Using story-based methodologies to explore physics identities: How do moments add up to a life in physics?

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[This paper is part of the Focused Collection on Qualitative Methods in PER: A Critical Examination.] This article details methodologies employed to enable sharing and coconstructing the stories of three women's lives in physics. The first case explores the usefulness of timeline interviewing, where participants narrate episodes that are coconstructed with the researcher as meaningful over time. We illustrate this method in the case of a mature student in Sweden from a working-class background who shared moments that added up to a life outside of physics and then a sharp turn into physics later in life. The second case explores life-history interviewing using a narrative-inquiry approach and deep relationship building which enabled the coconstruction of stories of experiences over time. These moments are coconstructed with the researcher and analyzed using an intersectionality lens to yield a story depicting the transnational experiences of a woman of color moving across various European contexts into the North American physics context. The final case is of a first-generation Canadian woman of color who shared her navigations of in and out of school physics via a method known as the "Rivers of Life." Using this method, the participant narrates their experiences with physics as a river, using metaphorical tools like rafts, rocks, rapids, tributaries to discuss various moments described as twists and turns over time that together amount to a life in physics. We discuss the value of different approaches to coconstructing narratives with participants and, in particular, the need for this kind of research in physics contexts.

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I. INTRODUCTION

"How do *moments* add up to *lives*?" [1] Lemke's question foregrounding time and space in identity work has prompted us to share our research experiences with story-based methodologies that invite participants to reflect on moments that have led them to and propel them forward toward lives in and out of physics. Methodologies that illuminate moments that add up to lives in physics can help us to address important calls for equity and inclusion in physics education by providing perspectives that are often missing from large-scale studies that seek to measure and map identity in statistically generalizable ways. We suggest that qualitative, story-based methodologies like biographical stories, life histories, and narrative accounts of bodily experiences provide a useful lens for exploring the meshwork of trails [2,3] which make up individuals' trajectories into and around physics and shape belonging in physics.

This paper will detail methodologies employed to enable sharing and coconstructing the stories of three women's lives in physics. The emphasis we place on moments across time in women's stories of being and becoming in physics is grounded in feminist standpoint theory [4]. Standpoint theory privileges the perspectives and experiences of members of minoritized groups and regards these perspectives as critical to understanding the entirety of experiences in a social context. In physics education, this means listening carefully to the experiences of minoritized groups and regarding these perspectives as critical to understanding the range of social, cultural, and political issues connected to physics identities. Thus, we discuss the value of research methods that can highlight the microlevel aspects of "context" that are essential to understanding

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physics experiences, especially from voices that are minoritized in the field.

A. Storying identities

While narrative research in science education more broadly is a well-established methodology (e.g., [5–7]), in physics education, we see fewer instances of small-scale stories of experience (c.f. [8,9]). We regard stories as critical to our understanding of experiences in physics, and we highlight the particular importance of listening to and highlighting the stories of students who are minoritized in physics learning environments. Stories can help us to attend to the meaning that people make of culture and of their experiences and can help us to understand and explain actions that individuals take in response to these experiences [6]. Connelly and Clandinin argue that humans are story-telling organisms and that these stories are situated in who we think we have been and who we wish to become [10]. These stories are also negotiations within ourselves and our surroundings, particularly negotiations of our pasts and who we consider ourselves to be now, and how we conceive of our futures [7]. As researchers, we enter a story at a specific time, we ask participants to position share their stories as they are in the middle of their story, and we recognize that we leave participants in the middle of their story [5]. Like Holmegaard *et al.* [5], we also recognize that how stories are told about the past may change as participants see their futures changing or as their present circumstances change. However, capturing these stories is still crucial to understand physics experiences as they may help us to understand not only students' actions but also how physics has figured throughout their life course in ways that may not be about persistence, but rather about moments over time; moments that add up to a life in and around physics [3].

In this article, we bring attention to narrative inquiry and three different approaches to coconstructing and sharing stories of experience—lives in physics. The common theoretical underpinning to these three examples is narrative inquiry and identity which we regard as an ongoing storying of ourselves in social interactions [11,12]. We understand the storying of life histories to be more than just the telling of experiences from interviewee to interviewer. Rather, our approach to narrative inquiry treats conversational partners in interviews as collaborators in ways that share discursive authority, and where the trajectory of the conversation is often guided by the interviewee (such that they "*story* themselves" into physics, or "*story* physics" into their lives) [13]. The researcher's motivation is to remain open to the worldview of the interviewee and thus becomes implicated in the life of the interviewee, often deeply (as described in case B). This requires researchers to constantly consider the consequences of the research relationships they build with interviewees and to attend to the difficulties of reporting the outcomes of research conversations. We elaborate on the affordances and constraints of this perspective on life-history interviewing in the three cases presented in the next sections.

All three of these cases are situated in different geopolitical social contexts, and the different approaches to narrative methods permit a more nuanced depiction of the life contexts of the participants that larger-scale studies would miss. In what follows, we will detail these methodologies and discuss how they were employed to enable sharing and coconstructing the stories of three women's lives in physics at different places or times.

We begin in Sweden with a case of life history interviewing using the timeline methodology [14]. A. D. and A.-S. N. present data from a single participant to discuss how the timeline method helps to elicit memories at the moment during interviews, which may meaningfully situate participants' experiences in time. We then move to a case from the Netherlands, where L. A. discusses the role of relationship building in the coconstruction of life histories, and how deep relationality can yield not only stories of experience but also friendships and meaningful moments together with participants. Finally, we present a new perspective on life-history interviewing from research in Canada. A. J. G. and R. E. share their method "rivers of life" which they piloted with physics graduate students to understand their life experiences in and through physics. We spend more time elaborating on this method, as we expect it will be new for physics education research audiences, and therefore, we present details of the method as well as a manual for researchers interested in employing it themselves (see the Supplemental Material [15]). We end with a discussion section in which we describe the importance of collecting life-history data in physics and also the need to attend to our roles and responsibilities as researchers engaging with these methods.

