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Beyond performance, competence, and recognition: forging a science researcher identity in the context of research training

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Abstract

Background Studying science identity has been useful for understanding students' continuation in science-related education and career paths. Yet knowledge and theory related to science identity among students on the path to becoming a professional science researcher, such as students engaged in research at the undergraduate, postbaccalaureate, and graduate level, is still developing. It is not yet clear from existing science identity theory how particular science contexts, such as research training experiences, influence students' science identities. Here we leverage existing science identity and professional identity theories to investigate how research training shapes science identity. We conducted a qualitative investigation of 30 early career researchers—undergraduates, postbaccalaureates, and doctoral students in a variety of natural science fields—to characterize how they recognized themselves as science researchers.

Results Early career researchers (ECRs) recognized themselves as either science students or science researchers, which they distinguished from being a career researcher. ECRs made judgments, which we refer to as "science identity assessments", in the context of interconnected work-learning and identity-learning cycles. Work-learning cycles referred to ECRs' conceptions of the work they did in their research training experience. ECRs weighed the extent to which they perceived the work they did in their research training to show authenticity, offer room for autonomy, and afford opportunities for epistemic involvement. Identity-learning cycles encompassed ECRs' conceptions of science researchers. ECRs considered the roles they fill in their research training experiences and if these roles aligned with their perceptions of the tasks and traits of perceived researchers. ECRs' identity-learning cycles were further shaped by recognition from others. ECRs spoke of how recognition from others embedded within their research training experiences and from others removed from their research training experiences influenced how they see themselves as science researchers.

Conclusions We synthesized our findings to form a revised conceptual model of science researcher identity, which offers enhanced theoretical precision to study science identity in the future. We hypothesize relationships among constructs related to science identity and professional identity development that can be tested in further research. Our results also offer practical implications to foster the science researcher identity of ECRs.

Keywords Science identity, Research training, Autonomy, Career decision-making, Epistemic involvement

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Introduction

Science identity, or the degree to which one recognizes themselves as a "science person", is a major interest of STEM education researchers (Carlone & Johnson, 2007; Gee, 2000), and for good reason. The rich history of science identity scholarship shows that how students see themselves in relation to science matters. Students with robust science identities are more likely to intend to pursue a career in science (e.g., Chemers et al., 2011; Estrada et al., 2011; Robnett et al., 2015), and to follow through on these intentions (Estrada et al., 2018). Yet, while the importance of supporting students' science identity development is broadly recognized, we are still developing knowledge about the meaning of science identity and specific factors that affect its formation and evolution.

The prevailing science identity model

Carlone and Johnson's (2007) canonical study of science identity established a model of "being a science person" that encompasses three factors: performance, competence, and recognition. This model posits that individuals who see themselves as scientists **perform science**—meaning they use the tools and language of science, **feel competent**—meaning they perceive themselves as knowing and understanding science content, and **are recognized**—meaning they see themselves as science people and perceive that "meaningful" others also see them this way.

Hazari and colleagues built upon this model through a series of studies examining science identity in a range of STEM disciplines (Ambrosino & Rivera, 2022; Cribbs et al., 2015; Dou et al., 2019; Godwin et al., 2016; Hazari et al., 2010, 2013; Mahadeo et al., 2020). They found that interest in physics and recognition by others as a "physics person" predicted undergraduates' identifying as a physics person (Hazari et al., 2010). Additional research confirmed the importance of interest and recognition by others in mathematics and physics identity (Cribbs et al., 2015; Godwin et al., 2016). These studies also revealed that performing work in the discipline and feeling competent in doing work were integral to science identity because students must perform to be recognized by others and feel competent in order to express interest (Cribbs et al., 2015; Godwin et al., 2016). Collectively, this research enabled refinement of the science identity model to comprise **interest**, **performance-competence**, and **recognition by others** (reviewed in Potvin & Hazari, 2013). The contributions from Carlone and Johnson (2007) and Hazari and colleagues generated a model that guides much of the current research on science identity (e.g., Lockhart et al., 2022). We refer to this model as the **"prevailing science identity model"**, which encompasses interest, performance-competence, recognition of self, and recognition from others.

Theoretical limitations in the prevailing science identity model

The prevailing science identity model has afforded broad insights into the science identity of students, yet even developers note that it needs further refinement (Carlone & Johnson, 2007; Hazari et al., 2020). For a full accounting of the limitations in the prevailing science identity model, we refer readers to recent discussions of science identity theory (e.g., Danielsson et al., 2023; Lockhart et al., 2022). Here, we highlight just three specific opportunities to enrich the prevailing science identity model.

First, although the prevailing science identity model is useful for conceptualizing what dimensions encompass "science identity" in a variety of settings (e.g., formal and informal science settings, K-12 and higher education, classrooms and research training experiences), it lacks descriptive power to theorize how science identity might change when individuals are embedded within a specific science setting (Danielsson et al., 2023). For example, the prevailing model does not account for contextual influences, such as how opportunities to grow in interest, performance-competence, or recognition might differ between the context of an introductory biology laboratory course and a biology research training experience. The qualities of these science experiences are likely to be quite different in terms of what students do, with whom they interact, and whether and how they engage in activities that facilitate their own recognition of self as a science person and recognition from meaningful others. To understand science identity and its contextual influences, science identity should be examined with respect to its context.

Second, the prevailing science identity model is arguably removed from established identity frameworks that delineate various identity meanings, which precludes precise definitions about what identity is and what forms it can take (e.g., Danielsson et al., 2023; Lockhart et al., 2022). For instance, identity theory (e.g., Burke & Stets, 2022) conceptualizes identity as the constellation of meanings someone makes for themselves about who they are. Identity theory considers any individual's identity to possess several simultaneous "bases". These bases include the "person" ("me", or the characteristics that makes someone unique compared to other people), the "role" ("me as role", or the expectations someone can assume when functioning in a social group), the "group" ("we", or the social group someone sees themselves as part of), and the "social identity" ("us", or the demographics that society uses to categorize people, such as citizenship, race, ethnicity, gender, class, etc.). Although bases of identity can function simultaneously within a person, context imparts an effect. For example, while person-level identity is thought to persist across situations, role and group identities are thought to be most salient when someone is functioning within a certain group and interacting with people embedded within that group (Burke & Stets, 2022). The prevailing science identity model has been theorized primarily at the person- and group-levels (Hazari et al., 2010), with some attention to social identities such as race and gender identity (e.g., Carlone & Johnson, 2007; Hazari et al., 2013). Yet, the model does not attend to role-level identities or theorize about the contextual influences of group-level identity.

Finally, the prevailing science identity model is disconnected from knowledge and theory regarding how identities evolve in professional settings. Some science students seek out research training in pursuit of a science research-related career. They join a group of science researchers who function as "professionals", as "an organized group" that "holds knowledge with economic value when applied to societal problems" (Pratt et al., 2006, p. 235). As a result, their science identities may take on qualities of a professional identity (a group and/or role identity). Research on professional identity indicates that the work individuals do, their perceptions of how the work is done, and the people with whom they interact while doing the work all influence how they recognize themselves as professionals (e.g., Ashforth & Kreiner, 1999; Ibarra, 1999; Pratt et al., 2006; Wrzesniewski & Dutton, 2001). We expect that similar aspects of a professional research setting influence how science students come to see themselves. However, these factors, are not yet specified within the prevailing science identity model.

With these theoretical limitations in mind, we sought to generate a refined science identity theory by conducting a qualitative study of science identity in the context of science research training experiences. We elected to focus on research training experiences because of their prominent role in preparing the next generation of science professionals (National Academies of Sciences, Engineering, and Medicine, 2017). Below, we provide a high-level overview of what is currently known about science identity in research training.

Science identity in research training experiences

Research training experiences in higher education are an important venue for students to explore interests in science research and, if they desire, to train to become a professional researcher. Undergraduates who participate in science research report learning to think and work like a scientist, increased confidence in their ability to carry out research tasks, and stronger identification as a scientist (Adedokun et al., 2013; Estrada et al., 2011; Frantz et al., 2017; Hernandez et al., 2018; Robnett et al., 2015; Thiry et al., 2011). Similarly, studies of science identity among postbaccalaureate and graduate students show that students can further identify as a science person after engagement in research training experiences (e.g., Gazley et al., 2014; Maton et al., 2016; Remich et al., 2016). Many of these studies treat research training experiences like a singular experience, with little or no attention to the features of a research experience that may influence particular science identity outcomes. However, it is becoming increasingly clear that aspects of one's research training can and do impart effects on science identity (Camacho et al., 2021; Goodwin et al., 2022; Limeri et al., 2019; Remich et al., 2016; Robnett et al., 2018; Rodriguez et al., 2022; Thiry et al., 2012; Tuma et al., 2021).

