Investigating Undergraduate Biology Students' Science Identity Production

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ABSTRACT
Identity production is a complex process in which a person determines who he or she is via internal dialogue and sociocultural participation. Understanding identity production is important in biology education, because students' identities impact classroom experiences and their willingness to persist in the discipline. Thus, we suggest that educators foster spaces where students can engage in producing science identities that incorporate positive perceptions of who they are and what they have experienced. We used Holland's theory of identity and Urrieta's definitions of conceptual identity production (CIP) and procedural identity production (PIP) to explore the process of students' science identity production. We interviewed 26 students from five sections of a general biology course for majors at one higher education institution. The interview protocol included items about students' identities, influential experiences, perceptions of science, and perceptions of their classroom communities. From the interviews, we developed hierarchical coding schemes that focused on characterizing students' CIP and PIP. Here, we describe how students' socially constructed identities (race, gender, etc.) and their experiences may have impacted the production of their science identities. We found that authoring (i.e., making meaning of) experiences and recognition by others as a community member influenced students' science identity production.

INTRODUCTION
Identity is a complex construct that can be thought of as having both socially constructed (e.g., race, ethnicity, gender identity) and experiential (i.e., perceptions of lived experiences) components. Identity is important in science because of the general perception held among students that one must be a "certain kind of person" to participate in science (Calabrese Barton, 1998). However, what does it mean to be that "certain kind of person"? Do we assume that someone should be intelligent to participate in science (Lemke, 1990; Schinske *et al.*, 2015)? Does that "certain kind of person" happen to be a white male or Asian (Carlone, 2004; Carlone and Johnson, 2007; Yu, 2006; Museus and Kiang, 2009; Riegle-Crumb and King, 2010; Walls, 2012; McGee *et al.*, 2017)? Educators should foster spaces where undergraduate science students can develop identities in which they see themselves as science people. This is in light of evidence that students' identities impact their classroom experiences (Eddy *et al.*, 2015) and willingness to persist in science (Aschbacher *et al.*, 2010; Andersen and Ward, 2014). Identity is difficult to study because of the complexities of defining who we really are and how we come to see ourselves as certain types of people (Brickhouse, 2001; Aschbacher *et al.*, 2010). This speaks to the fact that our identities are working at the individual level (e.g., what we internalize, how we construct our sense of self), interactional level (e.g., how we belong or are othered [made to feel as though we are different and/or do not belong], what expectations people have of those with our identities), and institutional level (e.g., how resources are distributed across different identities, how identities are impacted by organizational practices; Risman, 2004). Experiences at these different levels impact the sense of and creation

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of self. In other words, differences matter, because they affect how we view ourselves as science people and how easily we can form authentic science identities (i.e., identifying oneself as a member of the scientific community; Brickhouse *et al.*, 2000; Brown, 2004, 2006; Hazari *et al.*, 2013).

For educators focused on educational equity and inclusion, understanding students' identities and their lived experiences is vital for transforming classrooms into spaces where students can thrive (Brickhouse *et al.*, 2000; Carlone *et al.*, 2014; Trujillo and Tanner, 2014). Understanding student identities and experiences allows us to recognize and problematize existing discourses that hinder student access to the science classroom community. One example of a prevailing discourse is deficit thinking, or the conception that some students are more likely to perform better than others based on a socially constructed identity, such as race or gender (McGee and Martin, 2011; Settlage, 2011; Le and Matias, 2018). Though many educators recognize and articulate how this can be dehumanizing to students, the unconscious enactment of institutionalized and organizational norms inadvertently reproduces some of this deficit thinking (Bourdieu and Passeron, 1990; Carlone and Johnson, 2012). Scholars argue that we can make science education more accessible to all students by challenging norms, understanding who students are, and reimagining how their identities can operate in a science world (Freire, 1970; English and Bolton, 2015). Our work aims to increase the knowledge base surrounding undergraduate student science identity production by examining that construct in introductory biology classes.

Using Holland *et al.*'s (1998) theory of identity production as a framework, we examined and characterized undergraduate introductory biology students' conceptions of who they are, their goals, their practices in the classroom, and the resulting science identity production. We emphasize that the focus of our work was *not* on characterizing students' current science identities during an introductory biology course. Rather, we focused on the ongoing production of students' science identities.

In the remainder of this *Introduction*, we briefly review literature related to identity and focus on how personal experiences and recognition impact identity production. Next, we introduce *figured worlds* as described by Holland *et al.* (1998) and, more specifically, how figured worlds impact identity production. Finally, we provide an overview of other identity frameworks and discuss why we chose to use figured worlds.

Defining Identity

Identity is a complex construct and is defined and conceptualized in different ways. For example, Gee (2000) defines identity as "being recognized as a certain 'kind of person,' in a given context" (p. 99). Nasir and Saxe (2003) state that identities "are not located solely in the individual, but rather are negotiated in social interactions that take form in cultural spaces" (p. 17). Authors such as Avraamidou (2018a) and Lave and Wenger (1991) situate understandings of identity within a person's lived experiences. Other scholars view identity as socially constructed components of who we are, which may include gender identity, race, ethnicity, sexuality, and ability. Additionally, identity may be context specific, and how we define ourselves at work may or may not be how we define ourselves in other settings (Trujillo and Tanner, 2014). We acknowledge the intricacies of identity and recognize that identities go beyond the labels that people can place on themselves or others. Identities are formed by the environments in which we exist, the people with whom we interact, and the histories that shape the communities to which we belong (Rubin, 2007; Urrieta, 2007a; Avraamidou, 2016). The science classrooms in which students reside operate with unspoken norms and rules regarding who and what are valued, and that context will impact the science identities that students construct. We define identity using Holland *et al.*'s (1998) conception, which is the sense-making *process* of determining who a person is via internal dialogue and sociocultural participation.

The Role of Experience in Identity Production. Identity production is an ongoing process, and the science identities that individuals produce are dependent on the experiences that either support or destabilize how they may perceive themselves in science (Robinson *et al.*, 2018). For example, Robinson *et al.* (2018) concluded that one's perception of competency in science was a significant predictor of maintaining a robust science identity. Varelas *et al.* (2012) concluded that students make meaning based on the experiences and support that they had in school. These experiences affected how students viewed themselves in science and mathematics. Carlone (2004) studied how female high school students' participation in science impacted their science identities. She explicitly recognized how traditional meanings of school science (e.g., being perceived as smart and attaining good grades) can impact how students connect with science and recognize themselves as "science people." In her study, the emphasis on good grades and rote memorization perpetuated students' disconnect with the nature of science (e.g., science as collaborative, science as a means to discovery) and impacted the experiences female students had in science. In another study, Carlone *et al.* (2014) showed that students struggled to construct a personal and meaningful science identity in traditional science courses that emphasized rote-learning experiences. Carlone *et al.* (2014) concluded that pedagogy that incorporated scientific practices like those expected of scientists in the community (e.g., providing explanations, data analysis and interpretation, building models) resulted in more positive science identities, because classroom experiences allowed students to view themselves more as science people. Martin (2006) described racialized experiences in mathematics and how negative experiences can destabilize a student's perception of his or her own ability in learning and identifying with that community. Jackson and Seiler (2013) showed that authentic engagement (or lack thereof) in the culture of college science resulted in some nontraditional students either continuing in science or leaving science. The experiences of an individual are important in identity production, because individuals *author* or define their experiences and internalize what the experiences mean to them (Holland *et al.*, 1998). Therefore, if students have had poor previous or current experiences in science, the way in which they are authoring these experiences may result in an aversion to science later in their lives.

