DR. NATHAN EMERY (Orcid ID : 0000-0002-9766-8044)
DR. AMANDA KATHRYN HUND (Orcid ID : 0000-0001-7758-6757)
DR. MEGHAN DUFFY (Orcid ID : 0000-0002-8142-0802)

Article type : Academic Practice in Ecology and Evolution

Title

Students as ecologists: Strategies for successful mentorship of undergraduate researchers.

Short Title/Running Head

Mentoring undergraduate researchers

Authors & Affiliations

Dr. Nathan Emery
Department of Plant Biology
Michigan State University
emeryna1@msu.edu

Dr. Amanda Hund
Ecology and Evolutionary Biology
University of Colorado, Boulder
Amanda.Hund@Colorado.edu

Dr. Romi Burks
Biology Department
Southwestern University
burksr@southwestern.edu

This is the author manuscript accepted for publication and has undergone full peer review but has not been through the copyediting, typesetting, pagination and proofreading process, which may lead to differences between this version and the Version of Record. Please cite this article as doi: 10.1002/ECE3.5090

Dr. Meghan Duffy
Ecology and Evolutionary Biology
University of Michigan
duffymeg@umich.edu

Dr. Christine Scoffoni
Biological Sciences
California State University, Los Angeles
cscoffo@calstatela.edu

Dr. Andrea Swei
Department of Biology
San Francisco State University
aswei@sfsu.edu

Abstract

Guiding undergraduates through the ecological research process can be incredibly rewarding and present opportunities to break down barriers to inclusion and diversity in scientific disciplines. At the same time, mentoring undergraduate researchers is a complicated process that requires time and flexibility. While many academics receive extensive guidance on how to be successful in research endeavors, we pay much less attention to training in mentorship and working collaboratively with undergraduate students. This paper seeks to provide a framework for successfully collaborating with undergraduates including initial recruitment, development of a contract, fostering student ownership of research projects, and submission of a polished manuscript.

Keywords:
Mentoring, undergraduate research, professional development

Introduction

Involving undergraduates in genuine research experiences has tremendous positive impacts on their education and learning outcomes when done well (Lopatto 2007, Linn et al. 2015). Research experiences can empower students to conduct independent investigations and exercise critical thinking skills while providing opportunities for building diversity and inclusion in the sciences (Haeger et al. 2016, Davidson & Lyons 2018, Parker 2018). Mentoring undergraduates through research and publication comes with its own set of challenges (Lunsford et al. 2013) but can have many positive effects on faculty mentors (Burks & Chumchal 2009, Adedokun et al. 2010, Laursen et al. 2012, Hayward et al. 2017, Hall et al. 2018) and can significantly impact scientific progress across disciplines (Rovnyak & Shields 2017). Particularly for ecologists, collaborating with undergraduates on research should feel natural, as collaborative research occurs frequently across the discipline (Leimu & Koricheva 2005, Gorham 2014). However, while mentoring and working with undergraduates comprises one of the core aspects of being a faculty member (Austin 2002), academics often receive little to no training in mentoring skills and strategies (Hund et al. 2018). As ecologists with positions at a number of different universities, we sought to identify and describe best practices for collaborating with undergraduates on research projects including recruitment, development of a research question, submission of a publication, and to highlight strategies for success that apply to a variety of situations.

Undergraduate students differ from graduate students and postdoctoral researchers (postdocs) in several ways. First, often new to science, undergraduates likely have limited experience working within the scientific process and may be wholly unfamiliar with academic research and culture (Ovink and Veasey 2011). Second, they may be juggling many outside demands on their time including classes, work, extracurricular activities, and/or family obligations that prevent them from dedicating significant time to research (Fairchild 2003). Lastly, while graduate students have committed themselves full-time to scientific research, undergraduates are likely still figuring out what career they want to pursue. Thus, they may justifiably question whether research will help them in their long-term goals. These unique characteristics of undergraduate researchers reinforce the importance of being flexible, patient and cognizant of students' individual needs when developing one's mentoring approach.

Although many diverse ways exist to collaborate with students in ecological research, experiences typically fall into two categories, Undergraduate Research Experiences (URE) and Course-Based Undergraduate Research Experiences (CURE; Auchincloss et al. 2014). CUREs can be a useful way to involve many students in genuine research experiences. However, given the limited time scale of most CUREs (usually as semester at most), students may have difficulty in participating throughout the entire process from question to publication. Targeted at fewer students, more focused UREs provide opportunities for quality 1-on-1 mentoring (Lunsford et al. 2017) and more in-depth professional development (Shellito et al. 2001, Shanahan et al. 2015). Involving undergraduates in a research program and guiding them through the scientific process from research question to publication submission often involves a complex path of obstacles and opportunities (Laursen et al. 2012). These bumps in the road might be novel for early career mentors, and this paper seeks to provide some guidance for research mentors interested in advising undergraduates through the entire research process.

The six authors of this paper come from diverse institutions and career stages. All have experience collaborating with undergraduates and are passionate about mentoring young scientists through the ecological research process. We have all been student researchers at one point, and we now navigate the role of research mentor at institutions across the United States. We all agree that successful collaboration with an undergraduate is a partnership between the mentor and the student. This partnership can be described by the following quote:

"…good supervision is characterized by trusting relationships where students and supervisors share research interests and supervisors provide advice without undermining students' ownership of projects, resulting in evolving supportive relationships that foster student growth" (Roberts & Seaman 2018)

A framework for successfully collaborating with undergraduates from scientific question to publication

We have organized the many facets of collaborating with undergraduates into several sections:

1. **Recruitment and Retention**: When bringing on new students, mentors must take many things to take into account, including their own resources and limitations. Below, we describe strategies and advice on recruiting and retaining students for undergraduate research projects.
2. **Communication and Contracts**: Because clear communication plays such a crucial factor in collaborating successfully with undergraduates, we give specific advice below on how to develop a mutual agreement with a student, and how to maintain effective communication.
3. **Peer mentors**: Involving others in the mentor-mentee relationship can be beneficial for both parties. We discuss how to effectively leverage peer mentors in the process of guiding students through independent research projects.

4. **Benchmarks, Deadlines, and Rest**: The undergraduate research experience, from start to finish, takes a lot of time and varies in its intensity. Mentors offer professional development, boundaries, and rest stops for students as they navigate through the scientific process.

5. **Student ownership and publication**: In addition to student ownership of a project, mentors need to consider how to work with students through the publication process, especially once they have completed their undergraduate degree. We detail ideas and discuss strategies for guiding a project to completion.

