Physics identity: examining the role of recognition for undergraduate women in physics

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Physics identity is developed over time as a result of students' experiences in and beyond physics. Prior studies demonstrate that physics identity predicts choice of major, success, persistence, and sense of belonging in physics. In this study, we highlight the cases of two undergraduate women in physics from a larger project focused on the formation of physics identity. We examine the role external STEM and physics recognition plays from early experiences through their current undergraduate studies. This study calls attention to the importance of context, and the gendered role that family, community, and society play in accumulation of STEM capital, and physics identity formation.

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I. INTRODUCTION

Women comprise nearly half of students taking physics in high school [1], albeit less represented in advanced levels. Yet, despite a multitude of studies and programs (e.g. [2–5]), the percentage of women earning physics bachelor's degrees has remained stagnant at 25%, one of the lowest in the STEM fields.

Students with a strong physics identity are more likely to choose and persist in physics majors, graduate programs, and careers [6, 7]. They are more likely to have greater positive beliefs about their competence, and view the costs (such as hours studying) as worthwhile [8]. These findings support the use of identity as a powerful tool in understanding women's underrepresentation in physics. Many studies have revealed gender differences in physics identity, with women reporting lower scores in interest, perceptions of performance and competence, and recognition by others than men in physics [9–11], even in the same environment. Although recent studies have highlighted the importance of context (e.g., [12]), questions remain about how the environment and/or students' reaction to the environment, may contribute to these differences.

Recognition itself is multidimensional, including both internal (recognition of self) and external (recognition by others) aspects [13]. These may exist independently of each other, yet are highly complementary. Furthermore, there is substantial interrelatedness between recognition, interest, and performance/competence; each has been shown to influence the others [12]. This case study of two undergraduate women in physics, part of a larger project, focuses on experiences of external recognition from many sources: including society, family, friends, peers, teachers, and mentors.

Perceptions of recognition as a STEM person (in general) or as a physics person (specifically) may be positive, negative, or absent [13]. They begin in early childhood, set by familial habitus [14], and include societal messaging in the media and entertainment, peer interactions, and experiences in learning (in and out of the classroom and lab). We hope to illuminate the role that external recognition plays in the formation of women's physics identity.

II. ANALYTICAL FRAMEWORK

A. Recognition in physics identity

Recognition is one of three dimensions of science identity proposed by Carlone and Johnson [13]. They drew on Gee's [15] definition as recognizing oneself and being recognized by others as a certain kind of person. In addition to recognition, the two other highly interrelated dimensions are performance and competence. Work by Hazari et al. applied these dimensions to physics, adding interest [16] and sense of belonging [12] to the intersecting dimensions. In Hazari's physics identity model, recognition focuses on that received from others, placing it in a more contextual and social realm. A student's perception that they are recognized by others as a physics person increases their sense of belonging.

B. Recognition is context-dependent

Recognition from others depends on context. Early in life, the community and family in which one is raised establish a STEM habitus, which recognizes science in general as present, valuable, and a possible topic of study. This recognition is one of many experiential factors that contribute to science capital, defined by Archer [17] as "science-related forms of cultural and social capital, ... embodied, institutionalized, or objectified resources." Early recognition from teachers and peers also significantly contributes to science capital [18]. Cohen ties capital to identity, by defining STEM identity capital as "early experiences that can be formative for STEM identity years later," and integrating it completely within STEM identity [19]. Although related, STEM identity and STEM capital are different. STEM identity is a perceived and affective construct, where STEM capital refers to the real "wealth" and resources that you accrue from environmental conditions. External recognition is a form of STEM capital, but its contribution to STEM identity depends on how it is internalized. STEM capital has been theorized to provide inoculation, a protective factor, and a resistance to challenges to one's STEM identity [20]. As students progress into high school and into the undergraduate level, perceived external recognition become discipline-specific. Recognition is possible when STEM-based competencies are shown in STEM-established performances that are in line with discipline norms [13]. Past studies have characterized physics as different from the other STEM fields in terms of its culture: more masculine-dominated in percentage, representative historical figures, pedagogy, and stereotypical male traits. This creates a more challenging environment for women regarding external recognition by meaningful others [21, 22], and subsequent development of physics identity.

