ARTICLE
Integrating Research into the Undergraduate Curriculum: 3. Research Training in the Upper-level Neuroscience Curriculum

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The benefits of undergraduate training in research are significant. Integration of such training into the undergraduate experience, however, can be challenging at institutions without extensive research programs, and may inadvertently exclude some populations of students. Therefore, inclusion of research into the academic curriculum ensures all students can access this important training. The 2019 annual meeting of the Society for Neuroscience included a workshop on integrating research into the curriculum at primarily undergraduate institutions (PUIs). In this last article of a three-part series, we describe models for integrating research into advanced stages of the undergraduate curriculum, specifically for juniors and seniors. First, we describe multiple models of faculty-mentored group-based research. Second, we detail a peer-mentored research system, in which seniors mentor groups of first through third year students. Third, we describe multiple examples of integrating research into "capstone" courses for seniors. Fourth, we describe models in which a senior thesis is a graduation requirement for all students. Lastly, we describe several models of implementing an optional honors thesis for students. Although similarities exist across these programs, their differences allow for specific secondary objectives to be met, which are often unique to institutions and/or departments. Therefore, for each of these examples, we describe the context, specific design, and required student assessments. We conclude by discussing some of the key successes and challenges of developing programs that facilitate undergraduate research by upper-level students, and suggest a number of concepts that should be considered by individuals developing and assessing new programs.

Keywords: pedagogy, undergraduate research, underrepresented groups, high impact practice, CRE, Honors, upperclassman, PUI, thesis

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The new blueprints for an undergraduate neuroscience education intentionally focus on research as a core skill (Wiertelak et al., 2018), and several national STEM organizations, such as the National Research Council and the American Association for the Advancement of Science, have issued calls to include research in undergraduate STEM training (National Research Council, 2003; Brewer and Smith, 2011). In addition, assessment of undergraduate research experiences has identified critical academic, social, and professional improvements that research engagement provides to students, thus designating undergraduate research as a "high-impact" practice (Kuh, 2008; Lopatto, 2004, 2007, 2010; Dolan, 2016). Specifically, undergraduate research experiences promote identification as a scientist, independence, self-efficacy, knowledge, problem solving related to research, and technical skills. Research experiences also improve persistence in STEM fields specifically and towards graduation more broadly, and help students to clarify their career paths (Seymour et al., 2004; Russell et al., 2007; Yates and Stavnezer, 2014; Linn et al., 2015; Dolan, 2016). Research ability is highly valued not only in decisions related to graduate admissions in neuroscience and clinical neuroscience programs (Karaszia et al., 2013; Boyette-Davis, 2018), but also in non-academic settings. Although only some undergraduates pursue graduate degrees in neuroscience, the critical thinking, reading, and writing skills, and growth in problem solving achieved through persistence and deep thinking, are highly sought-after skills for nearly any career path (Kinzie, 2013).

Underrepresented students are defined here as any group of students who make up a smaller proportion of STEM majors than their national representation. Underrepresented students who participate in active learning, of which undergraduate research is an ideal example, are more likely to graduate and remain in STEM, and stand to benefit the most from research training (Jones et al., 2010; Ramirez, 2012; Weekes, 2012; Bangera and Brownell, 2014; Martinez-Acosta and Favero, 2018; Theobald et al., 2020). The opportunity to build a strong, academically meaningful relationship with a faculty mentor is a reliable indicator of satisfaction on the National Survey of Student Engagement (NSSE, 2020), improving outcomes for underrepresented students especially (Nagda et al., 1998; Seymour et al., 2004; Ramirez, 2012; Weekes, 2012; Finley and McNair, 2013; Estrada et al., 2018; Dewsbury, 2020). Underrepresented students who feel a sense of belonging, which can be successfully fostered in research experiences, are more likely to persist in STEM (Estrada et al., 2018; Fromherz et al., 2018; Rainey et al, 2018). Therefore, it is important for undergraduate programs to offer opportunities for all students to engage in research opportunities in groups or independently, and when possible to include a local or regional poster presentation. Curricular-based solutions to research training offer one means of improving access to research opportunities in an inclusive and equitable manner. This article explores many avenues for upper-level student engagement in research, following on the guiding principles explained in related papers in this issue that discuss early research engagement and scaffolded research opportunities, respectively (Buffalari, et al., 2020, Morrison, et al., 2020). This series of papers extends from a well-attended workshop on integrating research into the curriculum at primarily undergraduate institutions (PUIs) at the 2019 annual meeting of the Society for Neuroscience (Fernandes, 2020).