II. CASES OF LIFE-HISTORY INTERVIEWING

A. Timeline interviewing (A. T. D. and A.-S. N.)

The first case explores the usefulness of timeline interviewing [14] where participants narrate episodes that are coconstructed with the researcher as meaningful over time. We illustrate this method in the case of a mature student in Sweden from a working-class background who shared moments that added up to a life outside of physics and then a sharp turn into physics later in life. Through this case, we suggest that the coconstruction of timeline interviews in real time (during the interview) might yield stories that the participant may not have identified as important but then become important in the context of the interview.

Tina is a mature student in her early forties, enrolled in the bachelor of physics program at a large, research-intensive Swedish university. At the time of the interview, she was taking some second-year courses at the same time as she was retaking first-year courses that she had failed the

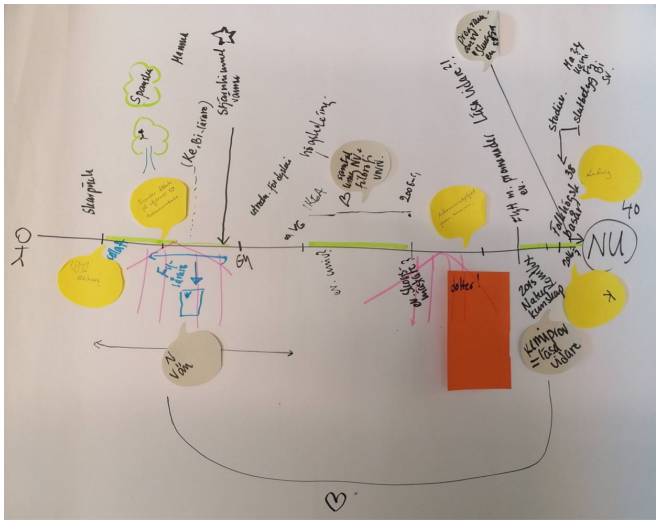

FIG. 1. Tina's timeline.

first time around. The interview had the character of a life-history interview and was guided by a timeline [14] constructed collaboratively by the interviewer and the interviewee (Fig. 3). Interviewer (A.-S. N.) and interviewee (Tina, pseudonym) were seated at a table with a large paper (where the timeline was to be constructed) and numerous post-it notes and pens in different colors. The interviewee was encouraged to make use of these things in the construction of the timeline (Fig. 1). A.-S. N. explained that the timeline could be used to mark events and people that had been important to Tina's science trajectory. It is a visual support to assist in the recollection of memories, to situate those memories in time, and to document moments adding up to a life such that the participant and interviewer can revisit moments as the interview progresses. Before the construction of the actual timeline began, Tina had been asked to fill out a short questionnaire with basic biographic information as well as some items designed to capture her science capital—the science-related resources that an individual acquires through life experiences [16]. The timeline was introduced by A.-S. N. by asking "how Tina had ended up here" (i.e., at the university). This initiated a narration of Tina's trajectory to higher education that flowed back and forward in time. An issue with the timeline method can be that it imposes a false sense of linearity and causality among events. But the interview with Tina flowed forward and backward in time with ease. We will return to the issue of an imposed causality later.

One important aspect of Tina's story is her childhood. While her narrative did not focus strongly on the influence of science experiences early on, the openness of the timeline methodology still encouraged her to tell a complex narrative. Tina grew up in poverty in a suburb of a major Swedish city. Her father was largely absent and Tina mainly grew up with her mother and three sisters. She describes both parents as valuing learning and knowledge but without time or capability to support Tina's schooling. Despite the poverty, her childhood home had plenty of books. Tina describes her schooling as harsh; she was bullied, experienced outsideness, and had low academic confidence. Tina describes out-of-school experiences of science, in particular, popular scientific books and star gazing, as points of refuge. Still, in school science, she is not recognized as a good student. A conversation with her junior high school physics teacher at a parent-teacher conference still haunts her

> And then we had a test in astronomy. I think I got 4 out of 25. […] And then he told my mother that I was obstinate. And when I asked what obstinate meant I think it was actually my mother who said 'we'll have to look that up in the dictionary when we get home' or something [laughter]. And then my mum said, I remember, to him that 'it's still strange because Tina is very interested in astronomy and reads a lot about it'. The teacher then scoffed and said that 'yeah, but she might read things that are at a higher level than what we do here then'.

The narrative about her school that Tina is weaving in the interview is a dark one, but out-of-school experiences in astronomy provided light in that darkness. Star gazing is something she returns to on several occasions during the interview, focusing on the beauty and tranquility of the experience

> Every winter we sat there and counted the stars in Orion and kind of searched for the Pleiades and… That's what's beautiful, the Universe, kind of. That's what my brain gets turned on by.

The star gazing may in some ways be rather weakly linked to Tina's science identity trajectory but the timeline interview method encourages the interviewee to bring out experiences that, at first glance, might not be so strongly associated with her educational trajectory. With the clear marking of important events on the physical timeline, the method furthermore zooms in on turning points, possibly exaggerating the shift in these. During the interview, Tina tells a story of how she had decided that if she did well on a particular chemistry test in the folkhögskola,[1] she would apply to a preparatory year to make her eligible for higher education science studies. She then also began to link up her new-found interest in school-based science (as taught at the folkhögskola) with her childhood star gazing and out-of-school interest in astronomy. This ability to bring out what may seem like rather minor occurrences and also constructing them as turning points on the timeline is both a

[1] In Sweden, Folkhögskola are "folk high schools" which offer a variety of specialized courses in arts, vocational training, and preparation for university.

strength and a weakness of the method. This retrospective allows the interviewee to tell a story of what resources were available or unavailable during a particular period of time—things that would have been difficult, if not impossible, to voice during the actual period. Speaking from the position of a university physics student, Tina is, for example, able to see how science was never really perceived as an option in high school: she did not opt out of it; it was never even considered.

