Doctoral student experiences in biological sciences laboratory rotations

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Abstract

Purpose – The purpose of this study is to explore the experience of selecting and engaging in biological sciences laboratory rotations from the perspective of doctoral students.

Design/methodology/approach – Within the socialization framework, this study uses a qualitative approach whereby 42 biological sciences students enrolled at highly selective US universities were interviewed in the first and second year of doctoral training about laboratory rotation experiences.

Findings – The study revealed how doctoral students used formal and informal information networks, explored research topics, struggled with funding concerns and learned about the social aspect of the laboratories in which they rotated.

Originality/value – While rotations are considered a signature pedagogy in the laboratory sciences, students' experiences within them are understudied. This study offers new knowledge about what doctoral students experience while rotating that can be used to inform and improve rotation processes for both students and universities.

Keywords Doctoral education, Laboratory rotations, Doctoral student socialization, Doctoral advisor selection

Paper type Research paper

Faculty principal investigators (PIs) in the sciences have long depended on doctoral students to staff their university laboratories (labs), generate scientific findings and contribute to publication production (Dundar and Lewis, 1998; Kyvik and Smeby, 1994; Lee and Bozeman, 2005). Student graduation, and sometimes attrition, necessitate that PIs regularly replenish their doctoral student workforce to keep their labs fully functional. As such, PIs have a vested interest in attracting incoming students to their labs whose research interests and working style are well aligned with their own. In turn, for students, a critical task within their first year of doctoral training is identifying a PI willing and able to offer the research

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guidance, lab resources, financial assistance and the professional network needed to support their transition into specialized disciplinary researchers.

To sort and assign incoming students into the faculty lab in which they will spend the remainder of their doctoral training, many doctoral programs in laboratory-based sciences in the USA use rotations (Conti and Liu, 2015; Mendoza-Denton *et al.*, 2017; Ullrich *et al.*, 2014). Rotations require students to spend some or all of their first year of doctoral training rotating through multiple faculty labs (Barker, 1998). Further, they allow incoming students exposure to differing research topics and lab environments (Hall, 2006). The end goal of rotations is to match the incoming student with the PI who will become that student's permanent faculty advisor (Golde, 2007; Holley, 2009). The rotation period sets the stage for the doctoral advisor–advisee relationship to develop. Despite the vital function that rotations serve in initiating the doctoral advisor–advisee relationship, one that can "make or break a Ph.D. student" (Lee, 2008, p. 267), exploration of how students select rotational labs and their subsequent experiences within these rotations is remarkably sparse.

In this study, we explore the experience of selecting and engaging in lab rotations from the perspective of those who are less empowered in the selection/placement dynamic – doctoral students. We first consider how rotations serve as a mechanism by which incoming students are socialized into the doctoral research enterprise. We then describe the study's research methods. Next, we analyze students' descriptions of their experiences as they selected, engaged in and reflected upon various lab rotations during their first year of doctoral training. We end by using study findings to highlight pedagogical and practice-related implications associated with the use of rotations in doctoral training in the sciences.

Contextual and conceptual background

As a fixture of scientific training in many disciplines, lab rotations have been identified as a "signature pedagogy" (Golde, 2007, p. 350). This term was coined by Shulman (2005) to describe "the characteristic forms of teaching and learning [...] that organize the fundamental ways in which future practitioners are educated for their new professions" (p. 52). Changes in scientific curriculum through the second half of the twentieth century facilitated the adoption of this specific signature pedagogy in doctoral training, as the instructional context in the sciences shifted "from a place where students *read* about science to a place to *do* science" (Welch, 1979, p. 290; emphasis in original).

As Holley (2010) notes, in the USA, "Doctoral students in a range of scientific disciplines participate in laboratory rotations during their initial years of study" (p. 109). The US National Science Foundation's Integrative Graduate Education and Research Traineeship (IGERT) program, created in 1998 to promote interdisciplinary research projects and encourage students and universities alike to both master disciplinary knowledge and think beyond departmental borders, provided an impetus for developing and popularizing the use of rotations (IGERT, 2015). The program, though serving disciplines beyond the sciences, provided financial support to more than 4,000 doctoral students in science, technology, engineering and mathematics (STEM) within the program's first decade (1998 to 2007). For those studying in the sciences, the IGERT program required that funded students be enrolled in a doctoral program with rotations embedded into its curriculum (IGERT, 2015). The stated rationale for this requirement was to expand the breadth of learning without sacrificing depth (Borrego and Cutler, 2010). Though funding for the IGERT program ceased in 2015, rotations remain an important institutionalized component for many US doctoral programs (Dasgupta *et al.*, 2015; Mendoza-Denton *et al.*, 2017).

