling conflicting identities, especially in a field that remains the least diverse across STEM fields [7]. Diverging from the dominant norms, these "markers of differences" shape both how they see themselves and how others perceive and interact with them, which consequently impacts their engagement and association to physics [8].

For many marginalized students—especially Women of Color—success in physics can require a suppression or *fragmentation* of their racialized and gendered identities. Ong [9] highlights how Women of Color who persist in physics often do so by making significant personal compromises to be recognized as competent within predominantly white, male-dominated spaces. This negotiation is emotionally taxing and contradicts what research shows to be most supportive of STEM persistence: affirmation of the whole self.

The dominant framing of physics as objective, apolitical, meritocratic, and individualistic falsely reinforces a narrative that underrepresented groups are less involved by choice or lack of interest or ability, rather than as a result of systemic exclusion [10]. This cultural narrative can lead students to disconnect their social experiences and identities from their academic experiences. However, Nasir [10] asserts that learning is inherently cultural, shaped by social norms, values, and power dynamics embedded in educational institutions. Classrooms, therefore, are not neutral spaces; they are governed by cultural stereotypes about who belongs and who succeeds. In this study, we investigate how introductory physics students conceptualize the factors that shape their experiences in physics. We analyze survey data to answer the research question: *What aspects of personal identity and perspective are relevant to introductory physics students' learning experiences?* By centering student perspectives, we aim to better understand how physics culture is perceived and navigated by learners, particularly in relation to physics learning.

II. THEORETICAL FRAMEWORK

We adapted the Critical Physics Identity (CPI) framework to analyze the dimensions of identity and experience that students identified as relevant to their experiences in physics classrooms. We define relevance as what students deem as salient to their physics experience, marked by what emerges in their written responses. Originally developed by Hyater-Adams et al. [11] the CPI framework builds on the foundational Physics Identity model by Hazari et al. [2], expanding it to better capture the racialized experiences of Black physicists. Hyater-Adams and colleagues introduced three additional constructs that influence an individual's association with physics: Ideational Resources (ideas and beliefs shaping one's engagement with physics), Material Resources (tangible supports such as access to tools or spaces), and Relational Resources (social connections and support networks).

Within the Ideational Resources construct, the framework is further divided into four subcategories: Positioning in Physics (ideas about one's place in physics and how one navigates their position), What is Valued in Physics (ideas about what the physics community cares about and values), Perceptions of Physicists (perceptions about who/what physicist are from those within and outside the field), and Personal Characteristics (ideas about who one is as a person). These categories and subcategories provide a more comprehensive understanding of how identity develops in relation to physics, particularly for those whose experiences may not align with dominant cultural narratives.

The CPI framework was previously used to examine the experiences of Physicists of Color across various stages of their academic and professional careers [11-13]. While our research applies the framework to an introductory context and is not limited to students' racialized experiences—as was the focus of Hyater-Adams' original work [11]—we recognize that all students enter physics classrooms with complex, intersecting identities shaped by privilege and marginalization. The CPI framework offers an effective lens through which we can capture the ways students' identities inform their engagement, understanding, and experiences in physics.

III. METHOD

A. Context

This study draws on responses from end-of-course surveys administered in two calculus-based introductory physics courses at a four-year undergraduate-serving university: a classical mechanics course (Physics 1) and a light and waves course (Physics 3). The survey, distributed online and required as part of the courses, received a total of 669 student responses in the 2023 academic year. It included several items addressing students' overall experiences in the course—such as their reflections on the lab component—as well as questions about their demographics and general attitude toward physics. For this analysis, we focused on responses to the open-ended question: "How has your perspective influenced your understanding of physics?" (hereinafter referred to as the Perspective question). This question was selected to explore how students perceive and articulate the relevance of their personal perspectives to their physics learning.