<<Insert Figure 1 here>>

1. Recruitment and Retention

Research experience as an undergraduate is an important step for many scientists on their way to graduate school and careers in STEM (Hathaway et al. 2002, Linn et al. 2015, Estrada et al. 2018). For many young researchers, this experience plays a critical role in building one's identity as a scientist (Lopatto 2007, Palmer et al. 2015, Robnett et al. 2015). Students arrive to college with different motivations and aspirations and can feel intimidated by scientific research and senior academics. As a mentor, it is incredibly important to build an environment where students feel empowered to ask questions and contribute their ideas (Matthews & Rosa 2018). Through good mentorship, students gain confidence in their research abilities and develop an identity as a scientist (Linn et al. 2015; Davis & Jones 2017; Roberts & Seaman 2018), notably an important component in the retention of underrepresented student groups in science, technology, engineering, and math fields (STEM; Strayhorn 2012, Wilson et al. 2012, Rainey et al. 2018). Research experience also yields value to students who do not pursue careers in research, as it gives them first-hand experience with the process of generating scientific knowledge. While it would be ideal to offer this opportunity to every interested student, quality mentoring requires a considerable amount of time and funding, and resources for projects are finite (Johnson et al. 2015). Given these constraints, mentors should think intentionally about how they recruit, choose students for research positions, and offer students opportunities to advance to independent research projects.

1.1 Selection

From the mentor's perspective, it seems obvious and beneficial to offer research opportunities to the students who will make the most of the experience, contribute to research, and be a positive member of the research community. However, this selection process can be difficult. In our collective experience, choosing talented, self-motivated students willing to commit to a long-term research project increases the likelihood of project completion and publication. Research opportunities should be advertised widely and some students, such as those from groups traditionally underrepresented in STEM fields, may need special encouragement to apply (Crisp et al. 2015, Estrada et al. 2016). Advertising in courses and holding open informational meetings where students can learn about different research opportunities in a department provides equal footing for students. When choosing among applicants, mentors need to be aware of biases, both conscious and subconscious, that could discriminate against certain students and influence the hiring process (Milkman et al. 2015, Houser and Lemmons 2016, Hansen et al. 2018). We recommend that mentors take the time to recognize one's/their own implicit biases through training exercises (See Supplement S1).

Before interviewing potential incoming students, mentors need to take two steps. First, make a list of the different projects students could join/lead in the lab and identify any challenges and constraints for each (Table 1). The success of a student in research depends partly on the project assigned: an appropriate project will be one within the student's abilities, while leaving room for them to grow in skills and knowledge (Hunter et al 2007). Second, as a mentor, identify what student traits hold the most value. Student success is predicted by more than just their current GPA (Dennis et al. 2005, Komarraju et al. 2008). During the interview, ask the student what motivates her/him/them to do ecological research. We suggest that the best students include those excited about the topic, motivated, hard-working, curious, and reliable. While not an exclusive characteristic of quality students, undergraduate researchers also tend to be more inclined towards pursuing an advanced degree (Lopatto 2004, Russell et al. 2007). While it might be hard as a mentor to identify these traits in one "interview", we suggest including other lab members in the "interview" process as it may reveal more information and increase the comfort level of the potential student. During the first term of the student working in the lab alongside other lab members, look for signs of motivation, independence, and reliability. The mentor ultimately decides whether the student can oversee an entire project (i.e., become first author on a paper) (Burks and Chumchal 2009), participate as a co-author alongside other students that would lead it, help out in the lab on lower level tasks, or leave the lab to continue different pursuits next term.

<<Insert Table 1 here>>

1.2 Inclusivity

Mentors must also consider larger issues of inclusivity and diversity when recruiting and hiring undergraduates (O'Donnell et al. 2015, Carpi et al. 2017, Hernandez et al. 2018). Because research experience serves as such an important step in pursuing a career in STEM, mentors, as the gatekeepers, need to carefully consider their recruitment practices to ensure an equitable and inclusive process. We know that student participation in classrooms can differ across demographics and personalities (Fritschner 2000), and peer interactions are affected by student characteristics (Eddy et al. 2015). We can surmise that some students will feel comfortable directly contacting faculty to ask about and pursue research opportunities. By only hiring the most vocal students, we possibly miss out on high quality talent and diversity. Good advertising and conscientious hiring practices help diversify undergraduate research but making undergraduate research more inclusive should not stop there.

Too often student research positions go unpaid, or offer very little compensation, particularly over school breaks. This problematic practice limits the students who can participate. For example, students who have less financial support from their families may have to take on jobs to help pay expenses, rather than volunteer for a research position (Fournier and Bond 2015, Holford 2017, Shanahan 2017). The same issues apply to field positions that require students to pay for their own travel or living expenses or have access to a vehicle to get to field sites. We acknowledge that research funding to pay students and cover their expenses may be very difficult to come by, however, this 'norm' represents a critical issue that we need to think about and address as ecologists (Fournier and Bond 2015). As a start, mentors could seek out programs, both at the institutional level and nationally, that focus on promoting inclusion and diversity in undergraduate research and offer funding opportunities. These programs are opportunities to find students, provide financial support, and help build a sense of community among student researchers (see Supplement S2). Funding for undergraduate researchers should also be included in grant budgets and funding agencies need to recognize the importance of this support. Through recruitment practices, mentors have the potential to remove barriers and adopt inclusive practices that chip away at the long-standing discrepancies in ecology and other scientific disciplines and help retain STEM students (Hurtado et al. 2009, Moss-Racusin et al. 2012).

1.3 Diversity of student opportunities

Once students are selected for research positions, their commitment and success depend heavily on how much support they receive from their mentor (Hunter et al. 2007, Russell et al. 2007, Hartmann et al. 2013, Linn et al. 2015). Given this, mentors need to consider carefully how many students they can take on and be realistic about their capacity (see Table 1). We believe that fewer, well-supported students with consistent access to a mentor generally translates into higher quality research, and a better experience for both students and mentors. At the same time, involving multiple undergraduates at once can foster a sense of community and provides opportunities for students to help one other.

Undergraduate research takes on a variety of shapes from a student who helps complete a small task for an existing project to a student conducting an independent research project and authoring a publication. To see a project through to publication, a student and their mentor need to be prepared to commit time and energy over several semesters (if not years) (Morales et al. 2017). Scaffolding student experiences to build up to conducting independent research helps ensure the commitment level required to see a project through to completion. New students can join pre-existing projects working on "low-stakes" tasks and progressively work up to more "high-stakes" and independent tasks. During this development period, students require guidance through carefully chosen readings and discussions to better understand how the current research fits into a larger scientific framework. By incorporating new students into the lab community (e.g. have them attend lab meetings), they also observe more advanced undergraduates and graduate students. Though this process, students learn about the scientific process and gain a more realistic view of what it takes to do independent research. With this knowledge in hand, they become better equipped to decide if an independent project fits into their goals. This process also gives the student time to develop their own scientific interests and preferences. As students develop, mentors can determine which students should move on to independent research and help them to develop a project that provides a good fit.

