Analyzing identity trajectories within the physics community

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We analyze the identity trajectory of a single case study, Cassidy, within the physics community. We focus our analysis on two settings in the physics community: an undergraduate research experience, and undergraduate coursework. We use video data from three interviews (spanning roughly fifteen months) to longitudinally analyze shifts in participation. We discuss Cassidy's experience through two constructs: *normative identities*, Cassidy's sense of the valued roles within physics, as well as *personal identity*, who Cassidy is within the physics community and the extent to which she aligns with *normative identities*. In attending to shifts in the alignment between personal and normative identities, we identify several *entry points*, or salient events that open up new opportunities for participation.

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I. INTRODUCTION

This article seeks to understand how student identities are shaped in relation to students' evolving participation in the physics community. Understanding identities, and particularly changes in identities, can help us understand the processes by which students move into or out of the physics discipline [1–3].

This work is especially important, given that representation and recruitment of white women and students of color is low in physics [4]. Many white women and students of color have the potential to be talented scientists but are marginalized by harsh practices and the unwelcoming culture of science, technology, engineering, and mathematics (STEM) disciplines [3,5,6]. This misalignment is evident in classroom practices which negatively impact students in coursework; additionally, such misalignment can also turn away students who are successful at their coursework [5,7].

Common ways of discussing retention fail to account for the complexity of students' experiences, and can invoke goals of assimilating students into the current system [8]. Given the diverse backgrounds of students, we believe it is important to move beyond the "pipeline" metaphor of retention, which assumes a singular pathway for students to become scientists [9,10]. Instead, we ask how one might foster a diversity of successful STEM pathways. An important step toward fostering a diversity of pathways is to closely study individuals' trajectories as they move through learning experiences [1,11,12]. This paper expands our understanding of students' trajectories into or out of physics by studying shifts in students' identities over time. Understanding the nuanced ways that students are supported (or not) in physics can point to how we can create conditions in which a diversity of students can succeed.

In this paper we focus on a single case study, Cassidy. As a white woman, transfer student, and older than other students, Cassidy holds multiple intersecting nondominant identities in undergraduate physics which contribute to unique external pressures and her experiences of marginalization. We discuss Cassidy's experience through two constructs: her perception of *normative identities*, the accepted and valued roles within physics, as well as *personal identity*, who Cassidy is within the physics community and the extent to which she aligns with *normative identities*. Cassidy experienced both shifts in personal and her perceived normative identities, which contributed to her increased participation in the physics community. These shifts in her participation over time point to several *entry points* that opened up new opportunities for Cassidy. After articulating the challenges and entry points in Cassidy's trajectory, we discuss implications for making physics more inclusive.

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II. THEORETICAL FRAMEWORK

In this section, we describe how we conceptualize identity. We first present *situated learning theory*, which describes identity as who one is within a community of practice. We elaborate on this definition by looking at studies of identity within STEM disciplinary contexts, and introduce the concept of *normative identity.*

A. Communities of practice

Within *situated learning theory*, identity and learning are inseparable from participation within a *community of practice* [13,14]. Newcomers to a community of practice engage in *legitimate peripheral participation*, interactions between newcomers and old timers on authentic joint work of the community. These interactions facilitate opportunities for new kinds of participation in the community, which is synonymous with learning and identity formation.

We conceptualize the relevant community of practice to be the physics community. The physics community of practice is distributed across many settings and its members engage in a wide set of physics-related activities. For example, being part of the physics community can involve taking or teaching courses, doing research in a research group, attending colloquia and seminars, and going to a departmental holiday party. Our analysis specifically zooms in on two major settings within the physics community, physics research activities and undergraduate student academics. These two realms are connected but distinct. Physics research involves many of the same people that participate in undergraduate coursework. In both settings, old timers in the community play important roles in supporting newcomers in learning the practices of the discipline. There are also nuanced differences between the settings. The common practices, norms, and what counts as being good at physics all look different. Becoming an "expert" in the physics community writ large, in part, involves understanding these differences between the settings.

We intentionally choose to look for identity development in both classroom and nonclassroom settings. Prior research has shown that a wide array of nonclassroom communities bear on identity development at the undergraduate level. In physics departments, such settings have included student lounges [15], peer study groups [16,17], learning assistant (LA) programs [15,18], informal physics programs [19], and retention-focused programs [20,21]. With the exception of Goertzen, Brewe, and Kramer [15], we know of no other studies that have taken into account a diversity of these kinds of physics contexts in a single case study. By doing so, our analyses contribute to the literature by identifying how multiple contexts afford different opportunities for identity development.

B. A situated perspective on identity

To conceptualize identity, we draw from Holland's *practice theory of identity.* This perspective on identity includes not only how one understands oneself, but also how one is recognized by others. These two aspects interact with one another; how one is seen by others impacts their understandings of themselves, whereas the ways that one sees oneself can impact the identities that others ascribe to them [11,22,23]. Holland emphasizes this dual nature of identity, which is "always, but never only 'in' the person, never entirely a matter of autobiography nor, on the other hand, entirely reducible to membership…[in] distinctive groups or social categories." ([22], p. 6) Descriptions of an individual (or the self) in relation to a community are called *positioning* (e.g., saying "she belongs in physics" positions her as belonging within the physics community) [24].

In this paper, we focus on *identity trajectories*, longitudinal (long-timescale) descriptions of how students' identities shift within a community over time [11,14,23,25]. Such trajectories can be inbound (greater identification with the community), outbound (lesser identification with the community) and no changes in identification [14,23]. These trajectories are informed by students' participation in the community's practices, recognition by others, and self-identification [2,11,26–29].

Studies of identity in STEM have shown that identity trajectories within a discipline are shaped by the locally enacted disciplinary practices. Within a given classroom, the prominent activities and practices impact how students understand the discipline, and the extent to which they identify with that discipline [3,28,30]. For example, a classroom in which "science" is defined as memorizing facts might lead a student to disidentify with science; the same student in a classroom where science is defined as developing coherent explanations might identify with science. Different contexts also afford different resources for identity development [31]. Research on identity development has also shown that the identities available to students are mediated by students' gender, race, culture, socioeconomic status, and the intersections of these identities [1,25,27,29,32–37]. In order to describe the extent to which students' identities relate to the disciplinary context we draw on the notion of *normative identities*.

1. Normative and personal identities

In their study of high school mathematics learning, Cobb *et al.* [38] describe *normative identities* as who is recognized as good or competent at mathematics within a given classroom, and is typically associated with what it means to know or do mathematics within that setting. These normative identities are not tied to any given member of the classroom, but rather are idealized types of members of the community. For example, in a reformed physics class, the normative physics identity might be someone who explains their reasoning and looks for real world examples

of physics concepts. Normative identities are aligned with Stevens, O'Connor, and Garrison's notion of *accountable disciplinary knowledge*, or what counts as doing engineering competently [11].

Cobb *et al.* define *personal identities* as how one see themselves and one is seen by others within a setting, including how one relates to the normative identities of the classroom [38]. Cobb *et al.* outline three ways that personal identities relate to normative identities: (i) Personal identities *align with* normative identities; in their study, this was identified by students describing themselves as fitting into a normative identity or aspects of a normative identity. (ii) Personal identities can *comply with* normative identities; this was identified by students "merely cooperating with the teacher" and doing math that aligned with the teachers' expectations (e.g., "playing school" [39]), (iii) Personal identities can *resist* normative identities; students "develop oppositional identities" to the classroom expectations and act in ways that defy what is normative. They identified the relationships between *normative* and *personal identities* in interviews with students.

We differ from the original study of normative identities by Cobb *et al.* in two major ways. First, we define *normative* to include what is accepted in physics (instead of merely what is good). That is, we use the term *normative* to refer to acceptable or recognizable ways of being in physics. This includes aspects of identities that are not associated with disciplinary practices or doing well in the discipline. For example, within physics it can be normative to enjoy science fiction and play video games (cf. [40]). These identities are normative in the sense that they are recognizable and accepted hobbies in physics, though they do not centrally contribute to knowledge building about physical phenomena. We include aspects of *normative identities* that are recognizable but not explicitly valued because this bears on students' senses of belonging within the discipline. Such expansive definitions of normative connect to existing studies of acceptable and/or celebrated identities in STEM education [1,25,28].