The Role of Recognition in Identity Production. In addition to authoring experiences, another component of the identity framework described by Holland *et al.* (1998) suggests a social component to identity production. This social component, also posited by other scholars (e.g., Lave and Wenger, 1991; Carlone and Johnson, 2007), highlighted the importance of being *recognized* as a science person by others in the community. Carlone and Johnson (2007) studied the experiences of women of color in science and noted the importance of being recognized as a science person in identity production. Chapman and Feldman (2017) studied an urban high school science classroom and highlighted that students' science identities are affected not only by recognition by others but by self-recognition as a science person. Another study with Latino male college students found the same results, noting that recognition by others, typically through doing well on assessments, and self-recognition fostered the development of a science identity (Lu, 2015). Being recognized as a science person and recognizing oneself as a science person are significant components of identity production, because such recognition facilitates a sense of belonging that strengthens a person's sense of who he or she is in a community, in this case, a science person in a science community (Wenger, 1998; Carlone and Johnson, 2007).

These examples illustrate how personal authored experiences and recognition by self and others may impact the production of a science identity. Many of the studies offered only snapshots of identity. However, we acknowledge that research into identity production generally recognizes that identities are dynamic and in constant flux (Holland *et al.*, 1998). In this study, we focus on students' sense of *becoming*. This is because identities are constantly being reimagined and reconstructed and should not be thought of as final products. Identity production is influenced by culture and mediating artifacts (i.e., the tools and symbols used by members of a community) and, therefore, can change depending on the meanings that individuals give to different past and current experiences (Price and McNeill, 2013). These get internalized and shape the reality of the student's experience and consequently, his or her identity. In this paper, we work from the premise that science identity has no endpoint and is multidimensional, relational, and impacted by cultural, historical, and social institutions of a time and place (Avraamidou, 2018a).

Identity within Figured Worlds

We grounded our understanding of students' science identity production using Holland *et al.*'s (1998) theory of identity within figured worlds and Urrieta's (2007b) operationalization of Holland's theory using conceptual identity production (CIP) and procedural identity production (PIP). Holland *et al.* (1998) defined figured worlds as "socially and culturally constructed realm[s] of interpretation in which particular characters and actors are recognized, significance is assigned to certain acts, and particular outcomes are valued over others" (p. 52).

Figured worlds have four characteristics (Holland *et al.*, 1998; Urrieta, 2007b). To elaborate on each characteristic, we have chosen to illustrate figured worlds using an example of the application of the No Child Left Behind (NCLB) Act of 2001 to science education among Indigenous people in the United States. NCLB was passed under the premise that many schools were failing to meet the needs of their student population and were not adequately preparing students for higher education. As such, schools were required to administer annual standardized testing and achieve a certain percentage of students who were "proficient" to not lose federal funding (Fusarelli, 2004). The high-stakes testing situation forced many schools to create policies and curricula that focused on test preparation, often at the expense of authentic learning. Indigenous communities opposed the sweeping changes and desired a greater tribal control over education (Castagno and Brayboy, 2008). Below we illustrate the four facets of a figured world using this example.

1. Culture and History. Figured worlds reflect the cultural and historical context in which the figured world develops and changes. Figured worlds are based on historical traditions that impact culture. This culture can change with time depending on what norms and values people uphold. This means that people are impacted and influenced by the figured world, but the figured world is also impacted and influenced by people. The figured world of U.S. education exists in its current state because of the cultural and historical influence of Western nations. Our educational system has particular norms and values that teachers and administrators uphold (e.g., the roles of assessment, the learning outcomes of each grade level, the ways in which success and failure are communicated). This influences how people think of and converse about education and guides the changes that people would want to see. Indigenous education, particularly science education, also has its own norms, values, and ways of knowing that are based on the language, metaphysical beliefs, place, and history of the particular tribe (Brayboy and Castagno, 2008; Castagno and Brayboy, 2008).
2. Power and Agency in Individuals. Figured worlds have specific sets of meaning in which both where and when the actions and activities conducted by people of different positions are significant. There are particular ways to act and communicate in the figured world, and what we do has meaning. What we do demonstrates how/where we are situated within the figured world and that some individuals may have more agency and power than others. In the United States, the most dominant form of science education is Western based, which divests (sometimes intentionally, but often unintentionally) students from knowledge and discourses that are practiced in other cultures (Harding, 1994). NCLB inadvertently considered Western ways of explaining and understanding the natural world as the "standard" science to learn and used that as a benchmark for school proficiency. This highlights ways in which those who have power and agency can determine what is considered proper "knowledge." Indigenous tribes argued that they have always done science but typically do not possess the power or agency to influence legislative definitions of what "science" is (Cajete, 1999).
3. System of Social Reproduction. Figured worlds are socially produced and reproduced. Norms and power differentials, described in point 2, influence how people sort and relate to one another (Bourdieu and Passeron, 1990). This means that each figured world has norms and values that impact how individuals act. These norms and values are historically situated and reinforced by generations of individuals before us. The ways in which current students and educators in the United States know science is in large part the result of social reproduction. Current science educators "teach" what science is supposed to be and look like, and these current

science educators learned most of the norms and values they enact from their predecessors. This social reproduction can occur intentionally, but often occurs tacitly or without intention. Because these norms and values have been established and passed through subsequent generations, they become embedded and invisible to many individuals. As a result, a majority of students and educators may not question *why* science is represented in the way it is and, as such, may not understand why Indigenous communities desire a science education that highlights their histories and cultures (Brayboy and Castagno, 2008).

4. Figured Worlds Overlap and Influence One Another. Figured worlds distribute "us" by allowing us to fashion stories from personal experiences that we bring to the various figured worlds of which we are a part. Figured worlds are not independent. Participation in one figured world influences actions in and perceptions of other figured worlds. This emphasizes the ability of people to "author" and make sense of their own experiences. For example, Indigenous students live in multiple figured worlds that include their tribal communities and cultures as well as Western-influenced U.S. communities and cultures. They have rich experiences in these different worlds and make sense of who they are based on what has happened to them. If they are told that Indigenous knowledge and culture are not valuable by individuals in different figured worlds, the experiences may impact their identities.

These characteristics mean that each figured world has norms, practices, and discourses that are socially and historically constructed and given meaning by the people in that figured world. Individuals within these figured worlds participate and construct identities to navigate these spaces and contexts (Chang, 2014). These identities, however, are impacted by systems-level meanings of a science person that are culturally and historically produced. This makes figured worlds a useful framework to learn how, in a particular setting, the identity production process can take place (Rubin, 2007). In our conceptualization of figured worlds, we focus on the people (i.e., the "figures") and how their histories and engagement in a localized figured world (i.e., the science classroom) influence their process of becoming science people.