2. Communication and Contracts

Successful mentoring relationships have a foundation of clear and open communication (Nakamura et al. 2009). Differences in expectations between the mentor and mentee is the most common factor underlying problematic research experiences (Roberts & Seaman 2018). When mentors make themselves accessible and students feel comfortable communicating, mentors can better help students through difficult periods, research progress goes more efficiently, and students have more positive experiences. Carrying out scientific research likely differs substantially from a student's past experiences. Most notably, research involves a lot of failure, something that many undergraduate students often fear, work actively to avoid, and typically lack the experience to understand that failure is a teacher (Linn et al. 2015). Clear and frequent communication with a mentor helps students understand that scientific insight often comes from failure (Burger & Starbird 2012), bolstering student confidence and motivation, increasing satisfaction with their research experience, and fostering a sense of project ownership (Hunter et al. 2007, Eller et al. 2014; Linn et al. 2015). One possible way to facilitate a positive attitude about research is by sending an encouraging note to the student from time to time as they persevere through research objectives.

2.1 The contract

Communication plays a key part in a successful research experience and many undergraduates may not be familiar with the norms and expectations of how they should interact with their mentors, or may be uncomfortable initiating conversations or meetings. We recommend that mentors take the lead in establishing effective and frequent communication and clearly outlining the research process. While we have developed a base contract based on the collective authors' experiences, we suggest that mentors develop their own undergraduate mentoring contract that can be shared and discussed with students (see example guide in Supplement S3). The contract clearly outlines expectations, both for the student and the mentor. It should formalize policies on expected behavior, means and frequency of communication, participation in the lab community and activities, rules regarding lab equipment or resources, required safety trainings, schedule and flexibility of research work, authorship, deadlines, and other important information that will help students succeed and work well with others. Beyond making expectations clear and explicit, discussing this contract early gives the mentor and student a common language and something to refer to when needed. It also helps to keep both the student and the mentor accountable. Most conflicts and issues that arise in mentoring relationships stem from miscommunication and misunderstandings (Burk & Eby 2010; Eby et al. 2010).

Much of the mentoring contract can be standardized for all students working in the lab, but we find the best contracts contain customizable elements for each individual student. Students differ in their personalities, working styles, goals, and backgrounds (Rose 2005). Student needs will also change as they gain experience and develop as scientists (Thiry & Laursen 2011). Thus, individual students will need different types of support from their mentor, requiring different mentoring strategies that best fit a given student (O'Meara et al. 2013, Opengart & Bierema 2015, Hund et al. 2018). Developing a flexible communication plan starts with personalizing components of the mentoring contract and engaging in early discussions with students about the mentoring style that will help them thrive.

2.2 Meetings

The initial meetings with a new student provide a critical opportunity for setting the right tone and establishing expectations=. Mentors should aim for one-on-one weekly meetings with each student, or in some cases, bi-weekly. Regular meetings provide time not only for tracking progress, taking care of practical research business, and addressing problems early, but also time to build a good mentoring relationship (Baker & Griffin 2010). During these meetings, mentors should allow space for students to discuss their projects in a broader context, their future goals, general science questions and interests, and questions they have more broadly about academia and research.

Collectively, these conversations contribute to a student's sense of belonging, improve their science communication skills, and help them articulate their goals for science and research (Elgren et al. 2006). Frequent communication and support also improve student mental health and persistence, helping them to persevere when problems arise and research does not go as planned (Estrada et al. 2018, Hernandez et al 2018). By asking questions and being a good listener, mentors demonstrate to students that their work and ideas have value.Students, in turn, develop ownership over their research with increased incentive to work hard and invest more in their projects (Hanauer et al. 2012).

Lastly, documenting meetings provides accountability and a record of research progress. One easy way to do this involves creation and maintenance of a shared, online document that highlights the topics discussed at each meeting and sets the short and long-term goals for the student's research. This can be helpful for the student as a reference and equally useful for busy mentors as it serves to document what previously occurred. If the mentor expects a student to work a certain number of hours, this shared document can also serve as a time and activity log.

3. Peer Mentors

Individual weekly meetings with undergraduates can seem like a daunting time investment, particularly when several students work in the lab at the same time. Many senior mentors simply lack time in their schedules to meet with undergraduates as often as they might wish (Lunsford et al. 2013, Baker et al. 2015, Roberts & Seaman 2018). While understandable, a lack of contact and feedback is problematic as it undermines student confidence and motivation if students perceive a lack of interest, rather than a lack of time. When available, sharing the responsibility of mentoring with a postdoc or graduate student, particularly if they work on similar projects, can increase frequency of feedback and provide professional development for the junior mentors. This allows the undergraduate to still have regular access to a mentor and would also be a chance for the postdoc or graduate student to gain valuable mentoring experience (Dolan & Johnson 2009). In this situation, faculty mentors should check in regularly to ensure that the student receives the support they need. It is also important that mentors have discussions with their graduate student or postdoc about mentoring best practices and support further mentorship training for these early career scientists (Dooley et al. 2004, Weigel 2015, Hund et al. 2018). These training opportunities are sometimes difficult to find, although many institutions provide mentorship resources or mentoring programs. Some training materials are freely accessible online, such as the mentoring manual from Pathways to Science (https://pathwaystoscience.org/manual.aspx) or the *Entering Mentoring* training curriculum developed by the University of Wisconsin, Madison (https://cimerproject.org/#/curricula/training-materials).

Lab productivity depends strongly on building a friendly community among students, staff and faculty and establishing a culture of hard work and scientific ethics. Indeed, the friendlier and more supportive students act towards one another, the more each learns, and the more motivated and hardworking they become (Kobulnicky et al. 2016). Peer mentoring has long been studied as a means of helping undergraduates succeed (Budge 2006, Nicholson et al. 2017) by helping students work through periods of failure or frustration (Baker et al. 2014) and reducing barriers to seeking help (Gross et al. 2015). If students do not get the chance to know one another, they may become less motivated and not put in the extra mile required in research. Having a socially well-adjusted lab group with fun activities such as potluck dinners, karaoke, or sporting events for example, also serve as a mentor’s future recruitment tool as new students witness the community established in the laboratory. Incorporating students into a community of mentors within a lab group and beyond can improve undergraduates’ performance, confidence, and sense of belonging, which play particularly important role in retention of underrepresented minorities and first-generation students (Good & Halpin 2000, Kobulnicky & Dale 2016). Peer mentors typically function in two types of roles, either as a research partner (paired projects) or as a “senior” undergraduate in the lab (“senior” researchers).

3.1 Paired projects

Pairing students on projects often provides a good way to foster a friendly and supportive lab environment and increase research productivity and enthusiasm. Peer mentoring experiences have positive impacts for all students involved, building confidence, motivation, and communication skills (Lopatto 2010). Collaboration is an essential part of scientific research and is becoming increasingly important in the field of ecology (Goring et al. 2014, Perez et al. 2018). By working as a team, undergraduates have the opportunity to develop and practice the skills necessary for collaboration. Team-based research, while providing multiple benefits, could come at the cost of independent ownership and development of each student. We suggest a possible compromise is to have each student responsible for different parts of a larger project, specialize on different aspects of the same project, or have them give separate presentations at the end of a term. Even if accomplished in a pair setting, the satisfaction of providing solid contributions could guide the student towards a career in a scientific discipline (Russell et al. 2007; Kobulnicky & Dale 2016).

