ARTICLE
Integrating Research into the Undergraduate Curriculum: 1. Early Research Experiences and Training

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Undergraduate research experiences have emerged as some of the most beneficial high-impact practices in education, providing clear benefits to students that include improved critical thinking and scientific reasoning, increased academic performance, and enhanced retention both within STEM majors and in college overall. These benefits extend to faculty members as well. Several disciplines, including neuroscience, have implemented research as part of their curriculum, yet many research opportunities target late stage undergraduates, despite evidence that early engagement can maximize the beneficial nature of such work. A 2019 Society for Neuroscience professional development workshop provided multiple examples of integrating research into an undergraduate curriculum, including early engagement (Fernandes, 2020). This article is the first in a series of three that expands upon the information presented in those workshop discussions, focusing on ways to promote early research opportunities. The benefits and challenges associated with early research engagement suggest thoughtful consideration of the best mechanisms for implementation are warranted; some options might include apprenticeship models or course-based approaches. Regardless of mechanism, early research can serve to initiate more prolonged, progressive, scaffolded experiences that span the academic undergraduate career.

Key words: undergraduate research, first-year students, mentorship, PUIs, curriculum, diversity, inclusion, pedagogy

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Undergraduate research is well-documented as a high-impact practice that has substantial academic, career, and personal benefits for students (Seymour et al., 2004; Russell et al., 2007; Kuh, 2008; Yates and Stavnezer, 2014; Linn et al., 2015; Dolan, 2016). Accordingly, multiple national reports have issued and emphasized calls for increasing research experiences for undergraduates in STEM disciplines (American Association for the Advancement of Science [AAAS], 2011, 2018; President's Council of Advisors on Science & Technology [PCAST], 2012; American Psychological Association [APA], 2013; National Academy of Sciences, Engineering and Medicine [NASEM], 2015, 2017), particularly given the ability of such programs to broaden participation in STEM (Russell et al., 2007; Kuh et al., 2008; Bangera and Brownell 2014; Estrada et al., 2018). The importance of undergraduate research is well-established in neuroscience (Frantz et al., 2006; Hardwick et al., 2006; Wiertelak et al., 2018; Gage, 2019). Undergraduate research can be incorporated into a neuroscience curriculum in a number of ways. This paper discusses the benefits and challenges of varied mechanisms to engage undergraduates in neuroscience research early in their college career, provides examples of implementation, and aims to enable educators to evaluate which options might be well-suited to their institutions and contexts. Efforts towards research engagement will likely impart benefits on a diverse set of students and faculty members engaged in such work, and may provide means and mechanisms to improve overall outcomes for neuroscience curricula.

IMPORTANCE OF RESEARCH AS A HIGH-IMPACT PRACTICE

Multi-year, progressive research experiences that begin early in the college experience are most beneficial for achieving maximum impact (Thiry et al., 2012), and more substantial research experiences may yield greater benefits (Buckley et al., 2008; Jones et al., 2010). These benefits include, but are not limited to, improved critical thinking, better understanding of scientific content, and stronger overall academic performance. Sustained undergraduate research also increases student confidence in scientific ability (Thiry et al., 2012) and retention and performance in both STEM majors and college overall (Jones et al., 2010; Thiry et al., 2012). These experiences also increase the likelihood that students will pursue graduate school and careers in STEM (Lopatto, 2007; Russell, 2007).

Yet undergraduates who participate in research may be chosen based on prior experience and/or academic performance (Murray et al., 2016; Colbert-White and Simpson, 2017). Consequently, early career undergraduate involvement in research may be rare (Thiry et al., 2012; Murray et al., 2016). The National Survey of Student Engagement (NSSE) reports that in 2019, 5% of first-year students at US institutions report having conducted research with faculty members, compared to 25-40% of seniors in the same year (NSSE, 2020). Even among STEM majors, few students engage in research during their first year of college (Hurtado et al., 2008, Colbert-White and Simpson, 2017). Therefore, those students who are not retained in STEM beyond their first or second years do not receive the clear benefits of undergraduate research training (Desai et al., 2008). As members of groups currently underrepresented in STEM show higher rates of attrition from such majors early on, a lack of early research opportunities could mean underserved populations are less likely to gain the documented benefits of such experiences (Bangera and Brownell, 2014).

Despite the lack of engagement of first-year students in undergraduate research, evidence suggests that some benefits of research are enhanced by early exposure (Brownlee et al., 2009) and that the benefits of early experiences are often as significant (Jones et al., 2010) or more significant (Thiry et al., 2012) than those that occur in the third and fourth years (Jones et al., 2010). In fact, some researchers and educators argue that research participation in the last year of college, which is the most common, may be too late to receive maximal benefit from such practices (Thiry et al., 2012). Accordingly, recent calls for expanded inclusion of research opportunities for students have placed emphasis on early engagement (AAAS, 2011, 2018; Blockus et al., 2012; Weekes, 2012; APA, 2013; NASEM, 2015; Awong-Taylor et al., 2016; Ramos et al., 2017).