Multiple studies have revealed that research mentors can influence students' science identities (Alston et al., 2017; Atkins et al., 2020; National Academies of Sciences, Engineering, and Medicine, 2017; Robnett et al., 2018). For example, undergraduate researchers who are mentored by both a faculty member and a graduate or postdoctoral researcher identify more strongly as a scientist than those with only one mentor (Aikens et al., 2016), but the mechanism of this effect has not been delineated. Thompson and Jenson-Ryan (2018) found that faculty members who mentor undergraduates in research may under-recognize undergraduates as "science people" when students do not conform to what faculty think of as a "science person". Faculty could mistake exposure to science and previous experience doing science as signs of being a science person. Particularly, faculty recognized students as "science people" if they expressed interest in science that related to what faculty were interested in, espoused science-related education and career aspirations, described science-related family attitudes and familial exposure to science, and had trained with other prominent researchers. Notably, these traits reflected students' cultural capital, or "an enculturated set of norms, values, and preferences" (Thompson et al., 2016, p. 962), rather than students' scientific abilities. Even when students recognized themselves as a science person, were highly interested in science, and had been working in a faculty member's research group for years, faculty could misinterpret or under-recognize a student's science identity if the student did not share the same scientific interests as the faculty and if the student engaged in science-related work that faculty do not consider to be "research". For some students, when faculty overlooked their science identities, they started to see themselves less like a science person. This study demonstrates that faculty who mentor undergraduates may misinterpret or under-recognize the science identity of undergraduate researchers, inadvertently discouraging undergraduates from continuing in research (Thompson & Jensen-Ryan, 2018).

Postbaccalaureate and graduate students' science identities are also affected by aspects of their research training experiences, including their interactions with research mentors. Research experience features, such as sufficient time to work on a research project and clear expectations from mentors, help support postbaccalaureate students' science identity development (Remich et al., 2016). Graduate students whose faculty mentors prevent them from making presentations at conferences take this as a sign their work is unworthy of recognition, potentially hindering a student's science identity (Tuma et al., 2021). These findings underscore how aspects of an individual's research training experience, such as how research is accomplished and interactions with others in the research environment, have the potential to affect their science identity. Thus, while it is known that research training experiences can influence students' science identity, theory about which aspects of research training experiences have influence and how this influence occurs has yet to be developed.

Rationale for our study

In this study, we aimed to further develop science identity theory to better account for the influence of context on science identity in research training experiences. We sought to understand how the ways in which research is done and with whom students interact while doing research influences their science identity. Given this goal, it was imperative that we collect a sufficient depth and variety of student data. We needed to develop rich knowledge about how students conceptualize their science identities and how students perceive factors of their research training experiences to influence how they see themselves in relation to science.

To accomplish this, we opted to interview a cross-sectional sample of undergraduate, postbaccalaureate, and doctoral students who had been engaged in a research training experience in the natural sciences for at least two months. We surmised that a cross-sectional sample could offer insights about variations in science identity across levels of research experience that were more nuanced than "more" or "less" like a science person. We collectively refer to our cross-sectional sample as "early career researchers (ECRs)" because research training at the undergraduate, postgraduate, and/or doctoral levels often serve as credential for being a "legitimate" scientist, or science person in research contexts. We opted to include students who span the continuum of research experience from undergraduate to doctoral levels because undergraduate research is generally considered a requirement for admissions into doctoral training in the natural sciences, with postbaccalaureate research as an alternative or additional avenue for gaining research experience in preparation for pursuing doctoral training (National Institute of General Medical Sciences, 2023; National Science Foundation, 2022).

Pratt's professional identity development model

Because we sought to enhance science identity theory in the context of research training, which we define as the stage of transition from being a science student to being a science professional, we identified a model of professional identity development that we could use in tandem with the prevailing science identity model (Danielsson et al., 2023; Greene et al., 2022). Specifically, Pratt and colleagues (2006) developed a model of professional identity development through a longitudinal study of medical residents engaged in primary care, radiology, and surgery training tracks, which we refer to as **"Pratt's professional identity development model"** or **"Pratt's model".** Pratt and colleagues (2006) found that the work medical residents were assigned and the professionals with whom they interacted affected their professional identity development. Like the prevailing science identity model, Pratt and colleagues (2006) found that performance-competence and recognition played an influential role in whether residents saw themselves as medical professionals. Beyond the prevailing science identity model, residents described how their professional identities evolved through two interconnected cycles: work-learning and identity-learning. Specifically, residents experienced **work-learning** as they engaged in assigned work and made assessments of how that work aligned to their notions of work in their field (i.e., what work primary care physicians, radiologists, and surgeons do and how they do it). In addition, residents received informal feedback through interactions with other healthcare professionals, which influenced their perceptions of their performance-competence through an **identity-learning cycle**. When residents found that the content and process of their work did not align with their notion of work in their field or when they saw themselves as incompetent, they reconceptualized their professional identity from being a doctor to being a "baby doctor", meaning that they were not yet a fully fledged physician even though they had completed their medical degree and were called "Doctor". Given the potential parallels between residency as training in the practice of medicine and research training experiences as training in the practice of research, we surmised that Pratt's model would offer a useful framework for elaborating theory of science identity in the context of research training.

Scope of our current study

We use theoretical insights from both the *prevailing science identity model* (interest, performance-competence, recognition of self, and recognition from others) and *Pratt's professional identity development model* (work-learning and identity-learning cycles) to investigate the science identity of ECRs (undergraduates, postbaccalaureate, and doctoral students) engaged in research training experiences. Our study was broadly designed to address the research question: how do ECRs recognize their science identity?

Methods

We designed our study to intentionally query science identity across undergraduates, postbaccalaureate, and doctoral researchers–early career researchers (ECRs)—in the context of research training. ECRs had completed at least 2 years of undergraduate education in a natural science discipline and been engaged in a research training experience in a faculty member's research group for at least two months. Because we wanted to understand nuance in the factors affecting science identity in research training, we conducted a qualitative study using semi-structured interviews. Our study was deemed exempt by the University of Georgia's Institutional Review Board (PROJECT00000870 and PROJECT00005063).

Participant recruitment

We recruited ECRs from several natural science disciplines (e.g., life sciences, geosciences, oceanography, environmental sciences) in spring 2022 using purposeful and snowball sampling. We identified potential participants by contacting research training program directors and principal investigators (PIs) associated with science and technology centers funded by the National Science Foundation. We emailed study information to potential participants and made brief presentations about the study during research group meetings. We asked individuals interested in participating to complete a screening survey about their current level of research training, program or institutional affiliation, research focus, demographic information, and contact information (see Additional File 1). A total of 57 individuals completed the screening survey. We invited 35 for interviews and 31 completed an interview: seven undergraduate researchers, seven postbaccalaureate researchers, ten doctoral students who had not yet advanced to candidacy, and seven doctoral candidates (see Table 1). One interview was not analyzed due to problems with recording quality, bringing the final sample to 30 participants. Participants were compensated with a $25 gift card. All participants provided informed consent.

Table 1 Summary of interview participant characteristics

	Sample size (*N* = 30)	Sample percentage
Research methods primarily used		
Bench (including fieldwork)	13	43%
Computational	10	33%
Both	7	23%
Institution type		
Private doctoral university, very high research activity	11	37%
Public doctoral university, very high research activity	17	57%
Private baccalaureate	1	3%
Public doctoral university	1	3%
Race and ethnicity		
Asian	4	13%
Black	2	7%
Latine	5	17%
White	16	53%
Indicating two or more races/ethnicities	1	3%
Prefer not to disclose	2	7%
Gender		
Nonbinary, transgender, or third gender	2	7%
Woman	14	47%
Man	14	47%

Interview protocol development

Our interview protocol was informed by findings of a separate and larger study of undergraduate research training experiences. In this study, undergraduate students were conducting life science research either as an intern in a faculty member's research group or as part of a course at one of nine universities across the United States. From open-ended survey data collected during fall 2020, spring 2021, and fall 2021 we made initial observations of ECR science identity that informed the questions of the semi-structured interview for the present study. Undergraduates responded to the prompt: "Has this research experience made you feel more or less like a scientist? Please explain." A total of 548 students responded to the prompt. Demographic characteristics of survey respondents are provided in Additional File 1. Student responses ranged from a few words to several sentences.

Initial observations of science identity

In survey responses, students described how they thought about their own science identities. Intriguingly, some responses differentiated being a "science student" from being a "researcher" or "scientist". We provide example responses in Additional File 1. These data suggested that undergraduates involved in research hold a more nuanced understanding of their science identity that is not fully captured in the prevailing science identity model. That is, instead of seeing science identity as an all or nothing identity, responses described gradations or nuances within student conceptions of science identity. With this insight in mind, we decided to focus our interview study on understanding *science researcher identity* in ECRs (as opposed to "being a scientist" or "being a science person"). We provide a detailed rationale for our choice of the term "science researcher" in Additional File 1.