3.2 "Senior" undergraduate involvement

One way that mentors can recognize and reward the progression of undergraduate researchers as they gain experience and grow as scientists, is to give them increasing responsibility and place them in leadership roles (Shanahan et al. 2015). Mentors may assign "senior" undergraduates in the lab with a number of tasks that keep the research lab functional. Such delegation acts demonstrate the mentor's trust in the student and make it clear that the student is an essential part of the research team, which increases their sense of self-worth and belonging. For example, as part of their contributions to the lab, "senior" undergraduates may conduct routine inventories of supplies, oversee animal care or perhaps even update a lab website. "Senior" undergraduates can also be given the responsibility of training new students in the lab. In this case, mentors often treat responsible "senior" undergraduates more along the lines of graduate students, which prepares them well for the transition to graduate school if they choose to pursue a career in STEM. This experience provides the opportunity to practice mentoring and science communication skills, while giving new undergraduates role models (Kobulnicky and Dale 2016). New students may also feel more comfortable learning from and asking peers for help compared to more senior mentors (Zaniewski and Reinholz 2016, Cutright and Evans 2016). Lastly, "Senior" undergraduates play a key role in "lab memory" or "institutional history" as long-term projects continue, but students rotate in and out of the lab. Over time, the new students in the lab learn what it takes to conduct collaborative research and take on new roles as they in turn become more experienced.

4. Benchmarks, Deadlines, and Rest

Deadlines, self-imposed and otherwise, act as important regulators of time for all researchers, but especially for undergraduate students who are learning time management and often juggle far more activities and responsibilities than mentors may realize. In addition to their coursework, undergraduates may have jobs to help pay for expenses, family responsibilities, school clubs, or other obligations (Berker et al. 2003, Fairchild 2003). Therefore, we find it exceedingly important to set clear and reasonable benchmarks for student research activities (Shanahan et al. 2015), while recognizing that undergraduate research takes time. Limitations on student time and availability probably poses one of the most challenging aspects of working with undergraduate students, but it need not be an insurmountable barrier. Providing short-term tangible goals, frequent check-ins, long-term objectives and rest stops along their journey all help students progress through their research.

4.1 Checkpoints and deadlines

As described earlier, clear communication underlies setting reasonable deadlines that advance the research (Linn et al. 2015, Reed 2018).Exams, illnesses or holiday breaks can often disrupt progress, so we reiterate the importance of meeting regularly with undergraduates to discuss progress, problems, and to adjust expectations and workloads as necessary. Students (as well as faculty) often start out overly optimistic about what they can do with their limited time. When students do not meet deadlines, they may not want to admit their mistake as it makes them feel like they have failed. Frequent meetings can help the student and the mentor realize an unrealistic pace or goal earlier, rather than later, and then adjust. We do not find it unusual to shift or recalculate deadlines and timelines based on these meetings. By doing so, mentors keep the research moving and help their student stay focused and motivated.

Collaborative research with students is a balance of flexibility and clear benchmarks for progress. One example benchmark includes a contractual agreement for an end-of-term presentation or write-up to present to the lab or colleagues. Presentations, even when given to a small intimate group, can be immensely helpful in motivating students to accomplish a research objective. Presenting in a lab meeting is important for students before they present at larger venues such as off-campus regional or national scientific meetings. Informal lab presentations provide opportunities to assess efforts and progress in a casual atmosphere and, importantly, provide a chance to reward students for their successes, accomplishments, and hard work. After the presentation, the mentor and colleagues should provide truly constructive feedback. No doubt, students will have some difficulties in their research methods or data presentation. The mentor’s responsibility includes providing quality feedback without being overly judgmental or critical in expectations that go beyond the experience of the average undergraduate (Estrada et al. 2018). These early presentation experiences help shape students' confidence and a sense of belonging, both of which contribute to STEM retention of underrepresented groups (Gray, 2000, Perez et al. 2014, Shanahan et al. 2015).

4.2 Rest

Conducting research at any stage can be physically and emotionally draining. Although easier said than done, we acknowledge the importance of providing students (and mentors) a chance to rest. Intervals between academic terms provide obvious opportunities for such breaks. Although it can be tempting to have students work through school breaks when they are free from their coursework responsibilities, many students may greatly benefit from the opportunity to rest and recuperate from their research. Furthermore, as one of the ten salient practices for undergraduate research mentors, Shanahan et al. (2015) argued that mentors need to balance clear and high expectations with emotional support and an appropriate personal stake in the lives of their students. Undergraduate students experience many obstacles during their college experience and mental health issues are common (Hunt & Eisenberg 2010). Maintaining awareness of your students' mental health and ensuring rest stops helps provide better balance in their lives as well as the laboratory community. This is not only important for student health, but is an opportunity to establish the expectation of a good work-life balance as the student progresses in their career (Tan-Wilson and Stamp 2015).

5. Student Ownership and Publication

Undergraduate perceptions of independence and ownership over research projects can increase confidence, retention, and positively influence students' intentions to pursue a career in research (Hanauer et al. 2012, Corwin et al. 2018, Hernandez et al. 2018). The longer students engage in a research project, the more likely they are to develop feelings of ownership. Roberts and Seaman (2018) identified student ownership as a central theme contributing to a good relationship between research mentor and student. As students gain more responsibility and positive reinforcement from mentors, their sense of ownership should grow (Shanahan et al. 2015).

Managing student ownership undoubtedly comes with its own set of difficulties. As the project progresses, the mentor needs to make thoughtful decisions about the feasibility of guiding a student's project through to publication (Burks & Chumchal 2009). When the mentor clearly depends on publication of the work for advancement, then the extra time necessary to shepherd a student-authored work to publication may negatively affect the mentor's motivation (Hardré et al. 2011). In those cases, we recommend that students serve as co-authors until the mentor establishes more security in her/his/their position. On the other hand, primarily undergraduate institutions often recognize and reward mentors that successfully include undergraduates as co-authors or mentor students to earn the position of first-authors. Thus, a multitude of reasons, including their own experience, will drive a mentor's negotiation of authorship and ultimate decision to publish with undergraduates (Burks & Chumchal 2009).

5.1 Publication take time

While many undergraduate projects never reach the submission phase, undergraduates routinely contribute to peer-reviewed publications across fields. In the biomedical sciences, Morales et al. (2017) found that several characteristics of mentors and students led to greater productivity in terms of publications:1) students and mentors worked together for more than a year; 2) mentors found it rewarding to work with students; and 3) mentors possessed more experience in both publishing and higher education. Interestingly, when biomedical faculty mentored black or disabled students, they achieved a significantly higher rate of successful publication (Morales et al. 2017). The authors speculated that a diversity in team performance or a stronger commitment on part of the faculty member or student contributed to this result.