Given the complexities of conceptualizing the full extent of figured worlds, Urrieta focused on identity formation via CIP and PIP within these figured worlds. CIP refers to the students' conceptions of who they are and who they want to be (Holland *et al.*, 1998; Urrieta, 2007b). This is a mental process in which students consider their socially constructed identities, lived experiences, and aspirations and how those elements impact their conceptions of their science identities. PIP refers to "the performance" or "the practice" of their science identities (Alexander *et al.*, 2004; Urrieta, 2007b). In PIP, the students engage within a scientific community socially (interacting with others in the classroom community), culturally (embodying the norms and values of science), and intellectually (taking opportunities to participate and learn about science). The responses that they get from other actors in the community (e.g., professors, peers) as they engage in tasks and conversations impact their conceptions of their science identities.

CIP and PIP are not isolated but are incorporated into a culture with history, norms, and structures (i.e., the figured world). Like Urrieta (2007b), we posit that, through students' interactions and experiences in the figured world, they are able to reimagine who they are and construct an identity (in this case, a science identity). The manner in which a student authors his or her identity is related to the student's subjective experience and personal participation in the cultural activity (i.e., learning science knowledge and discourse).

Alternative Identity Frameworks

Though Holland *et al.* (1998) and Urrieta (2007b) used CIP and PIP in describing the elements of identity production within figured worlds, there has not been empirical work beyond the theoretical considerations that Holland and colleagues and Urrieta have provided. We sought to advance research in this area by applying this theory of identity production to a science classroom context. There have been scholars who do not explicitly use CIP and PIP but still use identity frameworks that parallel the constructs of CIP and PIP. We provide a summary of some common identity frameworks in Table 1.

Holland *et al.*'s (1998) original framework was influenced by Lave and Wenger's communities of practice (Lave and Wenger, 1991; Wenger, 1998). The concept of communities of practice describes the engagement of individuals within a community that has explicit goals and ways of being and negotiating meaning. Individuals who are novices engage and practice with tasks that are deemed important to the community of practice. Through "legitimate peripheral participation," novices master the ways in which experts understand, interact, conceptualize, and communicate within a socially constructed context that is significant to the members of that community (Lave and Wenger, 1991; Wenger, 2000).

Lave and Wenger describe identity development as intertwined with the community of practice. As novices (in our case, students) engage with the day-to-day phenomena and norms of the community, they internalize and continually conceptualize who they are within the community. Ultimately, cultural elements of the community of practice may shape how students interact with others, what students value, and how they feel they belong (Lave and Wenger, 1991). This idea of "practice" and engaging with a community culturally is directly associated with PIP, because students' identity formation is linked with how well they feel they can develop an identity that parallels the norms and values that are inherent within a community of practice.

Cobb *et al.* (2009) studied student identities formed in mathematics education and proposed the constructions of normative identity and personal identity. Normative identity describes the student as a "doer" of mathematics and how being a doer requires understanding the social structure and norms of the classroom. This parallels PIP, in that the doers are performing their mathematics identities and engaging in the culture of mathematics education developed by that classroom (Holland *et al.*, 1998). Personal identity describes how students identify with the obligations required in the classroom (Cobb *et al.*, 2009). Holland *et al.* (1998) noted that the activities and individual decisions that occur are used "to understand and organize aspects of one's self and at least some of one's own feelings and thoughts" (p. 121). In

TABLE 1. Summary of some common identity frameworks and how they relate to CIP and PIP

Author	Framework overview	Relation to CIP	Relation to PIP
Gee (2000)	Identity is "being recognized as a certain 'kind of person' in a given context." There are four perspectives of identity given by Gee: nature based, institution based, discourse based, and affinity based.	Gee's nature-based perspective acknowledges people's socially constructed identities (e.g., race, gender), because society imposes certain norms based on people's identities.	Gee acknowledges that identities can be practice based, because people talk to and interact with one another within a particular group.
Lave and Wenger (1991); Wenger (1998)	Identity is formed within a "community of practice," in which novices, via "legitimate peripheral participation," start to exhibit expert thinking and begin to start seeing themselves as members of that community.		Lave and Wenger acknowledge that people "practice" their identities via participation and begin to develop a sense of who they are in a community.
Cobb *et al*. (2009)	Student identities within mathematics are impacted by their sense of a "normative identity" (being a doer of mathematics) and "personal identity" (how they navigate the expectations of the classroom).	The activities that occur in a mathematics classroom help students understand who they are. Personal identity acknowledges the importance of students' own feelings and perceptions.	Students are expected to participate in the activities of a classroom by being "doers" of mathematics. This requires that students understand the norms of acting in a classroom and the social structure.
Carlone and Johnson (2007)	Science identity production requires that students perform an identity, be recognized by themselves and others as science people, and master conceptual knowledge.		The model focuses on the participation of the student in science activities as well as interaction with peers (who have to recognize the student as a member of the community). The mastery of conceptual knowledge showcases an intellectual engagement with science.
Holland *et al.* (1998)	Identity production occurs within a figured world in which individuals must learn to navigate social norms and activities to construct identities in the figured world.	Socially constructed identities impact how individuals perceive the world and their experiences. Everyone perceives their histories differently because of social norms and culture.	Individuals "perform" their identities within a figured world by engaging with others and the day-to-day phenomena.

other words, the activities of a classroom aid in the self-making process of identity production, which parallels CIP and PIP.

Carlone and Johnson (2007) studied the experiences of successful women of color in science, and their model for science identity included performance, recognition, and competence. Their conception of performance related to social performance and being able to interact with other individuals and artifacts in sophisticated ways, which parallels the conception of PIP (Holland *et al.*, 1998; Urrieta, 2007b). "Recognition" described the ability to recognize oneself as a science person and for others to recognize you as a science person, which can be done through interaction with others (Carlone and Johnson, 2007). "Competence" referred to the mastery of scientific conceptual knowledge, which is done by purposefully engaging with scientific content. In our further theorization of PIP, we referred to this as "engaging with science intellectually."

All of the identity frameworks described here have merits for studying science identity. They capture the importance of "performing" a science identity and acknowledge the social components of identity production. However, many do not readily consider understanding institutional and cultural norms and personal histories and experiences, likely because of the inherent complexity in operationalizing those concepts. Carlone (2012) recognized this deficit in the science education literature and noted that focusing just on agency and participation is not enough, because the self-making process is affected by social structures that impact how we make meaning of our experiences. Ultimately, we chose CIP and PIP within figured worlds as our framework, because we wanted a framework that not only highlights the "performance" but better conceptualizes culture and emphasizes the ways in which socially constructed identities and experiences intersect and impact identity production (Holland *et al.*, 1998; Urrieta, 2007b). We wanted a framework that more fully acknowledged socially constructed identities (e.g., gender identities, racial identities, and ethnic identities) and the social, cultural, and institutional histories that undergird socially constructed identities. By doing so, we validate the experiences articulated by the students who participated in the study and begin to understand how students' perceptions of these experiences aided them in figuring out who they were in the figured world (Holland *et al.*, 1998).

Using figured worlds as the framework and student interviews as the data source, we addressed the following research question: How do CIP and PIP inform the production of introductory biology students' science identities?

METHODS

In the *Methods*, we describe our context, student participants, selection criteria, data collection, and data analysis. This research was approved by the local institutional review board (IRB #14-0028).