Rotations fundamentally organize a student's entry into and initial engagement within the doctoral research enterprise. As such, they serve as a key mechanism by which students

are socialized into the labor of the discipline. Socialization, a common conceptual approach within studies of doctoral education, is, broadly defined, the process through which a student acquires and internalizes a discipline's knowledge, skills, norms and values at a level that enables participation as a recognized member (Austin and McDaniels, 2006; Gardner, 2009).

As Perez (2014) notes, the concept of socialization upon institutional entry has been examined from the institutional and the individual perspective. To tease out pedagogical and policy-related implications associated with the use of lab rotations in doctoral training, both perspectives are useful. From an institutional perspective, Van Maanen (1978) described how organizations used these strategies to shape or "process" individuals into organizational members (p. 19). He emphasized that every socialization strategy, regardless of whether it is selected with intention and used with care, has enormous consequences for both individuals and the organization. As such, Van Maanen urged organizations to have a greater appreciation for the unintended consequences of their chosen 'people-processing strategies'. In response, we argue that the use of lab rotations as a people-processing strategy that sorts, slots and assimilates doctoral newcomers into the doctoral research enterprise deserves close scrutiny to reveal consequences, intended and otherwise, for doctoral programs, associated students and faculty.

At the individual student level, the socialization process is generally traced through a series of interactive stages, with lab rotations typically falling into the 'formal' stage (Gardner, 2009; Weidman *et al.*, 2001). Doctoral socialization can be framed as a bidirectional process of acculturation (Anthony, 2002; Tierney, 1997; Tierney and Rhodes, 1994). In this stance, students are not passively processed by socialization strategies, but are "active players who [. . .] socially construct their environment, and who attempt to alter that environment" (Ashforth *et al.*, 2007, p. 5). Within the lab rotation environment, there are many agents of socialization, and students both influence and are influenced by several 'active players' beyond themselves. Most notably, these include rotation PIs and those who work as part of their research teams, including an "ever-changing wave of students and postdocs" (Knorr-Cetina, 1999, p. 225).

To gain insight into how students actively participate in lab rotations and how the context in turn shapes their socialization, we interviewed 42 students recently admitted to nine different universities, each with biological science doctoral programs ranked top 50 of total research and development expenditures in the biological sciences in the USA (National Science Foundation (NSF, 2014)) that include lab rotations in their program structures. Our rationale for targeting these highly selective programs was that they should have the requisite resources to fully implement the signature pedagogy of lab rotations. Learning from students' experiences in these well-resourced programs might provide insight into best practices, as well as highlight any concerns regarding this signature pedagogy. We focus on the following research question: What are biological science doctoral students' experiences as they select, engage in and reflect upon time spent in rotation labs? Our research question informs our project aim (to gain insight into how students actively participate in the lab rotation context and how this context in turn shapes how they are socialized into doctoral education) by delving into the actions, interactions and reactions of students as they participate in a process that is both a signature pedagogy and a socialization mechanism.

Method

Because students' experiences during lab rotations are largely uncharted, we selected a qualitative approach for our study to explore students' experiences and meaning making processes (Patton, 2015). As Miles, Huberman and Saldaña (2014) noted, qualitative data

"often have been advocated as the best strategy for discovery, for exploring a new area [. . .]" (p. 12), while Corbin and Strauss (2015) observed that these data "can open minds, bring another's experience to life, and explain that which we might not understand" (p. 66). We listened to doctoral students to uncover what they learned about themselves and their profession within a lab rotation process designed to socialize them to participate in their discipline.