The road to quality peer-reviewed publication is long and writing with undergraduates often further extends the journey (Burks and Chumchal 2009). The slow pace of publications can be particularly difficult during the review process. Across the last 40 years, Powell (2016) reported 100 days as a consistent average review time for articles published in Pubmed. While this average wait of three and a half months does not seem long for experienced researchers, it feels much different from the undergraduate perspective. This average time to review occupies an entire semester of a typical four-year undergraduate education and does not take into account time for revisions. Consequently, even in a best case scenario, undergraduates would likely need to submit a paper within the first semester of their last year to see the article in print by the time they graduate. As this submission scenario is unlikely given a student's commitments in their last semester, paper writing and publication can often spill over into post-graduation territory.

5.2 Post-graduation mentorship

Working with students after they graduate introduces several new challenges for the student-mentor relationship. These include finding time to meet, tackling complex tasks with less supervision, or working without the logistical support of the institution. Without routine face-to-face meetings, the importance of good communication and accountability increases exponentially. Former students often encounter new conflicting demands and face a choice between their new post-graduate obligations and their prior commitments and investments. Mentors too must contend with time dedicated to their current students, while still keeping track of recent graduates. We suggest that mentors and students develop a new plan for communication and work flow post-graduation. Establishing a consistent schedule for communication may prevent procrastination or loss of motivation that can occur post-graduation.

Mentors and students often take on-campus resources for granted, including access to primary literature, digital storage, and specific software. Before the student graduates, students need to arrange a plan to access electronic library resources, software licenses, and dedicated cloud storage space to back-up their research and work on the manuscript. Virtual communication may also be disrupted if the partnership relies on university-licensed software or email services with expiration dates so it’s important to establish a line of communication that works for both the mentor and the college graduate.

Conclusion

As institutional and faculty support for undergraduate research in ecology grows, potential mentors need to be prepared to guide students through the complicated process. Research experiences have numerous benefits to mentors and students alike, including the breaking down of barriers to inclusion and diversity in the sciences (Nagda et al 1998, Jones et al. 2010). This paper sought to provide a working framework to guide academic mentors as they collaborate with undergraduates from developing a research question to submitting a publication. The future of research lies with the younger generation of scientists. Effective mentorship in research experiences will only improve academia and drive scientific progress.

The publication process more closely resembles a marathon than a sprint, an intimidating concept for many students. Scientific publication as an enterprise, and even more so when including undergraduate researchers, takes drive, persistence, and patience often coupled with a sense of humor (Burks and Chumchal 2009, Fox et al. 2017). As mentors experienced in publishing with undergraduates, we all feel it is worth the effort and hope that the advice in this article makes it a little bit easier. While unpublished science reflects unfinished science and publication is the ultimate goal, not all undergraduates will reach that goal, and the journey they take along the way will be incredibly beneficial for their professional development regardless of publication success.

Acknowledgements

The authors would like to thank the Ecological Society of America: Early Career Ecologists Section for bringing them together at the ESA Annual Meeting in New Orleans for an INSPIRE session in August 2018 that culminated in the writing of this collaborative paper.

Author Contributions:

NE designed, organized, wrote, and edited the manuscript. AH wrote, edited, and contributed supplemental material. RB, MD, CS, and AS wrote and edited the manuscript.

Data Accessibility Statement

There are no data associated with this article.

References:

Adedokun, O. A., Dyehouse, M., Bessenbacher, A., & Burgess, W. D. (2010). Exploring Faculty Perceptions of the Benefits and Challenges of Mentoring Undergraduate Research. In *2010 Annual Meeting of the American Educational Research Association* (pp. 1–11).

Auchincloss, L. C., Laursen, S. L., Branchaw, J. L., Eagan, K., Graham, M., Hanauer, D. I., … Dolan, E. L. (2014). Assessment of Course-Based Undergraduate Research Experiences: A Meeting Report. *CBE - Life Sciences Education*, *13*, 29–40.

Austin, A. E. (2002). Preparing the Next Generation of Faculty: Graduate School as Socialization to the Academic Career. *The Journal of Higher Education*, *73*(1), 94–122.

Baker, M. J., Cluett, E., Ireland, L., Reading, S., & Rourke, S. (2014). Supervising undergraduate research: A collective approach utilizing groupwork and peer support. *Nurse Education Today*, 34(4), 637-642.

Baker, V. L., & Griffin, K. A. (2010). Beyond Mentoring and Advising: Toward understanding the role of faculty “developers” in student success. *About Campus*, (February), 2–8.

Baker, V. L., Pifer, M. J., Lunsford, L. G., Greer, J., Ihas, D., Baker, V. L., … Greer, J. (2015). Mentoring & Tutoring: Partnership in Learning Faculty as Mentors in

Undergraduate Research, Scholarship, and Creative Work : Motivating and Inhibiting Factors. *Mentoring & Tutoring: Partnership in Learning*, *23*(5), 393–409.

Berker, A., Horn, L., & Carroll, C. D. (2003). Work First, Study Second: Adult Undergraduates Who Combine Employment and Postsecondary Enrollment. *Postsecondary Educational Descriptive Analysis Reports*.

Budge, S. (2006). Peer Mentoring in Postsecondary Education: Implications for Research and Practice. *Journal of College Reading and Learning*, *37*(1).

Burger, E. B., & Starbird, M. (2012). The 5 elements of effective thinking. Princeton University Press.

Burk, H. G., & Eby, L. T. (2010). What keeps people in mentoring relationships when bad things happen? A field study from the protégé's perspective. *Journal of Vocational Behavior*, *77*, 437–439.

Burks, R. L., & Chumchal, M. M. (2009). To co-author or not to co-author: How to write, publish, and negotiate issues of authorship with undergraduate research students. *Science Magazine*, *2*(94), 1–7.

Carpi, A., Ronan, D. M., Falconer, H. M., & Lents, N. H. (2017). Cultivating Minority Scientists: Undergraduate Research Increases Self-Efficacy and Career Ambitions for Underrepresented Students in STEM. *Journal of Research in Science Teaching*, *54*(2), 169–194.

Corwin, L. A., Runyon, C. R., Ghanem, E., Sandy, M., Clark, G., Palmer, G. C., … Dolan, E. L. (2018). Effects of Discovery, Iteration, and Collaboration in Laboratory Courses on Undergraduates' Research Career Intentions Fully Mediated by Student Ownership. *CBE - Life Sciences Education*, *17*, 1–11.

Crisp, G., Taggart, A., & Nora, A. (2015). Undergraduate Latina / o Students: A Systematic Review of Research Identifying Factors Contributing to Academic Success Outcomes. *Review of Educational Research*, *85*(2), 249–274.

Cutright, T. J., & Evans, E. (2016). Year-long peer mentoring activity to enhance the retention of freshmen STEM students in a NSF scholarship program. *Mentoring & Tutoring: Partnership in Learning*, 24(3), 201-212.

Davidson, J. M., & Lyons, M. (2018). Undergraduates as Researchers – the Impact of Active Participation in Research and Conference Presentation on Psychology Undergraduate Identity and Career Aspirations, *6*(1), 39–46.