While the story constructed in the timeline interview with Tina can be viewed relatively straightforwardly as a story about her engagement with science at different times in her life it is also clear that a story of emancipation is at the core of her narrative. In bite-sized pieces, she talks about mental health issues, school bullying, and an abusive relationship, all of which have contributed to a wavering sense of self-worth. The way these issues are woven into different parts of the interview narrative gives a sense that we are not being served a previously constructed and thought-through narrative, but rather a story that unfolds in the interview with the help of the interviewer (a woman of similar age and ethnicity). A.-S. N. reflected that having the timeline present in the interview allowed Tina to reflect on previous episodes or moments in her narrative that connected to her ongoing narrative in ways that were not evident at first. They permitted a possibility to "connect the dots" of the interview narrative. Here, the combined structure and openness of the interview methodology allow Tina to stray from the core theme of the interview (her science engagement trajectory), while simultaneously pulling different aspects of her story together, through the marking of them on the timeline. As such, we would argue that the timeline methodology can function as empowering for the interviewee in that it allows them support in telling one version of their life story.

B. Stories and relationships (L. A.)

The second case explores life-history interviewing using an intersectional narrative-inquiry approach [17] and deep relationship building which enabled the coconstruction of stories of experiences over time between the researcher and the participants. These moments are analyzed using an intersectionality lens [18,19] to yield a story depicting the transnational experiences and identity intersections of a young woman in physics in various geo-sociopolitical contexts.

In the next paragraphs, a reflection is provided on two interrelated aspects of the work carried out as part of a single case study in the context of physics identity research: stories and relationships. The case study explored the life events that Amina (pseudonym), a young Muslim woman, immigrant in Western Europe experienced throughout her trajectory in physics and the ways in which her multiple identities intersected [8]. Amina shared her story with the researcher as part of a three-yearlong project and following a close friendship she developed with L. A., the researcher, both newcomers to a country in Western Europe.

The story documents Amina's journey to becoming a physicist, her persistence and failures, and her sense of never really belonging in physics throughout her studies and career. The story also highlights another important issue; Amina is not just a woman physicist. Amina is also a Muslim, a Kurdish-Turkish migrant to Western Europe, a daughter, a sister, a wife, a mother, and a friend. The intersection of these identities has positioned her as an outsider in physics, which has historically been a largely white, male field, and a "culture of no culture" [20]. A first-person narration by the researcher follows from now on that best exemplifies this relationship building that afforded the cocreation of Amina's life story.

Amina completed her bachelor's and master's degrees in the western part of Turkey, considerably less conservative than the eastern part, where she had to take off her hijab every morning when entering a secular university. In this context, as a religious student, she was minoritized. After graduating from university, with the support of her parents, Amina moved to the United States to pursue a Ph.D. in physics, where she lived for six years. When she graduated, she moved to a country in Western Europe to take up a teaching position in physics at a higher education institution, where she identified as a minority because she is a young Muslim woman in a predominantly white, Judeo-Christian, masculine, and heteronormative context.

Embarking on this research project, I (L. A.) brought in my methodological "messes," my ethics of *being with* the participant, as well as my own life story as well. These are elaborated on in the methods section of previous publications [8,21]. I had all these with Amina, throughout our close friendship that was formed a year and a half prior to the beginning of the study, and which was reinforced through this study. Despite our main difference in terms of religion, Amina and I shared similar experiences related to crossing geographical borders as well as navigating through similar cultural contexts. We bonded through these experiences as well as our desired futures. Our conversations typically took place at cafes, over dinners at my place, as well as through long walks. Dichotomies of researcher or participant, and friendship or research were always very blurred if ever existed. These conversations were typically unstructured and ranged from talking about our everyday experiences, trying to find our place in a new cultural context and male-dominated working environments, negotiating between the Mediterranean and Western European cultures, complaining about the weather, and trying to get some sun, finding good baklava, to cooking the same dishes and claiming it our own, ethnically. In a way, these conversations provided the space for our identities to come together and serve as resources for coconstructing and telling Amina's life story in physics.

Overall, the findings illustrated that Amina encountered different kinds of obstacles, barriers, difficulties, and conflicts throughout her life and professional career that were associated with her place in or better said mostly out of physics. These cultural narratives were connected to social- and gender-science stereotypes, her ethnic status as an immigrant, conflicts related to religion, and difficulties related to working in a male-dominated, Judeo-Christian context. Moreover, the analysis of the stories indicated that, as a learner of science, Amina had a strong science identity throughout her schooling and university years. She identified as a competent learner of physics during her childhood and throughout her university studies and she performed specific social performances of relevant scientific practices (e.g., taking a leadership role in the lab). Amina recognized herself as a successful physicist and she was also recognized as such by others (i.e., a female religious teacher, family members) at the time that she entered graduate school. As a physicist in academia, in Western Europe, her science identity was challenged because of various experiences that caused her to feel (in her words) as "*being a constant outsider*". More specifically, her science identity started to weaken since she was *not* recognized as a physicist by her academic and social community, and instead, she was assigned various other undesired identities.

In the next few paragraphs, I reflect on how stories and the relationship I had formed with Amina manifested in the methodology and shaped the outcomes of the research. My purpose is not only to highlight the value and potential of a life-story approach in exploring identity-related questions in the context of physics but to also argue for the imperative of forming close and ethical relationships (*being with*) with the participants when attempting to pursue a life-story project.

The idea that physics identity is a life-story project resonates with sociocultural theory that emphasizes the role of place and time in its formation and harmonizes with the conceptualization of identity as situated, cultural, and always in the making and on the move. The value of treating physics identity as a life-story project lies in the potential of gaining an intimate understanding of the stories that individuals carry with them as they (dis)engage with physics and how these stories are nested in larger narratives, for example, sexism and racism. By adopting a life history perspective, emphasis was placed on the historicity of Amina's physics identity or how identity was (re)shaped over time within various kinds of contexts.

In this single case study, stories served as a methodological approach, as well as the outcome of this approach: a storied-based approach to eliciting stories situated in specific places and time periods that shaped how Amina viewed herself as a physics person and how she was recognized by others. Essentially, these stories were coconstructed through our multiple interactions and conversations. They were prompted through pictures, at times featuring images of delicious main dishes and desserts, first lines, and opening paragraphs, while we took turns to add pieces to the story related to both of our life experiences. These stories shed light on various events, experiences, interactions, struggles, failures, successes as well as relationships that were instrumental in Amina's becoming a physicist. As such, they invite us to speculate what could have changed if events, experiences, and relationships were different and open up the possibility of thinking of what could have been done differently to support Amina's journey of becoming a physicist.