Study sites

Beginning in fall 2014, 336 first-year doctoral students across 53 US institutions participated in a longitudinal, mixed-method study funded by the National Science Foundation to explore student experiences in doctoral programs that included microbiology, cellular and molecular biology, genetics and developmental biology. Because a specific study focus was to investigate inequity in graduate school experiences and outcomes, student interviews were conducted only at the 27 (of 53) institutions at which underrepresented doctoral students (i.e. those who self-identified as Black or African American, Latino/Latina, Native Hawaiian or Other Pacific Islander or as belonging to "Other" racial-ethnic groups beyond White, Asian or Asian American) were study participants. The current effort, which stems from this larger study, uses student interview data from this subset of institutions but does not itself investigate inequity in graduate school experiences and outcomes.

Further, as a focus of the current analysis was to explore students' lab rotation experiences at the best resourced institutions, only the institutions (n = 11) with biological science doctoral programs ranked in the top 50 of total research and development expenditures in the biological sciences in 2014 were considered for inclusion in this study (NSF, 2014). One of these 11 was a medical center and was deemed not comparable in nature to the remaining ten universities. One additional university did not offer rotations, so it was also excluded as a study site, leaving nine top-ranked universities geographically dispersed across the nation in our study sample. All biological science programs at these universities required students to complete at least two lab rotations and most required three. Rotations varied in length across programs, with each ranging from seven to ten weeks.

Participants

In all, 42 PhD students participated in interviews across the 9 programs selected for this analysis. Of these, 24 (57 per cent) were female. Also, 24 (57 per cent) identified as White, 3 identified as Black or African American, 1 identified as Black or African American/White, 2 identified as Latino/a, 3 identified as Latino/a/White, 6 identified as Asian or Asian American, 1 identified as Asian or Asian American/White, 1 identified as American Indian/White and 1 identified as American Indian, Asian and Hawaiian. Three students identified as international students. At the time of doctoral program entry, students ranged in age from 21 to 33 years (Mean = 24 years; SD = 2.7 years). We use pseudonyms for both universities and individual participants and omit demographic information to protect participant confidentiality.

Data collection procedures

In the fall of 2014, all students who took part in the larger longitudinal, mixed-method study from which the current effort stems completed a survey capturing demographic information. These survey data allowed us to provide race/ethnicity and age for the 42 students in the current study. In early-mid spring 2015 (Year 1), when all either were undergoing or had recently completed lab rotations, students participated in a semi-structured interview designed to garner information about their doctoral experiences during

their first year of enrollment. In summer 2016 (Year 2), students were again interviewed about their doctoral experiences when all had completed lab rotations and were assigned within their permanent labs. All interviews were conducted by phone to accommodate geographic dispersion. With participant permission, interviews were recorded and transcribed verbatim. In total, 83 interviews inform the current study (one Year 1 interview was lost, but the student was retained in the study because her Year 2 interview contained extensive information about her rotation experience). The first author conducted 55 (66 per cent) of the phone interviews, while the second author conducted 17 (21 per cent); the remaining 11 (13 per cent) interviews were conducted by doctoral students who were part of the research team. Every effort was made to ensure that the same researcher interviewed the same students from Year 1 to Year 2. Most interviews lasted between 30 and 45 minutes, but some lasted almost an hour.

Protocol questions that informed this study from the 2015 (Year 1) and the 2016 (Year 2) interview protocols are presented in the Appendix. We did not design Year 1 protocol questions to directly ask about rotation experiences, as we did not anticipate the extent to which the rotation process would dominate students' lives in their first year. However, students responded to our generalized Year 1 questions with fairly detailed descriptions of rotation engagement, and we learned to probe for additional information when the topic of rotations emerged. In Year 2, we directly asked students to recount their rotation experiences. Using a longitudinal approach with two years of qualitative data provided us with a rich understanding of students' perspectives in real-time (i.e. during rotations) and reflective (i.e. in the year following rotations) ways. Additionally, we accessed websites of the programs in which students were enrolled to review university-specific rotation-related policies and procedures. These were helpful both in providing contextual understanding about each university site and clarifying any ambiguities around student descriptions of rotation-related policies and procedures in their program.