A wide variety of models exist to provide research experiences to students, including apprenticeship-based models, group projects within courses, group projects within a research lab, individual projects within a research lab, and more (see Appendix 1 for the variety of names and definitions that are used to describe such experiences across institutions). If students and faculty members had unlimited time and funding, a best-case scenario for training undergraduate researchers might incorporate all aspects of the papers in this series. Early experiences would introduce students to inquiry-based learning, exposing them to the ideals of research science, including ways to frame and assess empirical research with guiding questions, and opportunities for them to create a small research question within narrow content constraints (Buffalari et al., 2020). With mid-level experiences, students would begin to engage more fully with empirical research, integrate a variety of theories or findings to determine the next interesting path forward, and learn lab techniques while completing studies in a small group setting or as individuals (Morrison et al., 2020). Completion of each of these scaffolded steps should lead to upper-level students possessing the confidence and sophistication of thought to craft their own independent research questions, conduct experiments, and present results in a talk, poster, or written thesis (Lopatto, 2010).

Although the scenario described above may be ideal, more typically this four-year scaffolded research experience is difficult to implement due to programmatic constraints, staffing limitations, and/or resource availability. In these cases, it is important to consider how to design an upper-level research experience that "meets the students where they are" so they can achieve the gains in all of the skills discussed above. It is equally important to consider how that program will ignite students' passion for seeking new knowledge and foster the students' sense of ownership of their research (Aguanno et al., 2015; Cooper et al., 2019). Although many institutions offer optional apprenticeship-based research experiences, these can serve only a limited number of students, and the pathways to access these limited experiences are not always transparent to all student groups. Therefore, making research a part of the required curriculum can be a key component of inclusion and equity. Integrating research into courses can be costly, both in time and money, but to help defray that cost, courses can be designed in ways that maximize outcomes for students and faculty members, such as increased presentations at national meetings, publications, and grant funding. Thus, such programs allow for important gains for students while also benefiting the faculty, program, and institution.

In the sections that follow, we discuss five different upper-level research experiences designed to meet the specific needs of their respective programs and institutional objectives. The first example described, the Broadening Undergraduate Research Program in Behavioral Neuroscience (BURP-BN) in the Department of Psychology at Miami University, was designed to provide a course-based research program for junior and senior undergraduates who have no prior research experience. The second example is the scaffolded approach to research used at Westminster College, where seniors mentor younger students through stages of research skill development. The third example is an Advanced Neuroscience Research (I and II) Capstone Experience that is required of all neuroscience majors and minors at Hope College. Students participating in this two-semester series of courses often have different disciplinary expertise and research backgrounds, and must work collaboratively as a group on a common research goal. The fourth example is the Senior Independent Thesis Program at the College of Wooster, which all students are required to complete (regardless of major) after preparing during their first three years. The fifth example is an honors-based undergraduate research approach, using Lycoming College and Miami University as examples, but recognizing that this is a common mechanism for undergraduate research opportunities across types of institutions. Although these models share similarities, important differences allow for secondary objectives to be met, which are often specific to institutional and/or departmental goals. Therefore, for each example, we describe the context, design, and required student assessments. We then describe some of the important successes and challenges of developing programs that facilitate undergraduate research by upper-level students. It is noteworthy that these examples are all implemented at PUIs, which generally lack graduate students, research technicians, and postdoctoral fellows. As a result, all instruction, training, mentoring, oversight, and guidance come directly from faculty members.

SENIOR LEVEL GROUP RESEARCH EXPERIENCE

Neuroscience research opportunities are often limited at smaller institutions without medical schools, making research positions highly competitive. Additionally, students who develop interests in research late in their undergraduate training are often less competitive for a limited number of traditional research apprenticeship positions. Because of these issues, many students graduate without obtaining critical research training, which is especially problematic for students hoping to pursue further study in graduate, medical, or other professional schools.