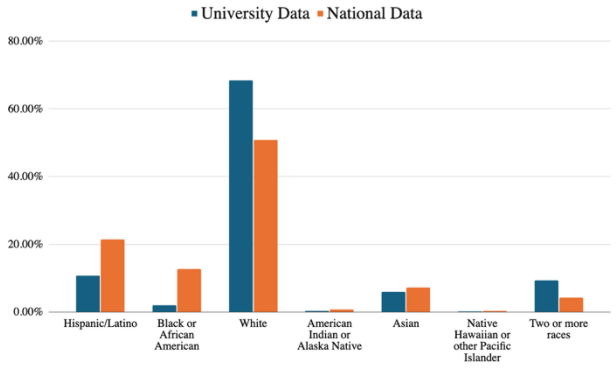

FIG. 1. Undergraduate racial and/or ethnic demographics of the university in our data (dark blue) versus the national undergraduate race and/or ethnicity demographics (orange), constructed using data published by the university and data from the National Center for Education Statistics [14], repectively. As shown, the university enrolls a disproportionately higher percentage of white and multiracial students, while students from other racial and ethnic backgrounds are underrepresented compared to national averages. This limits the generalizability of our findings.

Both courses included lecture and lab components. While lecture styles varied by instructor, labs were structured around group work and led by undergraduate teaching assistants. These courses serve a broad mix of students—some fulfilling general education requirements, others pursuing STEM majors—resulting in diverse academic backgrounds and levels of physics experience. Physics 1 often includes first-time physics learners, while Physics 3 students typically have taken prior courses and are more likely to be STEM majors. As part of our analysis, we examine how students' responses differ between these two courses, particularly in relation to their exposure to physics coursework and culture.

B. Data analysis

We began our analysis by adopting the original codebook developed by Hyater-Adams et al. [11], which encompasses the main constructs of the CPI framework and includes several subcategories within each construct. The first author (CB) initially applied this codebook to a subset of 40 student responses. Both authors then collaboratively reviewed and discussed the coding of each response, which led to several modifications to better suit our dataset.

Specifically, we chose to remove the Internal/External sub-coding used in the original study [11], as the open-ended survey responses in our data often limits the depth and nuance—compared to interview data—that is necessary to make such distinctions and to apply reliably. We also excluded a sub-code for Interest—Teaching and Outreach—as this category was less relevant to introductory-level physics students. The final version of our codebook includes 18 codes in total, which are summarized in Table I.

TABLE I. The finalized codebook with main categories and subcodes.

Main categories	Subcodes
Ideational Resources	Positioning in Physics, What's Valued in Physics, Perception of Physicists, Personal Characteristics
Material Resources	Positive, Negative, Neutral
Relational Resources	Positive, Negative, Neutral
Interest	Content, Non-Content
Recognition	Positive, Negative, Neutral
Competence/Performance	Positive, Negative, Neutral

Next, authors CB and TH independently coded 20% of the dataset to assess consistency in code application. The inter-rater reliability was calculated at 96%, indicating a high level of agreement. During discussions of the few disagreements that emerged, we refined our shared understanding of how the codes applied to our dataset.

For instance, we interpreted Positioning in Physics to include responses that referenced social or demographic aspects of identity as they related to learning physics. What is Valued in Physics encompassed ideas students associated with success or failure in the discipline—such as grit, determination, or mathematical ability. Perceptions of Physicists reflected students' views of who physicists are and the broader culture of physics, such as recognizing physicists are commonly white men. We interpreted Material Resources as encompassing prior coursework, tutoring, and affiliation with specific majors or programs since students frequently mentioned these as key resources that shaped their physics learning.

After establishing consistency in code application, CB coded the remaining responses. Any complex or ambiguous responses were flagged for collaborative review. These responses were re-coded through discussion to ensure fidelity, and the codebook was revised as needed to reflect evolving interpretations. Finally, CB reviewed the full

dataset to ensure that all codes were consistently applied according to the finalized version of the codebook.

Our analysis is also informed by our positionalities. CB is a white, middle-class, queer, neurodivergent, fat, able-bodied undergraduate physics student. TH is an Asian im/migrant, Ph.D-holding, able-bodied, cisgender women. Both coders have experienced physics spaces that were inaccessible or conflictive to certain aspects of our identity, which informs our attentiveness to how students frame their relationships to physics spaces and how systemic advantages or barriers shape their navigation within physics.