Analytic procedures

Analytic procedures began with all transcripts being uploaded to Dedoose, a web-based qualitative coding platform. The first and second author then independently reviewed Year 1 and Year 2 transcripts from five randomly selected students. Transcripts were analyzed using the constant comparative method (Glaser, 1965) in which interview data were compared and contrasted within and between transcripts, grounding initial interpretations in data. Specifically, interview data around topical areas (e.g. advisement during rotations, selection of rotations and interactions during rotations) were categorized using open coding methods, defined as "breaking apart and delineating concepts to stand for interpreted meaning of raw data" (Corbin and Strauss, 2015, p. 239). The first and second author met to compare initial coding results and resolve differences. To further refine thinking around codes, the first author created and shared memos and diagrams designed to both tease out intricacies within participant cases and discrete codes and discover the larger pattern across the data.

The first and second author created a codebook designed to be flexible throughout the coding process. The first author used this codebook to open code all remaining transcripts, taking care to identify negative cases, defined as those that "stand in contrast to the main findings of the study" (Corbin and Strauss, 2015, p. 295). The low frequency of negative cases offered a sense that in general, student rotation experiences followed a defined pattern. After open coding was complete, the first author undertook axial coding to identify overarching themes and the interconnections between these themes. Careful attention was given to how students' actual words, or *in vivo* codes, illuminated these overarching themes. These themes were then placed in sequence to provide a unified story of students' rotation experiences. To

increase trustworthiness of interpretation, the second author closely reviewed the resulting unified story and interpretations supporting it to ensure that they recognizably reflected and plausibly explained independently observed patterns within the data.

Findings

Four themes emerged that presented a holistic and interconnected portrait of doctoral students' experiences as they selected, participated in and reflected upon time spent in rotation labs. They are labeled Information Networks, Pigeonholes and Exploration, Elephants in the Room and Science and the Social Aspect. The theme Information Networks highlights the critical importance of formal and informal information networks as students learned about available rotational labs, while the theme Pigeonholes and Exploration underscores the tensions associated with identifying a scientific content area in which to specialize. Elephants in the Room reveals difficult questions to pose during lab rotations, while the theme Science and the Social Aspect explores students' experiences as they came to grips with the social nature of the scientific enterprise.

Information networks

Most of the university sites in this study offered a sometimes dizzying variety of specialty biological science areas, each containing several faculty labs. As Byron noted, "In my program we have 130-some faculty members that you could choose from". Extensive variety was a key feature that attracted many students to their programs, allowing them to explore their scientific interests. However, this variety also challenged them to find suitable rotational labs, often under tight deadlines. Mason remembered, "As soon as you got on campus, you had a two-week period of orientation, but you were expected to set up your first rotation that would occur at the end of that two-week period".

In response, students relied on both formal and informal information networks to learn about available rotational labs. In terms of formal networks, in all but one university, students described a range of departmental and programmatic personnel, including, in some cases, lab PIs, who advised them before their assignment to a PI. Students referred to these people by many titles, including 'first-year advisors', 'rotation advisors', 'academic advisors' and 'faculty advisors'. However, we found notable variation in the extent to which students perceived that these personnel were helpful, even within the same university. For example, Amelia stated, "I had an academic advisor and he was wonderful [. . .] he gave me his honest opinion on who he knew and what the labs were like. He really helped me pick those rotations", while Isabella, attending the same university, lamented, "There's absolutely no guidance of how to choose a lab to rotate in". Additionally, even when rotation advisors were available, not all students fully used them. As Erica recalled, "I only met with him once at the very beginning of the year". Beyond assigned personnel, students at two universities described sessions in which PIs accepting rotational students "come and talk to the first-year students" (Nigel), while at three universities, students reported that they were formally assigned an advanced graduate student to serve as a first-year mentor. Universally, reports of student mentors were positive, such as that offered by Ana: "I can ask her [student mentor] all these different questions about different labs that I want to rotate in or classes that she took".