C. Research questions

Early experiences that provide recognition are typically related more to general science or STEM than physics, specifically. As students matriculate through their schooling and undergraduate years, they begin to specialize in one content area. Much of the current research on women in physics has focused on quantitative methods (e.g., [16]), or looked more broadly at undergraduate experiences and physics identity [23]. In this study we focus on experiences that provide recognition to women in physics and how these shaped their identity development. With this in mind, we aim to address the following research questions:

1. How does recognition from others contribute to undergraduate women's physics identity?

2. How do beliefs about women in STEM held by women's families and communities impact their identity development?

III. METHODS

We employed a multiple case study approach [24] to examine the experiences of the participants in this study. Case study methods provide an in-depth and contextualized understanding of experiences of the participants highlighted in this study.

A. Participants and data collection

The participants in this study include two women who were part of a larger funded project examining the experiences of undergraduate women in physics. The larger study recruited participants (n=122) from the 2023 Conferences for Undergraduate Women in Physics (CUWIP) to complete an open-ended survey, followed by interviews with 31 of the survey participants. To date, we have analyzed 20 interviews representing 19 unique colleges and universities spread across the United States, including HBCUs, community colleges, and 4-year institutions. Our interviews include students from all years, mostly juniors (n=10). Previous studies on recognition and physics identity have focused on single institutions or physics courses and cited the need for greater qualitative understanding. Our interviews include details of experiences over time from pre-K through their current undergraduate level. The two women were selected because their interviews offered rich evidence of the role of recognition in identity development. Mary (pseudonym) is a first-generation college student of mixed race, and attended a large public university. Ava (pseudonym) is a Hispanic/Latina immigrant, and was enrolled in a small private university.

The semi-structured interviews included questions about their experiences during K-12 schooling and during their undergraduate physics coursework. Sample questions include "Tell me a little about your background. How did you first get interested in physics?," "In what ways have family, gender, language, and culture played a role in your academic journey to getting your degree?," "What exactly has made you feel welcomed/valued in physics? Has there been a time when you felt the opposite (unwelcomed and unvalued)?," and "How confident do you feel that you'll be successful in physics?" The interviews were held online using a video-conferencing platform and lasted around 60 minutes.

B. Data analysis

Interviews were recorded using the video-conference software and transcripts were created using the Descript AI transcription tool. All transcripts were checked carefully by a member of the research team to ensure accuracy.

We engaged in multiple rounds of coding of the interviews, utilizing a priori coding based on our models and in vivo coding [25]. Initially coding collaboratively, with dialogic engagement, we developed our initial codebook. Our team then individually coded one interview, then met to discuss additional findings and the alignment of our initial code set to our model. An additional individually coded interview and discussion led to thematic clustering around emerging patterns and relationships. We engaged in consensus coding and employed a peer debriefing process. The remaining interviews were coded by at least two coders, each followed up by a discussion with additional team members addressing any discrepancies. Dedoose was used to organize the data and share the codes. In this paper we present the experiences of two representative undergraduate women in physics who serve to illustrate the role that external recognition plays in the formation of physics identity.

IV. FINDINGS

Although Mary and Ava have unique backgrounds and circumstances, perceived external recognition affected their physics identity, both negatively and positively. STEM/physics capital acquired through experiences and interactions with family, peers, teachers, and mentors served as a protective factor when challenges to their physics identity arose.

A. Early experiences

Mary and Ava's early experiences with family and community had a large influence on their identity as a whole, and laid the groundwork for establishing science/physics identity. Exposure to scientific concepts and messaging that science is valued, encouraged interest and the idea of possible future study. It provides an external recognition and sense of belonging that they are part of a tradition that values science.

Mary credited her interest in physics to her family's emphasis on STEM from when she was a child, including trips to libraries and museums, and opportunities for awe-inspiring moments peering through telescopes. Mary described how her family connected to astronomy through their culture, "my mom telling me so many, like, stories between, like, Khmer people and astronomy, old astronomy, new astronomy." She went on to say, "It's kind of in my blood to be doing something like this. My middle name, it translates to moon."

