Science Identity and Its Implications for STEM Retention and Career Aspirations Through a Research-Based First-Year Biology Seminar

By Krista L. Lucas and Alexis D. Spina

According to the National Science Board (2016, p. 6), about half of beginning bachelor’s degree students who declared a major in a science, technology, engineering, or mathematics (STEM) field between 2003 and 2009 had either “left school altogether by spring 2009 (20%) or left STEM for another field (28%).” Additionally, the Bureau of Labor Statistics (Fayer et al., 2017) expects jobs in STEM fields to increase by about 1 million by 2024, so graduates from STEM majors will need to increase to meet this demand. While national programs specifically aimed at increasing interest in STEM already exist at the K–12 level, the increase in the demand for STEM graduates requires universities and educators to find new ways to retain students in STEM majors (U.S. Department of Education, n.d.).

Some attempts at increasing STEM retention in universities include implementation of STEM learning communities, interdisciplinary collaborations, and student engagement in research (Bouwma-Gearhart et al., 2014; Dagley et al., 2016; Schneider et al., 2015). Some attempts at increasing STEM retention in universities include implementation of STEM learning communities, interdisciplinary collaborations, and student engagement in research (Bouwma-Gearhart et al., 2014; Dagley et al., 2016; Schneider et al., 2015).

This study took place at Canyon University (all proper nouns have been replaced with pseudonyms), where the biology faculty initiated a first-year seminar program whose primary focus was to involve new students in research. This program was an attempt to increase STEM retention by providing students an opportunity to build a science identity through authentic research experience early in their college careers. Faculty use the word “authentic” to mean that the students are proposing, planning, and carrying out a novel research project with faculty guidance in a group ranging from two to five peers. Therefore, the scope of this seminar went beyond the general introduction to the university in that small groups of students planned and carried out a unique biological research project. While many universities include broad first-year introductory seminars as part of their general education studies to increase retention, the question about whether discipline-based first-year seminars impact STEM major retention and important characteristics of such seminars remains (Toven-Lindsey et al., 2015). We looked to address the following research questions:

1. How does participating in a seminar for first-year biology students help develop students’ science identity?
2. Which characteristics of the first-year program do students recognize as contributing to their...
persistence in the biology major and their career aspirations?

**Conceptual framework**

This study is guided by the theories of identity, situated learning, and constructivism. Constructivist theories of learning suggest that experiences are important for building knowledge, which is “actively built up by the learner” through individual and social experiences (Driver et al., 1994, p. 5). Historically, a goal of STEM education has been to increase students’ science content knowledge in addition to their understanding of scientific inquiry (Carey & Smith, 1993). Though it can be difficult for university faculty to determine how to implement them in the classroom, it is still clear “to many college science faculties that constructivist approaches facilitate producing meaningful understanding of science” (Leonard, 1997, p. 6). In this article, we are specifically concerned with one type of laboratory experience that engages students in authentic research, allowing students to construct scientific knowledge for themselves.

Situated learning theories place the learner as an apprentice to an expert, usually a teacher, within the community (Lave & Wenger, 1991). Situated learning includes a social practice component, which in reality makes learning inseparable from being in community (Lave & Wenger, 1991, p. 31). Situated learning also encompasses the idea that learning happens relationally, with the learner gaining all-inclusive comprehension and not just being a container for knowledge. As a novice researcher in science, the student is an apprentice to the faculty member and peer mentors, who are the experts. This happens through involvement in “communities of practice,” which are composed of educators, other students, mentors, the school itself, or research scientists (Lave, 1996, p. 150).

Related to the social practice of learning, Carlone and Johnson (2007) assert that science identities are enacted through performances for others who recognize the performer as competent. This idea has strong implications for how identities might be developed through membership in a learning community. Specifically, a person’s science identity can be defined as “the sense of who students are, what they believe they are capable of, and what they want to do and become in regard to science” (Aschbacher et al., 2010, p. 566; Brickhouse, 2001). Additionally, science identity development is at least partially influenced by peers through sharing science experiences (Carlone et al., 2015) and by educators who recognize and reinforce scientific identity work (Calabrese Barton et al., 2013).

