Call Her a Scientist: The Role of Mentors in Faculty Lab-Based Undergraduate Biology Research Experiences & Outcomes for Student Science Identity

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Abstract
Mentorship plays an important role in the experiences of undergraduate researchers, and students may interact with multiple potential mentors in laboratory settings. Using qualitative methods, we explored the relationships between undergraduate students engaged in research and their mentors in faculty-led laboratories, with particular attention to the roles that mentors play in the enculturation of undergraduates into science. Students rarely considered faculty as their primary mentors, rather whoever they spent the most time or worked most closely with—usually a graduate student or postdoc. There was a large disparity between women and men students identifying as scientists, and in the criteria by which they claim science identity. However, nearly all faculty members considered undergraduate researchers as scientists. This suggests that faculty members might boost the science identity of undergraduate women by simply calling them scientists.

Key Words: undergraduate research experience; mentoring; science identity; mentorship; lab-based research.

Introduction
Faculty-student relationships play a critical role in many aspects of undergraduate science students’ experiences. Faculty members often have multiple roles in the development of undergraduate science students, including being course instructors, serving as academic advisors, and mentoring their undergraduate students in research experiences. Effectively carrying out such roles can positively affect student outcomes, with students consistently ranking mentorship as having the largest impact on academic success (Kendricks et al., 2013). Within challenging science courses, such as organic chemistry, students who have a better connection with their course professors perform better in the course (Micari & Pazos, 2012), highlighting the importance of these relationships within the classroom. While faculty-student relationships play an important role in the classroom, these relationships are a particularly important part of any undergraduate research experience where students are engaging in research in faculty labs (Thiry et al., 2011). Such relationships have been shown to play an important role in significantly improving students’ science self-efficacy and future goals (Campbell & Skoog, 2004; Carpi et al., 2017; Frantz et al., 2017; Hammick & Acker, 1998; Kardash, 2000; Robnett et al., 2018).

However, these relationships play an especially important role in increasing student’s science identity, which can lead to an increase in students’ desire to pursue future research in graduate school (Dolan & Johnson, 2010; Estrada et al., 2018). Effective mentor-mentee relationships are important and beneficial for all undergraduate students in the sciences. However, it has been shown that these relationships are especially important for women and members of underserved minority groups (sometimes referred to as underrepresented minorities, or URMs), as they provide the students with a positive and relatable role model (Campbell & Skoog, 2004; Carpi et al., 2017; Herrmann et al., 2016) and help students to feel included in the scientific community and increase self-efficacy, thus improving retention in the sciences (Robnett et al., 2019; Wilson et al., 2012). In addition to providing women and URM students with role models, faculty mentors may also provide these students with important networks within the scientific community that they would not have access to otherwise (Towns, 2010). Within a mentor-mentee relationship, communication is a key component. Studies have shown that the gender of the mentor and mentee often shapes how they communicate, particularly with women (Carlone & Johnson, 2007; Hammick & Acker, 1998). Providing these groups of students with a positive and productive mentorship experience has been shown to increase the retention of these students in the sciences (Carpi et al., 2017; Estrada et al., 2018; Griffin et al., 2010; Hippel et al., 1998; Wilson et al., 2012), and it helps to work toward the broader goal of making science a more inclusive field.

While faculty mentor-mentee relationships are an important and beneficial part of a student’s experience working in a faculty lab, these relationships can be complex because they involve different personalities. An effective mentor-mentee relationship is driven by a variety of factors that are determined by the nature of the relationships and the role that the mentors play in an undergraduate’s research experience (Byars-Winston et al., 2015; Daniels et al., 2019; Hammick & Acker, 1998). The mentor’s ability to give
constructive feedback, help the mentee to understand the project's context and broader impact, and help the mentee feel included in the lab are key components of a successful mentoring relationship (Byars-Winston et al., 2015).

The traditional apprenticeship-style mentoring model, consisting of a faculty mentor and student mentee, has long been the most common formal mentorship model (Griffin et al., 2010). While faculty mentors play an important role in undergraduate students' experiences within their labs, a network of mentor-mentee relationships can actually exist between various people at different career stages in lab groups. This includes faculty and student, postdoctoral researcher and student, graduate student and undergraduate student, and peers (Kobulnicky & Dale, 2016). The idea that there can be multiple mentors that an undergraduate encounters while working in a lab has resulted in the advent of multiple different mentoring models. Evidence suggests that having multiple mentors is beneficial to the student (Daniels et al., 2019; Kobulnicky & Dale, 2016; Wilson et al., 2012).