Context and Student Participants

Data were collected from an institution in the central United States in 2017 and 2018. The institution's undergraduate population is ~56% white students and 44% racial minority students (approximately 21% Hispanic/Latinx, 10% Asian, 5% Black/African, and 8% mixed/unreported). This study focused on five introductory biology courses taught by five different faculty members at the institution (two in Spring 2017, two in Fall 2017, one in Spring 2018). Enrollment for each course was ~120–175 students. Instructors in all five courses used active-learning tasks such as clickers, think–pair–shares, and/or worksheets. We provided examples of daily in-class tasks in the preceding sentence to readers because the tasks were readily referred to during students' interviews and were a part of their identity production. Four of the five courses included traditional lecture (e.g., instructors speak at the front of the class and students are expected to listen and take notes), and the other course was a "flipped" classroom. Four of the five courses also incorporated learning assistants (LAs), undergraduate students who help facilitate interaction and discussion during classroom tasks (Talbot *et al.*, 2015). Recruited LAs closely mirror classroom demographics and receive pedagogical training their first semester (more information can be found at www.learningassistantalliance.org). We provide this context because, during their interviews, students reflected on classroom experiences and interactions that sometimes included LAs.

All students in the institution's introductory biology courses completed the Classroom Community Scale (CCS; Rovai, 2002) as part of a larger research project. The CCS is a 20-item Likert-scale survey that asks students about their perceptions regarding classroom climate, interactions, and norms. We used the CCS to gain insight into the social and learning components that occur in classrooms. We did not analyze class-level responses from this survey. We used the CCS as a way to select a cross-section of students to interview, and further, the interview protocol referenced student responses to specific items (example statement to student available in Appendix 1, Supplemental Material). This survey was given in class during week 8 of the semester because classroom norms and routines were likely established by that time. We combined student responses to survey items related to affect (e.g., sense of belonging, trust, care) with demographic information (e.g., gender identity, ethnicity, age) and purposefully selected students of different demographics and perceptions to email, recruit, and interview. We emailed white students and students of color of different gender identities who we perceived answered positively, neutrally, or negatively to CCS items related to affect in order to interview students who perceived the classroom in different manners. Selected students were directly emailed by a member of the research team and asked to participate in 30-minute interviews. Students were informed that their responses were confidential and that their instructors would not have access to any of the interviews. Two follow-up emails were sent to students who did not respond. We emailed 95 students total, and our final sample included 26 students, for a response rate of ~27% (demographic information about interviewed students available in Table 2). We recognize that there was a volunteer bias with the study because many students who were contacted did not reply to our email. Students who participated were interviewed during the same semester they took the course and compensated with a US$10 gift card for their time.

Data Collection

We did not attempt to generalize across instructors or semesters, but we sampled from a large number of sections to get a cross-section of students in different classroom contexts. Interviews were conducted either by P.T.L. or A.N.T. P.T.L. and A.N.T. were graduate students and were not part of the instructional team in any of these courses. We acknowledge that the visible socially constructed identities of the two interviewers may have influenced the responses given by interviewees. We used semi-structured interviews and broadly focused on identities, past experiences, perceptions of science, and classroom community (our interview protocol is available in Appendix 1, Supplemental Material). The goal of the interview was to understand how students' socially constructed identities and past and current science experiences impacted science identity production. Questions from the interview protocol were asked verbatim, though members of the research team often asked students to explain or expand on lived experiences students discussed in order to get more context for interpretation of a student's response. All questions were asked of students during the interview, and questions were repeated or clarified if students requested. If students were confused, we clarified questions by first using the example (e.g.) statements in the protocol and then by explaining the framing of the question to the student if necessary. Students also had the option to not answer questions in the interview and could tell us if they preferred not to answer a question. No student stated that he or she did not want to answer any of the questions.

To facilitate discussion regarding identity and to prime students to think of identity throughout the interview, each interview began with a card-sorting activity. Card-sorting activities are common in education research and vary depending on discipline and purpose, but are generally used to facilitate communication and reasoning with participants (Schoenfeld, 2015; Berryhill *et al.*, 2016). In our activity, students were given 21 premade identity cards and a stack of blank cards. Their task was to choose premade cards with which they identified (available in Appendix 2, Supplemental Material), to write additional identities they felt were important to them on blank cards, if desired, and to rank their cards from most to least important to them. We recognize that conceptualizing identity is abstract and difficult to think about in the moment. We believe that students' responses may have been different had they been given time to think about questions before the interview or if we had prompted them with other activities than the card sort.

The interviewer then asked questions regarding the student's reasoning for the top-ranking identity (e.g., "Why did you decide to put daughter first?") as well as the placement (or lack thereof) of a "Science Learner" card. Because we were looking at a snapshot of students' science identity production,

TABLE 2. Student-reported gender identity, race/ethnicity, and major[a]

Student	Gender identity	Race/ethnicity	Major
Alice	Female	Black[b]	Nursing
Alli	Female	Asian	Nursing
Amanda	Female	White	Psychology
Brandy	Female	White	Public health
David	Male	Asian	N/A
Ethan	Male	White	Nursing
Hala	Female	Black[b]	N/A, pre-pharmacy
Henry	Male	Asian	Business
Isaac	Male	Black[c]	Biology, pre-medicine
Jason	Male	White	Biology, pre-medicine
Joscelin	Female	Latinx, Hispanic	N/A
Kaitlyn	Femme gender, nonconforming	Asian and white	Biology, pre-medicine
Karen	Female	White	Biology, pre-pharmacy
Kayleigh	Female	White	Public health
Lorenzo	Male	Latinx, Hispanic	N/A
Mai	Female	Asian	N/A
Megan	Female	White	N/A
Sabrina	Female	White	N/A
Salacia	Female	Latinx, Hispanic	N/A
Sally	Female	Asian and white	Biology, pre-medicine
Tamara	Female	Black	Biology, pre-medicine
Tiffany	Female	White	N/A, pre–physical therapy
Vajra	Male	Asian	Biology
Valeda	Female	Latinx, non-Hispanic	N/A
Yasar	Male	White[d]	Biology, pre-medicine
Yulia	Female	Latinx, Hispanic	Public health

[a]Reported demographic data had to be explicitly stated during the interview to be included. Students who did not report declared majors at the time of the interview were classified as "N/A."
[b]These students reported being from Sudan.
[c]This student reported being from South Africa.
[d]This student reported being Middle Eastern.

we decided to go with "Science Learner" in lieu of other identifiers (science person, scientist, etc.), given that they were currently taking introductory science courses. Additionally, pilot interviews with six students who were not part of the final sample of 26 indicated that identifiers, such as "scientist" or "science person" were not used by students, because they felt that their content knowledge was insufficient to be considered a "scientist" or "science person." Though the card sort included "science learner," we still use the terms "science person" or "science identity" in the *Results*, because we were interested in the *process* of science identity production and not in describing who students *are* as science learners.

Next, students were asked questions regarding their past experiences and perceptions of science. We then asked questions regarding classroom community, and these questions were tailored to parallel students' responses on the CCS. Students were asked to reflect on their responses to several items on the scale (the items we chose to discuss with students are available in Appendix 3, Supplemental Material) and share personal classroom experiences. Finally, students were asked to provide descriptions of what they believe a positive classroom could look like. Our goals for the interview were to capture student perceptions of their socially constructed identities and of the classroom and to understand how all of their past and current experiences impacted their sense of who they are in science contexts. All the interviews were audio-recorded and transcribed using Trint (https://trint.com/services). Student names were changed after transcription for confidentiality.