In addition, students' responses showed that, when they assessed their own science identities, they considered aspects within and outside themselves as influential factors, such as the type of work they were doing in their experience and whom they were interacting. These initial observations helped us to select Pratt's professional identity development model as a supplement to the prevailing science identity model (Pratt et al., 2006). We anticipated that the "work-learning" and "identity-learning" cycles from Pratt's model would help us generate enhanced theoretical understanding of science identity. Thus, our initial observations from undergraduate open-ended surveys, Pratt's professional identity development model (Pratt et al., 2006), and the prevailing science identity model (Carlone & Johnson, 2007; Hazari et al., 2010; Potvin & Hazari, 2013) were used to develop our interview protocol.

We created an initial interview protocol with 12 questions to query ECRs about their research training experiences, their views of science researchers, their views of the work that science researchers do, and how they see themselves with respect to these views. We also inquired about how their views had changed, if at all, during their research training experiences. After the first few interviews, we added two questions to enhance elicitation from participants. Specifically, we asked participants to describe what, if any, work they did that they do not consider to be the work of a science researcher, and to explain how the culture of their lab group affects their science researcher identity, if at all. These questions helped us understand how ECRs perceived their work and the influence of their lab environment on their identities.

The final interview protocol included 14 questions. In Additional File 1, we share our final interview protocol and describe the rationale for each interview question so that readers can follow how we developed each question. The first author (M.A.P.) conducted all interviews over ZOOM™ using a semi-structured approach. Interviews lasted ~ 1 h.

Data analysis

Interview recordings were transcribed by a professional transcription service (Rev.com). We checked each transcript for accuracy and then we analyzed the interview data using a three-step process: initial coding, first-cycle coding, and second-cycle coding. First, we reviewed and made analytic memos regarding our impressions of the data with the research question and ideas from the science identity model (i.e., performance-competence, recognition of self, recognition from others, and interest) and the professional identity model (i.e., work-learning and identity-learning cycles) in mind. Then we iteratively developed our qualitative codebook.

Given the nature of the data, we used an eclectic coding scheme. We generated our initial codes using a variety of coding types: in vivo codes that use participants' verbatim language in the code name, descriptive codes that use nouns to capture the topic of the data segment, process codes or gerunds to summarize actions described in the data, and versus codes (Saldaña, 2016). Versus codes use dichotomous terms to reflect tensions individuals exhibit within themselves (Saldaña, 2016), such as belonging versus being excluded. We applied our initial codes to subsets of the data, and then met as a group to discuss the codes and associated data. During these discussions, we revised code definitions as needed and resolved any coding disagreements, producing the next iteration of the codebook. We applied the refined codebook to a new subset of data until the codebook stabilized.

With our stabilized codebook we then coded all data to consensus. At least two researchers applied the final codebook to all of the data and agreed on the application of the codes. At the end of this first-cycle coding process, we engaged in pattern and axial coding. We grouped the codes into larger, more abstract categories and themes while connecting them to the science identity and professional identity models guiding the study to address our research questions. First, we identified categories that summarized groups of related first-cycle codes. Then we grouped related categories into themes. As needed, we referred to existing literature sources and theories to make sense of the ideas emerging from the analysis. We found that we also needed to draw from elements of identity theory to interpret our findings coherently (Stets & Serpe, 2016). Descriptions of the resulting themes and sub-themes are included in Additional File 1 as a codebook that could be used for the purpose of replication.

In presenting our findings, we have lightly edited quote data for readability. Brackets indicate words added to enhance clarity. Ellipses represent words or phrases removed for conciseness. ECRs are assigned pseudonyms to protect confidentiality.

Trustworthiness and positionality

We endeavored to conduct and present a trustworthy qualitative study. We provide descriptions of how we collected data and highlight key analytic decisions and processes used to arrive at the themes and categories we propose (Tracy, 2010). Throughout the course of our study, we wrote analytic memos and detailed each decision we made along with our rationales for these decisions (Charmaz, 2006). We engaged in forms of triangulation by coding data to consensus with multiple researchers (Krefting, 1991). During our analysis, we presented our findings to researchers unfamiliar with our data corpus. We also engaged in a form of member checking by presenting a summary of our findings at a research meeting where ECRs in the study could view and comment on our results (Krefting, 1991). Questions and comments from these sessions helped us to clarify the findings and implications of our study as well as enhance their trustworthiness.

Another component of trustworthiness is acknowledging our positionalities that may influence how we interpreted our data (Suddaby, 2006). As a research team, we represent perspectives of faculty, postdoctoral researchers, graduate students, and undergraduate researchers familiar with research training experiences in the natural sciences. We engaged in bracketing as a tool to recognize our positionalities. Bracketing helps researchers identify and reflect on how their own experiences of the topic they investigate may manifest during the research process and complements analytic memo writing as a form of reflexivity (Tufford & Newman, 2012). Specifically, we wrote responses to the questions: (1) How do I see my own identity as it relates to science and/or research? (2) In what ways, if any, am I like "an insider" to the ECRs in this study? (3) In what ways, if any, am I like "an outsider" to the ECRs in this study? (4) How could my own views and perspectives influence data analysis? A summary of researcher responses to the bracketing exercise are provided in Additional File 1. By coding to consensus as well as clarifying and revising findings based on feedback from the member check and researchers unfamiliar with the data corpus, we strove to mitigate the effect of any individual researcher biases.

Limitations and transferability

Several aspects of our study have the potential to limit the transferability of our findings. ECRs volunteered to participate in a study regarding research training experiences and science identity. Thus, our sample is likely enriched with individuals with a relatively robust science researcher identity, or who may otherwise feel comfortable discussing their science identities. We purposefully selected ECRs to optimize the diversity of our sample in terms of amount of research experience, research type, race/ethnicity, and gender. Our sample is relatively representative of the national population of undergraduate and graduate students in terms of race, ethnicity, and gender (National Science Foundation, 2021).

We did not prioritize participant selection by institution type. Most of the ECRs are from institutions with very high research activity. ECRs must have completed at least 2 years of an undergraduate degree in the natural sciences to be eligible to participate in our study, which could mean that our findings may not reflect the experiences of first or second-year undergraduates. All data were self-reported by participants, no observations or interviews with research mentors or research group mates were conducted. During interviews, we asked participants about their science researcher identity directly. We explain our rationale in making this decision in Additional File 1. As detailed in our results, some ECRs reported not seeing themselves as a science researcher. In these interviews, ECRs further discussed what other identities, or roles, they use to describe themselves that do not necessarily relate to a science identity (i.e., being an artist, a parent, a partner, etc.). Because these data do not directly address our research questions, they are not included here.

Results and discussion

We structured our "Results and discussion" to align with the major themes and sub-themes that emerged from our qualitative analysis. We begin by detailing ECRs' science identity assessments. Then we describe how these assessments were shaped by factors from the prevailing science identity model and by work-learning and identity-learning cycles. As we present our findings, we connect our results to relevant literature. We close by synthesizing our findings in our emergent conceptual model and presenting the implications of our study and directions for future research.

Science identity assessments

In our study, early career researchers (ECRs) were presented with multiple opportunities to engage in what we term "science identity assessment". Science identity assessments occurred when ECRs considered how they viewed themselves with respect to being a "science person". We considered science identity assessments to reflect the science identity factor "recognition of self". When making these assessments, ECRs conceptualized science identity as having three forms, science student, science researcher, and career researcher, which relied on their views of the purpose of their daily work and the tasks typically executed by individuals at each level (Fig. 1). ECRs who recognized themselves as "science students" tended to call themselves science majors or science graduate students and saw the purpose of their daily work as learning about research or learning to conduct research. ECRs who recognized themselves as "science researchers" tended to see their daily work as addressing research questions or testing hypotheses. ECRs in our study described themselves as different from a "career researcher" because they perceived the daily work of career researchers to be securing funding, setting big-picture research goals, and mentoring a team of researchers. For example, Andrew indicated he saw himself as different from a career researcher, explaining:

> *If I can be called a science researcher and [my principal investigator (PI)] could be called a career researcher our lives look a lot different. [They're] managing the lab and keeping it afloat, doing a lot of administrative stuff, writing grants, reviews, keeping up with the literature, and looking at the things that [the entire research group is] doing and trying to synthesize, and know where everyone's at and have the big picture in mind... My day-to-day is just—I'm down in the weeds. I'm not worrying about trying to write grants... My job is pretty much [having research] questions that I need to answer.*

Like other ECRs, Andrew noted that his daily work differed from the daily work of his research advisor and thus he did not see himself as a "career researcher".

Performance-competence

ECRs' science identity assessments were shaped by their "performance-competence" beliefs from the prevailing science identity model. ECRs explained that they saw themselves as science researchers because they felt confident in their research skills and abilities. Valerie reflected on how her science identity changed over the course of her research training, "I learned a lot of things along the way, I've gained experience. Now I'm at that point where I feel like, yes, I am sure in my knowledge and my abilities…So I do feel like a researcher today." Because Valerie views herself as performing research and competent as doing so, she sees herself as a science researcher.