The second way we differ from Cobb *et al.*'s study of normative identities is that we foreground *Cassidy's perceptions of normative identities*. In the studies described above, normative identities (and similar constructs) are identified through classroom observations [28,38]. In using only interview data, our paper focuses on Cassidy's perceptions of *normative identities* in physics.

We believe that Cassidy's perceptions of normative identities would correspond (but not 100% overlap) with what other members of the physics community or an outside observer would identify as normative. Normative identities are, in part, constituted by the perceptions of those within the community (including Cassidy). Additional analyses, such as classroom observations or analyses across multiple interviewees, would be necessary to understand *normative identities* in a broader sense. We see Cassidy's perceptions of normative identities as a useful starting point for understanding *normative identities* [41].

To summarize, our definition of *normative identities* includes the broad set of roles that are available to students as acceptable ways of being in the discipline. These roles include what is recognized as competent in physics (e.g., being able to solve a problem correctly) as well as the accepted social roles that are less centrally tied to doing physics (e.g., having an in-depth knowledge of Star Wars). We define *personal identities* to be how one see themselves, how one is seen by others within a setting, and how one engages in the practices of the discipline. We look for the relationship between personal and normative identities, as either *aligning* or *misaligning*. Our analysis contributes to the literature on identity trajectories by illustrating how "identity development" can be due to a shift in personal identity, a shift in normative identities, or both.

III. ANALYTICAL APPROACH

A. Context

The context for this study is a large public university, which enrolls roughly 30000 undergraduate students per year. The physics department at this university typically has about 50–60 first-year freshmen students and transfer students per year. In this section, we describe the research and seminar context that was the focus of this study. We also describe other physics spaces that Cassidy and other students were embedded in.

1. Researcher positionality

As researchers, our choices of what to study and how we study it are informed by our identities and histories, and it is important to consider how this impacts our findings [42,43]. For example, our choice to foreground marginalized aspects of students' identities is informed by our own personal motivations to support inclusiveness in physics.

The three authors have been in the same physics department as students in this study, and are involved in departmental activities beyond the research project.

Cassidy participated in a physics research seminar that was co-developed and co-taught by G. Q. and another instructor. In subsequent semesters, the course was taught by other instructors. Cassidy took the course in a semester that was not taught by G. Q., but G. Q. met regularly with the course instructor to reflect on the course and discuss lesson plans. G. Q. was introduced to students as a researcher studying the course. She attended every meeting of the course and regularly participated in discussions. Before and after course meetings, G. Q. would occasionally talk to students about their school-related experiences and personal life.

Participating in the same classroom and department community as students afforded G. Q. some degree of

shared meaning with participants that informed her research interpretations. During interviews, students would often reference aspects of the course, other courses in the department, or people within the department. Moreover, G. Q.'s role as a member of the department likely impacted how students chose to talk about their experiences in interviews.

G. Q. had more extended interactions with several students, including Cassidy, outside of the interview setting. She would occasionally stop by G. Q.'s office to discuss aspects of physics and her personal life. While these interactions are not written into the analyses in this paper, these inevitably informed our overall sense of her identity trajectory and supported our interpretations of her narratives.

As the interviewer, G. Q.'s proximity to the classroom and departmental community also has limitations. Because G. Q. was not completely an "outsider," students may have given limited accounts of their experience in the course. We did find that students willingly shared criticisms of the course, which suggests that they were not simply saying what the interviewer wanted to hear. It is plausible that in a more anonymous setting, students would have shared more vulnerable information about themselves or more open critique of the course.

2. Seminar context

The research seminar introduces undergraduate freshmen and first-year transfer students to physics research. All first-year physics majors who were not currently engaged in research were encouraged to enroll when meeting with their undergraduate advisor. The course typically enrolls 15–20 students in a given year. Instructors recruited mentors (faculty, post-docs, and advanced graduate students) whom they felt would create meaningful learning opportunities in their research labs. Mentors proposed projects of reasonable complexity for a first-year undergraduate to complete in one semester. Students were matched with mentors based on topical interest. For 3–5 h per week over 15 weeks, students worked with their mentors on research projects. Research projects spanned experimental and theoretical areas of physics and astronomy.

Cassidy worked with a mentor on a theoretical astronomy project. After the course ended, she continued working with her research mentor on a different project for another year.

3. Physics student communities

Students in this physics department have opportunities to participate in social and academic communities. The department has an active chapter of the Society of Physics Students (SPS). The club coordinates regular outreach, fundraising, professional development opportunities, and weekly seminars geared toward undergraduate students. In addition, the club also runs a tutoring center Monday through Friday evenings. The SPS chapter's tutors tend to be junior and senior level students, as student tutors are required to have taken quantum mechanics. The SPS chapter is comprised of 50 active members, but also serves approximately 150 undergraduate students through tutoring, socials, outreach, and seminars.

While the physics department spans several buildings across campus, undergraduate students most commonly gather in the physics building. This building is where most undergraduate physics lectures and labs are held and there are multiple classroom-style meeting rooms where physics students study. At the center of the building, there is an undergraduate student lounge where students study, do homework together, and socialize. The lounge is commonly discussed in our dataset as a salient aspect of the physics student community, both as a place where some students felt welcome and as a place where other students felt explicitly unwelcome.

At the time of the study, the department ran an NSF S-STEM funded community-building program. The program supported 8–10 scholars per year. The goals of the program were to increase student retention through providing scholarships to students with financial need, building community among the cohort of scholars, and supporting identity development. A requirement of the program is that students participate in two courses, the research seminar described above and a professional development course. Students typically refer to the professional development course as the "S-STEM course." This program is part of the Access Network, a national network of programs at nine universities. The Access Network is focused on supporting inclusiveness and diversity in STEM through student leadership, community building, and authentic physics opportunities [44,45].

B. Data collection and selection

This work is embedded within a larger study which aims to understand students' shifts in participation within the physics community of practice. In the focal semester, G. Q. collected classroom videotapes, observations of students in their labs, pre- and postinterviews with students and mentors, and follow-up interviews that occurred one year after the course had ended. G. Q. interviewed nine students across seventeen interviews. Throughout the interview process, G. Q. was particularly interested in understanding the experiences of students from communities that are not typically represented in physics, for example, women, students of color, transfer students, parents, students from low socioeconomic backgrounds, and first-generation college students.

Within this paper, we only draw from three interviews of a single student, Cassidy. The first occurred several weeks into her research seminar project (t_1), when she was in her start of spring semester in her first year as a transfer student. The second occurred immediately after the research seminar ended (t_2) at the start of summer. The third

interview (t_3) occurred two semesters after the research seminar project ended, after she had finished her second year as a transfer student. Interviews were semistructured; the protocol loosely directed the conversation and the interviewer pursued in more detail ideas and experiences that were most salient to students. Interview topics included students' attitudes toward their research project, students' sense of belonging within the physics major, and what they felt like they were getting out of doing research. In the t_2 and t_3 interviews, the interviewer also followed up with students on themes discussed in the first interview. We did not collect information about the specific physics courses Cassidy took in between these interviews.

We selected Cassidy as the focus for this study because in many ways Cassidy's experience in the physics department at this university is unique. As a woman who is a transfer student, and several years older than most undergraduate students, Cassidy experienced multiple forms of marginalization and unique external pressures. (We note, however, that Cassidy was not the only student in the dataset who was an older transfer student). At the same time, Cassidy drew on relationships in several physics settings to ultimately find community membership. We see these dramatic shifts in her participation over time, and her continued persistence through challenges, as illustrative of many of the challenges that students from nondominant communities face in physics. Her successes also point to several entry points that were consequential for her increased access to physics. Cassidy's case is of particular importance for understanding how students from nondominant backgrounds find entry points into physics; we have a lot to learn from case studies in which the student is marginalized in multiple interacting ways but nonetheless finds multiple entry points. Additionally, studying these "outlier" cases are often the students who face the most challenges, and thus the students we should care the most to understand [1,8].