Data Analysis

We conducted thematic analysis and constant comparative coding (Richards and Richards, 1995; Creswell, 2013) using Dedoose software (SocioCultural Research Consultants, 2016). One member of the research team, P.T.L., read all the transcripts and created preliminary descriptors related to CIP and PIP based on students' responses during the interviews. These preliminary descriptors focused on students' self-making (how they construct identities) and sense-making (how they make sense of what happens in their worlds) regarding who they were and their experiences in the classroom. Primary codes were derived from the figured worlds framework. Secondary and tertiary codes were derived from the interviews. All authors engaged in a systematic coding process, which started off with coding two transcripts as a group to familiarize the research team with CIP and PIP and amending codes to better operationalize identity production. After this, three of the authors (P.T.L., L.D., and A.N.T.) coded two new sets of two interviews (four new interviews total), with discussion of coding after each set. After the first set of interview transcripts, these codes went through several iterations to create more distinctive categories, and we achieved >90% coder agreement (e.g., P.T.L., L.D., and A.N.T. marked quotes with the same descriptors >90% of the time) by the last set. Three authors (P.T.L., L.D., and A.N.T.) split the remaining transcripts and coded them independently. To ensure intercoder agreement, we randomly selected one individually coded transcript from P.T.L., L.D., and A.N.T. for further coding by the other two coders. Coding agreement was again >90%. The codes were organized into two hierarchical coding schemes (Creswell, 2013). In hierarchical coding, some codes may act as umbrella codes under which other codes fall. One coding scheme focused on CIP, and we organized descriptors under theoretical constructs that provided evidence to conceptualize CIP. The second scheme focused on PIP and was organized in the same manner.

As we analyzed the transcripts, we noted that many students did not talk about their socially constructed identities separately, and opted to discuss their identities holistically or in combinations (e.g., being a Middle Eastern male, being a Hispanic female). As such, we acknowledge the importance of intersectionality in describing how students' science identities form. Intersectionality describes the inseparability of different components of our identities (race, gender, ethnicity, sexuality, etc.; Johnson *et al.*, 2011; Avraamidou, 2018b). All of these identities interplay with one another and result in unique experiences that are not additive (Johnson *et al.*, 2011; Hazari *et al.*, 2013). For example, the experiences of being female and the experiences of being Black do not necessarily mirror or parallel the experiences of being a Black female. We were cognizant of and open to intersectionality in interpreting students' CIP and PIP.

TABLE 3. Coding scheme to understand the process of student identity production

Student identity production
Students engage in conceptual identity production (CIP)
• Students conceptualize who they are.
○ Students are shaped by their stories (e.g., familial experiences, school experiences, cocurricular experiences).
○ Students have socially constructed identities that impact their lived experiences.
• Students conceptualize who they want to be.
○ Students have clear long-term goals and aspirations.
■ Students reiterate short-term goals related to long-term goals.
○ Students do not report clear long-term goals and aspirations.
Students engage in procedural identity production (PIP).
• Students engage with science intellectually.
○ Students participate in course-related activities.
○ Students participate in non–course related activities.
• Students engage with science culturally.
○ Students voice elitist and/or exclusive discourses.
○ Students voice inclusive discourses.
• Students engage with science socially.
○ Students interact with students, LAs, and their instructors.
■ Students interact around science material.
■ Students get to know other actors personally.
○ Students want opportunities to interact but do not have them.
○ Students choose not to interact with others.
○ Students have perceived leadership roles in class.

RESULTS

The research question focused on the roles of CIP and PIP in facilitating the production of students' science identities. All of the interviewed students had unique experiences and ways in which they identified themselves. While we have highlighted illustrative instances from student interviews, our results are not meant to be generalized, because it is plausible that students who are at other institutions that have different cultures and distinct classroom contexts will have different experiences and make unique meanings of them. We also did not feel it appropriate to make inferences about differences among students in different sections of the course. Rather, we wanted to describe the variation in student responses and how students make meaning of their experiences and how that informed the production of their science identities. We want to again emphasize that we view identity production as a dynamic and constant process and acknowledge that students' views of themselves as science people will undoubtedly change as they progress through their schooling and experience new courses and opportunities. In this section, we describe findings for CIP and then findings for PIP. After, we present ways in which components of CIP and PIP interact to facilitate identity production.

CIP

CIP illustrated that students engaged with the process of conceptualizing who they were and who they wanted to be (Table 3). When students articulated who they were, they made meanings of past and current lived experiences (familial, school, etc.). The meaning given to these lived experiences appeared to be impacted by students' socially constructed identities, such as being female or an immigrant. When students articulated who they wanted to be, they discussed their goals and aspirations. Some students also discussed their reasons for taking the biology course and offered short- and long-term goals that relate to future aspirations. We viewed students who had concrete goals as those with a clearer direction, which better informed their CIP. Other students either stated that they did not have clear goals or did not fully answer the question. Exemplar quotes are available in Table 4.

During the interviews, some students reported past lived experiences that strengthened their ideas of who they are and who they want to be. This is because their lived experiences helped them see the application of science and invoked feelings (positive or negative) toward the subject. Some of these lived experiences included past careers, past and current school experiences, and familial influence. For example, one of the students we interviewed, David, talked about how one of his hobbies led him to pursuing science. He stated,

> A couple years ago, I started fly fishing, and it just consumes you to a new level, and it's kind of driven me to interests in conservation, in rivers management, in population control, so it's basically what brought me to the sciences. I say that, more than any of this other stuff. Now that I've been doing really well, I'm thinking about switching to something in health care. That's kind of crazy that it even evolved into that point.

Additionally, students' reflections on their lived experiences coincided with explicit considerations of their socially

TABLE 4. Exemplar quotes regarding CIP

Students engage in CIP	Example quote
Students conceptualize who they are.	
Students are shaped by their stories (e.g., familial experiences, school experiences, cocurricular experiences).	Also, we took, back in Africa, that's probably like 2009 or something—we took this field trip to the forest. We were experiencing nature and all of those surroundings and all that, it was just really beautiful, a beautiful Saturday. I love nature.—Isaac I mostly come from a science background. My parents and my family are all in science, and I started learning through that way.—Vajra The biggest experience for me in science would be junior year [Advanced Placement] biology. I went into that class thinking that I was going to ace it because I love biology so much, but little did I know that I would struggle a lot in biology because I've never taken biology before and I just started biology. I struggled a lot in that class.—Hala
Students have socially constructed identities that impact their lived experiences.	[I put Latina as my top identity] because my dad is from Brazil. He's an immigrant, so like it's really important to me. I go to Brazil every year. I speak Portuguese. I studied there many times so it's important to me.—Valeda
Students conceptualize who they want to be.	
Students have clear long-term goals and aspirations.	Long term, hopefully getting through the pre-med track and you know and end with a strong [GPA] and get into medical school.—Yasar
Students reiterate short-term goals related to long-term goals.	[The] short term goal is to pass all of my classes with A's, you know. Doing well on the midterms, or the finals I should say, because I'm at that borderline risk, you know. I'm working on them.—Yasar
Students do not report clear long-term goals and aspirations.	I don't really have a future goal right now, but I'm taking psychology class right now with biology, so the biology we can relate to psychology.—Henry

constructed identities, such as how gender identity and race/ethnicity may have intersected with their lived experiences. For example, interviews with some students of color contained detail about building community with other students of their race and ethnicity, and some discussed the difficulties they faced as minority groups in science. Some of the female students we interviewed expressed that some disciplines were still male dominated and how representation was important. For example, Megan stated,

> I think that being female is important because, going back to the inequality thing [in science], it makes me want to be successful because I am female, and there could still be past notions [or stereotypes] against us.