Davis, S. N., & Jones, R. M. (2017). Understanding the role of the mentor in developing research competency among undergraduate researchers. *Mentoring and Tutoring: Partnership in Learning*, *25*(4), 455–465.

Dennis, J. M., Phinney, J. S., & Chuateco, L. I. (2005). The role of motivation, parental support, and peer support in the academic success of ethnic minority first-generation college students. *Journal of College Student Development*, 46(3), 223-236.

Dolan, E., & Johnson, D. (2009). Toward a holistic view of undergraduate research experiences: An exploratory study of impact on graduate/postdoctoral mentors. *Journal of Science Education and Technology*, *18*(6), 487–500.

Dooley, D. A., Mahon, R. M., & Oshiro, E. A. (2004). An Undergraduate Research Opportunity: Collaboration Between Undergraduate and Graduate Students. *Journal of Food Science Education*, *3*.

Eby, L. T., Butts, M. M., Durley, J., & Rose Ragins, B. (2010). Are bad experiences stronger than good ones in mentoring relationships? Evidence from the protégé and mentor perspective. *Journal of Vocational Behavior*, *77*, 81–92.

Eddy, S. L., Brownell, S. E., Thummaphan, P., Lan, M. C., & Wenderoth, M. P. (2015). Caution, student experience may vary: social identities impact a student's experience in peer discussions. *CBE—Life Sciences Education*, 14(4), ar45.

Elgren, T., & Hensel, N. (2006). Undergraduate Research Experiences: Synergies between Scholarship and Teaching. *Peer Review*, 8(Winter), 4–7.

Eller, L. S., Lev, E. L., & Feurer, A. (2014). Key components of an effective mentoring relationship: a qualitative study. *Nurse Education Today*, *34*(5), 815–820.

Estrada, M., Burnett, M., Campbell, A. G., Campbell, P. B., Denetclaw, W. F., Gutiérrez, C. G., … Zavala, M. (2016). Improving Underrepresented Minority Student Persistence in STEM. *CBE - Life Sciences Education*, *15*, 1–10.

Estrada, M., Eroy-Reveles, A., & Matsui, J. (2018). The Influence of Affirming Kindness and Community on Broadening Participation in STEM Career Pathways. *Social Issues and Policy Review*, *12*(1), 258–297.

Fairchild, E. E. (2003). Multiple Roles of Adult Learners. In *New Directions for Student Services* (pp. 11–16).

Fournier, A. M., & Bond, A. L. (2015). Volunteer Field Technicians Are Bad for Wildlife Ecology. *Wildlife Society Bulletin*, *39*(4), 819–821.

Fox, G. A., Kuster, E. L., & Fox, A. K. (2017). The Importance of Scientific Publishing: Teaching an Undergraduate How to Swim the Entire Length of the Pool. *Journal of Contemporary Water Research and Education*, (160), 1–4.

Fritschner, L. M. (2000). Inside the undergraduate college classroom: Faculty and students differ on the meaning of student participation. *The Journal of Higher Education*, 71(3), 342-362.

Good, J. M., Halpin, G., & Halpin, G. (2000). A Promising Prospect for Minority Retention: Students Becoming Peer Mentors. *The Journal of Negro Education*, *69*(4), 375.

Gorham, E. (2014). Multiauthorship, an Indicator of the Trend Toward Team Research in Ecology. *Bulletin of the Ecological Society of America*, *95*(July), 243–249.

Goring, S. J., Weathers, K. C., Dodds, W. K., Soranno, P. A., Sweet, L. C., Cheruvelil, K. S., ... & Utz, R. M. (2014). Improving the culture of interdisciplinary collaboration in ecology by expanding measures of success. *Frontiers in Ecology and the Environment*, 12(1), 39-47.

Gray, G. (2000). Producing results: Effective management and mentoring in academic labs. *AWIS Magazine*, 14–18.

Gross, D., Iverson, E., Willett, G., & Manduca, C. (2015). Broadening access to science with support for the whole student in a residential liberal arts college environment. *Journal of College Science Teaching*, 44(4), 99-107.

Haeger, H., Fresquez, C., & Marsteller, P. (2016). Mentoring for Inclusion: The Impact of Mentoring on Undergraduate Researchers in the Sciences. *CBE—Life Sciences Education*, *15*(3), ar36.

Hall, E. E., Walkington, H., Shanahan, J. O., Ackley, E., & Stewart, K. A. (2018). Mentor perspectives on the place of undergraduate research mentoring in academic identity and career development: an analysis of award winning mentors. *International Journal for Academic Development*, *23*(1), 15–27.

Hanauer, D. I., Frederick, J., Fotinakes, B., & Strobel, S. A. (2012). Linguistic Analysis of Project Ownership for Undergraduate Research Experiences. *CBE - Life Sciences Education*, *11*, 378–385.

Hansen, W. D., Scholl, J. P., Sorensen, A. E., Fisher, K. E., Klassen, J. A., Calle, L., ... & Narango, D. L. (2018). How do we ensure the future of our discipline is vibrant? Student reflections on careers and culture of ecology. *Ecosphere*, 9(2).

Hardré, P. L., Beesley, A. D., Miller, R. L., & Pace, T. M. (2011). Faculty Motivation to do Research: Across Disciplines in Research- Extensive Universities. *The Journal of the Professoriate*, 5(1).

Hartmann, J. Q., Widner, S. C., & Carrick, C. (2013). Strong Faculty Relationships and Academic Motivation as Potential Outcomes of Undergraduate Research. *North American Journal of Psychology*, 15(1).

Hathaway, R. S., Nagda, B. A., & Gregerman, S. R. (2002). The relationship of undergraduate research participation to graduate and professional education pursuit: an empirical study. *Journal of College Student Development*, 43(5), 614-631.

Hayward, C. N., Laursen, S. L., & Thiry, H. (2017). Why Work with Undergraduate Researchers? Differences in Research Advisors' Motivations and Outcomes by Career Stage. *CBE - Life Sciences Education*, *16*, 1–11.

Hernandez, P. R., Hopkins, P. D., Masters, K., Holland, L., Mei, B. M., Richards-babb, M., … Shook, N. J. (2018). Student Integration into STEM Careers and Culture: A Longitudinal Examination of Summer Faculty Mentors and Project Ownership. *CBE - Life Sciences Education*.

Holford, A. J. (2017). Access to and Returns from Unpaid Graduate Internships. *Institute of Labor Economics (IZA), Bonn*.

Houser, C., & Lemmons, K. (2018). Implicit bias in letters of recommendation for an undergraduate research internship. *Journal of Further and Higher Education*, *42*(5), 585–595.

Hund, A. K., Churchill, A. C., Faist, A. M., Havrilla, C. A., Love Stowell, S. M., McCreery, H. F., … Scordato, E. S. C. (2018). Transforming mentorship in STEM by training scientists to be better leaders. *Ecology and Evolution*, (July), 1–13.