C. Person-centered ethnographic approach

Our analysis adopts a person-centered ethnographic approach. Ethnography, a methodology rooted in anthropology, involves the study of cultures with researchers embedded within those cultures [5,6,25,46]. *Person-centered ethnography* (or "ethnography of the particular") is an in-depth study of individuals within those cultures [1,11,47], which foregrounds the unique aspects of an individual's experience as they move through a culture. As Foor, Walden, and Trytten describe, "This approach does not examine the institutional politics for themselves but rather the effects of these politics on everyday life and the ways power is experienced by an individual ([1], p. 104)." Such a lens can illustrate how small, sometimes idiosyncratic, experiences can have a cascading effect in students' broader trajectories [11]. An approach that aggregates student experiences can often miss these small, but consequential events [11].

Studying culture through the lens of a single person can be particularly insightful to understanding how marginalized students interact with sociocultural forces. Often in studies of marginalized students, researchers aggregate demographic categories and look for "gaps" between majority and minority groups. This implicitly treats the white male student as the "norm," and can reproduce harmful narratives about certain groups of students as "failing" or "behind" [8,12,33]. In contrast, a small-*N* approach can illustrate the different ways that people contest these narratives [33] and the resources they draw on to be successful [34,48]. As Slaton and Pawley describe, aggregating students into "tidy categories" not only risks essentializing students, but fails to account for how the overlap of such categories intersect in unique ways [8].

D. Analysis

After collecting seventeen interviews of nine students, G. Q. developed content logs [49] which described main themes of each interview. Because we were interested in students' participation in the physics community, G. Q. flagged moments in which students positioned themselves relative to the discipline (e.g., "I'm a theory person") or practices of the discipline ("I learned to not be afraid of coding"). Throughout this process, several themes emerged across interviews with multiple students, such as how students' sense of belonging with peers, students' relationships with mentors, and aspects of students' personal histories that impacted the way they interacted with peers or research mentors. During this process, we iteratively moved between themes that emerged in data and themes from the literature to refine our foci. We then selected Cassidy as the focus of this analysis for the reasons outlined in the previous section.

After refining categories, we fully transcribed the interviews and narrowed the focus of analysis to Cassidy's relationships with peers and research mentors. We then developed analytic memos in which we used transcript segments to develop claims [49,50] about Cassidy's personal identity, her perception of normative identities in physics, and the relationships between Cassidy's personal and normative identity. In order to characterize normative identities, we looked for moments where Cassidy described expectations of others or common behaviors of her physics peers. For example, saying "it's pretty acceptable at this school to just like walk into professors' offices and start talking to them" suggests that the normative identity for physics students includes initiating conversations with faculty in their offices. We also identified the roles and positions that were specifically available to women [25]. For example, saying that women have to either "be one of the guys or…be a lone wolf" indicates that she sees two

normative identities for women, either as behaving like the men or isolating oneself.

We analyzed for Cassidy's personal identity by looking for reflections of how she sees herself or her perceptions of how others see her. Personal identities also frequently were described in relation to normative identities. For example, when Cassidy describes "I was raised to give people space who are above you," this reflects an aspect of Cassidy's personal history that was in tension with the normative identity of knocking on faculty's office doors.

Similar to Cobb *et al.*'s analysis, we studied how Cassidy's personal identity related to normative identities and the level of alignment or misalignment between them [38]. The level of alignment between personal and normative identities was identified by Cassidy explicitly drawing connections between the two. For example, "I'm just as bad and just as good as everybody else… everybody's struggling," reflects the fact that her struggles are similar to those of her peers, and that her personal identity aligns with her perception of normative identity within the peer environment.

Within our analyses, we specifically looked for aspects of normative identities related to race, gender, socioeconomic status, and other dimensions along which students described marginalization. Interview questions at t_2 explicitly asked students about gender and race in physics, though some students also spontaneously discussed these dimensions of social identity when answering other questions. We identified themes connected to Cassidy's gender, socioeconomic status, transfer student status, and age. We analyzed for racial identity, but Cassidy did not discuss race as connected to personally meaningful stories in physics. In our other case studies, white students and students of color described the racialized nature of doing physics. While we do not analyze for race in this paper, we see it as an important area of study in future case studies.

We then analyzed for how personal identity, normative identity, and the relationship between the two evolved over time.

Figure 1 depicts our foci for analysis. Longitudinal analysis of normative identities (N_1 to N_2) were identified by changes or continuity in how Cassidy described what it means to be good at physics, and the roles that were available in the physics community. Similarly, we analyzed for changes and continuity in personal identity (P_1 to P_2). For example, Cassidy described becoming more outgoing between P_1 and P_3. And as both of these changed, we looked for whether there was alignment or misalignment between P and N.

1. Past, present, and future analyses

To conduct longitudinal analysis, we used what Stevens *et al.* refer to as a past, present, and future approach, which involves asking participants to reflect on the past, describe their current state, and project into the future [11]. This approach allows us to see continuity and variation over time in how students make sense of their experiences.

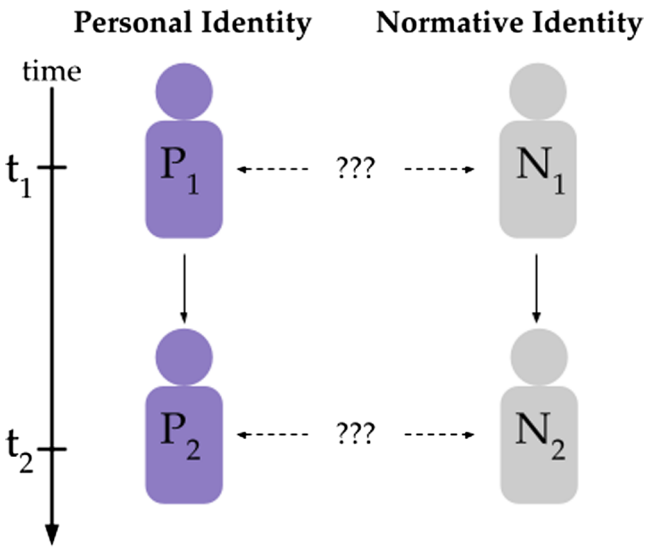

FIG. 1. Analytical framework of personal and normative identity. Time goes from top to bottom. Personal identities are purple and normative identities are gray. Both personal and normative identity can evolve over time in ways that lead to greater or less alignment.

Across the three interviews, we looked for *continuity, recontextualization,* and *shifts* in interaction patterns to understand shifts in normative and personal identities. *Continuity* refers to similar descriptions of identity over time. A student might consistently describe a scholarship program as helping her feel like part of a community. The continuity across accounts would strengthen the argument that the program was consequential. *Recontextualization* refers to how a student's interpretation of a single event changes over time. For example, a student might describe wondering whether he wants to stay in physics after doing poorly in a physics lab course, but later recontextualize doing poorly in the lab course as not being indicative of his ability to do physics research after learning more about the nature of physics research. Analyzing for recontextualization looks for changes in how students are making sense of their experiences and their relationship to physics. *Shifts in interaction patterns* are differences in interaction patterns between students and other physics community members at different points in time. A student saying at t_1 that he never talks to physics majors and at t_2 saying he regularly studies with other physics majors would reveal a shift in how the student interacts with peers.

After the completion of the analysis, we completed one final interview with Cassidy as a member check. G. Q. had given Cassidy a draft of the entire manuscript several months after the third interview was collected. During this interview, Cassidy had the opportunity to give input on whether she felt comfortable having the results published,

whether G. Q. should omit or correct any information, and her perspective on the analysis (particularly the discussion and implications sections). In the interview, Cassidy expressed her support and agreement with the findings in the manuscript.

IV. RESULTS

We now present analyses of several threads that illustrate shifts and continuity in Cassidy's identity within the physics community of practice. We first present about Cassidy's relationships to peers in peer environments, foregrounding her experiences with objectification of women in the department, and shifts in what it means to do physics competently among peers. We then present one thread about her relationship with her research mentor in her research experience, focusing on the ways that students and faculty work together. In each thread, we describe the normative identity at a given time (N_t), Cassidy's personal identity (P_t), and the relationship between them (relating N_t and P_t).

A. Objectification of women from peers

Throughout Cassidy's interviews, she described gendered interactions between herself and other male students in the department. One common theme in Cassidy's interviews is how Cassidy dealt with unwanted objectification from male undergraduate students.