One type of mentoring model that has been shown to be beneficial is the faculty, postgraduate (postdoctoral researcher or graduate student), undergraduate triad. Undergraduates who are interacting with both the faculty member and postgraduate report higher gains in thinking like a scientist (Aikens et al., 2016, 2017). Another model that has recently shown to be beneficial to students is the community mentoring model (Kobulnicky & Dale, 2016). Under this model, students interact with multiple faculty members, postdoctoral researchers, graduate students, and peers on a large collaborative project. This type of mentoring provides students with access to multiple mentors, limiting the possible negative effects of personality clashes. It also reinforces the idea that science is collaborative (Kobulnicky & Dale, 2016; Wilson et al., 2012). This model is likely not as common as a result of its reliance on a large collaborative project across multiple labs, however a version of this model can easily be implemented within a single lab or close-working lab groups. Mentoring models like these, or some version of these, where undergraduate students are mentored by multiple people at various career stages, including peers, can be implemented within a single lab or across labs to provide students access to multiple mentors and collaborative opportunities (Kobulnicky & Dale, 2016; Wilson et al., 2012).

If undergraduate students are interacting with multiple mentors, such as faculty and postgraduates, during their research experience in a faculty lab, and we know that effective mentoring plays such a critical role in science students' undergraduate experience, we are interested in investigating the roles that different mentors play in undergraduate research experiences. Additionally, since it has been shown that participating in these experiences is associated with an increase in science identity, we are interested in determining at what point in their training that students and their faculty mentors perceive students to be scientists. This study aims to qualitatively explore the following questions from both the students’ and the faculty mentors’ perspectives: What is the nature of mentor-mentee relationships that undergraduates perceive to exist within research labs? What roles do different mentors play in the mentee's undergraduate research experience? How do undergraduate researchers and their mentors articulate the undergraduates’ identities as scientists? Ultimately, this research will help better understand the complicated network of mentor-mentee relationships that emerge of undergraduate research experiences and their relative impacts.

**Table 1. Undergraduate student responses to interview questions regarding mentoring and science identity.**

|                        | ≤ 1 Semester in Faculty Lab | 1 Year in Faculty Lab | > 1 Year in Faculty Lab | PI Is Primary Mentor | PG Is Primary Mentor | 50/50 PI & PG Mentorship | Consider Themselves Scientists |
|------------------------|-----------------------------|-----------------------|-------------------------|----------------------|-----------------------|---------------------------|-----------------------------|
| **Women undergraduate mentee (n=10)** | 1 (10%)                     | 4 (40%)               | 5 (50%)                 | 1 (10%)             | 8 (80%)               | 1 (10%)                   | 3 (30%)                    |
| **Men undergraduate mentee (n=8)**     | 4 (50%)                     | 1 (12%)               | 3 (37%)                 | 2 (25%)             | 4 (50%)               | 2 (25%)                   | 8 (100%)                   |
| **Total (n=18)**         | 5                           | 5                     | 8                       | 3                    | 12                    | 3                         | 11                          |

**Methods**

**Participants**

This research was conducted under an approved IRB protocol (#17-249). Participants in this study included undergraduate students (n = 18) engaged in research in faculty labs in a biology department and faculty members (n = 14) in the same department at a large, research-intensive university (Carnegie R1 designation) in the northeastern United States. All participation by students and faculty was voluntary, and they were not given any compensation for their participation. The criteria for faculty participation in this study were that participants had undergraduate students participating in research in their labs. These faculty members were e-mailed to solicit participation in this research. The criteria for student participation in this study were that participants were working on their own project or contributing to a larger project within a faculty member's lab. These students were e-mailed to solicit participation in this research. Student participants ranged from first-year students to fourth-year students, and all but one were majoring in biology or a field related to biology (biotechnology, public health, etc.). Students also varied in the time that they had been conducting research in a faculty lab (Table 1). Faculty member participants were the research advisors of the student participants. They varied in the total time that they have been a faculty member (Table 2). They were asked to participate in this study to capture a more complete picture of mentoring roles and expectations within the labs; however, to maintain confidentiality, neither students nor faculty knew which students or faculty had volunteered to participate.
Table 2. Faculty mentor responses to open-ended questions regarding mentorship within their lab, as well as the science identity of their undergraduate students.