Another ECR, Danielle, described how she did not see herself as a science researcher because she did not feel competent, explaining that "at [the beginning of research training], I had no idea where to start. I was learning

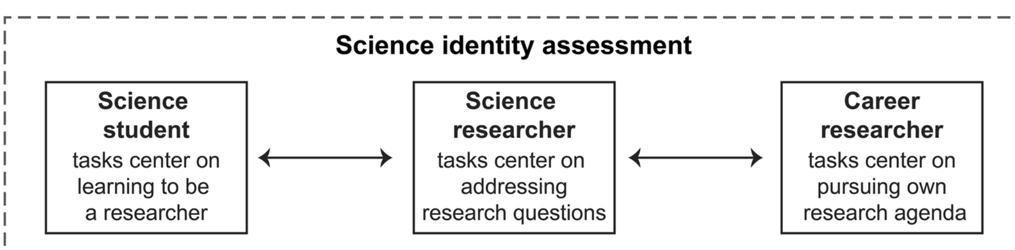

Fig. 1 ECRs' science identity assessment as a continuum. ECRs in our study conceptualized science identity broadly as being a science student, a science researcher, or a career researcher. ECRs defined each point in the continuum by the purpose of the work they associated with each identity. ECRs conceived that being a science student meant doing work for the purpose of learning to be a researcher. Being a science researcher meant doing work focused on addressing a research question or testing hypotheses. Being a career researcher meant doing work in the pursuit of one's own research agenda. To place themselves on this continuum, ECRs considered factors from the prevailing science identity model (Carlone & Johnson, 2007; Hazari et al., 2010; Potvin & Hazari, 2013) and work-learning and identity-learning cycles (Pratt et al., 2006)

how to [computationally] code. I wouldn't say I was a researcher because I was in training—just training how to code." As Danielle continued to work, she began to "feel comfortable with just the terminal [coding] environment and looking up things when I didn't understand them… I would say it took maybe two semesters for me to finally get the answer to that first [research] question." When asked when she began to see herself as a science researcher, Danielle replied, "It was when we finally figured out how to answer our first [research] question. We had results that we could show [our PI and our research group]." She interpreted her ability to generate results as evidence that she was moving beyond learning how to do research to competently performing it.

ECRs described reminding themselves of their performance-competence when they doubted their identities as science researchers. For instance, Max shared that at some points he "looks down on" himself and thinks "maybe I'm not good at research." When he has these thoughts, he described how he will "look back at previous versions of my CV [curriculum vitae] and look to my CV now. And it's like, you have done a lot…Look at all this on my CV. I have done all this…I am a science researcher." Collectively, these findings illustrate how ECRs' science identity assessments rely on their self-evaluations of performance-competence.

Interest

ECRs' science identity assessments also relied on their self-evaluations of "interest", meaning their scientific curiosity or desire to conduct research. All ECRs in our study described being highly interested in their research, which is unsurprising given that all ECRs were engaged in some form of research training. ECRs spoke about how their robust interest in research affected their science identity assessments. For example, Mitchell stated: "I see myself as a science researcher…I am using science to do the thing that I have wanted to do for my whole life, which is like save the world, you know? I think that this is a very raw expression of who I am." Mitchell perceived his deep interest in research as an instantiation of recognizing himself as a science researcher. Several other ECRs described their interest as a "passion", an aspect of themselves that informed and reflected their science identity assessments. Lynn explained that, early in her research training, she did not view herself as a science researcher partly because she felt very concerned by how "the world" perceived her. Lynn grew to consider herself a science researcher partially because of her "passion for science" and that this passion is evident to other people. Lynn continued by saying, "I'm not [as] worried [anymore] about how the world perceives me, because I just want to make my mark [on the world] by doing science."

We interpreted Lynn's statement, "I just want to make my mark [on the world] by doing science" as interest, which influences her science identity.

Collectively, these findings illustrate that ECR science identity assessments (recognition of self) draw from factors in the prevailing science identity model: performance-competence and interest. Yet, ECRs also assessed their science identity by evaluating the alignment between their own work and their conceptions of the work researchers do through a work-learning cycle. Furthermore, ECRs assessed their science identity by evaluating congruence between their own traits and their conceptions of the traits of researchers through an identity-learning cycle. We detail the work-learning and identity-learning cycles of ECRs in the following sections.

ECR work-learning cycles in research training

In assessing their science identity, ECRs considered their typical work during their research training and whether they found this work to reflect authenticity, autonomy, and epistemic involvement. Although ECRs held different conceptions of what constituted authenticity, autonomy, and epistemic involvement in research, all assessed whether their own work or experience aligned with their conceptions in recognizing themselves as science researchers. ECRs described how their conceptions of their research changed as they gained research experience and how they evaluated and re-evaluated this alignment in a work-learning cycle (Pratt et al., 2006). We describe ECRs' perceptions of authenticity, autonomy, and epistemic involvement in the following sections.

Authenticity

When assessing their science identity, ECRs considered whether their work was authentic, meaning that they perceived the activities they were doing in their research training were "real" science. This notion of the authenticity of work in research training being emergent rather than the work being pre-authenticated is consistent with prior research in other science education settings (Rahm et al., 2003). If ECRs perceived their own work as aligned with their conceptions of research—meaning they viewed their own work as real research—they recognized themselves as science researchers. If ECRs perceived a misalignment such that their own work differed from what they conceptualized as real research, they hesitated to recognize themselves as science researchers. One ECR, Talia, described the shift from a misalignment to alignment:

> *In undergrad, I felt like, even when I was doing independent research projects, I didn't feel like the research I was doing was like real, necessarily. So,*

> *the transition [to seeing myself as a researcher] probably happened somewhere when I was doing work that I felt like was part of a larger project. Something that, at least in theory, could be publishable someday. Something that could maybe enter a broader conversation than just my own education.*

Talia noted that, even when she engaged in work that ostensibly could be considered "real" research, she did not see herself as a science researcher. It was only when Talia's perceptions of her work aligned with her own conceptions of real research, which meant being publishable and relevant to others, that she began to see herself as a science researcher.

Phoebe had a different conception from Talia of what constituted research, yet she similarly emphasized how the misalignment between her work and her conceptions of research kept her from identifying as a science researcher. Phoebe conducted computational research. Early on in her training, she did not consider computational research to be authentic: "I wouldn't have considered [the work] I do 'science research' a couple years ago" because she was not aware "that computational research was even a realm of research." She elaborated:

> *My view of computational research is certainly broadened [through my research experience]. I knew that people used code to solve problems, but I didn't ever realize you could seriously apply it to science questions. In my head I thought it [bioinformatics] was a way of just displaying data and analyzing data. I didn't ever think about fully using it to solve the problem as well. So that has definitely shifted.*

Phoebe engaged in a work-learning cycle in which her conceptions of research broadened to include computational research, which then allowed for alignment between her work and her conceptions. Through this work-learning cycle, Phoebe explained, "I [now] consider myself, yes, a science researcher."

Autonomy

ECRs' science identity assessments also depended on whether they perceived they had autonomy in their research. ECRs' descriptions of "autonomy" resembled the notion of operational autonomy, or "the freedom, once a problem has been set, to attack it by means determined by oneself, within given resource constraints" (Bailyn, 1985, p. 134). ECRs who reported having operational autonomy described having freedom to carry out research tasks on their own, set their own hours, decide with whom they work, and, for some types of research, choose where they conducted their research. For example, Lisa described how she came to understand that being a researcher means learning to navigate the operational autonomy that is inherent to her work:

> *[As an undergraduate researcher] I was kind of helping someone else. Someone else was guiding me and providing help. [Now] I have to decide what I'm doing on a day-to-day basis. I get to decide what time I come into work and when I leave.*

Other ECRs talked about experiencing operational autonomy because their research advisors were "hands off", implying that they could decide how to execute their research. For instance, Shae talked about how her PI was available if she needed help, but she could otherwise work independently:

> *If I'm trying to run a specific experiment or work through this protocol, they're not standing over my shoulder making sure that I'm doing everything properly. They're hands off in the sense that they let us try things ourselves and if something is not working and we ask them for help, then they'll step in.*

ECRs explained how they developed greater operational autonomy as they gained more experience, as Harris described:

> *In your earlier days of grad school, you can't choose who you are going to work with, especially if your PI assigns a certain mentor to your research. As a senior graduate student, I feel like I have more freedom in choosing who I want to work with.*

All of the ECRs in our study indicated that their research decisions and directions were still guided and approved by their PIs, at least to some extent. Skylar explained that, as he gained research experience, he worked more independently, but he would still consult with his PI at key points in the research process:

> *I've progressed and sort of gotten more of that autonomy. I'm just kind of out in no-man's land for about a month [without much communication with my PI] just working on my own stuff and I come back and [check in] with them. It's like, "This is what I've done, and this is where I, we, need to go next."*

Thus, none of the ECRs in our study appeared to have strategic autonomy, or "the freedom to set one's own research agenda" (Bailyn, 1985, p. 134). Rather ECRs described having strategic autonomy as unique to being a career researcher, as stated by Jane:

> *I don't have the freedom of creativity that I would think that a typical [career] researcher would have in terms of making my own project. But I am a [science] researcher in the sense that I am actively doing*

research and contributing to projects…[I'm] just not at the top level yet.