1. t_1

At t_1, Cassidy's gendered experience with objectification intersects with her age. She describes how the objectification by men, in addition to being older than her peers, impacted or contributed to her isolation in the department:

> *Interviewer: Um, so would you say that like, in this physics department, you sort of feel connected to your peers?*
> *Cassidy: Yes and no connected… We're all really interested in the same stuff, but because I'm a lot older, it can get a little weird. (Laughing) It can, especially cause a lot of these umm- a lot of other physics students are boys and, and so, I prefer to geek out with other girls… if a young man approaches me to start up a conversation, I always feel obligated to be like, I'm married. I don't know cause, sometimes they don't know, you know? So I don't know, it just makes it odd. So I don't know, it's a weird dynamic (putting hands in face) But yeah I do feel like I'm around people that I belong and I really enjoy talking to them but at the same time it's still a little distant. Just because I'm in like another world, like I don't know, I'm in another ladder of society.*

In this quote, Cassidy points out her age and her gender as contributing factors to isolation. She brings up unwanted male attention from younger men in the department approaching her, which she feels "obligated" to deflect. Her descriptions of herself ("in another world" and "in another ladder of society") reflect a strong sense of otherness. This otherness stemming from her age and gender suggest that one aspect of normative physics identity (N_1) involves being male and late teens or early twenties but that differs from her personal identity (P_1). Cassidy continues from the previous quote, by elaborating on this misalignment and how she has to navigate the challenge of unwanted attention:

> *A lot of the times they'll assume like you're near their age group. I had one kid that like tried to date me… I don't know if I sound sexist like saying I just want to hang out with the girls, but, (shrugs) it's just easier that way. I get approached a lot actually by these young boys…it's really awkward cause I want to have friends, you know? Like I want to just talk to people, and be a person. I don't think they're used to, they don't see a lot of girls, you know? So they'll cling to girls. I don't mind conversing with them, and having conversation, and then something happens where they start to get a little like "Oooh, you want my phone number? You want to hang out?"… When I tell them how old I am, one even told me that I just ruined his whole day… I was like "Whaaat?"…they totally alienate me, they alienate me the second they find how old I am. Most- I mean not all of them. But that's why in class I try to announce it, like "hey I'm married, Yeah, I'm old, I'm a old lady. Like if you need some advice let me know" I try to like keep that but if I don't get the chance to announce it to the class, then it's I don't know, it becomes a very strange experience.*

Cassidy's descriptions of unwanted male attention reflect how it is normative for male students in the department to objectify women (N_1). Additionally, she is also assumed to be younger than she is, suggesting the normative identity for a student is someone younger than her. This misaligns with her personal identity (P_1), as someone who wants to have friends, which she poignantly expresses as "I just want to talk to people, and be a person." But because of the unwanted romantic attention, and backlash when she rejects this attention, she is alienated. At the end of this excerpt, Cassidy describes announcing up front her age and marital status, to make sure she is "found out" on her own terms. Cassidy's personal identity as an older and married person misaligns with the normative physics identity of being young and open to romantic invitations.

2. t_3

At t_3, Cassidy describes having a greater sense of confidence in her physics ability, and is more outgoing about making new friends in the department (this will be

elaborated on in the next subsection). At the end of the t_3 interview, the interviewer asked her to comment again on her experience as a woman in the department. Cassidy starts by describing some of the same kinds of feelings of loneliness and isolation, but she experiences those feelings to a lesser extent than before. She also describes how her approach toward being objectified has shifted:

> *Interviewer: I'm wondering if you could comment on what you think it's like for you to be a woman in this department.*
> *Cassidy: …I don't feel like I have to hide in the corner anymore. I feel capable if somebody oversteps their bounds that I can just like shut them down and be fine. Plus like, I'm older, like, I don't think a lot of these young men know how old I am. And so um, I can just scare them with my age and it's okay. But, but like it's, it's nice being able to just talk to people not hiding… that, I think, made it harder for me to evolve and do well. Like now I don't feel that so I'm not as stressed out.*

When Cassidy describes "if somebody oversteps their bounds," she seems to be referring to receiving unwanted male attention. She describes now being able to "shut them down" instead of "hide in the corner" which suggests a change in her personal identity. Her use of the word "evolve" suggests that she also perceives being different than she was before. Her age, which in P_1 was a source of isolation and otherness can now be used to "scare them" away. While Cassidy's personal identity shifts, male objectification is still present in N_3. Cassidy continues by elaborating on a situation:

> *At the end of the class, this one guy came up to me and he was like, "yeah, I heard you sounded frustrated like you didn't understand what he was doing but this is what he was doing." And I'm like, "I know what he was doing." He was just talking to me that was, like, almost belittling, like "oh how cute, let me help you," but also, like, flirtatious. And I was just like, "What?" He thought it was his in to talk to me… No, dude. I get what's going on. If there were other people in the class, you probably wouldn't have gone up to them, but since I'm a girl you feel like you're entitled to come and like grace me with your intelligence… I think when I shut him down I like, burned him with my gaze, (laughs) cause he disappeared when I was like, "I GOT IT."*

In this situation, Cassidy describes being similarly objectified as in t_1, but her approach to dealing with this is different. She "shuts him down" with her "gaze" and asserting that she's "got it." Throughout Cassidy's narration of this interaction, there's a strong sense of confidence in her own physics ability, and pride in being able to shut down her peer's advances. This is markedly different from Cassidy's reactions toward being objectified in t_1; she now has a stronger sense of agency in managing these interactions.

Cassidy uses her prior personal identity P_1 to interpret the behaviors of other women in her classes:

> *Interviewer: So you think that happens to other women in the department?*
> *Cassidy: …I think I've become more approachable this semester cause more people are talking to me cause I'm not like scowling at everybody now. So I don't know, like some girls I see in class have that look that I used to have, like don't look at me, I'm keeping my head down, I'm sitting in the corner. If you look at me, I'm gonna destroy you with my eyes, you know? And so, I am afraid to go talk to those girls. Cause they don't look like they wanna be talked to, and I get it cause I was that, I didn't wanna be talked to either… I don't do that anymore in my classes. I, like, sit like really open, like I do, I have my, like, feet up, I'm just like, yeah. I'll make eye contact with people and like, nod. And they'll, like, wanna talk to me because of it. You know? And so, I'm very much more approachable…I mean you're in a room with just boys. You don't wanna be objectified. It's easier to just be defensive and just stick to what you're doing and not think about anything else.*

Cassidy describes how it is common for some women to "sit in the corner" and scare people away. She attributed this as a defense mechanism to avoid being objectified, which she infers based on her prior experiences (P_1). Cassidy's comment that women have a look that says "I'm gonna destroy you with my eyes," echoes the experience with the male student at t_3, where she "burned him" with her "gaze," but this is a tool that she now uses more strategically and sparingly compared to before. Cassidy's descriptions of other women at t_3 illustrate the shift from P_1 and P_3; Cassidy's personal identity is more open and involves fostering more connections with people.

3. Summarizing shifts over time

Cassidy's continued descriptions of being objectified and other women's avoidance of male attention suggests that there is continuity across N_1 and N_3 in terms of the objectification of women (Fig. 2). The aspects of Cassidy's personal identity which are most salient at t_1 and t_3 are partly a result of these normative identities. Cassidy's initial personal identity P_1 is characterized by being older and uninterested in male attention. P_1 and N_1 are in tension with one another and lead to Cassidy avoiding interactions with male peers and volunteering information about her age and marital status to avoid being found out. Cassidy's later personal identity, P_3 is characterized by being outgoing and able to "shut people down."

An important aspect of Cassidy's experience is that even though her personal identity shifts and she finds greater sense of belonging in physics, she still has to manage the misalignment of normative and personal

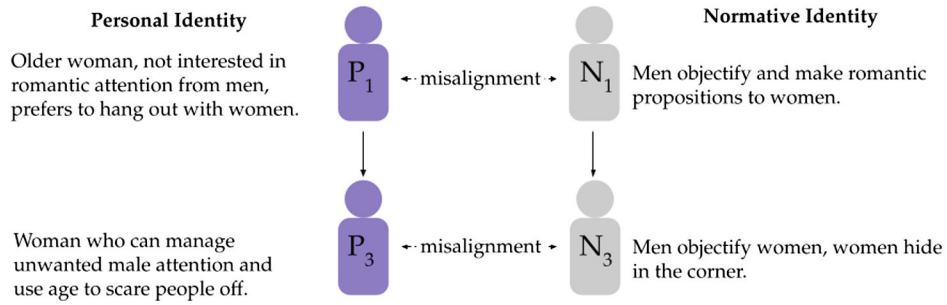

FIG. 2. Summary of Cassidy's personal identity and perceived normative identity with respect to objectification of women from peers.

identities, specifically by managing unwanted male attention. And while she seems to feel better about how she manages this attention, it still is an additional emotional burden she has to deal with in physics spaces.