| Women faculty mentor (n=5) | 1–5 Years as Faculty | 5–10 Years as Faculty | 10+ Years as Faculty | Meets with UG Mentees ≤ 3 Hrs/Wk | Meets With UG Mentees ≥ 4 Hrs/Wk | Consider UG in Lab as Scientists |
|----------------------------|----------------------|-----------------------|----------------------|---------------------------------|----------------------------------|---------------------------------|
| 1 (20%)                   | 3 (40%)              | 1 (20%)               | 2 (40%)              | 3 (60%)                         | 5 (100%)                         |
| Men faculty mentor (n=9)  | 0 (0%)               | 0 (0%)                | 9 (100%)             | 5 (55%)                         | 4 (44%)                          | 8 (88%)                         |
| Total (n=14)              | 1 (44%)              | 3 (44%)               | 10 (71%)             | 7 (50%)                         | 7 (50%)                          | 13 (93%)                        |

Interviews & Analysis

Semistructured interviews were conducted with student participants during a time that was mutually agreed upon. Interviews took approximately 30 minutes and were conducted in a private office at a table where the interviewer and interviewee sat across from one another. All interviews were recorded on a laptop using standard voice recording software and a microphone. Following the completion of all interviews, the audio recordings were uploaded and transcribed via Trint, an online transcription software tool.

Faculty participants were asked to complete a series of open-ended questions online via Qualtrics. These questions coincided with the questions asked of the student participants to allow comparisons to be drawn between student mentee and faculty mentor responses and perceptions of mentoring in the labs. Faculty participants received the link to the questions via e-mail and were able to complete it at their convenience. Faculty participants were given an online survey instead of being asked to participate in interviews as a way to increase participation. Furthermore, the questions being asked of faculty were fewer than those given to student participants and more suited for an online survey.

Following the completion of the interview transcriptions, the transcripts were read through completely and compared to the audio to check for any errors. Once all the transcripts were cleaned up, they were re-read. Using inductive coding, the lead author conducted two rounds of coding. The transcribed student responses were coded, question by question, by applying codes to excerpts of the questions. The codes were then grouped into themes and analyzed to see if there were common themes across all student participants or distinct differences of note. Similarly, once all the faculty participants had completed the open-ended questions their responses were downloaded from Qualtrics and compiled into an Excel file. Faculty responses were read through completely and coded. The codes were then combined into themes and analyzed to see if there were similarities across all faculty participants. Themes between student participants and faculty participants were also analyzed for similarities or differences in make-up between the two groups (Huberman & Miles, 2002). Additionally, frequencies were calculated for who students considered to be their primary mentor, student science identity, when faculty considered students to be scientists, and the length of time that faculty had been in that position.

Limitations

As this is a qualitative study and therefore more subjective, it is important to note the limitations. This data is not generalizable but rather a more in-depth look at student opinions and research experiences with a faculty lab at an R-1 research institution. Recruitment of students and faculty took place over two semesters, and there was no compensation for participation. The researcher that conducted the student interviews is a white woman who was a graduate student at the institution working on her PhD research.

○ Results

Undergraduates’ Perceptions of Mentors in Research Labs

When undergraduate students who were participating in research in a faculty lab were asked who they considered to be their primary mentor, 12 of the 18 interviewed students indicated that a postgraduate (graduate student, postdoctoral researcher, or lab technician) was their primary mentor, while 3 stated that their primary mentor was the primary investigator (PI, faculty member), and 3 stated that they were equally mentored by the PI and postgraduate (Table 1).

Students unanimously indicated that the person that they spent the most time with was whom they considered to be their primary mentor. Typical student explanations for this designation included, “She is always in the lab every day. So I kind of tend to go more toward her if I have a problem or a question because she’s either in the lab with me or she’s a lot more familiar with my project.” Another student stated “He’s the one that I see every day…. I’ve worked more closely with him. He’s helped me, and we’ve worked on things together.”