III. FINDINGS

In this section, we present the types of personal experiences and perspectives students described, focusing on three categories: Ideational Resources, Material Resources, and Relational Resources. We also focus on the frequencies of Ideational Resources subcodes, especially as Positioning in Physics and Perception of Physicists were often associated with students' social identities and experiences.

A. Ideational Resources are more common than Material Resources and Relational Resources

In both Physics 1 and Physics 3, the distribution of the three resource categories followed the same trend: Ideational Resources were mentioned most frequently, followed by Material Resources, and then Relational Resources, although the exact percentages varied slightly between the two courses (TABLE II). Relational Resources appeared at about half the rate of Material Resources, and both were mentioned far less than Ideational Resources. This suggests that students tend to view ideas about themselves and physics and material access as more relevant to their physics learning than relationships and social connections.

When students referred to Relational Resources, they often spoke about connections to their family members, professors, or teaching assistants. Some also described a broader sense of community or social experiences within physics. For example, one Physics 3 student shared:

"I've felt a bit alienated as a queer woman taking physics courses at first, but by this course I know multiple fellow Queers who are physics majors and myself have developed a deeper love and understanding of physics concepts."

This response was coded with multiple codes and subcodes, including Positioning in Physics, Positive Relational Resources, and Content Interest. For this student, relationships and community played a significant role in shaping her physics experience. Initially isolated, she found a sense of belonging that deepened both her understanding and enjoyment of physics. While most students did not explicitly mention relationships in their responses, those who identified with marginalized groups—often brought up in subcodes Positioning in Physics and Perception of Physicists—were more likely to highlight the importance of Relational Resources.

A clear example of a Material Resource came from a Physics 1 student who wrote:

"I was able to take AP Physics in high school, which made this class easier than it would have been otherwise."

This response was coded as Positive Material Resources. In this case, access to a prior physics course—specifically AP Physics—helped the student feel more prepared for college-level physics. In contrast, a negative Material Resource might involve having no prior exposure to physics or having had a discouraging experience in a past class.

TABLE II. Frequencies of each code and subcode.

Code Categories	Physics 1	Physics 3
Ideational Resources	46.55%	39.24%
Positioning in Physics	12.83%	8.86%
What is Valued in Physics?	14.49%	9.49%
Perception of Physicists	5.70%	3.80%
Personal Characteristics	30.17%	31.01%
Material Resources	18.28%	24.05%
Relational Resources	9.26%	10.12%

B. Positioning in Physics and Perception of Physicist are the least prevalent

We focused on the Ideational Resources subcodes in part because this category was the most frequently referenced in our dataset, and because it directly addressed our research question. We found that Positioning in Physics and Perception of Physicists were the subcode that best captured social identities and experiences brought up by students.

Within Ideational Resources, Personal Characteristics emerged as the most common subcode, appearing in over 30% of responses in each course. Students frequently mentioned innate personal traits such as "my brain doesn't work that way," "I have a genuine desire to learn," or "I have a predisposition to science," suggesting that these are some common personal characteristics that make one (un)fit to learn physics.

Although What's Valued in Physics was coded less frequently than Personal Characteristics, the two often appeared together in student responses. Examples of What's Valued in Physics include statements such as "physics requires hard work," "physics requires a math/logical brain," or "physics is a series of rules that objects obey." Together, these subcodes reflect a commonly held view of physics as objective and driven by individual effort and aptitude. For instance, one Physics 1 student rejected the idea that social identity plays a role in physics learning, stating:

"I keep academics and identity separate, so very little to no influence. Physics is an explanation of the working of the world, and should not be a political stage, in my opinion."

This response was given a subcode of What's Valued in Physics (physics *is* a study of the natural world, and thus must be objective), Personal Characteristics (a person who

keeps things neutral), and as a result, they perceived no influence of social identities and personal perspectives on their physics learning.