For Tiffany,

> [Science] still is definitely predominantly hetero white male, and I feel like that is starting to change … I feel like females that are in science, the ones that are known about tend to do things, like astronomy [which is more feminine] rather than astrophysics [which is more masculine]. I feel like the media gender roles people and just stereotypes everyone into little compartments. And I think that's sad, but, so yeah, that's how I feel.

One of the students we interviewed, Salacia, talked about immigration status as an identity and how being an undocumented student and having limited exposure to science made it more difficult to navigate school and fully participate in science and pursue a career in a health field. She explained,

> There are a lot of challenges and struggles just being undocumented. Like I want to do science programs for undergraduates, and I just can't do that because I'm [undocumented]. It's like I try to focus in school and do good … but it's hard for me to understand concepts easily because I am a first born [and have extra responsibilities]. I didn't take much science when I was in high school, so this is my first biology class. It takes me longer to learn, but I want to be successful and have a good career.

Finally, some students explicitly mentioned short- and long-term goals, while some students were less clear about goals when prompted. Some students, such as Yasar, were more explicit and had a better understanding of the requirements and the work that had to be done in order to achieve their goals (Table 4).

PIP

In the PIP coding scheme, we recognized that students performed their science identities by engaging with science intellectually, culturally, and socially (Table 3). When students engaged with science intellectually, they regularly participated in course-related activities, such as completing classroom clicker questions or worksheets, or non–course related activities, such as attending museum events or watching science films. Students who engaged with science culturally started to understand and embody the norms and values of a scientific figured world. Such norms and values may include adopting traditional science discourses that are commonly seen as elitist (e.g., science is only meant for the smartest) or reimagining science to be more inclusive (e.g., anyone can be a scientist). Finally, students who

TABLE 5. Exemplar quotes regarding PIP

Students engage in PIP	Example quote
Students engage with science intellectually.	
Students participate in course-related activities.	So, you know, we're doing the clicker exercises even though we're not actually using the clicker. Sometimes you get that multiple choice and you have to try and figure out what it is.—Kayleigh
Students participate in non–course related activities.	We go home and watch documentaries and learn about stem cells and all this other stuff that's going on and we come to class and see and learn all this stuff.—Lorenzo
Students engage in science culturally.	
Students voice elitist and/or exclusive discourses.	If I were to pursue a doctorate or something in science it's a little harder and it takes a little bit more, since it's a male dominant community. It would definitely create some tension if I happened to study hard or work better than my male counterparts.—Amanda
Students voice inclusive discourses.	Who is science made for? I think that that all people could be scientists. We can all study science in whatever facet.—Tiffany
Students engage in science socially.	
Students interact with students, LAs, and their instructors.	With this semester, I sit around with more people, and I kind of just talk to everyone around me.—Mai
Students interact around science material.	Within class, [the professor] separates us into groups, so every day we sit in groups, and we help each other through all the questions that we have and through notes and stuff throughout the classes.—Karen
Students get to know other actors personally.	[With the professor] being a mom and having a family, she's a really easy person to talk to and not just about science but just about really anything that you have in your mind. You know, you can go to her office hours and she is always just kind of a person to talk to and she is a very familiar face to see her on campus and she's also a very friendly face to see. So that's kind of nice, to kind of have that warm welcome from her whenever you see her.—Amy
	There's just something about [my instructor] that's very nurturing in general. You know, she talks like a person … and gets the fact that being in school's hard.—Kayleigh
Students want opportunities to interact but do not have them.	It feels like every time I say, "Let's get together," like [my classmates] all say "Sure," but they don't show up, and this is like the third time that it happened … And so every time I reach out to them and say let's do this, I just get no response or I get declined and that's why I'm not connected to them.—Alice
Students choose not to interact with others.	I feel uncomfortable asking [classmates] questions, just because I don't want to be judged. Same with the professor and some of the older people in class who have more experiences with the sciences.—Brandy
Students have perceived leadership roles in class.	Within the first couple of weeks of the classes, everyone around me realized I was doing good on the tests and homework and knew the clicker questions. I feel like I got to a point where they relied on me for everything. Definitely all the clicker questions … It has helped me. In the sense that teaching someone is the best way to retain information and the way to learn.—Jason

choose to engage with science socially may regularly interact with actors in a classroom, such as other students, the instructor, and LAs. Exemplar quotes are available in Table 5.

"The performance" of being a science person varied depending on the student. Some students expressed that they readily had opportunities to engage in activities and with their classmates and enjoyed their interactions. Lorenzo reported that he enjoyed his time with classmates during activities and that his instructor provided time for them to interact. He stated,

> The group where I sit up front, they're actually very interactive. They like to share their ideas and they can ask questions as well. "What do you think? Do you think this is the answer?" and you tell them, and they're like "Oh this is why I think this is the answer." Then we seem to come to sort of a conclusion of what is the best answer to choose. And we all as a group kind of choose the answer, and it helps us become better learners.

Lorenzo's example illustrates a way in which his instructor provided "space" in which students could participate and "perform" their science identities. From Lorenzo's perspective, students had opportunities to engage with the material and develop and build relationships, because his instructor provided discussion questions in class that students were expected to participate in answering.

Others reported poor interactions; they felt like they were not valued, such as Alice, who wanted to interact with classmates but was often ignored, or Brandy, who feared being judged by others in class (Table 5). Isaac, when discussing his experience, also described that he felt judged, particularly about what he wears to class. He stated,

> Basically, for the class I'm in right now, sometimes in a group, people think you're not smart just because they look at the way you dress and all that. I think that's just wrong because I participate a lot. I do.

These quotes suggested that not enough was done by instructors and students in these classes to establish norms of respect in which students felt comfortable sharing thoughts and taking intellectual risks. Additionally, these norms may have been established, but the classrooms did not continuously reiterate the importance of norms of respect throughout the semester. Without these norms, active-learning spaces can be compromised, and students may not be willing to engage with classroom material.

Within PIP, approximately half of the students had conflicting ways in which they culturally engaged with science. While these students embraced inclusive discourses within science, some of their responses simultaneously showcased elitist views regarding science. We provide an exemplar from Alice, one of the students:

> [A scientist is] someone who's always optimistic because they want to grow. I think scientists are always trying to learn, grow, and evolve into newer things. They need to have critical thinking, but I feel like anyone could be a scientist.

> Science is extremely difficult. It's a lot of critical thinking and society thinks that it's difficult too. I know a lot of people who are not in the biology field or in science. They are taking music or human development.

Interplays of Components of CIP and PIP

CIP and PIP were operationalized in this work to independently describe the importance of 1) internal dialogue and beliefs and 2) participation, but in many cases, what students believe or do is the result of the intersections of CIP and PIP. We saw that, in some instances, components of CIP interacted with other components of CIP, and components of CIP interacted with components of PIP. In the following section, we described two common interplays of CIP and PIP in our data to illustrate ways in which they influence science identity production.