The process of making meaning out of these stories included the following procedures that are aligned with narrative-based research: holistic-content reading of our conversations, chronologically plotting of the elements of the story, follow-up conversations as a way of collaborating and cocreating with Amina and developing the story through structural analysis. This structural analysis was guided by the following questions: What is the context (time-place)? Who are the main characters? What are the main events or actions in the story? What are the outcomes? How has the participant positioned herself in the story? [22] In doing so, I aimed to explore not only events but also how those events were connected to time and place, relationships, and interactions with other people as well as the inextricable relation between past experiences and desired futures. This is precisely where the value of a story-telling approach and structural analysis lays within. To examine how Amina's different identity intersections shaped these stories, an intersectionality lens to the analysis was deemed necessary. In Amina's words, as a minority in these multiple communities, she feels consistently like "a constant outsider" who must navigate through unfamiliar contexts, institutions, norms, structures, and systems where she finds herself in a nonprivileged and powerless position. Such complex social positioning can only be examined through intersectionality.

This single case study presents my narration of Amina's narrative or life history in relation to physics, which consists of a series of stories that took place throughout her life, starting from her childhood and cutting through the first years of her career as a physics university instructor. My narration is, in fact, a selection of small stories that construct and reconstruct her life story. As any other narration, this one as well is bounded by my subjective interpretations of Amina's story. It is, therefore, likely that through my subjective interpretations, I have highlighted certain identity negotiations, experiences, events, and relationships over others. Hence, this life story presents itself as a subjective, open to interpretation, and boundless project. This is precisely where the limitation of a life-story approach lies within as well as its beauty: it is a living project.

C. River of life interviewing (A. J. G. and R. E.)

The final case is of a first-generation Canadian woman who shared her navigations of in and out of school physics via a method known as the Rivers of Life [23]. Like the timeline method presented in case A, the river of life is a data generation method that positions the participant as a storyteller, wherein they get to determine the course of the interview. In this section, we offer a more detailed description of the Rivers of Life interviewing technique as it has not been documented in previous science education research, and it presents us with a method that draws on and incorporates elements of the methods presented in cases A and B. Therefore, we describe how we engaged participants in Rivers of Life interviewing, and we also present several examples of diagrams as examples of how participants respond to our prompts. In this life-history approach, the participant engages in a self-study, visual exercise prior to the interview to map out their trajectory into higher education physics and through their experience with physics. This method of eliciting life histories draws on the rich tradition of visual sociology and ethnography, in particular, the work of Harper's [24] photo-elicitation for interviews. In designing the river of life method for interviewing, we drew on Harper's suggestion that "images evoke deeper elements of human consciousness than do words" (p. 13), but also that relying on images can deepen the conversation and combat interviewer fatigue. Inspired by the timeline interview [14], we asked participants to take time before the interview to map out their life in and through physics as a river. Rather than coconstructing it in an interview, we asked participants to engage in this reflective activity on their own. Participants were asked to draw out their experiences with physics as a river, using metaphorical tools like rafts, rocks, rapids, and tributaries to discuss critical incidents and other moments that over time amount to a life in physics. The river drawing exercise prompts are detailed in the Supplemental Material [15].

Drawing their life as a river provides the participant an opportunity to describe their life events using images that might not otherwise come through in a verbal narrative account alone. As described in case B, the river enables prompts (images and metaphors) to elicit memories that come together as a story. Hoppe and Holmegaard [25] suggest that arts-based methods such as the river exercise permit the expression of nonverbal language. The use of metaphors or images to describe events can reveal how emotions are constructed alongside events in the retelling of life histories. Whereas the timeline uses a sticky note or writing on a line to document an episode, the river prompts the participant to consider an appropriate metaphor for that memory, which can elicit emotions. When memories and emotions are portrayed as images, they create the conditions to elicit meanings that may be hard to verbalize because of social norms. The elicitation interviews are then quite open ended and begin with the participant guiding the interview as they take the interviewer through their river drawing, narrating aspects of their lives in physics that they deemed to be significant. The interviewer can probe these memories, and in the course of the interview, often related episodes or incidents arise that were not depicted on the river drawing. Thus, we intend for the river drawings to create a "jumping-off point" from which the researcher and participant can create dialogue. Dialogue in the elicitation interviews begins on the participants' terms, with them defining the beginning and course of the journey, but like the methods described in case A and B, the narrative then emerges as a coconstruction between participant and interviewer as the story is elaborated during the interview.

In our interviews, we used the river of life to elicit descriptions of events that have influenced participants' life trajectories into and through physics. Participants were able to choose the direction of the story and the features that were highlighted, but probing questions from the interviewer permitted deeper exploration and questions about stories that were perhaps missing from the timeline. How the rivers were drawn was entirely up to the participant, as were the decisions about when and where the story or river started and when and where it ended. What emerged were several different interpretations of the activity. Figure 2 depicts the flow of rivers that participants constructed. Some rivers were vertical rather than horizontal. This was of interest to us, as it indicated less a passage through time and more a deepening of engagement. Adriansen [14] has discussed "learning journey" timelines that start at the bottom and move vertically upward like the roots of a tree moving up into diverging branches. Some participants [e.g., Figs. 2(a) and 2(b)] drew their rivers horizontally, or diagonally, and depicted many tributaries or log jams. Others (e.g., Fig. 3) tracked their rivers downward to indicate the flow of time (and water) and the various bends and turns that this takes as the water moves across rapids and barriers. The river started small and then gained size and volume as the student depicted their learning journey into higher education. The thickness of the river was a metaphor for their engagement in physics. Of note is that the river always carried on as more or less the same body of water. There were never depictions of journeys that changed course entirely or led into larger bodies of water. In this way, it appears that the "center holds" for these participants. By this, we mean that the rivers, while depicting many other tempting branches or paths, seemed to portray a coherent narrative (where looking back is coherent with what is ahead) [5]. Continuity and coherence in identities are expected because individuals make use of previous experiences to construct new narratives in new contexts because there is a strong expectation of coherent selves [7]. As a method to elicit narratives that yield stories about recognition, competence, and performance, the river provides visual cues for all of these. Participants often depicted people on the banks of the rivers who were "meaningful others" [17] engaged in their journey.