B. Competence among peers

Another thread in Cassidy's experience is her shifting sense of what it means to be good at physics and how one demonstrates being good at physics within peer settings. This is paired with her growing sense of competence in physics. In Cassidy's case, doing physics competently was interwoven with her participation in peer settings.

1. t_1

At t_1, Cassidy describes being tutored at the Society of Physics Students tutoring by a more senior student. Cassidy describes a disconnect between the way that concepts were explained to her in SPS and her courses, and attributes it to not being smart enough to understand them:

Interviewer: Can you tell me a little bit about the people you study with and how you study with them?
Cassidy: …I did try the physics tutoring. I don't know if you know-
Interviewer: From SPS?
Cassidy: Yeah the 4 to 6 [PM] tutoring, but that didn't, that didn't help me very much. It kinda overcomplicated some of the things. I noticed when I get help from people who are way smarter than me, they make me, I don't know how to explain it, like if I'm, I like to look for the simplest way to do things, and usually people who have a lot more knowledge will wanna tell you every awesome nuance of everything you're doing. Which is cool if I'm not studying for an exam, if I need to know something to know it to take an exam, it really doesn't help. So like, for my E&M exam, there are like, like our teacher told us there's a way to calculate the electric field without integrating and when I went in for help, I was like "ok, he told me to do this without integrating" and they're like, "no, you need to do triple integral, you need to integrate θ, ϕ, r all that stuff." And I was like, "Oh, god ok." And I was trying so hard to get down these triple integrals and the exam comes and I know I did awful, and after the exam, one of the kids in my class was like, "no it's just the area over such and such" and I was like, "what?" So it doesn't always help when people are so smart and I respect their intelligence, I think they're amazing. But I don't know, I need it to be dumbed down. I need someone on my level to study with.

In this example, Cassidy describes trying to calculate electric fields in an E&M course, and struggling when her peer tutor tells her to use triple integrals instead of a simpler way to solve the problem. In her narration, the simpler approach was what her professor had told her to use, and what she had been expected to use on the exam. Cassidy attributes her confusion in understanding the tutor's help to them being "way smarter" than her and not "on her level." She describes the tutor as being one of a certain type of student—those who are "way smarter" than her, suggesting that one normative identity (N_1) is a student who can solve complicated problems and understands "every awesome nuance." She contrasts this normative identity with her description of herself in that moment (P_1), who she describes as being at a different level and needs material "dumbed down." Another person might interpret the tutor as making the problems unnecessarily complicated (and a reflection of the tutor's lack of awareness of what Cassidy's course is teaching), but Cassidy describes this as a disconnect between her personal identity and a certain type of upper-division physics majors.

2. t_2

In t_2, Cassidy's description of the same physics spaces did not reflect the same otherness that she described in t_1.

Interviewer: Do you feel a sense of community in physics department?
Cassidy: Yes… I went to the tutoring room last semester and I got to know a couple of the higher level physics students. And I felt like there's community among them. And they relied on each other and they're friends. And I always feel welcome when I hang out in the physics students lounge. And you can just hang out there and you're part of the group, everybody feels like they're of some like mind, although it's probably not true.

The tutoring room is recontextualized as a place where she feels a sense of community, and where she gets to know more senior physics students. While this quote does not speak directly to how Cassidy is perceiving competence within peer settings, we do see evidence that she is not seeing her personal identity as so misaligned from the normative identities, as we saw in t_1. She had been prompted to describe her sense of community, so it is also plausible that the question did not cue similar feelings toward her competency in physics.

When asked about lack of gender representation in the department, Cassidy describes one way in which her normative identity and personal identity misaligned, particularly as a woman:

> *Interviewer: Why do you think there are so few women in this department? Or in physics in general?*
> *Cassidy: I noticed one thing, from my last class, my physics professor last semester was awful… I noticed that half the class dropped after the first exam. Of all the girls, there were only 2 of us left. So I noticed that like, and I'm the same way, is that, like when there's a threat of not doing well, a lot of girls quit. Cause they wanna be seen as on the level of the guys. This is speculation, okay, I can't speak for all women, um, but I noticed that all the girls were gone except for me and another girl. But me and this other girl are in like every class together. So she's, maybe more like me as far as you know, I'm gonna carry on, like screw this, like I don't care, I got my first C, okay so what? It's not gonna kill my GPA, and I probably won't get another C ever again. But it didn't- the other girls seemed like so afraid of being not as well- as good as everybody else, like they'd rather drop the class and retake it. Because it's almost like you have something to prove. And maybe that's why there aren't as many women in this department…it does kinda feel like a boys club in a way, cause when I got to tutoring like they're all boys, they're all hanging out, they're all friends. There's a couple of like, outstanding girls, but those girls, they either have huge personalities or they're kinda like shrinking violets. You know? There's like no, just like girls being themselves. Maybe there are and I just don't meet them. But, from what I've seen is that you have to like, be a part of it and be one of the guys or like separate yourself and like, be a lone wolf. You can't just be, you know?*

In this example, Cassidy describes how doing well in the course is tied to exam and course grades. To her, this is gendered; she characterizes the normative identity (N_2) for women as being more likely to quit when there's the threat of receiving a bad grade, since women "have something to prove." Cassidy describes herself (and another outlier woman) as being different from the typical woman in this class, because they are willing to accept getting a C in a course. Her personal identity at this time point (P_2) is someone who is willing to deal with poor grades and is less afraid of them than other women.

Cassidy's description of women feeling threatened by bad grades seamlessly ties into her descriptions of the gendered nature of normative identities in physics settings. Cassidy describes women as having two recognizable normative identities (N_2), being "outstanding" and "one of the guys" or "shrinking violets" and "a lone wolf." She says that in contrast, there are no "girls being themselves," suggesting that there is commonly some misalignment between normative and personal identities for women. This resonates with other work in undergraduate computer science [6] and engineering [25] which has illustrated how women are limited to a few ways of "being" in a domain, whereas men tend to have a broader set of identities available to them.

3. t_3

At t_3, Cassidy starts to see "being good" at physics in more multifaceted ways. She has the sense that her peers have strengths and weaknesses (like her) leading to greater alignment between her personal identity and normative identity.

> *Interviewer: It's been a while since we've talked, do you have any broad comments about how things have been?*
> *Cassidy: This is the first semester where I've felt like I belonged in physics. Like, I didn't feel like an outsider or like oh, I'm not as good as everybody else, you know? This semester I started to realize that I'm just as bad and just as good as everybody else… I think it was getting to know some of my classmates, finally. Now that I'm getting to know more people, I'm realizing that everybody's struggling. We are all kinda in this thing together and then, like. Some things that I know and they don't know and vice versa. And so, it just made me feel that I was at the level of everybody else. And like um, and like in my math class there's this one problem that the teacher assigned for homework and the teacher couldn't even do it but like, I had done it and I guess I was the only one in class who was able to do it and he used my answer as the solution on the website. And it felt good, like wow, like, I can do some of this stuff, like, legitimately.*

Cassidy describes coming to understand that her peers have strengths and gaps in knowledge, just as she does. This differs from previous semesters when she characterized "smart" in more absolute terms. Her wording, "just as bad and just as good," suggests that these two qualities now coexist for her. In Cassidy's narrative, this stems from getting to know her classmates better, and seeing them as more multifaceted people. We also see greater affiliation with other physics majors when she says, "we are all kinda in this thing together."

Cassidy then elaborates on one moment that demonstrates her competence, where she solved a homework problem that none of her classmates nor her instructor could solve. To her, this moment contributed to her sense that she can do physics "legitimately." We interpret this quote to also mean that a normative way that physics competence is demonstrated is through solving problems (N_3), and this aligns with her personal identity (P_3).