BENEFITS AND CHALLENGES OF EARLY RESEARCH ENGAGEMENT FOR STUDENTS

Benefits

Many of the overall academic, personal, and professional benefits of undergraduate research delineated above apply to early undergraduate students (Hathaway et al., 2002; Zydney et al., 2002; Lopatto et al., 2007, 2010; Jones et al., 2010; Gasper and Gardner, 2013). Additional gains include disciplinary writing, understanding of scientific literature, laboratory skills (Hayes et al., 2018; Reig et al., 2018), improved satisfaction with the first year of college (Bowman and Holmes, 2018) and retention into the second year of college (Kuh, et al., 2008; Chan et al., 2018). Engagement in research in the first year of college may enable timely evaluation of whether or not the work of scientists is a desired career path (Laursen et al., 2012); this perspective allows additional experience for those that stay on this path (Thiry et al., 2012; Hayes et al., 2018), and ample time to consider alternatives for those that do not. Involvement in early research experiences may particularly benefit underserved populations (Nagda et al., 1998; Hurtado et al., 2009; Jones et al., 2010; Fromherz et al., 2018) or students who enter college with lower levels of academic achievement (Kuh et al., 2008). Thus, if sustained, progressive research immersion is the ultimate goal; such practices rely on engagement of students early and often.

Challenges

Barriers exist to early student engagement with research, including lack of awareness of opportunities for undergraduate research and the benefits of such experiences. Perceived barriers such as hesitation to interact with faculty, and more personal barriers such as financial obligations (Bangera and Brownell, 2014) may prevent engagement in research. First-year students are likely to ascribe a different meaning to the word “research” than faculty mentors or trained undergraduate researchers. “Research” in high school likely means to explore a topic on the internet. But this conceptualization does have elements of the research process. Emphasis on the question, its importance, how it’s addressed, how we grapple with data; indeed, “finding an answer to a question” spans both information-based investigative research but also the scientific process within the laboratory. Faculty members can utilize familiarity with the former to promote engagement with the latter.

Beyond basic conceptualization of what is meant by the term “research”, first-year students have varied levels of preparation and background that may result from differing high schools and experiences. Faculty members must then grapple with emphasizing foundational skills and concepts for those students that are less prepared, while providing pathways to more complex material and concepts to engage students with more extensive background and preparation. In addition, first-year students are navigating the challenging transition to college and may experience many uncertainties. They may lack confidence in their abilities, have weak connections to the institution, faculty members, and/or other students, and have variable support from parents and guardians (Clark et al., 2005). Students in STEM-related fields often fail to “see themselves as scientists” (Seymour et al., 2004) and poor retention in STEM majors even within the first year of college suggests that students could use additional support to navigate this transition. Structured undergraduate research is a mechanism to provide mentorship during this challenging time; such practices may differentially benefit students currently underrepresented in STEM (Hurtado et al., 2009; Jones et al., 2010; Laursen et al., 2010; NASEM, 2011), and therefore may also serve to increase diversification in STEM. As such, early undergraduate research programs produce important outcomes for first-year students. This success warrants continued support for broadening and diversifying early undergraduate research programs as a gateway for more persistent, scaffolded experiences.

BENEFITS AND CHALLENGES OF EARLY RESEARCH ENGAGEMENT FOR FACULTY

Challenges

Beneficial undergraduate research experiences rely heavily on the mentorship and involvement of faculty members in the research process. Faculty contribution has been cited as critical to the impact such experiences can have on students (Joshi et al., 2019). Such efforts require extensive engagement, effort, and time on the part of faculty (Morales et al., 2017) who are already stretched with considerable responsibilities. Strategies to engage more students in undergraduate research must acknowledge the considerable workload placed on faculty as mentors (Schneider and Bickel, 2015; Schneider et al., 2015), as the neuroscience major sees continued growth (Rochon et al., 2019), and should provide teaching credit or other incentives for such efforts. The challenges associated with training undergraduates in research may be exacerbated when considering first- and second-year students. These students likely have little to no prior research experience (Lopatto et al., 2004) and are often grappling with more advanced coursework and increased workload compared to high school (Schneider et al., 2015). Further, these students may have academic and career goals that are less well defined, and may demonstrate less engagement in research topics (Hayes et al., 2018) or have poorer understanding of the benefits of undergraduate research to academic or professional goals (Vereijken et al., 2018). Faculty members are known to express reservations with regard to training early career undergraduate students appropriately (Adedokun et al., 2010) and may struggle with how to adjust the aims of their research program into projects that are both achievable in a single semester and accessible to early career students (Laursen et al., 2012). A system in which undergraduate researchers exist as “short-term helpers” in a long-standing, progressive research program (Laursen et al., 2012) might validate faculty concerns that mentorship of undergraduates threatens productivity (Guterman, 2007); therefore, structured, progressive systems in which mentorship of early students results in skilled and progressive advanced undergraduate researchers may alleviate such concerns.