Hunt, J., S, M., Eisenberg, D., & Ph, D. (2010). Mental Health Problems and Help-Seeking Behavior Among College Students. *Journal of Adolescent Health*, *46*(1), 3–10.

Hunter, A.-B., Laursen, S. L., & Seymour, E. (2007). Becoming a scientist: The role of undergraduate research in students' cognitive, personal, and professional development. *Science Education*, *91*(1), 36–74.

Hurtado, S., Cabrera, N. L., Lin, M. H., Arellano, L., & Espinosa, L. L. (2009). Diversifying Science: Underrepresented Student Experiences in Structured Research Programs. *Research in Higher Education*, *50*, 189–214.

Johnson, W. B., Behling, L. L., Miller, P., & Vandermaas-Peeler, M. (2015). Undergraduate Research Mentoring: Obstacles and Opportunities. *Mentoring & Tutoring: Partnership in Learning*, *1267*, 1–12.

Jones, M. T., Barlow, A. E., & Villarejo, M. (2010). Importance of undergraduate research for minority persistence and achievement in biology. *The Journal of Higher Education*, 81(1), 82-115.

Kobulnicky, H. A., & Dale, D. A. (2016). A Community Mentoring Model A Community Mentoring Model for STEM Undergraduate Research Experiences. *Journal of College Science Teaching*, *45*(6), 17–23.

Komarraju, M., Karau, S. J., & Schmeck, R. R. (2009). Role of the Big Five personality traits in predicting college students' academic motivation and achievement. *Learning and Individual Differences*, 19(1), 47-52.

Laursen, S., Seymour, E., & Hunter, A. B. (2012). Learning, teaching, and scholarship: Fundamental tensions of undergraduate research. *College Teaching and Learning for Change: Students and Faculty Speak Out*, *1383*, 81–92.

Leimu, R., & Koricheva, J. (2005). What determines the citation frequency of ecological papers? *Trends in Ecology and Evolution*, *20*(1), 28–32.

Linn, M. C., Palmer, E., Baranger, A., Gerard, E., & Stone, E. (2015). Undergraduate research experiences: Impacts and opportunities. *Science*, *347*(6222).

Lopatto, D. (2004). Survey of undergraduate research experiences (SURE): First findings. *Cell biology education*, 3(4), 270-277.

Lopatto, D. (2007). Undergraduate Research Experiences Support Science Career Decisions and Active Learning. *CBE Life Sciences Education*, *6*, 297–306.

Lopatto, D. (2010). Undergraduate research as a high-impact student experience. *Peer Review*, 12(2), 27.

Lunsford, L. G., Baker, V., Griffin, K. A., Johnson, W. B., Lunsford, L. G., Baker, V., … Baker, V. (2013). Mentoring: A Typology of Costs for Higher Education Faculty. *Mentoring & Tutoring: Partnership in Learning*, *1267*.

Lunsford, L. G., Crisp, G., Dolan, E. L., & Wuetherick, B. (2017). Mentoring in Higher Education. In *The SAGE book of mentoring*.

Matthews, S. J., & Rosa, M. N. (2018). Trials, Tribulations, and Triumphs: Research and Publishing From the Undergraduate Perspective. *Frontiers in Psychology*, *9*(December), 1–4.

Milkman, K. L., & Chugh, D. (2015). What Happens Before? A Field Experiment Exploring How Pay and Representation Differentially Shape Bias on the Pathway into Organizations. *Journal of Applied Psychology*, *100*(6), 1678–1712.

Morales, D. X., Grineski, S. E., & Collins, T. W. (2017). Increasing research productivity in undergraduate research experiences: Exploring predictors of collaborative faculty-student publications. *CBE - Life Sciences Education*, *16*(3), 1–9.

Moss-Racusin, C. A., Dovidio, J. F., Brescoll, V. L., Graham, M. J., & Handelsman, J. (2012). Science faculty's subtle gender biases favor male students. *Proceedings of the National Academy of Sciences*, *109*(41), 16474–16479.

Nagda, B. A., Gregerman, S. R., Lerner, J. S., von Hippel, W., & J. Jonides (1998). Undergraduate student-faculty research partnerships affect student retention. *The Review of Higher Education*, 22(1), 55-72.

Nakamura, J., Shernoff, D., & Hooker, C. (2009). *Good mentoring: Fostering excellent practice in higher education* (Jossey-Bas). John Wiley and Sons, Inc.

Nicholson, B., Pollock, M., Ketcham, C., Fitz Gibbon, H., Bradley, E., & Bata, M. (2017). Beyond the Mentor-Mentee Model: A Case for Multi-Mentoring in Undergraduate Research. *PURM Perspectives on Undergraduate Research and Mentoring*, *6.1*(November).

O'Donnell, K., Botelho, J., Brown, J., Gonzalez, G. M., & Head, W. (2015). Undergraduate Research and Its Impact on Student Success for Underrepresented Students. *New Directions for Higher Education*, (169), 27–38.

O'Meara, K., Knudsen, K., & Jones, J. (2013). The Role of Emotional Competencies in Faculty-Doctoral Student Relationships. *The Review of Higher Education*, 36(3), 315–347.

Opengart, R., & Bierema, L. (2015). Emotionally Intelligent Mentoring: Reconceptualizing Effective Mentoring Relationships. *Integrative Literature Review*, *14*.

Ovink, S. M., & Veazey, B. D. (2011). More than "getting us through:" A case study in cultural capital enrichment of underrepresented minority undergraduates. *Research in Higher Education*, 52(4), 370-394.

Palmer, R. J., Hunt, A. N., Neal, M., Wuetherick, B., Palmer, R. J., Hunt, A. N., … Hunt, A. N. (2015). Mentoring, Undergraduate Research, and Identity Development: A Conceptual Review and Research Agenda. *Mentoring & Tutoring: Partnership in Learning*, *1267*, 1–16.

Parker, J. (2018). Undergraduate research, learning gain and equity: the impact of final year research projects. *Higher Education Pedagogies*, *2696*, 97–109.

Perez, T., Cromley, J. G., & Kaplan, A. (2014). The Role of Identity Development, Values, and Costs in College STEM Retention. *Journal of Educational Psychology*, *106*(1), 315–329.

Perez, T. M., & Hogan, J. A. (2018). The changing nature of collaboration in tropical ecology and conservation. *Biotropica*, 50(4), 563-567.

Powell, K. (2016). The waiting game. *Nature*, *530*, 4–7.

Rainey, K., Dancy, M., Mickelson, R., Stearns, E., & Moller, S. (2018). Race and gender differences in how sense of belonging influences decisions to major in STEM. *International Journal of STEM Education*, *5*(1).

Reed, D. E. (2018). Six Steps for Cultivating Successful Undergraduate Research. *The Bulletin of the Ecological Society of America*, *00*(0), e01453.