Together, these perspectives suggest that students construct their scientific knowledge through experiences, which contributes to their identity formation as a scientist, and that this process is situated within particular contexts (Brickhouse, 2001; Driver et al., 1994; Vygotsky, 1978). This project focuses on the early research experiences for undergraduate biology students as a mechanism to help them both remain in STEM majors and impact their career choice. This happens by the construction of scientific knowledge along with development of a STEM identity, which happens through construction of scientific knowledge during research experience (Driver et al., 1994) alongside interactions between the student and faculty, the student and peers, and the student and peer mentors (Lave & Wenger, 1991). For this study, the authentic research project acts as the experience through which students, as the apprentices, are able to construct their understanding of science content alongside a faculty member as the expert.

**Literature review**

*First-year seminars as part of the undergraduate experience*

First-year seminars have been a part of the college experience for about 150 years and have expanded rapidly into American universities in the 20th century (Schnell & Doetkott, 2003). They offer students a smaller community within the larger context of the university to aid their transition to college (Barefoot & Fidler, 1996). These courses have been examined in terms of retention and graduation rates. Quantitative evidence shows that participation in first-year seminars results in higher retention rates and grade point averages through all 4 years of college (see, e.g., Goodman, 2006; Jamelske, 2009; Kuh et al., 2008).

*Undergraduate research and STEM retention*

Retention in STEM majors has been linked to authentic research experiences and a strong sense of belonging in science, especially for women and students from underrepresented backgrounds (Robnett et al., 2015; Vieyra et al., 2011). It has been noted that to increase student persistence in STEM, student self-efficacy and motivation are important and must be addressed (Graham et al., 2013). Thus, students must move from just learning science concepts in the classroom to identifying as scientists to persist and remain in STEM. Integrating research into existing coursework
will make research involvement more equitable, and further course-based undergraduate research experiences should therefore be integrated into introductory STEM courses (Bangera & Brownell, 2014). The benefits of undergraduate research are numerous: Multiple studies have found that students’ communication, technical, critical-thinking, and analytical skills have increased through participation in research projects when compared to students who did not participate in undergraduate research (Bauer & Bennett, 2003; Kardash, 2000; Lopatto, 2004; Thiry et al., 2011; Ward et al., 2002). The majority of studies on first-year seminar programs are quantitative (Gilmer, 2007; Hendel, 2007; Hoffman et al., 2002; Jamelske, 2009; Soldner et al., 2012), looking only at student retention in the university and not considering the qualitative components, such as the characteristics that lead to student retention within the major and specific activities students are engaged in during their first year. Therefore, our study addresses this gap in the literature by focusing on the qualitative components that lead to students remaining in a STEM major and the specific activities and components of the first-year seminar that help support them.

**Methods**

**Research context**

This study took place at Canyon University, which is located on the West Coast of the United States and has a student body of approximately 3,500 undergraduates. In the 2018–2019 academic year, 92 students declared a biology major, about 75% female (n = 69) and 25% male (n = 23). The biology department added a first-year program centered on authentic research experiences for new majors in 2015. This program included experiences typical in a first-year introductory seminar to the university, such as an orientation to the library and campus resources. However, students also undertook a group research project in biology, which included writing a group research proposal, learning how to carry out the research, completing and presenting the proposed project during a poster session at the end of the semester, and submitting an individual proposal to a panel for funding to continue the research.

Each seminar section was led by a full-time tenured or tenure-track faculty member along with peer mentors. The peer mentors were upperclassmen who had taken the seminar previously, and their role was to assist students with research projects, teach them how to use lab equipment, answer questions, and ask

| TABLE 1 |

**Details of the seminar program beginning in the fall semester of biology majors’ first year.**

<table>
<thead>
<tr>
<th>Sections</th>
<th>Faculty member</th>
<th>Number of peer mentors</th>
<th>Enrollment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Animal ecology and conservation</td>
<td>Dr. Marcos</td>
<td>2</td>
<td>13</td>
</tr>
<tr>
<td>Invasive predators and amphibian decline</td>
<td>Dr. Kennedy</td>
<td>3</td>
<td>16</td>
</tr>
<tr>
<td>Plant adaptations</td>
<td>Dr. Dawson</td>
<td>2</td>
<td>12</td>
</tr>
<tr>
<td>Cell biology of stress</td>
<td>Dr. Baxter</td>
<td>2</td>
<td>15</td>
</tr>
</tbody>
</table>