The integration of research into large introductory STEM courses must consider the nature of the physical space in which students are engaged in research, the ability of the faculty members to provide detailed feedback on assignments to high numbers of students, and the cost of research supplies for large numbers of students. Yet, creative revision of such courses can fulfill the important goal of providing universal and accessible opportunities to engage in research to large numbers of students from diverse disciplines. Many low-cost options do not dramatically increase the workload of faculty and can be implemented into such courses.

Benefits

The challenges associated with mentorship of early career undergraduate research students are worth overcoming because the investment in early training of students in research maximizes benefits to students and mentors in future years. Transforming students from single semester helpers into prolonged contributors to the laboratory will likely improve their productivity and the chance they will make significant progress on the research aims of the faculty members. Well-trained students may succeed in collecting publication worthy data and contributing to manuscript preparation and/or publication (Shortlidge et al., 2016). Indeed, one of the primary benefits of engaging first- and second-year students is the ability to retain students for multiple semesters so they can pass on laboratory and research project knowledge to new researchers entering the lab and increase competence and productivity over a longer time frame (Desai et al., 2008; Adedokun et al., 2010; Laursen et al., 2012). Retaining students in the laboratory across sequential terms would also allow consideration of larger projects and alleviate the challenge of designing small, bite-size research pieces (Laursen et al., 2012). These benefits should reduce the common concern that undergraduates, particularly those that are less skilled, may be impediments to productivity in the faculty research program (Guterman, 2007). Institutions can further support such endeavors by ensuring faculty members receive teaching credit for their efforts in mentoring early research students.

Overall, despite its challenges, faculty members report that undergraduate student researchers significantly contribute to their research programs (Zydney et al., 2002; Shortlidge et al., 2016) in a positive manner that promotes professional and collegial interactions (Adedokun et al., 2010). Other benefits of mentorship of research include satisfaction in the knowledge that students receive significant educational benefits, enjoyment in helping to guide students in their pursuit of a career, and watching students’ cognitive and intellectual development (Kardash, 2000; Zydney et al., 2002; Ramirez 2012). Even more significantly, faculty members report that undergraduate research provides measurable rewards but also significant personal satisfaction (Chopin et al., 2002), and that involvement in such mentorship improves their quality of life at their respective institutions (Zydney et al., 2002; Adedokun et al., 2010). It is likely the personal and practical benefits of students contributing to the lab would be enhanced with more prolonged mentorship of undergraduates through a research process that is initiated during the first year.

GOALS FOR EARLY RESEARCH EXPOSURE

Faculty members can draw from multiple resources to establish appropriate objectives and goals for early undergraduate researchers. CUR provides the following definition regarding undergraduate research: *an inquiry or investigation conducted by an undergraduate student that makes an original intellectual or creative contribution to the discipline* (Blockus et al., 2012). Although this definition may serve as an appropriate goal for upper-level students, first-year students will usually need a lot more guidance to make an original contribution. How, then, can the first-year research experience be structured?

Recommendations from disciplinary organizations have provided guidelines for scaffolding the development of student understanding of the scientific process, as experienced through research, across introductory, intermediate, and advanced levels (AAAS, 2011; Wei and Woodin, 2011; APA, 2013; Wiertelak et al., 2018). For example, APA goals emphasize that foundational students should be competent in a number of basic research skills, both inside and outside of the laboratory, including finding legitimate sources of information and reading and summarizing such sources, discussing the benefits of experimental design as important to discovery, describing the pros and cons of varied methodologies used by research scientists, and understanding basic graphs and statistical findings.

The core competencies set forward by the Faculty for

Research embedded in an Introductory Lab Course
- One to two semesters
- Three to six weeks each semester
- Lab meets once a week for three hours
- Single instructor
- Required course of the major
- Team projects

Course based Research
- Two semesters
- Meets two to three times/week for four to six hours
- Single instructor or instructor team
- Optional course
- Team projects

Research Skills
- Familiarity with faculty research programs
- Using scientific databases
- Conducting literature review
- Designing experimental set-up
- Lab practices/technique development
- Analyzing and interpreting data
- Writing research reports using disciplinary styles
- Oral presentations [posters/slides]

Research Embedded in an Introductory Lecture Course
- One semester
- Meets three times/week for three hours
- Single instructor
- Required course of the major

Research Skills
- Understanding of primary literature sources
- Basics of experimental design (variables, groups)
- Conceptualization of how research and data are interpreted to contribute to knowledge
- Writing basic summaries of scientific information