Another important resource in selecting rotational labs was the informal information network consisting of rotating students as well as advanced students, postdocs and others who worked within the labs. The information network provided students with guidance on lab selection [e.g. "I've talked to fellow students in my program a lot about how to choose a lab" (Wen)]; emotional support [e.g. "I talked to one of my [doctoral cohort] friends when I was stressing about what lab to pick (to rotate in)" (Erica)], insight about ongoing projects

across different labs [e.g. "My cohort has been instrumental because I can't rotate through all the labs. I don't know if there's something more interesting or maybe that I didn't consider when I began" (Joan)] and the 'inside scoop' on PIs [e.g. "Other classmates didn't realize how terrible certain PIs were, and they should have talked to current graduate students in the lab" (Amelia); "I talked to students and heard the horror stories, because inevitably there are horror stories" (Samantha)]. As Isabella summed up, "I would tell them [incoming students] 'Don't immediately lock into your three rotations. Talk to graduate students [first]'". We note, however, that Nolan offered the opposite insight, saying "Do not take anybody else's advice and make your own decision. If you're going to base your decision on somebody else's opinion, that's a poor way to choose a lab".

Together, formal and informal networks provided a patchwork of information about rotational labs. However, available formal networks were not equally resourced among and even within universities. Further, not every student was equally or consistently assertive or interested in using information available in formal and informal networks.

Pigeonholes and exploration

Although all students were pursuing a doctorate and intended to eventually master a highly specialized area of expertise, several described the danger of entering the doctoral program with circumscribed scientific interests. As Claire observed, "Some people pigeonholed themselves into a specific field and then realized that they didn't have hardly anybody to do rotations with, and that was extremely stressful". Gloria added, "A lot of people have this one thing that they want to study. Then they don't find a lab that studies that perfect one thing, so they end up feeling really disappointed or wanting to switch schools". Students also described limiting exploration for other reasons. For example, Francisco noted:

> A lot of people [. . .] rotate in one lab that they'd like to join, and the next rotation, they're like, 'I don't care about this one' because they want to join the other lab.

Byron described selecting a rotation because the lab undertook research similar to what he conducted as an undergraduate; he described the lab selection as "just a very comfort pick". Further, some students noted that they became overly focused on coursework, which may have contributed to restricting exploration. As Jackson recalled, "I almost took a sabbatical from the lab in one rotation because I really needed to focus on school and do well in the classes".

However, a much more common theme in students' descriptions of rotation selections was the need to be open to discovery and scientific diversity while making these selections. Comments such as "Be really open with the science" (Gloria); "Keep your mind open" (Francisco); "Try new things" (Mason); "Find new interests" (Elaine); "Just try something you never thought you'd be interested in doing" (Leah); "Explore many options" (Jane) and "Rotate outside your comfort zone" (Colt) were common in students' descriptions of what they had learned about selecting rotations. The spirit of exploration was captured in Jenna's voice as she reflected that incoming students should "[. . .] just try things that you haven't done before, because when you're a rotation student, you have this protected time to mess up, and for people to teach you new things". The reward of exploration was evident in Violeta's description of rotating in a lab she thought she would dislike, but later joined:

> It was really funny for me and ironic because I was always saying I would never do this type of science, and I ended up loving every single minute of it, loving my project, loving the relationships in the lab. I don't regret it at all. I think this lab that I'm in is the best choice that I could've made. It's the best science I've ever done and my growth as a scientist has been incredible and stunning to me as a human being. It's amazing.

Elephants in the room

As they rotated, students gathered information about the science being conducted and the people conducting the science. However, their purpose in rotating was not simply to learn about science and scientists, but also about how they, as emerging scientists, could secure a place for themselves within one of the labs. Securing a place required money, an uncomfortable topic for some. As Josiah stated:

> I would advise students to be upfront in talking to PIs about money. It's the elephant in the room in graduate school, finances and grants. The PIs are definitely under a lot of stress to get money [. . .] just opening up that discussion to talk about an aspect of graduate school that's a real one but nobody really want to address.

Not confronting 'elephants' proved deleterious for some rotating students. Some PIs appeared to be upfront about the limits to their resources. As Deanna recalled, "I had a very hard time figuring out where I wanted to rotate. A lot of them [PIs] said that they didn't have room in their lab, they didn't have space". Other PIs, however, appeared to be less candid. Students described situations in which they rotated in labs that they later learned did not have the space or money to accept them as a permanent lab member:

> Within two weeks of starting that rotation, I knew for sure the spot was filled [by the summer rotation student]. I wasn't allowed to switch, so it was fruitless for me to try and work in that lab because he [the PI] just didn't have the money for it. (Jackson)

> I didn't realize that even at [this university] there's turnover where faculty members don't get funding. The program itself doesn't want to fund students so you really need a faculty member who's independently funded. (Erica, who was forced to leave a lab she had recently joined as permanent member due to lack of funding).