| TABLE 2 |

**Summary of study participants.**

<table>
<thead>
<tr>
<th>Participant</th>
<th>Gender*</th>
<th>Race or ethnicity*</th>
<th>Seminar section</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abigail</td>
<td>Female</td>
<td>White</td>
<td>Animal ecology and conservation</td>
</tr>
<tr>
<td>Emma</td>
<td>Female</td>
<td>White</td>
<td>Invasive predators and amphibian decline</td>
</tr>
<tr>
<td>Jane</td>
<td>Female</td>
<td>Multiracial</td>
<td>Animal ecology and conservation</td>
</tr>
<tr>
<td>Melea</td>
<td>Female</td>
<td>African American</td>
<td>Plant adaptations</td>
</tr>
<tr>
<td>Nathan</td>
<td>Male</td>
<td>White</td>
<td>Cell biology of stress</td>
</tr>
<tr>
<td>Padma</td>
<td>Female</td>
<td>Indian</td>
<td>Cell biology of stress</td>
</tr>
</tbody>
</table>

*Note. *self-reported
leading questions to help first-year student groups form their research plans. Groups contained between two and five peers working together on a single project.

The project experiences were woven through the seminar, in which faculty would introduce students to a variety of background information, environments, and past projects. Both faculty and peer mentors would guide students in writing their project proposals, but the experimentation would be entirely done by the first-year students. For the Plant Adaptations seminar section, the faculty member spent 12 of 30 class meetings on topics like the nature of science, field trips to nearby sites, and topics pertaining to the environment surrounding the university. The remaining class meetings were reserved for project work, including critique of proposals, experiments, and practice presentations.

The experiment portions of the projects were done mainly in the last 6 weeks of the semester, culminating in poster presentations in the last week of classes. Some example projects by participants were “Comparison of Photosynthesis, Stomatal Conductance, and Water Potential Between Native Rhus integrifolia and Invasive Nicotiana glauca”; “The Effect of Conspecific Alarm Cues on Aggressive Behavior in Procambarus clarkia”; “A Study on the Relationship Between Chronic Nicotine Exposure and Chemotaxis on Caenorhabditis elegans”; and “A Determination of Sources of Water Contamination From 16s rRNA Sequencing of E. coli Bacteria.” Table 1 includes details of the program.

Participants were recruited through visits to each of the first-year seminar classes in the first week of school and through follow-up emails. The student participants represented all four of the seminar sections, with a total of six participants. (See Table 2 for a summary of the participants.)

Data collection and analysis
Interviews were held with first-year student participants at the beginning and end of each semester, lasting no more than 60 minutes. Questions included information regarding what a biologist does, whether the students saw themselves as biologists, and whether anything from their seminar experience impacted these decisions. To triangulate the interview data, researchers held interviews with faculty members and peer mentors and attended the final poster session.

All interviews were recorded and transcribed, and transcripts were checked for accuracy. The interviews were then coded using a priori (Maxwell, 2013; Saldaña, 2016) themes, which were best suited to answer the research questions from the conceptual framework (Brickhouse et al., 2000; Lave, 1996; Robnett et al., 2015). We coded the interview data in two rounds. First, a priori coding was done using themes from the framework and research questions. These codes were “becoming a scientist,” “community,” “major,” and “career aspirations.” In a second round of coding, the additional code, “adjustment to the university,” and more specific subcodes and definitions were added as they emerged through reading the interview transcripts (Strauss & Corbin, 1990). The subcodes—“descriptions of biology or what biologists do,” “selves as scientists,” and “science discourse”—were added to the main code of “becoming a scientist” during this round of coding.

Findings
We will discuss our findings in three sections: becoming a scientist, major retention, and career aspirations.