Research Apprenticeship
- Two semesters
- Meets once/week for approximately one hr
- One instructor
- Team projects

Research Skills
- Perform simple laboratory tasks
- Understand basic experimental design
- Summarize primary literature sources
- Advanced students serve as mentors

Figure 1. Characteristics of first year courses that can provide research experiences

Undergraduate Neuroscience (FUN; Wiertelak et al., 2018), can be used to establish neuroscience-relevant research goals for entry-level students. The FUN suggestions include topics relevant to undergraduate research such as: 1) exposure of students to the classic approaches in neuroscience with emphasis on quantitative and statistical analyses and 2) foundational learning of the language, scientific questions, and methodologies of neuroscience. Guiding entry-level students' ability to understand and summarize scientific literature, engage with research questions and experimental design, accomplish basic data summary and analysis, and communicate basic findings are appropriate foundational level goals. These early outcomes can also include building initial laboratory skills in the first year in a manner that promotes successful research endeavors as students continue forward.

The *research skills development (RSD)* framework, developed at the University of Adelaide (Willison and O' Regan, 2007; Willison, 2018), provides a useful rubric for planning and developing curricula that support progressive development of research skills and competencies. It identifies six facets of a research mindset that are nurtured not only through engagement with the subject matter, but also by increasing awareness of ethical, cultural, social, and team (ECST) considerations of the research process. These facets include identifying the purpose of the work, conducting necessary background work, determining credibility of information sources and data, managing data processes, critically analyzing the data, and finally, communicating and applying the results. For entry-level students, faculty mentors usually provide highly structured research experiences that serve as a foundation for subsequent work that is scaffolded to allow progression into more independent research experiences such as capstones and honors theses projects.

MODELS OF EARLY RESEARCH EXPOSURE

As institutions begin to include research and inquiry-based learning experiences for students from their first year onward, they should be mindful of what systems can both maximize the benefits of first year research exposure and minimize the costs of such an endeavor. Apprentice-based, or one-on-one, laboratory-based research experiences are limited by the number of students that can be directly mentored by a faculty member. They also often rely on a student taking the step of seeking out mentors and understanding the college and STEM culture, which may disadvantage individuals underrepresented in STEM (Haeger et al., 2018). Institutions can engage a larger proportion of their student body by offering research-based courses, modifying existing courses to include portions that emphasize research, introducing students to research in lecture courses, and providing research apprenticeships. In the following sections we describe mechanisms by which students can participate in research experiences in their first year; these are summarized in Figure 1.

Research Focus in Laboratory Courses

The integration of research into undergraduate courses has been a significant movement in education for several years (Alkaher and Dolan, 2014). Varied approaches have been used; inquiry-based learning has received attention as a model through which research skills may be developed (Weaver et al., 2018), and course-based research experiences [CREs] have also grown in popularity (Corwin et al., 2015). Although the most intensive exposure to research, aside from a directly mentored experience, might be an entire course or series of courses dedicated to research, smaller projects integrated into existing courses can be beneficial as well. If provided without prerequisites and listed in the course catalogue, any student can take such courses, which helps broaden participation in contrast to selective, application-based processes. Regardless of format, the exposure of students to this high-impact practice can provide benefits in isolation, or ideally, serve as a foundation upon which progressive experiences can build.

Introduction to Neuroscience Courses likely occur early in the curriculum, serving as an excellent opportunity to introduce students to research. A six-week research project has been integrated into such a course at Hope College; this experience has varied in format since it was first described (Chase and Barney, 2009). Originally, students conducted a six-week project focused on understanding the effect of hormones on behavior, brain structure, and function. After several years, however, this unit was adapted to a six-week animal behavior unit in which students addressed a novel research question of the faculty's choosing. This change was made to 1) allow students to take part in faculty research programs and give them an opportunity to contribute to new knowledge in the field and 2) give faculty members the opportunity to complete pilot research projects as a part of their teaching load. More recently, a new model is in place, where groups of three students identify a research question of their choice related to a research question or technique they used in a lab exercise earlier in the semester. The impetus for this change was to provide students more opportunity to learn how to ask testable scientific questions and design appropriate experiments. Regardless of the nature of the project, the outline of the unit has remained remarkably similar with the first week focused on literature review, followed by three to four weeks for experimentation. The final one to two weeks are dedicated to collaborative writing within the group and peer review between groups. The inclusion of mini-research experiences in the introductory labs allows students to meet many of the objectives for course-based research experiences such as practical experience in experimental design, lab techniques, data analysis and interpretation, as well as reading the scientific literature, writing research results using disciplinary styles, and collaborating with their fellow undergraduate researchers. These outcomes can be embedded in any introductory lab course of the major, providing students an introduction to research skills, which can be built upon in subsequent research experiences.