At every university study site, at least one student reported rotating in a lab in which there was no permanent placement available for him or her. Aaron observed, "Many professors are tight on funding, but just how tight is hard to tell sometimes". Jane advised students to "be up front about asking whether the professor has money to take on new students. Sometimes they'll take rotation students without seriously considering taking on a Ph.D. student. It's a waste of a rotation for the graduate student". Given that students have a limited number of rotations among which to find a permanent lab home, 'wasting' even one rotation is concerning. As Colt urged, rotating students should "talk to PIs, make sure that before you spend time rotating, it is a lab that could feasibly take you. Essentially make every one of your rotations a realistic job interview on both your part and the professor's part".

Science and the social aspect

As students rotated, they constantly weighed and balanced their evolving scientific interests within and against each lab's social context. As Luis explained when describing why he selected a permanent lab, "I really like the science, but the social aspect was also important". A primary concern was identifying a PI with whom students perceived they were intellectually and interpersonally compatible. As Aaron memorably described, "It's kind of like dating and courtship during these rotations. You're trying to make that match with that professor". For many, the process of finding a PI began with identifying the type of interpersonal relationship they sought. Levi recalled that it was important to "get a good idea for yourself what aspects are important to you [. . .] a hands-on professor or hands-off professor? Find out what is important for you and then choose accordingly". In each lab, students tried out different PI mentoring approaches and personalities. For example, Elaine stated:

> Each rotation was slightly different in terms of what the investigator was like. My current advisor [. . .] she's very invested in her students. The second lab was an established, older lab. The investigator met with me only twice, once was five minutes in the elevator, the other time ten minutes in an office. My last rotation was kind of in between. The professor was very hands-off, so while I did well in that rotation, I had to come up with a lot of my own ideas.

In addition to the PIs, most labs in which students rotated contained many other members, from undergraduate students to postdoctoral fellows. Rotating students had a chance to observe their potential lab mates up close, as they "tagged along with another graduate student in the lab for seven weeks" (Amanda) or were "pawned off to a post-doc" (Byron). Some reported that they "actually didn't do a whole lot of work during rotations" (Chelsea), as they were "bouncing around a lot" (Janelle) doing "a bit of everything" (Caleb). For many, the main task appeared to be keenly observing human behavior in the labs. As Avery noted, it was critically important to "pay attention to how people interact with each other in the lab". Claire elaborated on this idea, stating that in rotations, "You got to see your lab and your potential lab mates in a variety of settings [. . .] you have ample opportunity to see people at their best and at their worst". Violeta added, "It [participating in rotations] was a very interesting process because it's like you're visiting family homes, so you really got to see like a little bit of what the dynamic is in the family".

Many students' reflections clearly indicated that the social aspect of labs trumped whatever rotation project they were assigned [e.g. "The rotation project itself is not the most important thing [. . .] It's really meshing with the lab culture" (Aria); "Don't worry so much about the science, because ninety-five per cent of students do not do their rotation project in their thesis work [. . .] instead focus more on how you get along with your PI" (Amanda); "I don't enjoy doing experiments so much, but I did in that lab, really because I think the people were very nice" (Otis)]. For some students, the social aspect was even more important than the research:

> I would argue that the people who are in the lab are almost more important than the research because if you get along with the people and if you like working with the people you can learn to love the research. If you hate the people you work with, you're not going to want to come into lab every day. (Blake)

Clearly, balancing evolving scientific interests within and against each lab's social context to determine one's fit was a major task of these rotating students. However, perhaps the best advice on how to do this came from Morgan, who offered, "You want to make a good impression, but you have to remember to be yourself. Be who you are".