Becoming a scientist
Student participants spoke about science in three main ways: having knowledge of biology or what a biologist does, seeing themselves as a scientist, and speaking scientifically. We arrived at these subcategories within the “becoming a scientist” code based on student responses to the identity-based interview questions. In the initial interviews, students only briefly described what a biologist does in similar ways to one another. However, we saw changes when comparing their initial responses to this question to those given in their second interviews.

Descriptions of biology and what biologists do
When compared to responses from their first interview, the students’ understanding of what a biologist does expanded greatly following their seminar experience. They gave more specific and elaborate answers or reported actions related to the study of biology rather than the necessary knowledge. For example, Abigail initially said, “A biologist is someone who studies animal and plant interactions within the environment” (first interview). In her second interview three months later, she said a biologist is someone who “explore[s] different circumstances that are going on with animals and wildlife, and the ecosystems in different communities and populations around the world. Just someone who does research and tries to share with other people what they think is going on.” Abigail’s description of a biologist expanded from one who studies something to one who communicates what they have learned through their research.
Other student participants made similar statements about the study of biology and the communication of research or connections between biology and other sciences. For example, in her first interview, Melea said that a biologist “deals with science. I know that for sure. There’s different types of biologists. So, it just depends really.” In her second interview, Melea said, “There’s always a deeper meaning or deeper cause for something happening, and there’s a logical way to explain it, but that logical way is not always right because we don’t know the science behind it.” She continued, “Biology connects to math, biology connects to psychology, biology connects to everything, so I think they study everything and why.” Melea’s description of a biologist after the seminar describes how biology connects to multiple disciplines and that it involves logical explanations. This is much more descriptive than her earlier vague response that a biologist “deals with science.”

**Viewing themselves as scientists**

The students all entered the seminar experience stating that they were not scientists or possibly that they were emerging scientists, and of those who did speak positively about seeing themselves as a scientist, it was due to having research experience. Emma came into the university with research experience, and when asked if she sees herself as a scientist, she said, “I would, yes. I’ve had some great opportunities and this past summer I actually got to work in a lab” (first interview). In response to the question, Nathan stated that he feels like “an emerging one. I’ve never been in like a real research—never done any kind of real research or been in a real lab” (first interview). Therefore, students were equating their sense of self as a scientist with the action of doing research.

Following their experience with conducting scientific research, all six students began to see themselves as scientists. The experience of conducting the research was not the only aspect of the project that contributed to their science identity. The participants also discussed the poster session at the end of the semester as being important to them in terms of feeling like a scientist. Jane said that she feels like a scientist “when I’m talking to someone who’s not a bio major at all and telling them what I’m doing” (second interview). Likewise, Nathan said, “I think it’s preparing a presentation—and like doing real research and then preparing a presentation and sharing it” (second interview). Furthermore, Abigail said, “Even though we may not be very experienced scientists, I still like, count myself as one because we made the big scientific poster, because we had like some data to show and like presented it in like a formal way” (second interview). Another student, Padma, said her professor would refer to everyone as young scientists in the class, and she began to believe that “I am a scientist even though I am premed, and that I always associated scientists with like PhD” (second interview). When asked if she felt like a scientist now, Melea said, “Yes,” and when asked to elaborate on why, she said, “Research. Knowing how to do proper research” (second interview). Finally, Emma agreed that she feels like a scientist due to “working on a full project, from coming up with the idea yourself and performing that initial literature review to going all the way through and having, well, we have a poster presentation on a week from today, actually” (second interview). It was clear that undergoing the process of designing a research project and presenting it contributed to students’ science identities.