Similarly, all neuroscience majors and minors at Lycoming College begin to build their research skills in Introduction to Biology I. This course includes a two- to three-week Team Investigation group project with an overarching learning goal for students to apply the techniques from one of their regular teaching labs to test a new, original research hypothesis. They learn the differences between primary, secondary, and tertiary scientific literature, and how to access scientific literature using databases like PubMed and Medline. These skills can be used to read literature based on their own questions, develop testable hypotheses, and design simple single-variable experiments that they carry out in the lab. Data are collected and analyzed and compared to the data in their background literature as they write a journal article-style individual report. The materials for these experiments are variations on those used for the regular Introduction to Biology I lab, so added expense is minimal. The background literature research and experiment planning stages are dispersed across the semester. Team Investigation experimental days near the end of the semester allow students and faculty members to share their collaborative accomplishments. All neuroscience majors take this required course and the embedded research experience builds confidence, easing the transition to subsequent involvement with individual faculty members' research labs.

A two-semester research course sequence, similar to the First Year Research Experience (FYRE) program at Miami University, can provide students with a deeper research experience. This mechanism to engage first- year students in research was developed as a sustained outcome of a National Science Foundation (NSF) grant to increase retention. It was intended to provide students with early access to research opportunities, and to familiarize them with disciplinary practices of research. The Neuroscience FYRE courses are offered by instructors in the departments of Biology and Psychology who are involved with the interdepartmental Neuroscience Program. This course is not required for the Neuroscience curriculum, and is offered with variable credit hours, allowing the instructor to decide the intensity of the experience. The collective goals for a 2 semester FYRE course sequence are for students to receive an overview of faculty research programs, to learn about university resources that support research, such as facilities, libraries and the writing center, to participate in designing and conducting research, and to experience a community of researchers. Neuroscience researchers are invited with their lab groups to provide an overview of ongoing projects, with an emphasis on the significance of the research questions and routinely used methods. Students use skills developed through instructor-librarian collaborations to find, discuss, and then present topical popular articles and research articles in teams of three to four. These discussions are intentionally guided by instructors to identify the "what, why, how" questions, explore the context of the work (introduction), identify techniques and experimental design (methods), and examine figures, legends, and tables to get a sense for the scope of the results.

During the second half of the first semester, students learn routine techniques and prepare for animal research. They are led by the instructor and senior undergraduates, who may serve as TAs, to engage in discussions of novel project design for experiments that will occur in the following semester. The project is usually conducted in the second semester in teams of three to four depending on course enrollment; each student can be tasked with specific components of the project, or the varied tasks necessary for a given experiment can be spread across groups (i.e., experimental vs. control manipulations or measurement of different dependent variables).

While experiments are in progress during semester two, active data collection will cycle with periods of "down time". The down time can be used to continue article discussions. Instructors can also introduce research ethics, lab safety protocols, documentation through lab notebooks, and constructing "lab-meeting" styled presentations. The semester culminates with students developing final project reports and presentations. Participation in a campus wide undergraduate research forum held at many institutions can be a confidence boost for first-year students. Having such a two-semester experience under their belt, they are ready to move into research labs and contribute to ongoing research projects under the guidance of their chosen faculty mentor.

Research in Gateway Lecture Courses

The curriculum associated with the neuroscience major varies from institution to institution, but often includes introductory courses that are exclusively lecture-based. Introduction to Psychology is one such course; it is recommended as a foundational requirement for neuroscience majors (Wiertelak et al., 2018) and is seldom taught as a laboratory course (Thieman et al., 2009). Even in the absence of a full, separate lab, simple activities can be implemented that focus on foundational research skills and methodology. Such attempts must acknowledge that many introductory courses carry with them the expectation that students will come away with a strong background in content knowledge to facilitate progression to more advanced concepts. Yet, many disciplinary education groups urge movement away from pure content-based courses to those that place emphasis on the scientific process and adaptable skills (AAAS, 2011; Gurung and Hackathorn, 2016; AAAS, 2018). This emphasis can provide important foundational research understanding and skills upon which more advanced experiences can build. This approach has been taken at Westminster College with a recent redesign of the Introductory Psychology course goals and objectives to align course content with the foundational research goals for introductory level students, as recommended by the APA. Course objectives for content were specifically aligned with expectations for foundational research skills at the introductory level, and attempts were made to consider both skills and content during course assignments and assessments. This structure may provide a tenable way to integrate research without abandoning goals for broadening knowledge.

Biological psychology is often one of the earliest chapters in Introduction to Psychology textbooks, and a simple way to integrate research into these concepts is to use a series of popular science and research articles that describe the identification of MPTP as a trigger for hospitalizations of heroin users presenting with Parkinson's-like symptoms. As MPTP and Parkinson's disease both involve dopaminergic transmission, these concepts can provide examples of chemical transmission, which is likely a key focus of the introductory text. In discussion of these sources, instructors can emphasize how pathology can disrupt chemical transmission and behavior, which strengthens the brain-behavior connection, but also introduce and develop concepts of information literacy through the consideration of varied neuroscience sources for evidence and credibility.