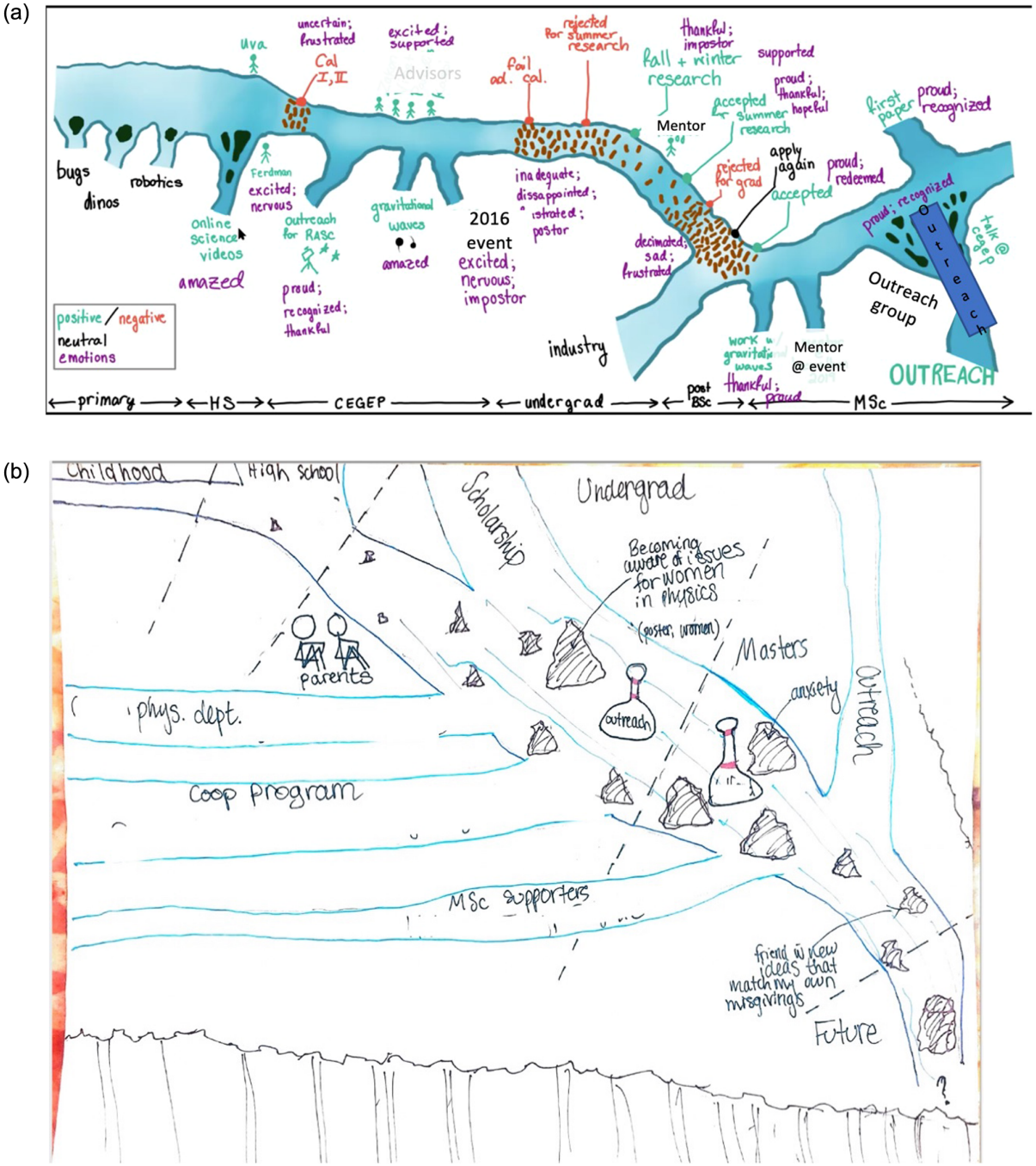

FIG. 2. (a) and (b) Rivers of life drawings collected from participants.

They also depicted events that shaped their trajectories, for example, one participant featured the 2015 detection of gravitational waves as a key event on their river diagram as a tributary, while others referred to sociopolitical events like the pandemic and the concurrent rise of violent racially motivated attacks as a jam in the river. Participants narrated identity positions into their rivers, which elicited stories about Whiteness or racialized identities in relation to physics. Some participants came to the interviews prepared to discuss injuries or other life events that marked the course of their rivers. These were depicted as boulders or rapids to navigate. Others indicated log jams as conflicts with the discipline where they longed for more meaningful impacts of their work or struggled with misgivings in their field. For this publication, we have redacted many of these depictions from the individual river diagrams shown in Figs. 2(a), 2(b), and 3 to preserve the participants' anonymity.