Some ECRs acknowledged in their science identity assessments that they would feel more like a researcher once they experienced full strategic autonomy, as Claire described:

I think I will feel more like a career researcher when I get to the point of fully creating my own project and answering questions from scratch because, up to this point, I still need some guidance. I think that is really common in [starting ECRs]. I was never going to walk in and be like, "I want to do this." Especially with my first project, it's building off of others. I have this dataset and a lot of direction… when I get to the point where I can direct my own research, regardless of what it is, I think that's when I'll feel like a researcher.

For Claire, "directing" her own research and thus having strategic autonomy would be the point at which she would consider herself a full-fledged career researcher. Regardless of the focus of their operational autonomy (e.g., which tasks to do, where, when or how to do them), ECRs gauged their level of autonomy in assessing their science identity.

Epistemic involvement

The more experienced ECRs in our sample described how they were building towards full strategic autonomy by engaging in epistemic involvement or taking intellectual responsibility for the research (Burgin et al., 2012). Burgin and colleagues (2012) found that the extent to which high school students perceived epistemic involvement in research influenced their science identities. Students with limited epistemic involvement may perceive themselves as having fewer opportunities for performance, having less competence, and being underrecognized as a science person. Similarly, ECRs in our study who felt they had limited epistemic involvement, such as being responsible for just "executing protocols" with little knowledge of the purpose of their work or limited involvement in data analysis, tended to see themselves more as science students. ECRs who reported having greater epistemic involvement, such as being responsible for formulating research questions, refining research questions, or troubleshooting unexpected results, identified more as science researchers. To see themselves as science researchers, ECRs described the need to contribute beyond "collecting data". For instance, Skylar described how he did not feel like a researcher when he was working as a technician for a government agency before graduate school because, "I just felt more like a gear in a larger machine… out there, collecting data and then handing off all that data to somebody else to analyze and draw conclusions from." Skylar felt more like a researcher when he was able to design aspects of his research project himself, as he explained: "I get to kind of design what I do, but definitely with some [input] from my advisor. So, it's not just my world, but I've been free as in terms of developing questions."

Justin echoed Skylar's views, describing how having more epistemic involvement in his current research experience would help him see himself as a science researcher:

I do participate in research, but in terms of the actual assay development and the thought processes behind this stuff, I'm not as involved as I was in my previous research [experiences] [in] undergrad. [There] I had full autonomy on my project. [Now] I basically just process samples and get stuff done. I don't have to think too deeply about what I do outside of how to be consistent and how to make sure things are in place so that people can do their jobs… I'm not involved in the decision-making for the projects.

ECRs described additional ways they were epistemically involved. For instance, Levi saw himself as a researcher when he contributed intellectually to troubleshooting:

I do make suggestions, and sometimes those suggestions are right. One time I made a bunch of agar with a different, a new brand of agar, and nothing grew on it. I wrote everything down, but [my mentor] didn't realize that I had to use the new brand since we were out of everything else. I was like, "Oh, this is probably the agar that's the issue." We did another test because of what I found out, and it was indeed the agar.

Levi elaborated why this made him feel like a researcher, "I think I add my own ideas to what's going on. I'm not just doing the program and doing the protocol; I'm definitely adding value to the research." Other ECRs also described their epistemic involvement as evidenced by their contributions, as Hazel expounded:

[The research I do], it's not totally independent. I do have supervision from the grad student I work under, but it's like I've grown to be more independent in what I'm allowed to do. [Another undergraduate researcher and I] led a project where we came up ideas we would present to [to our graduate student mentor], [Saying] like, "Hey, we wanna do this. Or we think that we should test this." Then she would use her expertise [to] veto or okay [our ideas].

ECRs in doctoral programs displayed epistemic involvement when designing their dissertations. Skylar expressed that he was trying to design his chapters in a way that addressed his own research interests and the interests of his PI, "[I am] just trying to find some link between what my advisor wants me to do and what I like, to sort of dovetail and merge paths." For ECRs, "merging" their own interests as well as their thoughts about the systems they investigate with their PI's interests and thoughts supported their science researcher identity.

Interestingly, ECRs exhibited varied reactions to being epistemically involved in their research. Justin stated that he felt "relief" in his current role where he is not involved epistemically, although his work would get "monotonous sometimes". Other ECRs found epistemic involvement, operational autonomy, and the potential for strategic autonomy appealing, as Harris explained:

> *One aspect of why I chose to go to grad school and took this career path is that it really allows me to be an independent person and to form my own projects that I'd like to work on. I get to set my own plans instead of someone else setting them for me.*

Even though Justin and Harris experienced epistemic involvement differently, they both emphasized the relevance of epistemic involvement in making their science identity assessments. In addition to the work-learning cycle, ECRs discussed aspects of their identity-learning cycle in the interview, which we describe in the next section.

ECR identity-learning cycles in research training

In assessing their science identity, ECRs reflected on their conceptions of the roles of researchers. Stets and Serpe (2013, p. 38) define "roles" as "the shared expectations attached to social positions." When discussing the roles of researchers, ECRs considered the work or tasks, in which researchers engaged and the traits that researchers possessed. ECRs described how their conceptions of researchers' roles evolved through their training and their perceived fit with these roles in an identity-learning cycle (Pratt et al., 2006). Overall, if ECRs perceived alignment between themselves and their conceptions of researchers' roles, they recognized themselves as science researchers. If ECRs did not see such alignment, they hesitated to identify as science researchers. We detail our findings of how tasks and traits inform roles in the following sections.

Tasks inform roles

All of the ECRs in our study described their conceptions about the roles of researchers, meaning the expectations they had for the kinds of work researchers do, in gauging whether they recognized themselves as science researchers. Some ECRs described how their conceptions of researchers' roles became more complex over the course of their research training. For example, Jane shared that, when she first wanted to do environmental research, they thought they would be outside most of the time. Jane stated:

> *It's super easy to kind of glamorize environmental science and be like, 'I'm gonna get paid to be outside all day. And it's super fun." ... Over time, I've kind of realized that a lot more of [being an environmental researcher] is paperwork and housekeeping and the literature review and the final presentation of the data...Maybe 10% of the time you're actually out in the field.*

Skylar experienced a similar shift in his understanding of the work he would do as a science researcher in the environmental sciences.

> *When I was younger, I would've expected a science researcher to just be in the field the whole time... But I spend like 95% of my life at a desk. When I first got into this, I imagined that I'd be in the field—I don't know, like Steve Erwin (a conservationist) or something—every day, like just chasing around animals and having a blast.*

Skylar's identity-learning cycle is evident in how he described coming to understand there are differences between being a science researcher and being a conservationist, and he saw himself as the former rather than the latter.

ECRs in our study emphasized identity-learning related to the notion that researchers do much more than collect data. In fact, most ECRs in our study viewed data collection as just a small part of their overall research work. For instance, Iris described:

> *I've realized how much [of research work] is stuck in setup. When you're in a teaching lab in undergrad [as a science student], all of the actual washing and most of the reagent mixing and stuff is done for you. You're not trying to locate things in a lab that hasn't been organized in years. So much of my work [now] is doing that. Then I'll spend an hour actually pipetting things into vials before then finally getting the data out.*

Iris recognized that her conceptions of the roles of researchers had shifted during her training, from having others set up experiments to doing all of the preparation herself. This shift informed her recognition of herself as a science researcher.

Again, the nature of ECRs' conceptions of researchers' roles mattered less in their recognition of self than whether their conceptions aligned with their personal roles. For example, Valerie questioned whether her administrative work of ordering supplies was science research, but then she reflected on how administrative work was a necessary part of being a researcher:

> *I feel like that's the reality, you know. To have things you need to pay for them. And you're always gonna have to talk to someone [in administration] about that. Science is expensive, it's so expensive to be able to do [research]... [When you asked the question] I wanted to say, 'No [administrative work is not research]', but I think actually the deeper you are in science, the more you do have to deal with that side [of the work].*

In making this assessment, Valerie compared the administrative work she was doing to the work of her PI. She continued, "I [initially] wanted to say no, [those tasks are not research], but then I think about my PI. I don't know how much time [they] spend just on grants, finding resources." Valerie compared the role she was taking on with her PI's role of procuring funds for research, which supported her recognition of her role as that of a researcher.

This pattern of identity-learning was also evidenced by Cindy. When asked if there were any tasks she did now that she did not consider to be research, Cindy replied:

> *That gets tricky because obviously there are roles [researchers have]. Educational roles, for instance, that people take on when they're working in science. Because, for instance, a lot of grad students are teaching assistants. A lot of PIs are also professors and teach classes. I guess I would say it's not research but it's part of what we do in sharing science with other people... There's also diversity, inclusion, and equity work, which a lot of people in science do. That type of work is also valuable...*

Cindy identifies as a researcher when she uses the first-person pronoun "we" as she considers the many roles of science researchers beyond addressing research questions. Although she did not necessarily consider some of the work she does to be "research", she still saw engaging in this work as consistent with her own meaning of what a science researcher is.