As a second example, textbooks often cover simple memory experiments with tasks that are easy to administer in class. Identifying an existing difference in the student population (athletes versus non, those who had breakfast that morning versus not, etc.) and administering the test in class can allow discussion of dependent and independent variables, within and between subject design, possible confounds and appropriate "controlling" of experiments, sample composition, and more. These data could also be used to review descriptive statistics and discuss how central tendency and variation are important in our understanding of data, and could even support basic hypothesis testing. Finally, discussions of reliability and generalizability could also follow. Such activities could be designed for nearly any unit within the Introduction to Psychology framework, and ideally these items would be specifically integrated in a way that educators do not feel obligated to omit content entirely.

Research Apprenticeships

Although robust and substantial research experiences in the first-year would be most beneficial, achieving a full one- or two-semester research sequence may be challenging for institutions with limited financial and human resources. A way to preserve the benefits of more extensive experiences, and improve scaffolding, may be to reconceptualize the senior capstone experience from a "one student - one project" experience that spans one or two semesters to a repeated, progressive exposure to team-based research. This apprenticeship-based solution has been recently implemented at Westminster College, where the senior research experience involves progressive steps initiated in the first year to improve preparation for independent research, but also to enable more senior students to mentor research teams of students in years one through three. First-year undergraduate students are engaged in this experience as research assistants or apprentices. This one-credit research course has a single course meeting per week that includes instructor introduction of main concepts, but often runs in a "lab meeting" style where students meet in research teams and spend time discussing project goals, progress, and questions with the instructor as well. This structure has much in common with other models (Mickley et al., 2003; Morris et al., 2015) and is similar in its purpose and scope to the global consortium Vertically Integrated Projects (VIP, nd) program, which seeks to increase access to project based learning and the development of practical and professional skills in STEM fields. Students work as part of a multidisciplinary team, with tiered mentoring, and are able to take on leadership roles as older students graduate. A global consortium of academic institutions using the VIP model was established in 2019.

The research projects conducted in the course introduce first-year students to research areas, primary literature sources, experimental design, and simple data summary and analysis. Students gain proficiency in basic laboratory tasks, with the goal of gaining independence in some such tasks by the end of the semester. Laboratory work also helps them understand the importance of precision, laboratory protocols, and documentation. The semester culminates in guided peer review of the paper written by the team mentor that summaries the entire project; the first-year student also writes a comprehensive abstract of that paper to demonstrate understanding.

Students take this course again in their second year, which can serve two purposes: 1) students can experience an alternate instructor and contribute to a different research project, adding breadth to their knowledge of research and diversifying their laboratory skills and 2) students can take a step towards independence and contribute as members of the team and begin to conceptualize their own research path moving forward. Although expectations for course work and contribution do not substantially change from year one to two given that this experience remains a one-credit course, the level of contribution observed in second-year students is often more advanced and substantial, and these students frequently begin to design their own projects.

CHOOSING A MODEL: CONSIDERATIONS

Undergraduate research is an established high-impact practice that has traditionally been most accessible to upper-level students. The one-on-one mentoring model used to support such students is gradually being supplemented with course and team-based experiences, achieving the important goal of extending the mechanisms by which students can become involved in undergraduate research. Early engagement of students in the research process is also taking hold, and structuring these early experiences with intentional and progressive steps can help to maximize their benefits. A wide variety of models exist for early engagement in research; these include research-based courses, research integration into introductory lab or lecture courses, and research apprenticeships. The challenges and benefits of these varied approaches are many, and the degree to which any one approach is appropriate for a given institution or curriculum likely depends on multiple factors including the availability of institutional resources and support. The mechanisms through which faculty members receive credit for mentoring research, the way research is currently structured into the curriculum, student preparation, the availability of graduate or undergraduate student mentors, and funding may all also impact model choice.