Ava identified her family as playing a huge role in her identity from their Colombian culture to their STEM occupations. "We're all nerds...my uncle is PhD in biology and my brother is studying right now mechanical engineering. My grandpa did electronics. My grandma did architecture, huge geometry nerd. It's like, it's everywhere, everywhere." Additionally, she recognized that moving away from Colombia and then moving a lot within the United States created even stronger bonds with her family and culture.

B. High school

In high school, Mary and Ava's physics identities began to emerge and solidify within the school setting. It was also the earliest time they recounted negative recognition experiences in physics due to culture or gender.

Mary cited amazing teachers "that kind of helped me sort of realize that this is a space for me. This is what's allowed for me. And those were female, like, physics teachers..., honing in on that sort of belonging for me." This positive external recognition from meaningful people that she belonged in physics, along with the support of her mom and dad, perhaps helped her withstand racist responses from classmates. When she expressed her desire to study astrophysics, classmates responded, "I thought you were going to be working in a sweatshop with your Chinese ancestors."

Ava's strong interest in math set the stage for her interest and love of physics. "Honestly, when I started, like, taking the [physics] class, I was like, Oh, this is really interesting. And I love it. End of story." It was not all positive, however, as she noticed her teacher who "wouldn't listen to me or he wouldn't listen to some other girls. He always paid more attention to the boys." Her high school was all girls, and there were 3 boys and about 20 girls in her class. Her observations were validated by her brother who, in the same school, also noticed he "got special treatment."

C. Undergraduate physics

In undergraduate physics, Mary and Ava's classmates and professors were physics-specific. They were introduced to physics-centered research and conferences. Their perspectives were expanded from physics as a subject to physics as a community with its own norms and characteristics. Their experiences - both positive and negative - formed their perceptions of the culture of physics. Negative recognition from peers regularly put Mary's competence into question, as she found herself arguing in weekly lab groups. In one instance a male classmate questioned her ability to use a ruler. "I was working with two men. He snatched the ruler out of my hand as I'm, like, quite literally using it. And he was like, do you even know how to use this? I was like, it's a ruler, why would I not know how to use this? And then he went into this whole thing about how you're supposed to measure it from like the very end, which was crazy because then he was wrong." Additional negative recognition about who belongs in physics came from outside the physics community. Mary is a self-described "girly girl" who loves pink and girly clothes. She described how, while exploring Boston during an internship, she "was always hit with this comment of 'what?!? you don't look like you do astrophysics. Are you sure you don't do like art or something?"' She noted that these comments were not from her research advisors, whom she considered very supportive.

For both Mary and Ava, positive recognition came many times in the form of expressions and feelings of belonging from peers and professors in spaces outside the classroom. In multiple groups of astrophysics undergraduate students, she found recognition through common past experiences, "a background where we know what it's like to get bullied. Like, we know what it's like to feel like you don't belong." Ava's advisor provided recognition that she belonged in the physics community by giving her information about the CUWIP conference, and "arranging all that...He made everything possible and he is, he honestly has given me any advice for like classes or anything...And he's also a really funny guy. He has so many dad jokes." At CUWIP, Ava found additional recognition "interacting with many other women in, like...that's a community. I honestly didn't feel that before...the bonding."

D. Altruistic identity

Mary and Ava were also recognized for their altruistic motivations, using physics as a means to help others and give back to their communities. Recognition and support from the STEM professionals in Ava's family help sustain her initiative to go back to Columbia and create an astrophysics major there "because I think that it would be really nice to give the opportunity to other people, because I have a deep passion for this and I know some other people do also." Mary's recognition as a leader on her university's diversity, equity, and inclusion committee has "made me more comfortable that I'm helping creating a space that's inclusive to everyone," and that it has "been kind of cool to be able to...take from my own experiences and be able to advise in that sort of way." Mary's PI from her internship in Boston also recognized these abilities and offered to fly her back to help lead an outreach activity. She reflected, "I think being involved in outreach right now has also kind of reminded me why I'm doing what I'm doing."