The subcodes Positioning in Physics and Perception of Physicists appeared the least but were highly associated with students' ideas about their social identities. This suggests that many students do not view their social identity, including their privilege and/or marginalization as central to their physics experience. However, when Positioning in Physics and Perception of Physicists were mentioned, students often reflected on marginalized aspects of their identity and how these shaped their experiences in physics courses. For example, a student in Physics 1 shared:

"As a woman, I often was exposed to the stereotype of girls not being good at math throughout my pre-college education. I internalized this to a certain degree for most of my life and have been working hard to unlearn that. I find that it can hinder my ability to apply myself and can give myself excuses to not put my all into a math-based subject."

This response was coded as Positioning in Physics, Perception of Physicists, Negative Relational Resource, and Negative Recognition. Here, internalized stereotypes around gender and math created significant barriers to the student's confidence and engagement—an impact felt far beyond just one class.

A smaller fraction of students referenced their privilege. One Physics 1 student wrote:

"I recognize I am in a very privileged category when it comes to STEM fields and in many places in the world in general. I think my perspective has probably made it much easier to understand physics, as it is easy to compare myself to the other humans in the past who have made advancements and see that I am not all that different than them. This is easier to do when all of the major physicists in history are white males similar to me."

This response was coded as Positioning in Physics and Positive Recognition. This student acknowledged that his identity as a white male aligns with the historical image of physicists, making it easier for him to feel a sense of belonging in physics—a privilege not shared by all. While identity and social positioning may not be top-of-mind for most students, for those who do reflect on these aspects, they appear to be deeply impactful.

IV. CONCLUSIONS

Using the CPI framework to analyze students' connection between personal perspectives and learning physics, we noticed some notable trends. Material Resources were more frequently referenced in Physics 3 than in Physics 1, possibly because more advanced students have greater awareness of and experience with available supports, such as university tutoring or study groups. There is also a possibility of survivorship bias, where students who had easier access to material resources proceeded to Physics 3 while those who did not have the same access did not proceed. Conversely, Ideational Resources appeared less often in Physics 3, suggesting that as students have more experience with physics, reflections on self and the physics field become less central to their learning experience. These patterns indicate that students may not view physics classrooms as spaces where social identity is relevant, which likely reflects the predominantly white population at the institution. Finally, the frequency of the Relational Resources was consistently low across both courses. This is especially notable given that part of the survey explicitly asked about students' interactions with their TAs and peers in labs where collaboration was a central element. The scarcity of this code may reflect the individualistic culture of physics, where emphasis is placed on personal progress rather than collaboration or community.

Physics culture places a strong emphasis on objectivity and neutrality, often minimizing the role of personal bias and lived experiences. This cultural norm may lead students to believe that individual identity should not or does not affect their physics learning. Our findings reflect this: many introductory physics students perceived social identity and relationships as unrelated to their learning. However, students frequently identified personal traits—such as a love for math and science, intrinsic motivation, persistence, and curiosity—as essential to success in physics. We argue that these narratives of meritocracy and individualism are deeply embedded in physics culture, reinforcing dominant norms of expectations and behavior in the classroom and community. As a result, other ways of engaging with science and relating to each other are excluded, shaping how individuals see themselves within the physics community [10,15]. These issues impact every student, but especially those that are marginalized. At the institutional level, we must acknowledge current social issues and how they affect students' daily lives and learning experiences. At the classroom level, we can implement structures and activities that foster meaningful connection, collaboration, and encourages students to be their authentic selves. Changes such as these will support students' sense of belonging and development of critical lenses to examine physics culture.

While we were able to analyze a large number of student responses, this also limited the complexity of our analysis. This study used secondary data, which prevented us from asking more specific questions relating to physics identity or asking for elaboration. The data was collected in the same academic year and anonymized, so it is possible that some students completed the survey multiple times as they progressed through the physics courses. A study expanding on this work is underway where we are conducting interviews with physics students to gain deeper insight into the connection between their physics and social identities.

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