Roles of Mentors in Undergraduate Research Experiences

In addition to their primary mentors, students also indicated other lab members who they considered to be mentors, including other postgraduates and the PI in the lab. This aligned with who the faculty members indicated were mentors in the lab. When asked who in the lab the undergraduate students spend the most time with, 10 of the 14 faculty mentors indicated that students spend the most time with postgraduates (Table 2). When asked whom undergraduates feel the most comfortable learning techniques from, asking questions, or going to with problems they encounter, faculty mentors indicated that if a postgraduate works in their lab, undergraduate researchers would look to the postgraduate for this because they are closer in age.

Representative explanations for this pattern included that this was “because I know they used to be undergrads, so they understand. Like, I told them I have a different way of learning, I’m like a slow
learner. They understood that.” Other students indicated that it was because they were more accessible, using explanations such as, “she is always there.” Students indicated that they would not ask the faculty PI because they are not perceived to be as accessible. Typical articulations included “He has classes that he teaches and has other things that he’s working on.” Students unanimously indicated that the PI is whom they would ask to write them a letter of recommendation, and who provides them with information regarding the broad context of the research they are working on. One student stated that “[my PI is focused on] funding … and grants and she’s teaching as well.” Another described this as “the PI is more like a boss than anything else.”

When asked what their role was in an undergraduate student’s research experience, faculty mentors tended to express that it is to help students understand the “big picture” of their research project and to advise on future goals. Representative explanations included “I tend to restrict my role to discussion of the bigger picture rationale of our research and assisting with data analysis and interpretation” and “I give practical advice about how their research experience can prepare them for the next steps in their career.”

Undergraduates’ Science Identity

Undergraduate researchers and their faculty mentors articulate the undergraduates’ identities as scientists differently. When asked whether they consider themselves to be scientists, 3 of the 10 women students responded that they considered themselves to be scientists, and all 8 of the men students indicated that they considered themselves to be scientists (Table 1). Among students, all 3 of the women who considered themselves to be scientists had been working in the lab for more than one year, while the men had worked in the lab for lengths of time that varied from one semester to two years (Table 1). Whether or not their primary mentor was a man or woman did not impact whether students identified as scientists. When the students who considered themselves to be scientists were asked when they perceived themselves to have become scientists, they tended to indicate that they became scientists before entering their undergraduate programs, with typical responses, including “I think I considered myself a scientist even [during] high school” and “I definitely think it started probably back when I was in first grade, just being exposed to it and just wanting to get more and more involved and get more advanced and stuff like that.”

However, other students indicated that they became a scientist once they achieved autonomy in their project, with representative explanations including “once I kind of found some autonomy in my project, and realized I’m able to interpret these papers and apply it to my project, and kind of figured out what I’m going to do by myself,” and when “doing experiments by myself, and I started collecting data by myself.” Similarly, when the students who did not consider themselves to be scientists were asked under what conditions they might consider themselves to be scientists, they indicated that this would be when they experience autonomy in a project in the lab, with typical articulations including “probably once I start doing my own research and thinking about stuff critically instead of just doing other people’s [projects]” and “being able to have my own experiment, knowing what data I should be collecting and what I should be analyzing.” Others stated that they would not consider themselves to be scientists until they earn a higher degree or certification, often explaining that one needs “a certain certification.” There were also some students who were unsure if they considered themselves to be scientists. When asked whether or not they considered themselves to be a scientist one stated, “Yeah, to a certain degree. I guess I’ve always thought of a scientist as someone who had a PhD.”

All but one faculty mentor reported that they considered the undergraduate students working in their lab to be scientists or at least scientists-in-training (Table 2). When asked when these students became scientists, they indicated that this occurred upon entering the lab and deciding to participate in a research experience. One mentor stated that this happens “when they walk in my lab.” Another stated, “Anyone can be a scientist. They became scientists when they made the decision to engage in research.” Many went on to explain that students become scientists once they engage in research. One mentor stated that they become scientists “when they start doing experiments in the lab,” while another stated this happens “usually during the first or second semester of active research.” There was no correlation between faculty members who consider undergraduate students to be scientists as soon as they begin research and student science identity.