V. DISCUSSION

Over time, STEM/physics capital in the form of external recognition changed in terms of its source (family, teachers, peers, society, etc.) and its form (from more general STEM to physics discipline-specific). Mary and Ava reported more experiences of negative external recognition as they progressed through their schooling.

Early experiences of Mary and Ava provided both with an environment of high familial science habitus [17]. The type and amount of science capital differed in that Mary's was built through stories and experiences, where Ava's included substantial concrete examples of science graduate degrees and careers. Both sets of experiences provided external recognition that they were part of a tradition that valued science. Early experiences with family further established a strong STEM identity by encouraging their interest and believing in their competence.

In high school as their STEM identities began to transform to physics identities, the inoculation effect of science capital provided resistance to threats to their identities [20, 26]. Negative recognition from peers and teachers resulted in them criticizing peers and teachers, and not questioning their own physics identities. However, having these salient experiences may have introduced or deepened an awareness that there is an aspect of physics that is exclusionary of race or gender. On the positive side, both Mary and Ava were impacted by family and teachers who validated their experiences and strengthened their interest and sense of belonging.

As Mary and Ava progressed into the undergraduate level of physics, they were fully introduced to physics culture and the community of physics scholars. At this stage, their recognition by others was determined by the physics-specific capital of the discipline's norms (e.g. mathematical fluency, research positions, technical knowledge and skills). Mary's frequent experiences of negative recognition in her labs were countered by a group of friends who validated her struggles and provided "social capital," which has been shown to have a positive effect on persistence of first generation engineering students [27]. Her experiences in Boston, when she was asked if she was sure she was studying physics and not art, illustrates the gendered differences in the type and manner of accumulation of science capital. Even after being accepted by the PI of the research group, she was not recognized as a physics person by some members of the greater community. However, the support of her research advisors and PI served to counteract the negative attention.

Ava's lack of negative external recognition reported during her undergraduate experience may be due to the continued inoculation effect of being surrounded and supported by family with STEM degrees and careers. Notably, her uncle who has a PhD in biology mentored her throughout her education. She explained that due to his advice she is pursuing a master's degree, "because a lot of people are not going to hire someone with an astrophysics bachelors only." This continued external recognition of her abilities and advice from a trusted STEM insider provided a strong source of STEM capital, a greater chance of internalization, and increased physics identity.

Recognition of Ava and Mary's abilities to give back to the physics community and their altruistic goals are paramount to their motivation and persistence in physics. Sociological and psychological studies reveal that women have a stronger motivation towards interpersonal (working with others) [28] and intrapersonal goals (maintaining multiple roles/identities) [29]. The preference towards working with and for others is born out in workforce trends, even in other STEM fields such as biology with its connection to human health and wellbeing. Goals centered on helping and working with others are at odds with the physics stereotype of the lone genius with goals focused on individual success and power. This external recognition of altruism for the physics community may be more readily internalized since it aligns with social expectation roles (women as caretakers)[30] and preferences for women.

VI. CONCLUSIONS

This study highlights the experiences of two women physics majors over time, from early childhood through undergraduate physics. Negative external experiences increased over time for these two women, and this experience may impact many women in physics. For both women, positive recognition from peers and research advisors was vital to their persistence. This recognition was less tied to their abilities, but to a belief in their abilities to solve physics problems, perform physics research, and contribute to the physics community.

The experiences of Mary and Ava illustrate how physics identity develops over time. Childhood environments and experiences can have a large impact on the formation and trajectory of physics identity. External recognition pertaining to messages of belonging to the physics community are particularly powerful. In terms of the inoculation effect of STEM capital, some experiences may build more capital than others. Knowing how the system works and how to navigate it can build confidence and resilience to threats to identity.

Future research should expand the sample size, particularly including the experiences of men and other gender minorities to better compare and contrast their identity formation with respect to external recognition. This study focused on environmental and sociological factors, external to the individual. Further study should examine the relationships between these external factors and an individual's psychological development and type, and internal sense of recognition specifically for physics identity formation. Examining the similarities and/or differences between external vs. internal recognition of women and the extent of overlap with the other factors of physics identity formation (performance/competence, interest, and sense of belonging) might also provide new insights.

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