To address this problem, the Psychology Department at Miami University developed the Broadening Undergraduate Research Program in Behavioral Neuroscience (BURP-BN; Quinn and Oswald, 2016). This curricular solution provides up to 20 students per year (drawn primarily from Psychology, Biology, and Neuroscience majors and co-majors) with experience in the entire research process: from hypothesis generation to experimental design, data collection, analysis, and publication/presentation. Students are admitted to the program by competitive application. They must be seniors or advanced juniors with no prior research experience in neuroscience. Other selection criteria are at the discretion of the instructor, and typically include career goals, grades, and courses taken, with a strong emphasis on diversity and inclusion. Admitted students enroll in three 300-400 level courses, one each occurring in the Fall, Winter, and Spring terms (students must enroll in all three). Instructors receive teaching credit for all three as well. During these semesters, students work in teams of three to four to develop and conduct novel research projects in live animals, on topics related to the instructor's expertise.

In the Fall, teams work with the instructor(s) to develop their research question, hypotheses, and outline their methods. Assessment is typically based on: 1) an application for internal funding from the undergraduate research office and the host department; 2) an application for the IACUC approval necessary to complete the project; 3) a presentation of their project to all behavioral neuroscience faculty members and graduate students in a poster-style presentation that includes figures of hypothetical results; and 4) peer evaluations of team member contributions. Completion of these goals ensures that the work is feasible, provides feedback on experimental design and hypotheses from experts in the field, and provides funding for their research if team applications are successful. While achieving these goals, students also gain experience in literature searching, hypothesis generation, experimental design, writing and presentation skills, responsible conduct of research, and general teamwork.

During the Winter term, students prepare for data collection by developing custom experimental protocols and detailed study timelines, as well as ordering supplies. Students also learn the technical skills necessary to complete the project, including animal husbandry, handling, injections, surgery, behavioral testing, staining, and other methods as needed to test their hypotheses. Assessment during this semester varies widely among instructors, but often includes peer evaluations and assessment of technical skills. Additionally, groups often set their own goals, which can then be included in assessments. Over the course of the Winter term, students gain experience in specific research methodologies and study planning, and continue training in the responsible conduct of research and general teamwork.

In the Spring term, teammates work together to collect and analyze their data. This semester is often the most challenging in the program, as students must balance their complex research schedules with their other academic and non-academic responsibilities. Teamwork and effective communication strategies are of paramount importance, as is the support of the instructor(s). As data are collected, students learn how to analyze, graph, and interpret them using various software packages. Training is done in a small group setting, with the instructor(s) providing individualized plans for each team/member, specific to their data and hypotheses. The project culminates in each team developing a final scientific poster and presenting their results at two local research symposia. Students are also invited to present their work at regional/national conferences, with approximately 20% doing so. Assessment during the Spring semester is based on team presentations, as well as peer review. Over the course of the Spring term, students learn the basics of data collection, management, analysis, and interpretation, while simultaneously refining their presentation and teamwork skills.

SENIORS AS MENTORS FOR GROUP RESEARCH PROJECTS

All neuroscience majors at Westminster College must complete a senior capstone experience in which they explore a novel research question through scientific experimentation, data collection and analysis, and a final comprehensive poster and paper. The structure of this experience has recently been revised from a two-semester, independent senior experience to a four-year, progressive experience where students in years one through three contribute to team research projects and seniors serve as team leaders in year four. This structure helps to create a pipeline of trained students and provides the opportunity to scaffold the development of skills across years rather than all training occurring in a single senior experience. Students in years one and two start with one credit, low commitment research experiences (Buffalari et al., 2020), proceed to the intermediate step of interrogating the primary literature and writing a proposal while still contributing to the team research (Morrison et al., 2020), and finish with a senior scholarship experience. As seniors, students assume the role of project leaders and oversee experimentation, while also serving as peer mentors for student researchers in years one through three (see Morris et al., 2015 for a similar model). As all students engage in this progressive experience, there are no limitations on accessibility across varied student groups.