Nearly all ECRs in our study readily identified a range of tasks that constituted their day-to-day work (Table 2). Drawing from social psychology identity theory (Stets & Serpe, 2013), we hypothesize that, as ECRs learn the tasks researchers do, they begin to associate these tasks with various roles a researcher can fill. As ECRs engaged in more research training, they described being exposed to more researcher roles, which then influenced their science identity assessments. For example, Iris stated, "I've realized how many roles there are…I just didn't know [these roles] existed until I started talking to different people, either at conferences or just friends that have gone in different directions [in science]." When asked how this realization affected how she saw herself as a researcher, Iris replied, "I think it just means that there are more open doors for me. If I want to go different ways." In the context of her full interview, Iris appeared more confident in identifying as a science researcher now because she recognized there were many possible roles she could fill as a researcher.

Traits inform roles

ECRs also spoke of the traits that researchers possess. Some ECRs reflected on how, when they first began their research training, they tended to hold stereotypical views of what it meant to be a science researcher. ECRs described identity-learning cycles related to the traits they perceived to be characteristic of researchers and the qualities that they felt individuals must possess to be a "science researcher". ECRs then used these traits as fodder for their science identity assessments. Mitchell explained:

> *If you asked an earlier version of myself to draw a*

Table 2 ECRs' descriptions of the work (roles) researchers do

Type of work	Description (*Tasks undertaken in the pursuit of…*)
Administrative	Preparing for or facilitating research
Coursework	Taking classes and doing assignments for the purpose of classes
Mentoring	Providing support to other researchers
Outreach	Communicating science to the public
Research	Addressing research questions or testing hypotheses
Service	Engaging in committee work
Teaching	Instructing students including preparation, teaching, and assessment

> *scientist, or science researcher, I'm sure I would draw a white man in a lab coat, whereas now that's changed. Now, I think of a researcher primarily by certain personality traits, like being inquisitive and creative and critical.*

Harris also described how his ideas of who science researchers are changed through his research training:

> *There's a diverse range of people, that's what I've learned, in terms of both their personalities and backgrounds. Not everyone falls into that scientist stereotype… all sorts of different people can and should become science researchers, but it's something you have to really experience and learn from interacting with people in your field to actually get a feel for it.*

Both Mitchell and Harris emphasized that they learned researchers' traits by doing research themselves alongside other researchers. ECRs described science researchers as people who are passionate and interested in a certain scientific topic and who will carefully collect data to address research questions that advance knowledge in some way. ECRs also described how the ability to navigate the frequent failures inherent in research was a key trait of researchers. Talia noted, "science involves just failing a lot." Hazel elaborated on how she has learned to navigate failure, "I know [now] that [doing research] is a lot harder than I thought it was. Like emotionally, continuing to give it your all when things have continued to fail over and over and over." From her experiences of failure, Hazel came to understanding that an expectation of researchers is to persist in these circumstances, which she referred to as "resilience". She continued, "You still have to keep trying new things and problem solve", which reflects determination, another trait that ECRs perceived researchers to have.

Some ECRs, like Phoebe, espoused that attributes such as interest, resilience, and determination were the only traits necessary to be a science researcher:

> *I feel like science researchers could honestly be anyone. Of course, you have to have some interest in science, but if you have an interest that's strong enough for you to pursue an answer [to a research question], no matter what happens, you're going to get no's, you're going to get mistakes. If you can pursue past that, then you can be a science researcher.*

Other ECRs commented that certain qualifications were necessary to be a "science researcher" and reported tension in calling themselves a science researcher if they had not yet earned those credentials. This tension was most evident with Claire, who described how she was still actively deciding if she considered herself to be a researcher:

> *I don't feel like earning a master's was enough [to call myself a science researcher] …I didn't necessarily feel like I was a researcher before I came here [to my PhD program], even though I had done some [similar types of research] work. …I think I'm just now grappling with what that label [science researcher] means and if I can accept it or not.*

The question of whether to "accept the label" of science researcher was also evident with other ECRs. Andrew called himself a science researcher because he did "science on a daily basis", but he did not see himself as a career researcher (yet) because he did not have certain qualifications, explaining, "I'm not necessarily a professional with a PhD yet."

When discussing their science identity, ECRs also spoke about what they learned about the work habits of researchers in their labs, departments, or fields and how those insights influenced their own science identity. Shae reflected:

> *When I first started my undergraduate thesis, I was working directly under a PhD student that worked in the lab. I learned a lot from working directly under him. It really shaped my initial perception of what being a researcher looked like. I think that also kind of goes back to initially not really thinking of myself or seeing myself as a science researcher because I saw how long he worked and all the skills that he knew obviously being a senior PhD student. So, I was like, "I'm not a researcher unless I'm working this many hours or unless I know all of these things."*

Shae assessed her prior science identity (not a science researcher) based on her observation of the work habits of someone she considered more of a science researcher, consistent with Bandura's social learning theory (1986). In other words, the PhD student portrayed what Shae perceived to be stereotypical behaviors of a researcher, which she then used as a "benchmark" against which to assess her science identity. She continued, describing how her work habits evolved and then affirmed her identity as a science researcher:

> *Then I [started] participated in a lot of the rituals of that lab, like going to lab meetings. I would have one-on-one meetings with the PI. Just having those experiences, I started to learn, okay, this is what it looks like to be a science researcher. You have meetings, and you have presentations, and you read papers and you do research…I guess just over time I've started to do more things that I would consider*

> *a researcher to do. So, then I just naturally fell into that role.*

In summary, ECRs described identity-learning cycles related to their conceptions of the traits of researchers. As they worked alongside additional researchers, ECRs shifted their perceptions of researchers' traits, which shaped their own identity assessments. It was also evident in our findings that ECRs' science identity assessments were influenced by "recognition from others", which we considered to be part of the identity-learning cycle. Findings reflecting "recognition from others" are detailed in the following subsection.

Recognition from others

ECRs' science identity assessments were shaped by recognition from other researchers, reflecting the "recognition from others" factor of the prevailing science identity model (Carlone & Johnson, 2007). ECRs described **proximal recognition** through one-on-one social interactions with other researchers, who recognized their work as "research" (or not). ECRs also described **distal** recognition in the form of interactions outside of their immediate research groups or departments, as well as their perceptions of how society broadly viewed them as science researchers. We observed that both proximal and distal recognition from others could be positive (i.e., science identity supporting) or negative (i.e., science identity limiting), as described below.

Proximal recognition from others

ECRs shared how positive and negative recognition through one-on-one social interactions with other researchers affected their science identity. These interactions primarily centered on whether other researchers recognized the ECRs' work as "authentic" research. When ECRs experienced proximal recognition (other researchers seeing the ECR as a researcher) their science researcher identity was bolstered. Skylar explained that, even though he struggled to call himself a science researcher, the endorsements of others prompted him to consider himself a science researcher:

> *Have I earned the right to call myself a science researcher at this point? You know, I think it's something that a lot of students struggle with, but I do see myself as a science researcher. I was just talking this past semester to a faculty member about this [struggle]. They told me, "If you think about it, you're probably in all regards an expert in whatever field you're studying, even though you're a graduate student. You're an expert in that specific thing that you're studying. So, feel free to call yourself a science researcher because you are."*

This positive, proximal recognition helped Skylar see himself as a science researcher. ECRs reported this type of recognition not only from faculty but also from peers. For example, Lisa described how her benchwork could become tedious, prompting her to lose site of the purpose of her work and undermining her science identity. Lisa reported how talking with members of her research group supported her maintenance of a science researcher identity by emphasizing the authenticity of her work: "My peers ground me a bit and make me take a step back and realize that I'm performing experiments that could be in a paper."

Not all ECRs in our study experienced positive recognition. Sutton described experiencing negative, proximal recognition of their computational research work, the goal of which was to make tools to help onboard new members of the research team. Sutton viewed their work as important because it enabled research. Sutton learned during interviews for graduate school that not all researchers considered their work as affording epistemic involvement and therefore did not consider their work to be "authentic":

> *One of the terms that people use that is derogatory in programming or [computer sciences] is [the term] "code monkey." [It means] someone who just is given a task and [told] to go code it, without any creative input. [During my interview] I was asked, "Are you doing modeling work for them? Or are you just like a code monkey in this lab?"*

In this exchange, Sutton felt their "creative input" was questioned and that the interviewer (a faculty member at a different institution) did not see them as a "real" science researcher. As a result, Sutton began to question their researcher identity. When asked how the social exchange affected them, Sutton replied "It's unfortunate, perhaps, to an extent [that this happened to me], but it is something that I'm keeping in mind now… Now, I'm working on what this person might consider to be science, anyway."