Discussion

Mentor-Mentee Relationships in the Research Lab

Undergraduate students engaging in research in faculty labs interact with a variety of lab members at different stages in their careers. While the PI of the lab plays an important role as a mentor in these experiences, we found that undergraduate students usually do not consider them to be their primary mentors (Table 1). Rather, students consider a person they work most closely with or spend the most time with in the lab to be their primary mentor. This person is usually a postgraduate. Students reported that this person is the person who they go to when they need to learn a technique, ask a question, or encounter a problem. Their reasoning for this is that they feel that these individuals are closer in age and experience, and they are more accessible. This is what Vygotsky (1978) describes as the zone of proximate development where learners seek help and knowledge from someone with more expertise that they consider to have been most recently in their position. No students, even when prompted, indicated that the gender of this person had a significant impact on their mentoring relationship. Students indicated that they rely on their PI for letters of recommendation and helping to better understand the big picture of their research. Student responses corresponded with those of the faculty, with faculty stating that undergraduate students spent the most time with postgraduates and that their role was reserved for big-picture context and advising on future goals and career plans. This suggests that there are multiple people within a lab group that the undergraduates consider to be mentors and that each of these mentors plays an important role in their research experience. While the role of the faculty mentor in undergraduate research is important and has been well studied, students have reported that it is the postgraduate they interact with the most, and therefore these individuals also play a potentially equally important role. Similar to our findings, Dolan and Johnson (2010) have found that postgraduates are an important part of undergraduate research experiences and are often considered to be more approachable than faculty. These results suggest that an undergraduate research experience that incorporates multiple mentors at various career stages, like a faculty-postgraduate-undergraduate triad, may provide undergraduate students with a more complete mentorship experience (Aikens et al., 2016, 2017) and may lead to beneficial outcomes such as increased science identity and self-efficacy, as well as plans to pursue research post graduation.
Disparity in Undergraduate's Science Identity

Science identity is one important outcome of an effective mentor-mentee relationship when students are engaging in research in a faculty lab (Dolán & Johnson, 2010; Estrada et al., 2018). Results from this research indicated that while all but one faculty member indicated that they consider the undergraduates working in their labs to be scientists, there was a disparity between women and men students on whether or not they consider themselves to be scientists, regardless of the time that they had worked in that lab (Table 1, Table 2). When exploring this further, undergraduate students fell into three categories regarding criteria for identifying as a scientist. One group considered themselves to be scientists before entering their undergraduate programs—from as early as first grade. Other students perceived status as scientists was achieved when they experienced autonomy in their research or when they received a certain certification or degree. Faculty mentors fell into two categories when asked this question about the students. Some stated that students became scientists as soon as they entered the lab, while others said it was when they began doing research. A disparity between genders has been previously documented with students who identify as women reporting feelings of inclusion and comfort when they have a mentor of their same gender to act as a role model (Blake-Beard et al., 2011; Daniels et al., 2019; Herrmann et al., 2016). This was not observed in this dataset, though it is possible that we did not have a sample size large enough to detect it.

This study has shown that each mentoring relationship within a lab plays a different role within the research experience for undergraduate students. Furthermore, these results have indicated that ideas surrounding what makes someone a scientist vary among faculty but have an even greater disparity among undergraduate women and men. While the idea of what makes someone a scientist is certainly subjective, this may be an indicator for other important factors, such as imposter syndrome and varying levels of inclusion in the scientific community. Given the disparity between undergraduate women and men and whether or not they consider themselves to be scientists, working to provide women with more opportunities to interact with other women in science may help to improve this, and providing faculty and postgraduate mentors with opportunities to develop their mentoring skills may help to mediate the differences in outcomes between genders (Prunuske et al., 2016). This was not observed in this dataset, though it is possible that we did not have a sample size large enough to detect it. While the idea of what makes someone a scientist is certainly subjective, this may be an indicator for other important factors, such as imposter syndrome and varying levels of inclusion in the scientific community. Given the disparity between undergraduate women and men and whether or not they consider themselves to be scientists, working to provide women with more opportunities to interact with other women in science may help to improve this, and providing faculty and postgraduate mentors with opportunities to develop their mentoring skills may help to mediate the differences in outcomes between genders (Prunuske et al., 2016). This was not observed in this dataset, though it is possible that we did not have a sample size large enough to detect it.

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Author Contributions

Schmid and Wiles participated in the design and execution of data collection, analysis, and interpretation as well as preparation of the manuscript.

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