Discussion and implications for practice

Rotations are a common feature in many doctoral programs in the lab sciences (Conti and Liu, 2015; Holley, 2010). As a signature pedagogy (Shulman, 2005), they organize what is taught and learned as students first engage with ongoing research within the doctoral program they chose to attend. As a socialization strategy, rotations are the training ground upon which doctoral students grapple with new disciplinary skills and knowledge in efforts to transform themselves from disciplinary outsiders to insiders (Austin and McDaniels, 2006). Further, as with all socialization strategies, they have enormous consequences for both individuals and the organization, intended or otherwise (Van Maanen, 1978). Yet despite the importance of rotations for these reasons, little is known about students' experiences within them.

Our findings speak to socialization theory in a number of important ways. First, highly selective institutions in our sample may have had rotation-related resources. However, these resources were not effectively used to help students learn about available rotational labs and support during the selection process. As reported by students, only two sites had rotation PIs talk with incoming students about their labs, and only three sites assigned advanced

graduate students as mentors to rotational students. Most students, thus, relied on the informal network of peers, advanced students and postdocs to learn about rotational labs.

The 'student grapevine' is, in fact, a recognized socialization mechanism in doctoral education (Gardner, 2007). Peers can provide keen insight into the inner workings of a doctoral program and labs within that program that may not be forthcoming from faculty and other programmatic personnel. However, needing to rely on such mechanisms opens the door to systemic inequity in information access. For example, Gardner and Holley (2011) found that first-generation college students in PhD programs reported experiences of social disconnect that hindered their ability to access and benefit from social and cultural capital within their academic institutions and that "such connections were haphazard, rarely part of a planned, deliberate effort on behalf of the educational system" (p. 87).

The relatively limited and haphazard advising that students receive with respect to selecting rotations, often under pressure and a short time frame, may be deleterious to their intellectual development as well as unproductive for the lab in which they are placed. We suggest that doctoral programs would do well to carefully review their advising processes related to rotation selection, provide lists of labs that have spaces available, encourage the PIs of these labs to meet with incoming students, ask advanced graduate students to serve as peer mentors and ensure that students receive consistent information and support throughout the decision-making process. This may be especially important for large programs with many potential rotation choices, where it is particularly challenging to identify a suitable rotation (and subsequently a permanent lab) and for individuals who may have limited access to or comfort with the informal networks that offer such guidance in the status quo. Thus, policies and information dissemination practices that provide explicit guidance on considering and selecting labs for rotation to all students as a matter of course would likely be of great benefit to students who are not positioned to benefit optimally from the 'student grapevine' or well-meaning faculty.

Our second key finding illuminated just how malleable students' scientific interests could be during the lab rotation period. We found students who significantly altered their scientific interests based on a single rotation. This finding illustrates the power of rotations to indelibly shape emerging scientists in ways that can be productive but also unanticipated. It also emphasizes the need for students not to foreclose on their scientific interests too quickly, even when doing so might lessen the uncomfortable ambiguity often associated with the first year of doctoral training (Golde, 1998; Keefer, 2015). We posit that students who self-circumscribe their opportunities to explore during rotations may unwittingly deter the development of their full potential as emerging scientists. Further, and pragmatically, students who set their sights on only one lab while discarding other options run the risk of being surprised, disappointed and potentially without a permanent lab for placement if this single lab falls through. Advanced graduate students, serving as mentors, could provide valuable information about their journeys and lab selection. Additionally, doctoral programs may deter a rush to foreclosure by allowing incoming students time to learn about available labs, instead of requiring them to secure rotations soon after program entry.

Our third key finding noted how money underpinned students' rotation options and experiences. This was not entirely unexpected, given that the mantra "funding or famine" has replaced "publish or perish" in the academy, at least the sciences (Stephan, 2012, p. 229). A program may boast 130 faculty labs, but only those with funding to accept new doctoral students are, in reality, viable rotation options. Some students appeared not to recognize this reality. Of considerable concern is the rotation that a student undertakes in good faith only later to learn that the PI cannot fund a permanent lab placement.