Who students were strengthened who they wanted to be. In some cases, students suggested that their socially constructed identities and experiences were inspiration for future goals and aspirations. Their goals were the result of their identities and what they have experienced in their lives. We present two examples here:

> I think being female and Black, you don't see a lot of Black females in a science field or a science career because just … I don't know if other Black females don't like that or we ourselves are just not get[ting] promoted or not working hard enough for that. I hope in the future I can change that … [We can] still be a part of that and still make way for other [people].—Tamara

Tamara explicitly discussed Black representation in her interview and noted that she perceives a lack of Black representation, especially Black female representation in science. Tamara's focus on the intersection of being Black and female also included the recognition of the racial disparities that are still apparent in science. Though she recognized that there were not many Black females in science, she found opportunities to change this disparity and focused on how she can contribute to changing the culture. In her interview, she stated that she wanted to become a neurologist and show Black females and males that they can be part of the science community.

Another student, Isaac, stated,

> I just decided to stay home and do the traditional way, the traditional treatment which is herbals and all that stuff. So that my grandpa was a great guy, seemed to be really good with herb[s]. He's a great herbalist, so I decided I want to do everything he does. I see him help other people, not just me, or his family. He helps people around the village and all that … I actually want to be someone like him but more advanced. And I really want to be in medicine, be a doctor or be a physician one day in the future to actually help out the community and give back.

Isaac was describing a past experience in which he broke his leg and was treated by his grandfather in South Africa. His experiences with his grandfather and how he perceived his grandfather were instrumental to his goal of wanting to be a doctor in the future. In this case, we see an explicit recognition of past events intersect with Isaac's future goal of attending medical school.

Who students were impacted how they acted in the classroom. In some cases, students' socially constructed identities influenced how they would interact with classroom material and with other actors in the classroom. While some students expressed that they had positive interactions, some struggled to engage with classmates or had negative interactions:

> "My identity as being Hispanic is very important to me, and meeting more people that are Hispanic in my classroom helps me be able to learn better and socialize better."—Salacia

> "Fortunately, I've succeeded this semester … but I think that's because you see more minorities and more Hispanics in my class. Like, for example, my professor, he's Hispanic. My [teaching assistant], my [learning assistant] are Hispanic … it's greater [*sic*] and positively affected me to continue to succeed in science [and] in my future endeavors."—Yulia

Yulia mentioned how having others who are Hispanic in class had been beneficial to her learning experience and emphasized the relative importance of the intersection of being Hispanic and a college science student. This may be because she perceived that other people who are Hispanic share common lived experiences and would be more relatable. In Yulia's case, her interview was conducted during her third attempt at general biology, and she mentioned that the lack of representation of Hispanics in biology made her question her place in science prior to this class.

For Alice,

> Well, since I identify as a minority, I feel like it's a little challenging to develop relationships, in a way, because in my class, the majority is Caucasian and it's like, not like it is a problem, but for me, it's harder to develop relationships and things like that.

Alice noted that her identity as African puts her in the minority with regard to the class population. Because of this, she felt as though it was tougher to meet others in her class, and it was difficult to make friends and have meaningful relationships. Though she recognized the importance of collaboration, she did not seem to have a personal support system in the class that she believed was conducive to learning and, therefore, had negative perceptions of the classroom community.

We presented these examples to showcase the complexities of CIP and PIP and provide examples from our data that illustrate the dynamic and multifaceted nature of identity production. The different ways in which CIP and PIP interplay will inadvertently impact the type of science identities that students construct and will affect how they perceive themselves within science and the science classroom.

DISCUSSION

The stories and experiences that students discussed in their interviews reveal the multifaceted and complex nature of science identity production. The interactions that the students had, the experiences that they shared, and their personal understanding of how they were situated in a cultural and historical place impacted how they viewed themselves as science people. We added to the literature surrounding identity production in science education by focusing on components of CIP. Additionally, we explicitly described certain interactions of CIP and PIP, which had not been done previously. We did so to more fully explore the phenomenon of identity production and recognize the complexity and incompleteness of the process. The following sections elaborate on these findings and invite readers to think about the implications of this study for both classroom teaching practices and future research about identity.

Research Question: How Do CIP and PIP Inform the Production of Students' Science Identities?

We found that students' mental self-making processes and "performance" of their science identities impacted their becoming science people. We interpreted a range of positive (e.g., going on influential field trips) and negative (e.g., struggling in a science class in high school) lived experiences and a mix of positive interactions (e.g., being able to interact with people of similar socially constructed identities) and negative interactions (e.g., being stereotyped by classmates) with other actors in the classroom. We observed a variety of science identity productions in the students we interviewed. We discuss here the ways *authoring* and recognition manifested in our data.

During the interview, students narrated their lived experiences, and how students authored these experiences impacted their views of science. Their authoring was an important tool, because it gave students space to process their experiences and relate that to how they cultivated their science identities. Within CIP, students used their lived experiences and goals as focal points in understanding how they would like to be situated within a context (e.g., classroom, home). For example, Hala's memory of struggling through biology in high school or Vajra mentioning that his family has a science background are all experiences that they internalize and author that add to the complexity of the identity production process (Table 4). Other studies, such as Basu (2008) and Avraamidou (2013), also found that lived experiences were instrumental in developing science identities and enthusiastically engaging with science.

In addition to lived experiences, many students, particularly females and students of color, brought their gender identities, races, and ethnicities to the forefront to author their experiences. Drawing from Table 4, Valeda focused on the fact that she has studied in Brazil and knew Portuguese as very important to who she was and how she could be uniquely situated, especially given generalized societal views, in the United States, of Latinx women. Calabrese Barton and Yang (2000) previously documented this phenomenon and studied the culture of power using critical theory perspectives. They described how sociopolitical systems elevate certain groups of people, such as upper middle-class whites while disenfranchising other groups. Some of the students interviewed seemed to have nuanced understandings of these systems. For example, Tamara's quote, presented earlier, focused on the representation of Black people in science, and Tiffany's quote focused on how there is still implicit bias against females in science.

The figured worlds literature suggests that there are significant historical traditions that impact both cultures and how people of different socially constructed identities act (Holland *et al.*, 1998). The interviews we conducted demonstrated how the figured world of science education impacted individuals with different intersections of identity. This study corroborated some of the common concerns females and students of color had about navigating their science identities (e.g., McGee and Martin, 2011; Kane, 2012; Teo, 2015; Close *et al.*, 2016). However, a limitation of our work being interview focused meant not being able to thoroughly describe the norms and values of the figured worlds of these classrooms. Some of the norms that the instructors upheld may have hindered the science identity production of some students.

During their interviews, students also recounted how they participated and engaged with science and the science classroom in different ways. In our study, PIP primarily focused on the how interactions with others play a role in identity production. Some students reported positive engagements with PIP and were more comfortable with the performance of being a science person, while other students were less comfortable with the performance of being a science person. Importantly, these interactions may have affected students' perceptions of being *recognized* as a science person. Recognition is highly important in figured worlds and is often a "space of struggle" for individuals as they produce an identity in that community (Holland *et al.*, 1998). For example, Alice discussed wanting to learn with her classmates and not having opportunities to do so, which was isolating and may have impacted her recognition in the science community (Table 5).