The interviewer asked Cassidy to elaborate on how she was able to meet other physics majors. She began by talking about the S-STEM course, a small scholarship program in the department that focuses on building community and doing physics together (though the research seminar is a component of the S-STEM program, Cassidy is referring to the professional development course). After meeting students through S-STEM, Cassidy went out of her way to study with other physics majors in an open room in the physics building where students tend to gather to study.

Interviewer: So where, so you mentioned like meeting more of your classmates, like is that happening in class or in other spaces?
Cassidy: Yeah, well I guess the S-STEM class helped somewhat because -like um, [Classmate] is in a couple of my classes and um, like, I always have been smiley with him in class, cause you know some people are awkward and some people like look at you and smile when you look at them, so he was one of those people… I was like oh hey we're in classes together, like we've acknowledged each other's existence before, and so he was easy to talk to, and then talking to him, you know I met other people I talked to. I don't know it kinda started to trickle down. Or like I'd run into people in like the [open studying room] studying for the same thing, so I met another person that way. Like, "hey look, we're doing the same thing, come over here, let's do homework together" and the guy was like, "yeah! that's a great idea," and he understood some quantum computing stuff and I understood like some integral that he didn't know how to do. So that like, getting to talk to people and like share your strengths together, like I don't know, I've just become more outgoing like forcing people to talk to me. (Laughs) It works sometimes.

Cassidy describes some physics majors as being "awkward," while others are more like the student in her S-STEM course. After getting to make friends through him, she says that meeting peers "started to trickle down." She then narrates an instance in which she went out of her way to study with another student in a study room. In this studying example, we see further elaboration on how Cassidy sense of normative identities (N_3) is more multifaceted in what counts as "being good" at physics. Now that physics majors all have strengths and weaknesses (N_3), there are more opportunities for alignment between N_3 and P_3. Cassidy brought her own unique strengths to the group (understanding an integral) as did the other student (understanding quantum computing). This distributed expertise echoes the "just as bad and just as good" from earlier in the interview. She also articulates how her personal identity is more "outgoing" (P_3).

4. Summarizing shifts over time

Cassidy's perception of normative identities shifts over time, as competence becomes more multifaceted between t_1 and t_3 (Fig. 3). Her personal identity initially involved needing material "dumbed down," but then becomes someone who can "carry on" through bad grades, and is finally someone who can solve difficult problems. Both this shift in how she sees physics competence, and her opportunities to perform physics contribute to greater alignment between her personal identity and normative identity over time. One contributor to Cassidy's expanded notion of competence is having the opportunity to meet and work with other majors more closely, through friends and tutors. As Cassidy's

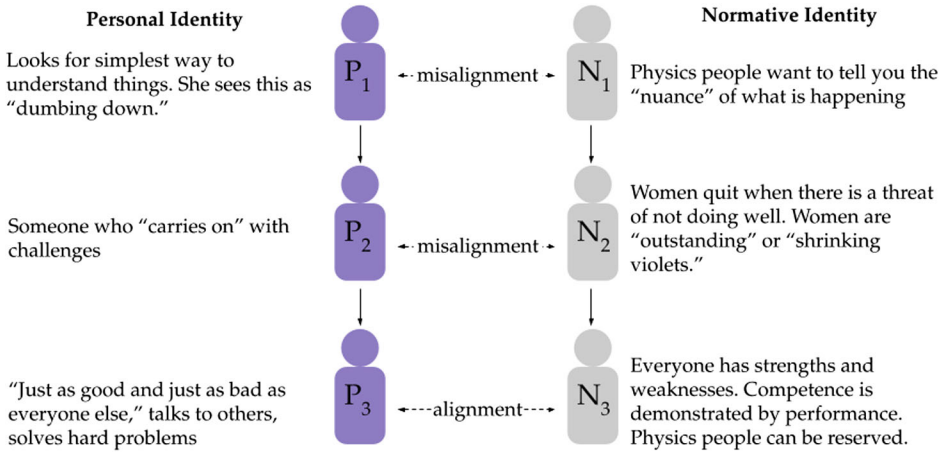

FIG. 3. Summary of Cassidy's personal identity and perceived normative identity with respect to competence among peer settings.

interactions with other physics majors increase, she also describes her personal identity as more outgoing.

Cassidy's alignment between normative and personal identities increased through coming to see physics majors as more nuanced people, and seeing a multiplicity of ways to be "good" at physics. This is aligned with work by Cohen [51], which emphasizes the unique strengths that individuals bring to challenging tasks. We find it noteworthy that the opportunities that led to Cassidy's increased interactions with peers happened in a nontraditional classroom space and nonclassroom spaces. Cassidy's experience shows how engagement with peers across multiple settings that celebrate different normative identities can enable students to see a multiplicity of ways of being "good" at physics. Cassidy sees these emerging relationships as being bolstered by engagement across settings. This points to the importance of creating multiple opportunities outside of traditional coursework for students to engage with one another.

C. Competence in physics research

We found continuity in Cassidy's description of the research seminar giving her the opportunity to work with her research mentor, which she felt like she would not have gotten otherwise. We also found that for Cassidy both normative and personal identity evolved in ways that led to greater alignment. We note that in this section we stay close to Cassidy's interpretations of events. In the discussion section, we elaborate on the implications of her adoption of meritocratic beliefs.

1. t_1

At t_1, Cassidy describes a history of wanting to meet her mentor before the course, but feeling unable to do so:

Interviewer: [In the context of your research project,] what are you most excited for?
Cassidy: I was really most excited about meeting [Mentor]. Because he's the college cosmologist and he's been on my radar for like, a while. And like, I'm gonna meet him one day. So I was really excited about that and I really wanna impress him.
Interviewer: When did you find out about him?
Cassidy: I found out about him the beginning of last semester when I was talking to my astro professor, and he was like, "you need to meet such and such, [Mentor]," and I was like, "oh? really?" And he was going on about how you should just walk in but I don't know I got nervous about just walking in and talking to him, so I didn't find another way to…I guess cause it's pretty acceptable at this school to just like walk into professors' offices and start talking to them and I didn't really know that. I think I was kinda raised to think that you give people space that are above you and I don't know. I feel like sometimes I, like I don't give myself enough credit, you know where like I'm not smart enough to go and talk to someone like that I don't know what it is. But it made me kinda nervous to go in there and strike up a conversation.

In this statement, Cassidy describes the sense of anticipation she had leading up to meeting her mentor, and positions him as an expert who is "above" her in status. Cassidy then describes an instance in which another professor tells her to go meet her mentor, but she hesitates and doesn't do it, suggesting that the normative identity for physics majors is to approach faculty doors (N_1). Cassidy attributes this to being "raised to think that you give people space that are above you." Her experience reveals how one of the physics norms of knocking on doors was in tension with Cassidy's personal identity (P_1). Though she was told by others that it is okay to do that, it didn't take away the discomfort or misalignment. She ultimately does not comply with this normative identity, and instead enrolls in the class.

2. t_2

At the t_2 interview, Cassidy reiterates that she had wanted to work with her mentor prior to taking the research seminar, and the course gave her that opportunity.

Interviewer: Um. so what was the experience of like getting started in this project like for you?
Cassidy: …I've been waiting for this for a couple of semesters and I've been like reading up on the mentor that I have, like waiting for my opportunity to work for him. So it was kinda like things just fell into place.

Cassidy describes this experience as an "opportunity to work for" her mentor. Her use of the word "waiting" and "things just fell into place" positions herself in a passive role with respect to starting this relationship; there wasn't space for her to initiate this relationship on her own.

But despite Cassidy positioning herself passively at the start of her mentoring relationship, she proactively managed their regular meetings:

Interviewer: So how was- what was your relationship like, with your mentors-
Cassidy: Umm, Scarce. (Laughs) I don't know, it was very easy to talk to him. Um, we got along pretty well and, it's just he was a busy person and preferred email exchanges. But I kinda forced him to see me anyways. Cause I don't know I just felt email exchanges were impersonal, and I didn't- if I had questions, you know on the fly, you can't really do that through email. But we- we didn't see him often, like maybe every other week… he wasn't a jerk or anything, but he was kind of an introvert. So you know, I had to work around that.