**Science discourse**

Finally, in terms of building a science identity, students began to speak like biologists. Brown (2006) found that the use of science discourse in the classroom was important for their access to the material. In their first interviews, the students gave general descriptions of their seminar topic or field trips but did not include very much detail. By the second interview, all six participants described their research projects clearly, including the process of hypothesis formation, methods they used and how they learned to use specific equipment, experimental design (including use of controls), and how they felt when presenting to other students. For example, in the first interview, Melea discussed her seminar topic, saying, “We talked about ethnobotany and that’s very important, and if we keep treating our environment the way we are, we will not have those things [species] that we need” (first interview). Then, in the second interview, she spoke at length and passionately about her group’s research project, saying they studied “how Nicotiana glauca and Rhus integrifolia are competing. We’re testing the stomatal conductance, photosynthetic rates of them when they’re right next to each other, and we’re doing this behind the greenhouse, because they’re right next to each other.” Melea did not provide a lot of detail when she initially spoke about the seminar content, but in the second interview she spoke at length about methodology and conveyed specific information about her research clearly. The other five participants also described their research projects in detail in both their second interview and poster session presen-
Major retention

In their second interviews, all six student participants said they planned to remain in the biology major following their seminar experience. They all highlighted the research project as the main factor in their desire to stay. Abigail was the least sure about continuing in the major but attributed this feeling to her experience in an introductory biology course and not the research-based seminar. In fact, she said, “If I wasn’t in the seminar, I probably would have already dropped out of biology” (second interview). Abigail’s statement suggests that the seminar and research experience was very important in her decision to remain in the biology major. Padma also said she planned to remain a biology major, and when asked what impacted that decision, she said, “Definitely doing the research … like, there are times when it’s not fun, but I really like it and being able to experience something like this I kind of realized like, I’m in the right field” (second interview). Likewise, Nathan highlighted the importance of the research project in his decision to stay in biology, saying, “Just doing research actually made me really like biology” (second interview); he expanded on this, saying, “Truly, the biology seminar and doing biology research makes me want to stay with it” (second interview). This early research experience appears to be a determining factor for some students when they are looking at remaining in biology by giving them authentic experience in what it means to be a scientist.

Career aspirations

Initially, all six participants expressed the desire to go to medical school and become physicians once they completed their undergraduate degree. In the second interview, five of the students were still interested in pursuing medicine, but each of these five participants also felt they wanted to pursue research as part of their career pathway. Abigail stated that following the seminar, “I thought I wanted to be premed, but then as I explored the options … I don’t really know if I want to be premed anymore” (second interview). She had started considering a career with animals and also attributed this interest to the seminar class. Additionally, when asked what from the seminar class was most meaningful to her future plans, Abigail said, “When you go into a science major, or you think you’re set in stone, you still have to keep your eyes open, [because] there are so many options.” The remaining five participants expressed the desire to pursue careers in medicine but mentioned that their interests had expanded to include medical research or combination MD/PhD programs due to the seminar. Specifically, the students pointed to the research project experience as being important to this slight change in their career aspirations. While most students did not make a large change in their career plans, the interval between the two interviews was short, and the addition of aspirations to continue doing research in some capacity in the future is interesting.

Discussion and limitations

To remain in STEM, students need to begin to see themselves as scientists. Research experiences play vital roles in accomplishing this goal. As shown in this study, first-year students pointed to the research component frequently as a reason they began feeling like scientists. The participants discussed specific characteristics from the seminar related to the research projects and the relationships they formed that contributed to their desire to remain in the biology major and pursue a STEM career.

The seminar course in this study focuses on involving students in research during their first semester at Canyon University in order to contribute to their science identity. Therefore, the students in this seminar should have stronger desires to persist as biology majors and, hopefully, continue in STEM careers. The six participants all felt they gained experience and knowledge that they would not have been able to acquire outside of this seminar. All six participants pointed to the research project as important in terms of both feeling like scientists and their decision to remain in the biology major. Additionally, the recognition they received from others in STEM fields was an important part of this process. Therefore, both completing a project and presenting their poster were important factors in this seminar. This aspect of community, along with their position as an expert in their project, was a part of their development as scientists. The participants’ ability to communicate scientific ideas expanded greatly in the 12 weeks between interviews as well. Additionally, the involvement in a scientific com-
Community within their seminars provides students a position as an apprentice, and by the end of the semester they are positioned as experts with respect to their projects.

While the number of participants was small and the authors were not the instructors and, therefore, were unable to provide details regarding the amount of time spent teaching various topics, we feel we captured the main themes that are important to identity development and major retention. This study is important for universities looking to expand opportunities in course-based undergraduate research, as it provides a framework for the creation of a class focused on research.

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