Seniors are enrolled in a one-semester, four-credit course that meets for three hours per week; some of those meetings also include younger students and are organized in a "team lab meeting" format. Seniors oversee the completion of the experiments that were outlined in the proposal they wrote in their junior year. The course is designed to address learning outcomes associated with scientific and research proficiency that include: 1) the ability to design and complete an experiment to interrogate a novel scientific question; 2) demonstration of critical understanding of how experimental results fit into the primary literature; and 3) communication of scientific results in both oral and written forms. In addition, because seniors serve as team leaders and peer mentors for underclassmen, additional goals include strong communication, creating a supportive intellectual environment, and mediating peer conflict. It can be a challenge to engage seniors in the team leadership role, but training in leadership and peer mentorship has been successful in helping to prepare them and build confidence. Such skills are relevant to a number of careers both within and beyond the STEM field, and serve to prepare our students for the future beyond their undergraduate degree.

Faculty members that oversee team research projects (from three to five teams, usually four to six students per team) receive credit for teaching a single course. They grade assignments for all students, although with careful design, seniors may be able to assist with grading. Faculty members also facilitate structured peer review of student written work and lead discussions early in the course regarding experimental design, data summary and analysis, and scientific writing. Seniors are expected to facilitate such discussions in their small research groups to an increasing degree as the semester progresses. With the guidance of faculty members, students set realistic goals regarding how they will contribute to the project and how their contribution will be evaluated. Seniors evaluate their peer mentees on established criteria at the midpoint and end of the semester; they are also evaluated by their mentees on stated goals. Seniors also complete self-evaluations at the middle and end of the semesters; all evaluations contribute to the course grade. The course culminates in an article written individually by each senior in the style of a scientific manuscript, and the presentation of a poster at a local, regional, or national conference. With the team structure, more comprehensive projects can be completed, as the work can be distributed across team members.

REQUIRED CAPSTONE RESEARCH COURSE EMBEDDED IN NEUROSCIENCE MAJOR

The neuroscience program at Hope College is rooted in the philosophy that students "learn best by doing" and therefore requires students to participate in meaningful, hands-on undergraduate research throughout the curriculum. These research experiences are scaffolded beginning with five-week small group research projects in the Introduction to Neuroscience Lab. Research practices are reinforced and additional medium-scale hands-on research experiences are woven into sophomore- and junior-level courses, such as Research Methods and Neurochemistry and Disease (Morrison et al., 2020). Therefore, all neuroscience majors experience a carefully scaffolded research experience that culminates in a year-long collaborative capstone research experience encompassing two courses taken in succession. The instructor rotates each year, thus providing varying areas of research opportunities for students from one year to the next.

The capstone experience is designed specifically to meet four objectives of the neuroscience program that students will: 1) synthesize and differentiate among the various disciplines that contribute to neuroscience; 2) critically evaluate the primary neuroscience literature; 3) collaboratively contribute to new knowledge through hypothesis development, experimental design, data collection, and data interpretation utilizing ethical practices; and 4) create and deliver effective written, visual, and oral communication designed for both scientific and non-scientific audiences. Thus, enrollment in the courses is limited to eight to twelve students.

Depending on the nature of the project, students work collectively as a single team on one project related to the faculty member's primary area of research, or as two different research groups working on distinct projects. In the fall semester, students meet for three hours each week for class discussion, and a minimum of three hours a week in the lab, the equivalent of one course. Class time is initially spent introducing students to the faculty member's area of expertise, developing project goals, honing the design of the experiment, and reviewing any necessary IACUC or HSIRB proposals. After the project is well defined and experiments are underway, the focus of class transitions to discussion of the mechanics of writing a grant proposal, weekly familiarization and critique of the literature through student-led journal club presentations,-faculty-mentored peer review of grant proposal drafts, and coordination/trouble-shooting of ongoing experiments. Students are ultimately assessed based on their individual NSF-style research proposal on a project of their own design, journal club presentations, primary literature critiques, written peer review, and contributions to lab work and class discussion.