Cassidy describes their relationship as "scarce," because they met "maybe every other week," and communicated via

email. She would have rather had more face-to-face time to ask questions. She attributes the impersonal nature of their relationship to being what she describes as an "introvert." This description suggests that a normative identity for faculty is to prefer email and be unresponsive to students, cueing up the stereotypes that physicists are socially awkward and don't like talking to people (N_2).

Cassidy also describes proactively seeking out meetings with her mentor, which she calls "forcing" him to meet with her and "working around" his introverted personality. This forcing language comes out several times in this interview. For example, Cassidy later states, "I think forcing him [mentor] to see me more, that probably would have been helpful, and probably like picking his brain more." This language positions her as someone who can be persistent about getting questions answered (P_2). In some sense, Cassidy was complying with the uncommunicative N_2, because they still met with "scarce" frequency. At the same time, Cassidy "forcing" her mentor to see her is also one way that she resists N_2 in an agentive way. By pushing for more meetings, she had some of her questions answered, and found ways to address the misalignment between N_2 and P_2 by shifting their interactions.

3. t_3

At t_3, Cassidy similarly reiterates this course as giving her the opportunity to work with her mentor, but she now describes the barriers to working with him in a more nuanced way.

> *Interviewer: I guess I wonder like do you think that the, if you had done the research experience without the class, like do you think it would have been different?*
> *Cassidy: Umm, I don't know. I guess um, I probably would have gotten research from whoever had taken me so maybe I wouldn't have done something I wanted to do. Whereas that class let me work with the person I'd been wanting to work with. So it was good… I know [mentor] is hard to approach and usually shuts down people who approach him. And when he does take on people, he's not available to them immediately…So definitely like, I think, let me work with who I wanted to work with.*

Again, Cassidy says the "class let me work with the person I'd been wanting to work with." In t_3, however, she elaborates that the class gave her the opportunity because her mentor is "hard to approach." She suggests that this initial unapproachability might have prevented her from working with him without the class.

Cassidy elaborates on her mentor's initial unapproachability:

> *Interviewer: Is it challenging to get to be able to sit down with your mentor and like talk face to face?*
> *Cassidy: No, because we schedule once a week. It was when I was in [the research seminar], we had to like find him, or he wouldn't always show up when he said he would, but now he's more invested. Like I think he's the type of guy that people have to prove themselves to, it seems that he gets people that aren't like um, I don't know they're kinda flaky. It seems like some of the grad students he works with, like, I don't know he doesn't talk to them a lot. They're not available, I don't know. So like when he saw that like, "No, I'll be in your face until you work like let me work," I think he realized that like OK she's serious…. I think he could tell that I really wanted to do this. Cause he told me after the [research seminar] class was over that he was like, "look you know, I end up, I try to work with a lot of people and a lot of people just don't seem to get it together." You know? And really push, so he said "I really wanna work with somebody who's gonna stick with this and push and do something" and I was like, "that's me!" And so I think he's had experiences in the past maybe with undergrads so I don't know.*

We see some shift in interaction patterns between Cassidy and her mentor. At t_3, they meet "once a week," which is different from the "maybe every other week" meetings Cassidy described at t_2. At t_3, Cassidy also elaborates that during the research seminar, she and her partner "had to find him" and sometimes he would not show up to their meetings. She now sees him as "more invested."

For Cassidy, her mentor's resistance to in-person meetings, being busy, and "introverted" personality from t_2 is now recontextualized as him being "the type of guy people have to prove themselves to." Cassidy directly attributes his lack of availability at t_2 to being less invested than he is at t_3. Cassidy interprets his lack of investment as stemming from mentees needing to "prove themselves," which is necessary because so many people are "flaky" and can't "get it together." We interpret Cassidy's perception of the normative role of faculty (N_3) as those who invest their time in students who are judged to be committed.

At t_3, Cassidy recalls seeking out meetings as she described in t_2 (e.g.,"no, I'll be in your face… let me work"). But what Cassidy described as "forcing him" to meet with her at t_2 became recontextualized as "proving herself" at t_3. She recontextualizes her persistent requests for meetings and face-to-face time as demonstrating to her mentor that she is a serious and committed person. Her personal identity (P_3) is someone who is the serious, committed kind of researcher that her mentor is looking for, in alignment with N_3.

4. Summarizing shifts over time

Across the three interviews with Cassidy, we identified continuity in how Cassidy saw the research seminar as an

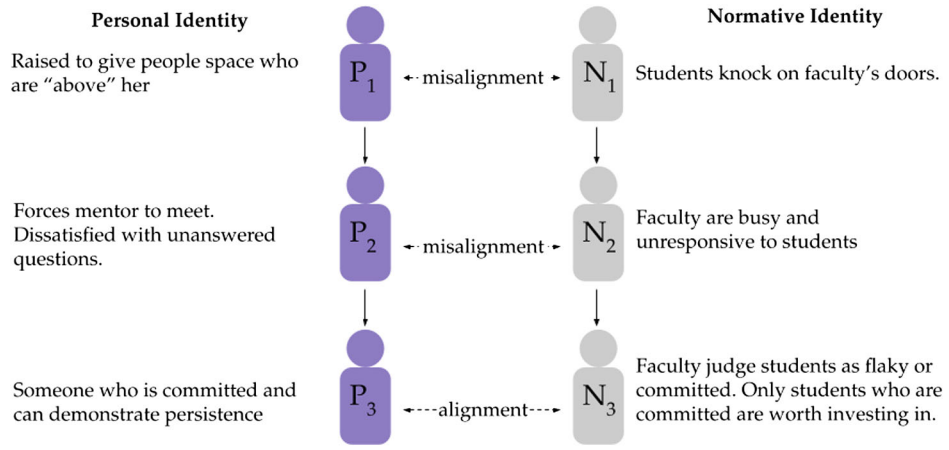

FIG. 4. Summary of Cassidy's personal identity and perceived normative identity with respect to relationships between faculty and students in research.

entry point to working with her mentor (Fig. 4). We also saw changes in how Cassidy recontextualized her resistance to infrequent meetings as her "proving herself" as a mentee worth her mentor's time. This recontextualization reveals shifts in Cassidy's personal identity and the normative physics identities. Cassidy at first "gave space" and saw herself below her mentor, which was in tension with the physics norm of knocking on doors to talk to faculty. She then "forced" her mentor to meet with her, which was both complying and resisting her mentor's unresponsiveness. Over time, the relationship between Cassidy's personal identity and normative identity went from being in discord to being in alignment, but this stemmed from both shifts in normative and personal identities.

The continuity of Cassidy seeing the course as giving her opportunities with her mentor suggests that the course is an entry point into Cassidy's more central participation in physics research. Over time, there are differences in how the entry point functions for Cassidy. In the first interview, she describes how nervousness and wanting to "give space" led her to avoid knocking on his door. By the third interview, she suggests that she might have been shut down by her mentor anyway, had she knocked on his door. This is another entry point which occurred in a nontraditional classroom setting. It may be particularly important for students, as we see in Cassidy's case, to have these well-scaffolded opportunities for engaging in research that are different from the "knocking on doors" approach.

V. DISCUSSION

In this paper, we longitudinally analyzed aspects of normative identities and personal identities using narratives from a single case study, Cassidy. We separated our analysis into three themes: the objectification of women among peers, the perception of competence in her peer community, and the relationship between students and mentors in research.

Within Cassidy's relationships to peers in peer environments, there is continuity in her experience of being objectified by male students in the department. Over time, her personal identity shifts from avoiding interactions with men to being able to respond to objectification in a more agentive way. Cassidy also experiences shifts in normative identity with respect to what it means to be good at physics among peers. She goes from seeing others as smarter than her to seeing "good" in a more multifaceted way, in which everyone has strengths and weaknesses. These both contribute to (and are fueled by) her greater sense of belonging among peers, and expanded opportunities for interacting with peers. We believe that increased interactions with peers and increased affiliation with physics is evidence of Cassidy's greater participation within the physics community, and can likely support future participation. Within Cassidy's participation in research, she experiences shifts in how she understands the way that faculty and students work together. At first the normative practice of students initiating meetings with faculty was in tension with her being raised to "give people space." After beginning to work with her mentor, she proactively seeks out more meetings with him, which she initially portrays as "forcing." This practice eventually becomes recontextualized as proving her commitment.