Roberts, L. D., & Seaman, K. (2018). Good undergraduate dissertation supervision: perspectives of supervisors and dissertation coordinators. *International Journal for Academic Development*, *23*(1), 28–40.

Robnett, R. D., Chemers, M. M., & Zurbriggen, E. L. (2015). Longitudinal Associations Among Undergraduates' Research Experience, Self-Efficacy, and Identity. *Journal of Research in Science Teaching*, *52*(6), 847–867.

Rose, G. L. (2005). Group differences in graduate students' concepts of the ideal mentor. *Research in Higher Education*, *46*(1), 53–80.

Rovnyak, D. S., & Shields, G. C. (2017). How Undergraduate Research Drives Science Forward. *Inside Higher Ed*, 1–11.

Russell, S. H., Hancock, M. P., & McCullough, J. (2007). THE PIPELINE: Benefits of Undergraduate Research Experiences. *Science*, *316*(5824), 548–549.

Shanahan, J. O. (2017). "I didn't think students like me got opportunities like this": Using the RSD Framework to Address Equity Gaps in Undergraduate Research. In *International conference on Models of Engaged Learning and Teaching (I- MELT), Adelaide, Australia*.

Shanahan, J. O., Ackley-Holbrook, E., Hall, E., Stewart, K., & Walkington, H. (2015). Ten salient practices of undergraduate research mentors: A review of the literature. *Mentoring and Tutoring: Partnership in Learning*, *23*(5), 359–376.

Shellito, C., Shea, K., Weissmann, G., Mueller-Solger, A., & Davis, W. (2001). Successful mentoring of undergraduate researchers. *Journal of College Science Teaching*, 30(May).

Strayhorn, T. (2012). College students' sense of belonging: A key to educational success for all students. Routledge.

Tan-Wilson, A., & Stamp, N. (2015). College Students' Views of Work – Life Balance in STEM Research Careers: Addressing Negative Preconceptions. *CBE - Life Sciences Education*, 14, 1–13.

Thiry, H., & Laursen, S. L. (2011). The Role of Student-Advisor Interactions in Apprenticing Undergraduate Researchers into a Scientific Community of Practice. *Journal of Science Education and Technology*, *20*, 771–784.

Weigel, E. G. (2015). Modern graduate student mentors: Evidence-based best practices and special considerations for mentoring undergraduates in ecology and evolution. *Ideas in Ecology and Evolution*, (October).

Wilson, Z. S., Holmes, L., DeGravelles, K., Sylvain, M. R., Batiste, L., Johnson, M., … Warner, I. M. (2012). Hierarchical Mentoring: A Transformative Strategy for Improving Diversity and Retention in Undergraduate STEM Disciplines. Journal of Science Education and Technology, 21, 148–156.

Zaniewski, A. M., & Reinholz, D. (2016). Increasing STEM success: a near-peer mentoring program in the physical sciences. *International Journal of STEM Education*, 3(1), 14.

Table 1.

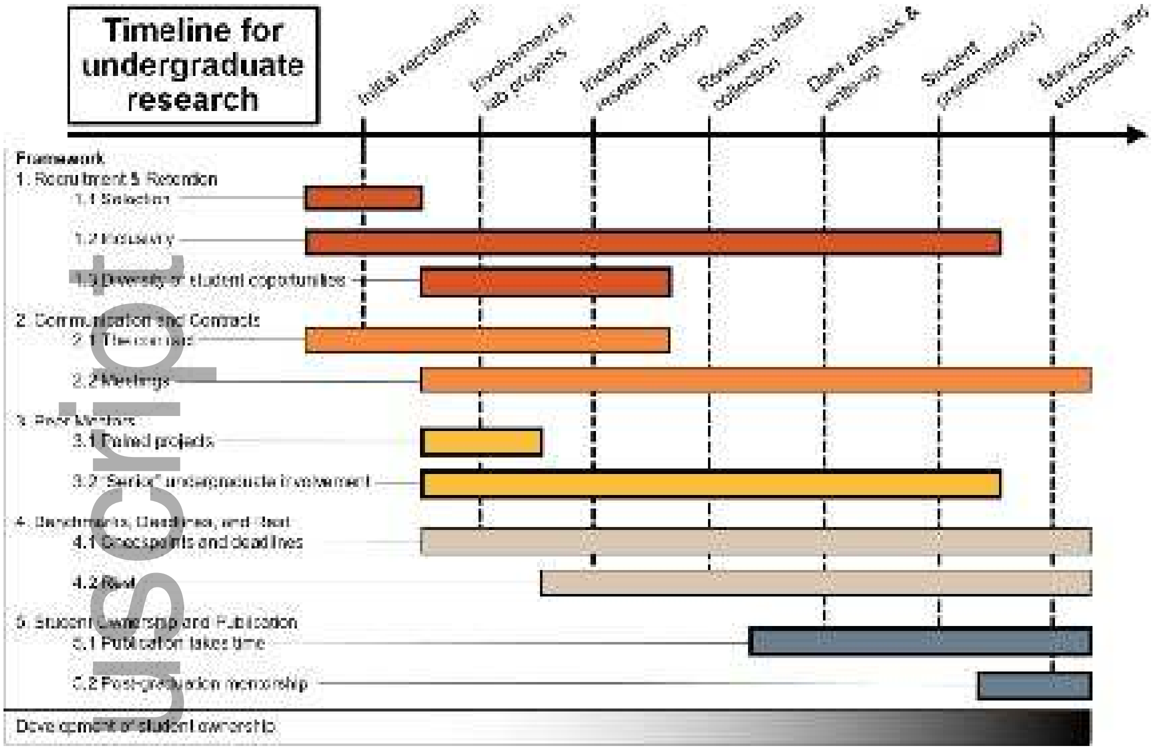
Identifying specific research project challenges and constraints prior to "interviewing" students

Question(s)	Explanation
How many students can you have working together on the project?	This will help you determine how many students you can accept in your lab, as well as accepting students that might need more supervision.
How long will the student need to be in the lab for each day? Will the project require field work on weekends/early mornings/late nights?	Student may need to have an open and accommodating schedule
Can the student work from home? (i.e, computer-based project)	Students can be more flexible, but need to be very self-motivated as they won't have the "lab

	environment” or community to motivate them
How much training will the student require? How difficult are the techniques the student will implement?	If training is intensive and long-winded, the student may need to stay in your lab for at least one year. Think of how she/he may be able to help train other students on the technique during that year
How many semesters/quarters does the project require the students to be in the lab for?	If the project requires multiple field seasons, the student needs to be able to sign on for multiple years
How time sensitive is the project?	Students will need to be hard-working and understand the time sensitivity of project goals
How will students access field sites?	Students may need to have a driver’s license/ be autonomous. Do you have funding to cover travel expenses?

Figure 1.

How mentors are involved in the undergraduate research experience over time. Each color represents a different topic described in the text and the bars indicate when a given mentoring effort generally overlaps with the undergraduate research timeline. The gradient at the bottom represents the development of student ownership over time.



ece3_5090_f1.tif