The absence of positive, proximal recognition also influenced ECRs' science identity assessments. Jane explained that in her previous research training environment she experienced more positive recognition than she does now: "I knew everybody and knew exactly what my role [in our research group] was and where my place was and what I was good at [in terms of research] and what people needed me for." Jane explained that in her previous lab she was known to be the resident-expert in a specific type of research technique. Her colleagues would seek her out to ask her questions, which made her feel more like a researcher. This notion of being recognized for expertise in research methods was also shared by Valerie. Valerie explained that in her lab she is seen as the "queen" of a particular technique and that "everyone now comes to me. I've dealt with just about any sort of sample that can [undergo this certain technique]." For Jane and Valerie, being seen by other researchers in their group as the expert in a particular aspect of research supported their science identities.

For Jane, the transition to her new research group affected her science identity assessment. She explained that she "honestly barely gets any interaction… A lot of it is solo work. It's very, very hands off." Because she is "flying solo", she does not experience frequent recognition from others from her peers and her science identity appears to be languishing as a result. "I don't really feel like anyone, no one really relies on me here yet. I'm trying to build that. To be like a go-to person for a certain thing." Jane reported that she was actively seeking more collaborative projects in her current lab, presumably so she would experience more positive proximal recognition from others, which would support her identity as a science researcher.

Distal recognition from others

ECRs also described how recognition from others outside of their immediate research contexts shaped their science identity assessments. ECRs who spoke about distal recognition primarily emphasized positive forms of recognition. For some ECRs, positive distal recognition stemmed from the reputation of their research groups. Skylar shared that he recently completed his master's research experience in a "humble" research group. Although he conducted similar research in his doctoral studies, the reputation of his doctoral research group changed how he sees the "validity" of the research he does and helped him see himself more as a researcher:

> *Now I'm in this lab where it's like super flashy… my lab mates, they're on [National Public Radio]… [The renown of the lab] makes [research] feel even more serious and more high stakes... [the reputation] of your lab group can shape how you see yourself as a researcher.*

For Skylar, the prestige of his research group bolstered his self-assessment as a science researcher. ECRs described other forms of positive distal recognition, including public views of "environmental scientists as like heroes" and doing science "an admirable pursuit" as well as positive recognition from family, friends, and community groups (e.g., when ECRs participated in outreach programs) and through involvement in prestigious academic and research training programs.

A conceptual model of science researcher identity

From our findings, we generated a conceptual model that highlights how ECRs engage in science identity assessments (Fig. 2). We consider the propositions of our model to be tentative, reflecting relationships that should be explored and tested through further research rather than as causal claims. Nonetheless, the model defines and connects the inputs and processes that inform ECRs' overall science identity assessment, which reflect the themes and sub-themes of our qualitative analysis. ECRs made science identity assessments in which they recognized themselves as science students or science researchers, but not (yet) as career researchers (Fig. 2 central box with dashed edges, depicted in detail in Fig. 1). In recognizing themselves as science students or science researchers, they drew on factors from the prevailing science identity model (Fig. 2 blue boxes)—namely, their perceptions of their performance-competence in research and their research interest. ECRs' science identity assessments were informed by work-learning and identity-learning cycles (Fig. 2 gray boxes) from Pratt's professional identity development model. In their research training contexts, ECRs' work-learning encompassed learning about the authenticity, autonomy, and epistemic involvement of their research work (left). Their identity-learning reflected learning about the roles of researchers, driven by learning about researchers' tasks and traits, as well as learning about recognition from others (right). The questions associated with each component in the model summarize what ECRs asked themselves as they recognized themselves as science researchers.

Implications

Science identity scholars have called for refined science identity theory that: (1) clarifies definitions in science identity investigations; (2) better accounts for the influence of context on an individual's science identity; and (3) better leverages existing theory, models, and findings to support the cumulation of knowledge about science identity across investigations (Danielsson et al., 2023; Hazari et al., 2020; Kim & Sinatra, 2018). We explain how our conceptual model attempts to respond to these calls in the following sections.

Clarifying definitions

We aimed to clearly define science identity in our study by characterizing how ECRs themselves defined science identity. ECRs defined their science identities along a continuum of science student, science researcher, and career researcher (Fig. 1), revealing nuance in how ECRs recognize themselves. We contend that this nuance is not fully understood because psychometrically sound

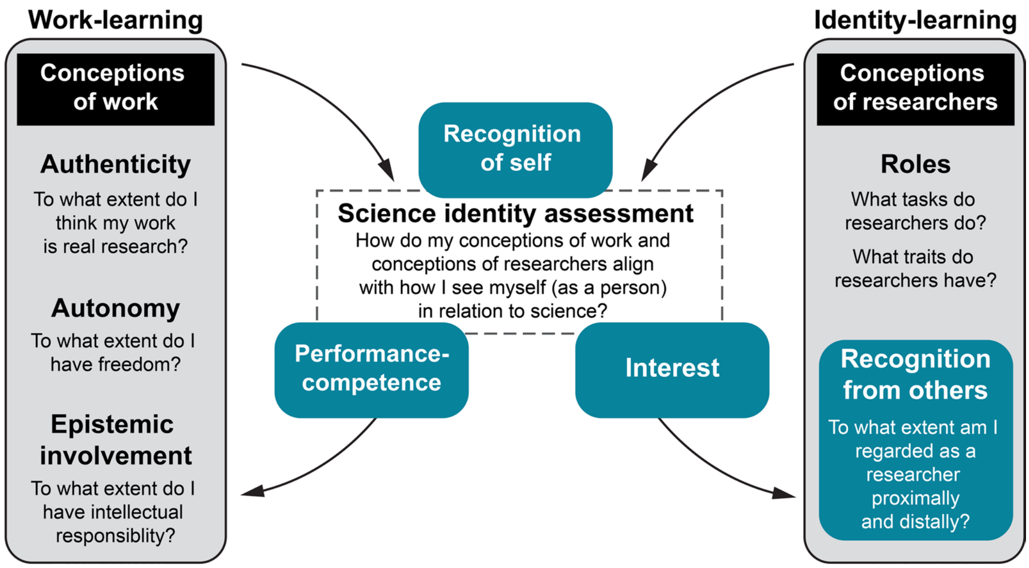

Fig. 2 Conceptual model of science researcher identity in research training contexts. ECRs recognized themselves by engaging in "science identity assessments" (Carlone & Johnson, 2007) that relied upon their assessments of their performance-competence and interest (center) (Carlone & Johnson, 2007; Hazari et al., 2010; Potvin & Hazari, 2013). ECRs made these assessments in the context of work-learning and identity-learning cycles (Pratt et al., 2006). Specifically, ECRs engaged in work-learning cycles through which they assessed alignment between their conceptions of research and perceptions of their own work, including its authenticity (Rahm et al., 2003), its affordance of autonomy (Bailyn, 1985), and their level of epistemic involvement (Burgin et al., 2012). ECRs also engaged in identity-learning cycles (right), assessing alignment between their self-perceptions and their conceptions of researchers' roles (Stets & Serpe, 2013) and recognition from others (Carlone & Johnson, 2007). Blue boxes with white text indicate constructs from the prevailing science identity model (Carlone & Johnson, 2007; Hazari et al., 2010; Potvin & Hazari, 2013), and gray boxes with black text indicate the work- and identity-learning cycles (Pratt et al., 2006). Questions embedded in the model are the questions ECRs considered as they recognize themselves as science researchers

measures of science identity have not been designed to measure across this continuum. Measures created for studying science identity among high school or undergraduate students with limited previous exposure to research may not be well-suited to understand science identity among ECRs who are still in training but have engaged more in research (Lockhart et al., 2022). In at least one study, existing measures of science identity fall short of passing tests of measurement invariance over time (Hess et al., 2023). That is, as students report more research training experience, they respond differently to survey items about their science identity (Hess et al., 2023). Our findings could be used to further develop or refine measures of science identity to better capture this range and inform research on science identity development and its antecedents, correlates, and outcomes during this important phase of research career development.

Accounting for context

By using our findings to integrate the prevailing science identity model with professional identity cycles of work-learning and identity-learning, our model specifies factors in ECRs' research training environment that shape their science identity assessments. These contextual factors include ECRs perceptions of their work (i.e., authenticity, autonomy, and epistemic involvement), conceptions of researchers (i.e., researchers' tasks and traits), including their proximal and distal recognition from others. Furthermore, we detail the questions with which ECRs contend with as they recognize themselves. These questions make more explicit how ECRs consider and reconsider the meaning of contextual factors as they iteratively assess their science identities during research training.