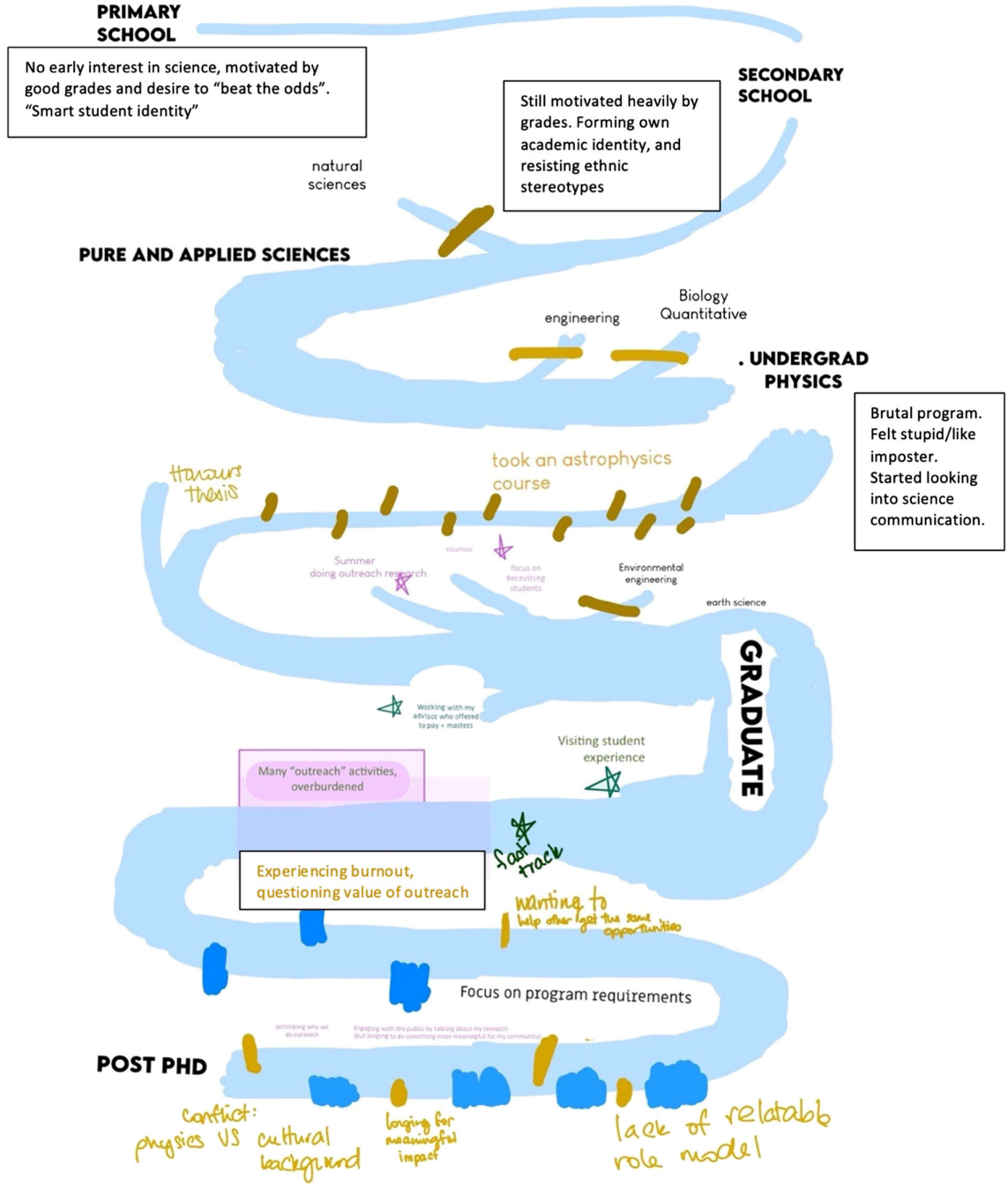

FIG. 3. Eloise's river of life drawing.

We conducted Rivers of Life interviews with five graduate students. As our participant group is very small, to preserve confidentiality, we will present the story of one woman of color in physics through fragments of stories [26] from her elicitation interviews, while following a partially redacted river of life drawing. Eloise (pseudonym) is a graduate student in physics who is nearing the completion of her doctoral degree at the time of our interview. We invited Eloise to participate in our study investigating physics students' engagement in "science outreach" programs. Eloise and the other participants in the study were all highly engaged in science communication and public engagement in physics and volunteered to be interviewed for our study which sought to investigate the impact of informal or public engagement on physics students' identity trajectories. We have chosen to present Eloise's river drawing and data as illustrative of this method because her drawing was presented with the most clarity for publication, and because she used numerous geophysical metaphors that we could discuss in relation to data. Furthermore, although we have redacted much of the written information that could compromise her identity,

the way that Eloise drew her river still permits us to describe major life events in a confidential way. We present Eloise's River of life drawing to illustrate how the exercise can bring aspects of physics experiences to the fore that may not have been elicited in interviews alone, and from our perspective, elicited emotions that would not have been probed for in an interview guide had Eloise not reflected on these experiences before coming to the interview. Eloise's river of life drawing (Fig. 3) makes use of numerous geophysical representations (wide or narrow rivers, barriers, waterfalls, tributaries) to illustrate her experiences in physics over time and across places. In what follows, we describe how Eloise uses geophysical metaphors in her drawing to discuss events that make up the river of her life in physics. For this reason, most written descriptions of events, episodes, or time periods on the figure have been removed or abbreviated (square text boxes), as they are not relevant to this analysis.

1. Widening and narrowing

When drawing her river, Eloise (like others in the study) depicted engagement with science, or "feeling like a science person" as a narrowing or widening of the river. This is seen in the early stages of her river drawing, where Eloise draws a very thin and uneventful stream from elementary school through to secondary school. During this time, she discusses struggling to push against stereotypes associated with her ethnicity and a deliberate disengagement with science as a result. We then see a bend in the river and increasing interest and engagement in science in late secondary school, and Eloise describes gaining confidence in science and finding ambitious friends in science courses during university preparation courses at college. These influenced her to continue in sciences and in physics, where she was recognized as being "smart."

2. Blockages and obstructions

Eloise enrolled in a physics program for her undergraduate which she then describes as a "brutal experience." This is depicted in the river drawing as boulders blocking the flow of the river. Eloise describes barely sleeping and experiencing her challenges with coursework as a threat to her identity, constantly asking herself if she is smart enough to continue. This is also seen as a narrowing of her river, as she contends with the realization of an increasing gender disparity in physics (with the numbers of women dwindling over time) and what Eloise describes as a persistent discourse that the courses were "weeding out people who were unworthy of being in the program." Eloise describes noticing that many people who are in physics programs are not first-generation students and these students had more "know-how" outside of the classroom. Eloise suggests that many students had an awareness of research opportunities and possibilities to develop research skills (or even knowledge about what research was) which was not something that was easily accessible in coursework. She describes this moment in her river as impacting her identity in a negative way "So that's why at this part of the river, it's starting to get narrow, because I think my identity as a physicist was, was very bruised."