Expectations in Early Models

The various models presented here vary in the level of time and investment for student success, but also in the structure, support, and credits associated with the course. The one-credit research apprenticeship model is a low-stakes, credited option which might be attractive to students who have full academic schedules or less availability due to extracurricular, work, or personal commitments. Such courses enable students to get a “taste” of research with minimal in-class time and graded assignments. One-credit apprenticeships potentially attract students who are less engaged or invested in the research, and faculty members and students may struggle to identify what level of contribution is warranted for a single credit experience. This challenge is easily mitigated by planning and early discussions with students about their reasons for choosing this option alongside clear expectations and guidelines for levels of contribution. In more standard introductory lecture and laboratory courses, expectations are likely more comparable to other courses that bear similar credit and include traditional items such as attendance, preparation, and completion of assignments, which make them more “familiar” to students. First-year research courses tend to be heavily structured by the instructor, and although students may not participate in research design, they can be invited into discussions of the choice of particular experimental strategies. A focus on iteratively developing practical skills such as writing, critical analysis, and scientific literacy through structured assignments and in-class exercises can increase the appeal of such courses for students and make expectations for proficiency and products clear. Yet skill development must be balanced with course content, as many such gateway courses provide a basis for more advanced content later in the curriculum. Creative approaches to integrating content and research skills can serve to alleviate this tension. The integration may be more easily accomplished in lab sections of introductory courses. The research experience can vary in length, scope, and structure, and can be built around the core learning outcomes for content. Faculty members may also want to consider that gains in understanding, skill, and attitudes may progress at variable rates, and learning goals and outcomes could be organized accordingly (Bhattacharyya et al., 2018).

The benefits of stand-alone research-based courses can be maximized when offered as a two-semester sequence, which allows for the progressive development of research skills, and a contextual understanding of content. Research based courses may provide more substantial opportunities for students to engage in quantitative skills through data analysis. Students can also gain experience communicating research to a broad audience through department- or institution-wide forums that usually occur at the end of the academic year. Although research-based courses provide immersive experiences, they can be an academic burden for students, in the first year, when the focus is largely on gateway courses.

Although the one-credit research experience is specifically aimed at first- and second-year students, standard lecture and laboratory courses may also be taken by advanced undergraduates with more well developed understanding of the research process and better research skills. Faculty members must consider this variability and could provide additional or advanced content to those seeking a challenge, or center assignments or assessments around topics with varying complexity. Reinforcement of research concepts is also beneficial, and giving students the chance to see these concepts applied in a different discipline can broaden student appreciation for the importance and breadth of research as a whole. In contrast, some students might come into college with credit for introductory courses and move directly to transitional courses (Morrison et al., 2020); this challenge may be minimized if research is integrated into multiple introductory courses rather than a single course, but also may have to be remedied by ensuring competency in research knowledge and skills upon entry into intermediate courses.

Community and Team Building

Mentorship is an additional practice associated with undergraduate research, and at Primarily Undergraduate Institutions (PUIs), this often refers to faculty mentorship of research. Considerable evidence suggests faculty mentorship is key; peer mentorship has additional benefits to both mentor and mentee, and can be utilized in courses to build community among students and support the mentorship efforts of faculty, which can be costly. Teaching mentors key leadership, communication, and team building skills (Hund et al., 2018), and providing students with instructional experience can improve their preparation for careers both within and beyond STEM (Akil et al., 2016). In the one-credit research apprenticeship model, as students are specifically placed in the team leader position, considerable training and preparation for such a role is critical. Yet the benefits are many. Mentors can serve as role models and teams can help build community. Underclassmen can see the progression in sophistication, proficiency, and knowledge in the context of a single uniform research project first hand through interactions with more senior students. Conversations with seniors can target which "piece" of the project they might take on as an advanced project; this supports continuity and research productivity (see below). This strategy also alleviates the need for faculty members to break down their research into small chunks that can be exclusively accomplished by a beginning student, because students are part of a larger team and can rely on support and training from multiple sources. Advanced students can fill the mentorship role in these other models as well, most easily through laboratory or teaching assistant positions, and achieve similar gains. In particular, if courses are used to collect data on faculty research, teaching and laboratory assistants may assume the role of research team leader as well. In addition, these assistants can increase the quality of data collection accomplished in early courses; these data can support presentation, publication, and grant application efforts for faculty members. These mentorship models promote a research community with layered mentoring from faculty, peers, and near peers invested in the conduction of high-quality research.

Institutional Support for Early Research Engagement

The integration of undergraduate research into the student experience requires investment on the part of students, faculty, and the institution. The mechanisms described here almost all suggest integration of research into existing courses to ensure that faculty members have the time to support such efforts adequately. The inclusion of research in introductory courses is a low-cost means through which research can be built into curricula. Faculty members usually receive credit for teaching such courses in their regular teaching load, while students receive credit for a required course. Courses or series of courses specifically focused on research, such as the FYRE, also garner faculty members course credit, but may create bottlenecks and challenges to ensure required courses for the major are offered with enough consistency to ensure timely student progression. As the number of students attracted to neuroscience continues to grow (Ramos et al., 2017, this tension may increase for many departments. The one-credit research assistantship model required creativity and the development of a new course; this course is unlike traditional courses in that faculty members teach it as a single unit (and get credit as such), but the students are enrolled in the course for varying degrees of credit and attend at different times and have different expectations for participation. While initially challenging to conceptualize and organize, this innovation was a direct effort to ensure faculty members received credit for the mentorship of research students at all levels. Yet the teaching of research-based courses allows faculty members to integrate their own research projects into the curriculum, which is an important component of their success as effective educators and productive scholars.