Leveraging existing theory and knowledge

Danielsson and colleagues (2023) described a rapid expansion of novel science identity theories. They also noted how these theories often do not build from one another, limiting the potential to draw wider conclusions about science identity per se and the factors affecting science identity broadly. Rather than propose a new theory, we leveraged existing theories to generate a refined model of science identity useful for understanding the transition during research training from being a consumer of science to a producer of science. Specifically, we integrated existing theory of science identity from science education (Carlone & Johnson, 2007; Hazari et al., 2010; Potvin & Hazari, 2013), professional identity theory from organizational psychology (Pratt et al., 2006), and identity theory from social psychology (Stets & Serpe, 2016). When salient, we used existing literature to make meaning of our findings [e.g., emergent notion of authenticity from Rahm and colleagues (2003), operational and strategic autonomy from Bailyn (1985), epistemic involvement from Burgin and colleagues (2012), learning from models from Bandura's social learning theory (1986)], and we used our findings to propose novel relationships among constructs and processes identified in this disparate literature. Our approach of using multiple theories and relevant findings from previous investigations to create a new theory aligns with recommendations for engaging in rigorous theory development (Greene, 2022; Suddaby, 2006). By proffering fresh theoretical insight into science identity, our model suggests directions for future research, which we describe next.

Directions for future research

Our findings suggest directions for future research aimed at understanding the interplay between work-learning, identity-learning, and being a science researcher, which we discuss below. We close by discussing recommendations for practice based on our study's findings.

Understanding the interplay between work-learning and being a science researcher

Notably, ECRs in our study could be engaged in "research", but not see themselves as science researchers. This finding adds to a growing body of knowledge indicating that, when studying science identity in the context of research training, scholars should consider individual ECRs' conceptions of their work as authentic (Rahm et al., 2003), autonomy-affording (Bailyn, 1985), and epistemically involved (Burgin et al., 2012), rather than assuming that "research" is predefined and pre-authenticated or that research training experiences are uniform or self-similar. Our findings could serve as the basis for developing robust and valid ways to measure ECRs' conceptions of their work or refining existing measures of similar constructs. For instance, undergraduates doing research as part of a science course are more likely to perceive that their work could generate scientific discoveries than undergraduates taking traditional "cookbook" lab courses where they are primarily learning techniques (Beck et al., 2023; Cooper et al., 2019; Corwin et al., 2015). In course-based undergraduate research experiences, students' experiences with failure and iteration as well as having opportunities to engage in scientific practices and make relevant discoveries bolstered their perceptions that their research was authentic (Goodwin et al., 2021). Future research could examine the relationships among ECRs' perceptions that their work could lead to discoveries, their view of their work as authentic, and their identification as a science researcher. Similarly, the construct of project ownership has been studied in undergraduate research training experiences. Items thought to measure project ownership resembled questions ECRs considered as they gauged their epistemic involvement in their research (Hanauer & Dolan, 2014; Hanauer et al., 2012). Future research could examine whether ECRs' sense of ownership for and epistemic involvement in their research can be distinguished empirically, or are one and the same and thus could be integrated to connect bodies of research on science identity and the design of research training experiences.

Students' autonomy in the form of agency to make decisions has been studied in science contexts. These studies have focused on decision-making about science careers, about socio-scientific issues, and about lab course tasks, but not to our knowledge about the influence of research decision-making in the context of research training (e.g., Fouad & Santana, 2017; Halverson et al., 2009; Holmes et al., 2020). Some research indicates that graduate students experience a lack of autonomy in their research as negative (Tuma et al., 2021). Yet, endorsement of this view may be influenced by how much research experience students have and thus how prepared they are to operate autonomously in their research. Longitudinal research is needed to understand ECRs' autonomy development during research training, to identify factors that afford or constraint ECRs' autonomy, and to examine how autonomy and its affordances or constraints relate to ECRs' identification as science researchers.

Understanding the interplay between identity-learning and being a science researcher

Identity theories underscore that identities are learned through socialization processes (Griffin et al., 2020; National Academies of Sciences, Engineering, and Medicine, 2019). Yet, the prevailing science identity model does not specify how characteristics of "being a science person" are learned by individuals engaged in research training. We used insights from identity theory (Stets & Serpe, 2016), along with Pratt's professional identity development model (Pratt et al., 2006), to locate "roles" as part of the identity-learning cycle affecting the science identity of ECRs. Consistent with Bandura's social learning theory (1986), our findings show that, as ECRs learn about the identities of researchers through interactions with research mentors, who are the more experienced researchers providing guidance to ECRs on their research.

Multiple studies have shown that research mentors, including faculty research advisors for graduate students and graduate or postdoctoral researchers for undergraduate students, influence the extent to which researchers-in-training endorse a scientific identity (e.g., Atkins et al., 2020; Estrada et al., 2018; Robnett et al., 2018; Thiry et al., 2011). Our findings add to these results by revealing the process through which this occurs and illustrating how exposure to a diversity of researchers can shift ECRs' identity assessments. Future research could explore whether learning about a diversity of researchers' traits and tasks could advance ECRs' science identity assessments. Such research could be accomplished through longitudinal research that follows ECRs through research training experiences that vary in their exposure to diverse groups of researchers, such as standard training programs and training programs specifically designed to expose ECRs to diverse research career paths. Alternatively, research could examine the effects of curricular or programmatic interventions designed to engage ECRs in learning about or working with diverse researchers. Some research has already demonstrated the potential for such curriculum to expand science students' views of who can be a scientist (e.g., Hernandez et al., 2020; Schinske et al., 2016) but have not to our knowledge focused on research training or research career paths.

In our study, ECRs made judgments about their identities as a science researcher based on their perceptions of their research mentors' tasks and traits. Yet, it was not always evident that ECRs had access to information that would allow them to create a more complete picture of their research mentors' tasks and traits. Interestingly, research on youth mentoring indicates the importance for mentees of mentors disclosing information about their school, work, hobbies, beliefs, self-esteem, and other personal details (Dutton et al., 2019). Such self-disclosure allows youth to see their mentor as "human". In contrast, research in work settings indicates that mentee self-disclosure is influential, while mentor self-disclosure is not, because learning about the mentee allows the mentor to provide more tailored guidance and support (Wanberg et al., 2007). Future research is needed to understand whether and how research mentor self-disclosure shapes ECR mentees' views of researcher traits and tasks and their science identity self-assessments. Some research has already begun to test the potential for self-disclosure interventions between female STEM major mentees and female scientist mentors to expand mentees' networks of mentoring relationships, strengthen mentees' scientific identity, and bolster mentees' STEM career intentions (Hernandez et al., 2017).

Recommendations for practice

If future research supports our model, practical steps can be taken to afford opportunities for ECRs to reflect on and grow in their science researcher identity. Research mentors can consider the extent to which they provide opportunities and support for ECRs to have greater operational autonomy and epistemic involvement in their research tasks, especially as they gain experience. Mentors can explicitly affirm how ECRs' work is authentic research that fits into a larger scientific picture and make efforts to recognize how ECRs' work is a research contribution. Research mentors and research training programs can work to ensure ECRs have opportunities to interact with diverse groups of researchers. Connecting with affinity groups locally and nationally, such as through professional societies and at conferences, could broaden ECR conceptions of researchers' tasks and traits. As noted above, curricula such as Scientist Spotlights (Schinske et al., 2016) and social media-based affinity groups (e.g., @BlackinMarineScience, @DisabledinSTEM) may also be useful for expanding ECRs' conceptions of who science researchers are. These resources may be especially beneficial if they highlight counter-stereotypical models of who researchers are and endorse a diversity of researchers' traits and tasks. Mentors and programs can also encourage ECRs to reflect on and recognize their growth as researchers through the use of individual development plans and competency-based assessments that are revisited annually to reveal change over time (Chang & Saw, 2021; Kuniyoshi, 2021; Verderame et al., 2018). As the interplay between work-learning, identity-learning, and science researcher identity is better understood, the field will be better positioned to intentionally design research training experiences and evidence-based supports to foster ECRs' science researcher identity.

Conclusion

This qualitative examination of early career researchers' (ECRs) science identity assessments reveals nuance in how ECRs conceptualize their science identity that has implications for studying science identity development in research training contexts. Our findings integrate the prevailing science identity model with a model of professional identity development and identity theory in a coherent conceptual model of science identity assessment in research training contexts, illustrating how ECRs' evaluate their own work, roles, and recognition in the context of their evolving perceptions of research and researchers. Our findings also suggest practical actions research mentors and research training programs can take to support ECRs in developing their identities as science researchers.

Abbreviations

ECR Early career researcher
PI Principal investigator

Supplementary Information

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Additional file 1. Supplementary Materials. The file contains a summary of open-ended survey respondents' characteristics, screening and demographic questions for interview participants, rationale for the use of "science researcher" and example quotes, interview protocol, and codebook and extended positionality statement of research team.

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Author contributions

M.A.P. and E.L.D. designed the study. M.A.P. collected the data. M.A.P., C.J.Z., J.M.I., O.A.E., and E.L.D. analyzed the data. M.A.P. and E.L.D. collaborated on manuscript writing. E.L.D. obtained funding for the study. All authors read and approved the final manuscript.

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Availability of data and materials

Interview questions and codebook are available in Additional File 1. Data generated and analyzed may be available from the corresponding author upon reasonable request.

Declarations

Competing interests

The authors declare that they have no competing interests.

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