3. Waterfalls

However, those blockages caused students to come together and work out how to teach themselves and learn collectively. This is where Eloise described getting involved in "science outreach"—opportunities to engage in science programming in schools and other forms of public engagement. This led Eloise to travel abroad as a visiting student to work in science communication. Eloise thrives in these projects, depicted by a widening of the river and a sharp bend. More opportunities arise and she describes these as waterfalls flowing into her river "opportunities flowing in." These lead to recognition in the form of prizes and more invitations to do outreach, even a project abroad. The waterfalls are then abundant, and the river carries on with a steady flow. Waterfalls bring in more opportunities, alongside increasing frequent obstructions. However, the river continues its flow despite the obstructions, indicating a resilience in her identity work.

The river ends with alternating waterfalls and blockages—forming rapids in the river through which Eloise describes the struggle to balance her first-generation and cultural identity with the cultural expectations of the field. For example, she describes conflicts with expectations to leave one's home and family and pursue multiple postdocs or balancing a desire to engage in physics research and also make a meaningful impact on society. These struggles come at the same time as multiple opportunities like awards and potential new positions, illustrating the vicissitudes of graduate student life, especially toward the end of degrees. In the interview, Eloise tries to capture how it feels to navigate these rapids without a relatable role model in her degree program and ends the river exercise with the following quote:

> "I think the lack of relatable role models has just made me question whether I was supposed to do this. And another silly thing, or maybe it's not super silly, is one of the, you know, father figures or just, just like men figure that I grew up in my life with was my dentist that I've seen since I was a little girl. And so, he's seen me grown up. And at some point, I went to get my teeth cleaned…. And so, when I told him, I was a [physicist], he was over the moon. And he basically told me about the time where he was doing a math degree and had been considering pursuing some, some similar type. And then, and basically was like, you know, I came to Canada, and we had about like, a T shirt and a pair of pants. So, what was I

> going to do with a math degree? So, he decided to reorient in dentistry. But then it made me question whether this was even a career that I could consider being the first like, university graduate."

We will return to this memory in the discussion as it raises questions about what we are trying to understand when we probe students' experiences in physics. The river exercise provides a means for participants to reflect not just on their experiences in physics programs, classes, or learning experiences but also on their life circumstances and stories and the stories around them that shape their own journeys.

III. DISCUSSION

We have presented three perspectives and approaches to narrative research that brings into relief the importance of understanding life histories in physics from the perspective of those who are minoritized in the field. We offer that narrative research, and the various methods that we have presented to elicit life stories have the possibility to help us to understand identity as a "dynamic process of *becoming* instead of a product" [8] (p. 323). As L. A. argues, this is an unfinished process and the stories we tell are likewise unfinished and open to change, reformation, and reification. While we advocate for deeper investigations into life stories (rather than simply experiences), we are cautious to suggest that stories yielded from interviews alone can render visible the personal and private aspects of experiences [27]. Life history narratives are data, which can be chunked, coded, thematized, fragmented, and retold just like any other form of data. As such, we have tried to suggest formats for eliciting stories that might permit some preservation of participants' experiences of the lifeworld. We argue that attending to the social and cultural contexts around narrated experiences is critical for understanding physics learning experiences in particular, as physics has so often been regarded as a discipline (and a learning and research environment) unaffected by culture [20]. Thus, understanding the experiences of minoritized students in physics means understanding how those experiences are not only responses to physics environments but also cultural narratives about physics, who can do physics, and whether physics is for "someone like me" [28]. Furthermore, we contend that attending to the narratives of minoritized physics students and researchers is critical to understanding and dismantling current notions about what it means to be a physicist or to do physics and exposing how these notions are rooted in settler colonial and racialized histories of science [29]. The narrative excerpt in case C is an example of how attending to what is happening around physics experiences can help us to understand decisions participants make or struggle to make. Eloise's story of her visit to the dentist emerges as a nonphysics experience that is meaningful to her own reflections on "what am I doing in physics?" Similarly, Tina's timeline included stories of being in an abusive relationship and experiencing bullying. Amina's narrative included stories that showcase how the intersections of her multiple identities that deviate from the culture of physics caused misrecognition by others across time and places. Her story highlights the need for a longitudinal and intersectional approach to exploring physics identity that promises to shed light on how place and multiple other identities shape physics identity.

A. Researcher positionality

As we collaborate with participants to coconstruct life-history narratives in and through physics, we are conscious that, as researchers, our responsibility is to ensure that participants' stories are told in a trustworthy manner and also that our interpretations are situated in our own histories, positionalities, and standpoints. Harding [30] argues that standpoint projects are "productively controversial" in that knowledge produced in such projects is socially situated. We regard this as a strength, but we also recognize that this compels us to articulate the positions from which we coconstruct knowledge with participants whose lives inform our research. We thus stress the importance of considering researcher positionality in relation to the stories that we coconstruct with participants, as a way to counter the epistemically privileged "view from nowhere" [31]. As researchers interested in life stories, we advocate for research that is done in relationship with participants [32]. For us, that has meant various ways of ensuring that participants' voices are foregrounded in data collection. We argue that the various methods we have described here provide possibilities for researchers to ensure this. We illustrate this with an example. When reviewing the transcripts from Eloise's interview, A. J. G. noticed that there were several moments in the interview when she shared stories from her own life experiences as a way of building rapport or at times solidarity with the participant. As a second-generation Canadian, A. J. G. shared examples of her own family's history of transnational migration and the resultant privileging of colonial science and its attendant high-status occupations. A. J. G. shared this at the time because it seemed appropriate to acknowledge the shared history of parental pressures that are rooted in similar expectations. However, the author's positionality in the interview as a white second-generation Canadian and a researcher in the relationship makes it easier or less risky to share these experiences and histories and in the interview could easily divert the attention away from the story Eloise was sharing. The river drawing, as a heuristic around which to conduct the interview, was helpful in this regard because it continually oriented the focus back to Eloise and her story. She could pick up where we left off, when the strands of conversation led us astray and petered out, and then she could decide what the

next most important thing was in her story. Having a map, as it were, of her life story, helped to ensure that the researcher's interests were not prioritized over the participant's story.