Research budgets may also require consideration; equipment, supplies, and instrumentation all must be purchased and maintained. Increasing numbers of neuroscience majors likely means more students engaging in research, which requires additional supplies. Creative use of existing resources and budget allocations or the adoption of more cost-efficient models can alleviate this strain. Further, some colleges or universities might have institutional funds that can support faculty and student research efforts; ensuring these funds are available for students at all levels is key to support early efforts. Applying for and receiving such funds also provides evidence of proficiency in research for faculty members and students.

Accessibility and Inclusiveness of Early Experiences

Whatever the chosen model, promoting diversification of the student population that is engaged in research should be a high priority. Early research has been suggested as a mechanism through which recruitment and retention in STEM for students from all backgrounds may be accomplished (Murray et al., 2016). Many institutions invested in increasing the diversity of the student population have mechanisms in place for targeted recruiting to expand participation. First-year research programs can work collaboratively with Admissions to aid in recruitment and to raise awareness of the benefits of undergraduate research and the opportunities available to engage in such work. On campus, first-year students will need built-in support systems to transition into college life and to navigate research opportunities. Course-based experiences and research experiences integrated into introductory lecture or labs are well positioned to raise awareness of ongoing research on campus and allow students to test the waters. Research apprenticeships that are low-commitment opportunities may also be more attractive than volunteer options or opportunities that are difficult to schedule amid a full academic course load or for students who have additional, non-academic responsibilities. The mentoring associated with apprenticeships or other models may be particularly beneficial for the support of underserved populations, as mentorship has been highlighted as key to providing academic, professional, and social benefits to such individuals (Estrada et al., 2018). Alternatively, creating inquiry and/or research-based courses that are required of all majors may be the best approach to alleviate issues of accessibility and ensure exposure of all students to these high-impact practices. Such active learning techniques have been demonstrated to narrow the achievement gap for students underrepresented in STEM (Theobald et al., 2020). Indeed, programs that incorporate mentorship, research, and educational support (Wilson et al., 2012; Estrada et al., 2018; Lisberg and Woods, 2018) may be best positioned to support the academic, personal, and professional development of all students.

Providing accessibility to research opportunities needs to be intentional. Miami's FYRE program works with Admissions to publicize the program, specifically with efforts to recruit first-generation and underrepresented students. Research opportunities in science and engineering fields for first-year students are also publicized through the Louis Stokes Alliance for Minority Participation (LSAMP) program and others that work with underrepresented student groups. In the last two years, Living Learning Communities overseen by Student Affairs, designed to improve retention of these student groups, have required enrollment in sections of the two-semester FYRE sequence, with assistance provided during first-year student orientation. Courses that start later in the fall semester, and one-semester spring courses are offered to recruit students who need the time to work through the challenges of transitioning into college life.

Combined Efforts for Maximum Impact

The ability to implement any of these various strategies in a manner that extends beyond a single course, or even a single institution, could broaden and amplify the benefits of such efforts. SEA-Phages, a mentored, two-semester research experience for first-year students, currently involves over 75 institutions, and is a demonstrated example of sustained and scalable efforts to engage first-year students in research (Jordan et al., 2014). The FRI model, developed at University of Texas-Austin, is being replicated at multiple institutions across the country, and involves developing three-semester experiences for students across disciplines (Rodenbusch et al., 2016; Killion et al., 2019; Sandquist et al., 2019). In addition, a network of faculty members across multiple institutions called *Research Experiences in Introductory Laboratory in Biology* [REIL Biology], engage first-year students in authentic research experiences, at their individual institutions (Spell et al., 2014). Such endeavors may impact neuroscience majors or students as many curricula include entry-level biology, chemistry, and/or psychology courses. Expanding such programming to support early engagement in neuroscience-specific research may provide a mechanism to expose students to interdisciplinary research, while promoting recruitment of students to the neuroscience major and the recorded benefits of early research for neuroscience students and faculty members.

Concluding Remarks

A first-year research experience has enormous potential to transition students into a scaffolded progressive research program (Fernandes, 2020), as described in two subsequent articles (Chase et al., 2020; Morrison et al., 2020). Investing the time and effort to design an integrated program through which students can enter and continue in undergraduate research can improve outcomes for all students, particularly those currently underrepresented in STEM disciplines. Benefits to faculty members are also considerable and extend beyond the practical benefits of research and educational outcomes. Among these are the immeasurable pleasures of supporting students as they discover science, grow in confidence and competence, and move towards a future that will be well served by a diverse group of thoughtful, curious, well-prepared individuals entering the workforce (Altman et al., 2019; Ramirez, 2012).

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