Through using the constructs of personal and normative identities, we see how Cassidy's evolving participation in physics can be modeled as both a shift in her personal identity as well as a shift in how she understood what is normative in the community.

A. Future causal stories about identity shifts

The purpose of this paper was to illustrate how we identified personal and normative identities, and shifts in personal and normative identities over time. As both of these can shift in ways that lead to greater and less

alignment, an important next step would be to more thoroughly model what caused each shift for Cassidy. Future work can develop mechanistic descriptions of how various contextual factors and experiences lead to these shifts. Cassidy's experience points to some of these already noted in the literature—for example, opportunities to perform particular physics tasks and opportunities to be recognized by peers and mentors (cf. Refs. [2,52]).

Additionally, throughout Cassidy's experience we see glimmers of how these identity changes are connected to shifts in other constructs from the literature (e.g., her sense of belonging, self-efficacy). While constructs like sense of belonging and self-efficacy have often been treated as separate from identity development, one might be tempted to model how these factors influence one another. However, a communities of practice perspective views learning and identity development as shifts in participation in a community. With such a perspective, we should not expect identity, self-efficacy, and sense of belonging to be separable. Indeed Cassidy's experience hints toward an interconnectedness of self-efficacy, sense of belonging, and identity. As she describes being "just as bad and just as good as everybody else," how she is thinking of physicists as individuals with multifaceted abilities (normative identity) is connected to seeing herself as one of those physicists with multifaceted abilities (personal identity), and this is connected to a sense that she is a part of that community (sense of belonging) and likely her belief in her ability to do physics (self-efficacy). Future studies of identity development that draw on a communities of practice lens may help us understand the coconstituted nature of such constructs.

B. The importance of nontraditional spaces

One specific type of experience that gave Cassidy different opportunities for participation and identity development were what we refer to as "nontraditional spaces"—learning settings outside of a typical classroom environment. Tutoring, though initially a place where Cassidy felt marginalized, was described as a place to meet other physics majors. Cassidy's participation in the S-STEM scholarship program and course also gave her opportunities to meet other physics majors. These different settings were places where Cassidy developed a sense of what is "good" within physics, and contributed to greater alignment between her normative and personal identities. Cassidy attributes the research seminar to giving her the opportunity to meet her mentor, whom she would not otherwise have sought out meetings with, and who might have pushed her away. The case of Cassidy suggests that these spaces, which provide scaffolded opportunities for students to interact with faculty and each other, can play a critical role in growing students' participation within the discipline.

C. Differences in what counts as "good" in each context

The normative identities within peer contexts differed from normative identities in the research context. Within the peer context, Cassidy described students' strengths as knowing how to solve problems or having some content knowledge. Though "competence" became more broadly defined over time, it generally referred to what people knew or were able to use to solve problems. In contrast, what was celebrated in the research context was being able to be persistent and hardworking. Cassidy recounts her mentor saying "I really wanna work with somebody who's gonna stick with this and push and do something," suggesting that Cassidy interpreted persistence as being an important quality to doing research. Across the interviews with Cassidy, she never describes specific scientific skills or content knowledge as evidence of her worth or skill as a researcher.

Cassidy and likely other students are experiencing different messaging about what it means to be good at physics between research and coursework experiences. Depending on a department's goals, we believe that this misalignment could inform changes at a departmental level. For example, if the department believes that coursework should align with the values of physics research, including valuing persistence through challenges, they might consider how the rewards structures of coursework could be shifted to value persistence in addition to conceptual and procedural knowledge. If a department believes that content and procedural knowledge are the end goals of a physics undergraduate degree, research experiences could be adjusted to emphasize the development of conceptual learning. Or, a department could deliberately decide it values students gaining these qualities in different settings and allow for this misalignment to continue.

Misalignment between what is valued between research and coursework has implications for equity. Prior research has described how what is recognized as "good" in STEM can look different across classrooms, which leads to students long-term identification (or attrition) within STEM disciplines [28,38]. One could imagine how a student such as Cassidy could have enough peer experiences like the one in t_1 and leave the discipline before having the opportunities to see that she has other qualities that make her good at STEM. Depending on what faculty believe are important qualities to doing physics, we believe that we should aim to cultivate and recognize those throughout physics coursework. Otherwise, the limited set of valued normative identities in physics risks losing students who have the potential to do well in physics [25,28,38].

D. Equity implications for the design of research experiences

These findings have several implications for the design of research experiences. Cassidy's initial resistance to

seeking out meetings at t_1 illustrates how it is not enough to simply tell students to knock on doors to find research experiences. We should also consider how these cultural expectations may sit in tension with students' personal histories. Courses such as the research seminar can lower the barrier to initiating research mentoring opportunities, and serve as valuable entry points for students to engage in research. This is especially important for students who might otherwise feel uncomfortable or unwelcome initiating first meetings with faculty.

Leaving the burden on students to initiate meetings may disproportionately favor more aggressive, or privileged students (e.g., students with more experience in higher education). Cassidy saw her mentor as being "hard to approach," and suggested that she might have been pushed away had it not been for the class. And while the process of "proving oneself" worked out well for Cassidy, we believe that mode of operation would likely feel threatening to other students. Given that many research experiences are acquired informally [53], and the kinds of expectations of research students are also implicit, leaving it up to students to initiate conversations could negatively impact many students.

The idea of "proving oneself" is highly gendered and racialized. Proving oneself evokes a sense of competitiveness to claim one's status, typically associated with male socialization. As Seymour and Hewitt describe, competition in undergraduate STEM is often seen by men as a challenge, but is far more threatening to women. They write, "in treating male and female students alike, faculty are, in effect, treating women in ways that are understood by the men, but not by the women." ([5], p. 261) How one proves themselves to Cassidy's mentor is also striking. One must be persistent and aggressive about scheduling meetings and demanding face time. But this approach can feel unfamiliar to students who are less familiar with the "rules of the game," which can likely lead to inequitable learning opportunities. We recommend that research mentors reflect on the expectations and assumptions they have about working relationships and students, and how those might marginalize students.

E. Socialization into (problematic) meritocratic notions of physics research competence

By t_3, Cassidy claims that physics students need to prove their worthiness or commitment to faculty in order to be worth their time. This perspective cues up the idea that physics is a meritocracy in which success is only limited by effort and ability, and that those who are unsuccessful simply did not try hard enough. Part of this stems from having seeing herself as having succeeded within this meritocracy. Cassidy interprets her prior struggle as having proven herself, and recasts other unsuccessful physics majors as simply too flaky to be worth faculty time. We offer an alternative interpretation: in becoming more like a physicist, Cassidy has also adopted problematic aspects of dominant physics culture.

We find the idea that science is a meritocracy problematic. Underlying the beliefs that students need to prove themselves and that failure is the fault of the individual is the assumption that the playing field is level. But myriad studies have shown that science is not a meritocracy; rather, students from nondominant backgrounds have limited access to professional resources, opportunities for learning, opportunities for identity development, and recognition in STEM fields [1,5,34,54,55]. Adopting competitive attitudes also comes at a greater cost for women, who have been socialized to be cooperative [5]. Even women who adopt competitive attitudes to succeed are often seen as unfeminine or have their successes questioned [5]. The idea that the playing field is level is simply not true.

Rather than seeing the purpose of university physics as sorting and filtering students, we offer an alternative vision for physics education that cultivates a diversity of successful trajectories. Within such a vision, we would see all students as having the potential to be successful at physics, and design for a diversity of pathways and starting points into the discipline. This involves questioning assumptions about why certain students are labeled as "flaky" or "lazy" [12,56], reflecting on if it is possible that there are unstated expectations for how these students should engage with faculty [1], and understanding that these expectations may conflict with students' cultural backgrounds. We also invite faculty to consider how those tensions could be mitigated. For example, for students who are hesitant to knock on doors it could be valuable to have lowered barrier-to-entry settings, such as undergraduate-focused seminars, where students talk with faculty about their research [57,58]. It would also be important to support collaboration instead of competition, creating a culture of learning together (cf. [59]) where we value individual's growth instead of comparisons across students [60]. Explicit attention to the meritocratic notions of physics is essential to making physics more diverse and inclusive.

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