To elicit stories that detail experiences that thread in and out of physics and which connect social, cultural, personal, and historical experiences with physics learning, all three of these cases illustrate the importance of a grounding artifact. For Tina, the story was elicited through the coconstruction of the timeline with A.-S. N. Drawings, sticky notes, arrows, and notes indicate a movement back and forth, as probing questions and Tina's narrative move together to create a timeline of her experience. For Amina, the story is elicited over a much longer time, through many encounters, and prompted through pictures, dinners, desserts, the bonds of a developing and deepening relationship, and the iterative writing and rewriting of her story. For Eloise, the reflective river drawing exercise and the use of metaphor grounded her story to create a rich narrative where twists and turns were narrated as a journey across time and place, captured in a drawing. In all cases, the researcher is participating not just as an ear, but as an interpreter to put together the story of how the moments that may seem disparate, or maybe unconnected, add up to a life in physics. Member checking or eliciting the meaning in stories is an iterative process and a relational one. What is understood initially as an event might be reinterpreted as meaningful in new ways after reflecting upon it through a river of life or timeline activity or after many discussions about its meaning in dialogue with the researcher.

B. Researcher responsibility

We recognize that as *mediators* for participants' stories [8], we must take care to preserve participants' anonymity. This is one of the greatest challenges of life-history interviewing, as stories are often collected over time and in depth with detail, among a small number of participants. Thus, collecting storied data from one department, for example, risks exposing the identities of those who are participating in the study. Despite involving participants in informed consent at the beginning of a project and ensuring that names, places, and identifying data will be removed, stories as data sources are still revealing. This is different from qualitative approaches that chunk or thematize data and present data excerpts as disembodied quotes. The life story approach to research demands that informed consent be a continual process with participants, where we constantly go back and ask if they are comfortable with the way their story is presented, or if there were information they would like to see removed or changed to make it less identifiable. We have struggled with this process as researchers, and at times have left out important pieces of stories that were critical to identity work, but too compromising to the participant. Leaving data unreported can be consequential for researchers hoping to engage in data-driven practices for change but attending to participant confidentiality is necessary to ensure comfort and to lessen the risk of recognition and possible negative consequences.

C. Reflections for selecting approaches to narrative inquiry

Finally, we have presented three different approaches to narrative inquiry, highlighting the different methods used in different contexts, and the role of the researcher in each approach. We suggest that, like all research methods, reasons for selecting an approach to conducting life-history interviews very much depend not only on the research context and research questions that guide the study but also on the ability of researchers to invest both in time as well as emotional labor in work that requires an insider positionality. A. T. D. and A.-S. N. present a method that was useful for collecting stories of experience over time from many participants (20+), from a single in-depth interview. To collect stories from numerous participants means compromising on the time invested in collecting those stories. On the other hand, L. A. described collecting data from a single participant, over time, through a friendship that developed over research meetings, dinners, and social events. This required allowing time to deviate from her research goal in order to engage in extensive empathetic listening and offering emotional support, which in turn would enable the possibility of establishing rapport. However, that was extremely time consuming. Typically, a three-hour conversation would yield one-hour of research data relevant to the study. A. J. G. and R. E. presented a method that requires a few participants to spend time ahead of the interview to reflect and memo and engage in art making on their own and then unpack that creation over the course of several interviews. To compensate participants for this time, researchers were remunerated both for the time spent on the river of life activity and also for their time spent in interviews, which were themselves often lengthy and repeated. Each of these approaches requires significant investment on the part of the interviewer but varying investments of time by participants. Limitations on research funds or research ethics restrictions may impact whether participants can be remunerated for their participation in a study. This may cause a researcher to choose an approach that does not demand a significant investment of time, whereas possibilities to remunerate participants may encourage more in-depth investments into the research process. We are aware that interview research can sometimes feel extractive for participants but that methods which involve participants as coinvestigators can be laborious and place extraordinary demands on time. In postsecondary physics contexts, this can be particularly challenging, where students and faculty already have considerable demands on their time.

Participant "buy-in" is an important consideration when selecting a method for narrative inquiry, and our decisions to take these various approaches were certainly informed by

our sense of this and the existing relationships we had with both the participants and the institutions they work in. For example, L. A. presented a research study that required a "total insider" status (i.e., sharing multiple identities as well as experiences) which besides its obvious benefits, also comes with the risk of never being able to gain this status and emotional challenges related to managing boundaries. Boundaries were necessary to maintain social and emotional distance while at the same time engaging in self-disclosure for the purpose of attending to power. Specifically, a challenge for L. A. as a researcher was the emotional investment in this work at the intersection of negotiating relationships: the relationship between the researcher and the participant, the relationship between two people engaging in disclosing personal experiences, and the potentiality of a new, yet *boundaried friendship*.

This reflection on challenges related to emotional labor and time investment is offered as an invitation for researchers to engage more thoroughly with questions of emotional intimacy and emotional embeddedness connected to carrying out life-history research that requires a total insider status. Relatedly, research proposals which demand the development of relationships with participants that are grounded in mutual care and trust may be challenging to put into words for the purposes of grant applications. This kind of data collection emerges in the meetings and relationships developed between interviewer and interviewee. Thus, research ethics review systems need to allow for changes to the method to be made along the way, for example, to permit deviations from proposed interview guides.

IV. CONCLUSIONS

In this article, we have argued that narrative methods, such as life-history interviewing, have the possibility to yield rich insights into the identity work of students and researchers engaged in physics learning and knowledge production. We presented three different approaches to gathering life-history data that can tell stories not usually available in quantitative or even larger-scale qualitative studies. Rather, we present a perspective on data collection where less is more, and we advocate for close and detailed explorations into participants' life histories that can only be told with interviewing methods that take time, involve artifacts other than the microphone, that involve the coconstruction with researcher and participant, and that depend on the development of trusting relationships. If we are to continue to learn about and address the various ways that physics perpetuates inequities, especially for women and racialized people who engage in physics practices, we need to understand how this culture impacts the multiple identities people bring to physics and how these intersect with the "culture of no culture" in physics [20]. To understand this complex identity work, more in-depth analyses using methods such as life histories are needed. The methods presented here are just a few of many promising qualitative and arts-based [25] approaches to generate complex pictures of the sociopolitical dimensions involved in becoming physicists.

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