Within PIP, we also noted that students may have situated themselves within a science community if they were recognized by others and if they recognized themselves as science people. Jason's quote focused on his ability to do well on assessments and help others (Table 5). His performance on assessments may have impacted his self-recognition as a science person in the community, and his interactions with peers showed that they recognized him as a significant member of the community. Carlone and Johnson (2007) showed that interactions were consequential in identity production. Women who were recognized by others as science people were more likely to have a stronger science identities, whereas women who had weaker science identities were not recognized by others as science people and had perceived trouble navigating their fields due to gender and racial factors (Carlone and Johnson, 2007). We also noted from our data that interactions with peers may have helped facilitate or hinder identity production and that professors and LAs who shared their own engagements, struggles, and understandings of science may have had better connections with students. Amy's quote showed how much getting to know her professor impacted how Amy viewed the class (Table 5). This was supported by Olitsky (2007), who studied student science identity formation via interactions in classrooms and noted the importance of interactions in students' identity production.

As noted in the *Results*, students engaged with the culture of science in conflicting ways, such as internalizing both inclusive and elitist discourses in their production of their science identities. We did not find this surprising, because the current science discourse prioritizes certain ways of knowing, speaking, and acting "scientifically." Stanley and Brickhouse (1994) focused on the Western nature of science education and noted that our knowledge of science may be distorted without acknowledging other ways of knowing science from different worldviews. Additionally, we prioritize a specific linguistic structure in science education, and students who regularly are seen as the "smart" student in class are those who have familiarity with common science vernacular (Lemke, 1990; Stanley and Brickhouse, 1994; Robertson and Elliott, 2017). This inadvertently places value on one form of speech over another and highlights a common bias in language. This may invalidate many of the voices of students who were commonly underrepresented. Students subconsciously internalize this, which may be the reason why many of the students make statements that suggest they think science is for everyone, but also make conflicting statements suggesting that science is for the smartest. Carlone (2012) coined the term "normative scientific practices" after the "normative mathematical practices" of Cobb *et al.* (2009) to remind identity scholars that the science community has shared values, tools, and meanings placed on day-to-day phenomena. These values, tools, and meanings are a substantial part of the figured world, and changing these historical traditions and ways of knowing are difficult (Holland *et al.*, 1998).

Through analyzing and coding student interviews using figured world*s*, especially the concepts of CIP and PIP, we noted a recurring idea of stereotyping and bias, especially in interviews from female students and students of color. Particularly, we noted that there may be an interplay in which CIP affects PIP and vice versa. Though previous research has noted the importance of how shifts in CIP and PIP impacted identity production, current research has not explicitly focused on the intersections of CIP and PIP, as described in the *Results* (Urrieta, 2007b). Institutionalized systems (cultural and historical ideologies that impact how people of different socially constructed identities make meaning and interact with one another and the world) such as racism, sexism, ableism, and so on undergird science education and perpetuate the status quo (Carlone and Johnson, 2012). This is an often taken-for-granted phenomenon that science educators do not think about that may result in deficit thinking models that essentialize and stereotype students, and it is commonly studied with regard to gender identity and race (Brickhouse *et al.*, 2000; Brickhouse, 2001; Solorzano *et al.*, 2000; Solorzano and Yosso, 2001; Teo, 2015). These institutionalized systems may impact CIP and PIP and affect the types of science identities that are afforded to students.

As science educators, we must be cognizant of the systems that we are reproducing in classrooms and think about the culture that is created from these systems. This is because educators can foster spaces where students can author strong science identities and be recognized by others and self-recognize as science people. If science educators want students to defy these norms and produce more positive science identities, they must be knowledgeable and work to create spaces where students can develop more authentic meanings concerning who they are in science.

Implications for Undergraduate Biology Educators

Because of the complexities of identity production, there is no one-size-fits-all approach. However, our findings indicate that there are some elements instructors must consider that may facilitate the creation of more inclusive classroom spaces. As seen earlier, students' identity production is partially contingent on the procedural elements of a classroom (e.g., the nature of interactions, the activities being implemented). These procedural elements were dictated early on by the instructor and were based on what instructors valued in a classroom. These values ultimately impacted the discourses, community interactions, roles, and responsibilities that were afforded in a classroom and may have affected students' science identity production (Engeström, 1987). Biology educators need to be cognizant and aware of *what* they value, especially in considering issues of inclusion and access in their classrooms.

Through student interviews, we noticed how classroom dynamics implicitly showcased instructional values and how that impacted PIP of students. Several students mentioned that the instructor's discourse made them feel as though they belonged. For example, Amy and Kayleigh discussed how the professor felt like a person who was approachable and relatable, which impacted their PIP (Table 5). As such, we recognize the importance of what an instructor may say or do in class and its influence on students' science identity production. Seidel *et al.* (2015) previously used grounded theory to categorize the noncontent instructor talk that occurred in a college biology classroom, which they posit can impact the learning environment. This is a valuable construct that can help instructors better understand what they are saying in classrooms and how their discourse can affect students' science identity production.

Additionally, all of the courses in this study provided opportunities for community interactions, but the implementation of these interactions were positive for some, such as Karen or Lorenzo, but negative for others, such as Brandy (Table 5). Some instructors implemented classroom environments that allowed students to have agency to establish their own roles, as we saw with Jason helping his peers (Table 5). This shows that intentionally thinking about the implementation of activities is paramount to facilitating more robust science identity production for students. Cooper *et al.* (2017) completed a study on a Summer Bridge program that was designed to help students transition from high school to college. Their program focused on teaching students biology via active learning and providing students strategies to maximize participation, and the authors' results showed that students who participated in the Summer Bridge program were more aware of their learning and used strategies to be more successful in their first semester at college. In another example, Schinske *et al.* (2016) studied an instructor who purposefully integrated homework assignments in which students learned about the contributions of scientists of various socially constructed identities. Their goal was to help students learn about how scientists and science can be diverse, and their results showed that the assignments strengthened underrepresented students' science identities.

Directions for Future Research

The exploratory nature of this study has generated thought-provoking findings that we feel are beneficial to starting the conversation about student science identity production in biology contexts. Future research on science identities within biology education research should focus more on understanding the context in which students are situated. This is because identity production is not solely dependent on the student. The places in which students interact with other actors and learn about cultural norms relate to the types of identities students create. Some of our future work will include a case study of a biology classroom and understanding how the norms and values that operate in that classroom affect students' science identities.

One potential research avenue could also track introductory students through time and place and study how their interpretations of past and current experiences change with time and impact their science identities. Additionally, many of these students were declared science majors or were interested in pursuing a pre–health track. We believe that it would be interesting to interview upper-division students who decided to leave science majors to understand the pivotal experiences during their schooling that affected that decision. This would give us a better understanding of the factors that may prevent students from succeeding in science courses and allow science educators to better theorize issues of equity and inclusion.

As students construct their science identities, they are situated in places and circumstances that impact how these science identities are produced (Lave and Wenger, 1991; Luehmann, 2007). Similar to Avraamidou (2018a), this suggests the importance of relationality when discussing science identity. The time, place, interactions, and context all matter when a student produces a science identity. The encounters that students have with the place and with other actors are significant, in that certain ideas and dispositions in that realm are more valued and may position students in certain ways (Holland *et al.*, 1998). As such, we also recommend that future research on identity be framed within relationality.

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