The practice of accepting rotation students for whom no funded permanent placement existed was noted across all universities in our study, suggesting that it may be endemic to

the rotation process. Given the continuous search for funding, PIs may not always know their funding situation for the next year. Nevertheless, rotating in a lab without funding could waste students' time and delay their progress through the program. It could also potentially contribute to an already high attrition rate, with 40 per cent of attrition among science, technology, engineering and mathematics doctoral students occurring in the first year of doctoral training (Lott *et al.*, 2009). The main implication for doctoral programs is clear: PIs need to be up-front about the funding situation, in terms of whether funding is available or is more tentative (e.g. a pending grant). Programs should also eliminate labs as rotation options if they cannot demonstrate a reasonable likelihood of prospective funding.

Our final key finding supports Kemelgor and Etzkowitz's (2001) observation that "Science is an intensely social activity" (p. 153). In science, relationships matter a great deal and can unlock (or not) access to an array of resources such as funding, publications and prestige (Gopaul, 2016). Most attention in doctoral education is directed to the advisor – advisee relationship (Zhao *et al.*, 2007). However, in the sciences, additional research now examines how others in the laboratory (peers, advanced graduate students, postdocs and other faculty beside the PI) influence the both the processes and outcomes of doctoral education (Golde *et al.*, 2009). Our findings contribute to and extend this literature by indicating that the need for students to consider both the science *and* the social aspect in which it is entangled begins immediately upon engagement in research as a doctoral student. Indeed, this is one true benefit of the rotation experience – as opposed to just reading about the labs' research online or through publications, incoming students get to experience those labs, along with the very important social dimension. This highlights the value of rotations beyond the development of research/scientific skills.

Conclusion and future directions for research

Scholars have long noted that rotations serve to introduce students to differing research topics and lab environments (Golde, 1998; Hall, 2006). However, our study is the first of which we are aware to examine the experience of selecting and engaging in lab rotations from the perspective of doctoral students. Our findings indicate that as a socialization mechanism, students' rotation experiences do indeed notably shape the scientist-in-the-making, even while the students actively and uniquely shape their own rotation journey. The decisions made during this time will in turn shape students' professional trajectories. Our findings also suggest that rotations provide students the chance to develop as scientists in both expected and unanticipated ways. While our study offers novel insight into a critical period of scientific development, it also uncovers a wealth of new directions to be explored.

Our study was purposefully situated at highly selective institutions with the rationale that they should have the requisite resources to fully implement the signature pedagogy of lab rotations. Further research is needed to examine whether these findings apply to less selective institutions, which educate the majority of the doctoral students in the sciences (Gardner, 2010). Notwithstanding, the institutions in our study evidenced variation in both the number and length of rotations, as well as the types of formal supports they provided. Future research is needed to examine which combinations of rotation requirements and supports may offer the most beneficial outcomes for incoming students.

Our study did not address individual differences among rotation students, but rather, students' rotational experiences as a whole. Teasing out how student differences, such as race/ethnicity, gender and first-generation status (among others), might influence rotational experiences could prove fruitful, especially as the role of social and cultural capital becomes more prominent in discussions of graduate education (Posselt and Grodsky, 2017).

Finally, our study provides the impetus to understand the prospective impact that students' rotational experiences have on doctoral outcomes, such as attrition, degree

completion time and career goals, as well as more distal outcomes, such as scholarly productivity and career attainment. Future studies may gain insight into these issues through comparisons of programs within individual disciplines that differ in their use or structure of lab rotations. Likewise, such research would benefit from exploration of potential differential impacts linked to students' demographic characteristics and other factors associated with access to academic social and cultural capital.

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Appendix. Interview protocol questions informing this study.

2015 (Year 1):

- Describe the biology program characteristics you considered as you were applying to program, and describe why these characteristics were important to you.
- Describe the research activities you are or anticipate undertaking in this program.
- Describe yourself as a researcher.
- Do you have a doctoral faculty advisor now?
- If not, how and when will you obtain one?
- If so, how was that relationship established?
- On a day-to-day basis, who do you turn to for support as you proceed through this program and why?

2016 (Year 2):

- Think back to your experiences as you were rotating and deciding on a permanent lab to join.
- What was it like going through this process?
- How do you feel about the process?
- What advice about this process would you give to PhD students in your area who will start their program this fall?
- What has been the biggest academic challenge you faced this past academic year?
- Who helped you through this challenge?
- Is there anything else you would like to share with me about your doctoral experience in the past year?

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