Lab time is dedicated initially to training students in specific laboratory procedures and then quickly transitions to all necessary experimental work that is documented in a common lab notebook. Although there is a designated common lab meeting time each week, students often meet in pairs or smaller groups throughout the week to allow for maximal data collection on shared instrumentation (e.g., video analysis of animal behavior). Because this course is required for both neuroscience majors and minors, the student groups have broad disciplinary expertise and perspectives. Even within neuroscience majors, there is a breadth of interests as some students have taken more classes at the cellular and molecular neuroscience level, while others may have taken more courses at the systems, organismal, or cognitive neuroscience levels. This range in expertise and interest adds a richness to class discussions, such that students gain a deeper appreciation for learning to communicate effectively with others whose expertise differs from their own. Students also learn that interdisciplinary collaborations allow the group to address more complex questions and scientific problems than if they were to tackle the problem individually.

In the spring, students meet for three hours each week without a lab component. Class time is dedicated to data analysis and interpretation, weekly journal club discussions/presentations, faculty-led mentoring of the manuscript writing process, peer review of writing, and preparation of a common research poster for presentation at Hope College's Annual Celebration of Undergraduate Research. A typical weekly schedule includes one class session for journal club, one class session for "group meeting" for data analysis/discussion and trouble-shooting, and one class session for mentored student writing/peer review. Students are assessed on their data analysis reports, individual research manuscript, journal club presentations, written peer review, and contribution to the common research poster.

INDEPENDENT SENIOR THESIS

All seniors at the College of Wooster, in all majors, complete an independent senior thesis project. This independent study is required of every student, not just those in an honors program or those selected by faculty members. Therefore, the sophomore and junior year curricula are specifically scaffolded to build the necessary critical thinking and writing skills, content knowledge, and methodological foundations necessary for students to define and conduct an independent project. In addition, because every student participates in this two-semester endeavor, an inclusive experience is provided to all students, across all levels of academic performance, and all racial and socioeconomic groups. Faculty members receive teaching credit, as it is a part of the fabric of the institution (five senior mentees over the course of one academic year is the equivalent of teaching one regular course), and students register for this as one of their four regular courses each semester of their senior year.

Research exposure and skill development is progressively developed across Wooster's Neuroscience curriculum to prepare students for the senior independent study. The two tracks of the Neuroscience major, Cognitive Behavioral and Neurobiology, share a common core of introductory STEM courses, including Introduction to Neuroscience, one macro-level neuroscience course, one micro-level neuroscience course, and a senior seminar, in addition to the independent study experience. The additional nine courses for each major are specific to the track, such that students develop a depth of knowledge in theory, methodology, and skill development. Majors in both tracks enroll in at least six laboratory courses, which progress through inquiry-based projects and eventually introduce opportunities to develop small group authentic research experiments, all the while developing technical skills (Morrison et al., 2020). In addition to building expertise in working with empirical research articles to define research questions, the students are also building skills in hypothesis generation, data processing, analysis, and presentation, responsible research conduct, ethics committee approval, as well as scientific writing skills in a variety of courses throughout the curriculum, including a required statistics course.

Although termed an independent study, this process is more aptly referred to as mentored undergraduate research as all aspects of the project take place with careful, involved mentorship of a Wooster faculty member. As students move through the spring semester of the junior year, they are provided opportunities to define their senior thesis research project, with input and oversight, by exploring the literature, developing a research proposal often presented in a poster session, and then being paired with a faculty mentor for their senior project. Although there are differing levels of constraints on the research question, sometimes tightly linked with faculty research areas or constrained by available methods, every student defines their own experiment, supported by the published literature.

Throughout their senior year, the student and faculty mentor meet one-on-one for an average of one hour each week for discussion, conversation, and training. They work on the iterative stages of the manuscript, discuss methodological concerns, roadblocks, and successes of each week for the entire academic year. In addition, a strong mentoring relationship develops, allowing for critical career or higher education conversations (Ramirez, 2012, Weekes, 2012; Martinez-Acosta and Favero, 2018). Meeting duration is adapted as needed, but is normally longer during methodological training, skill development, and data analysis. The time commitment for the student varies significantly based on their experimental design and chosen methodology, but is always outside of their scheduled coursework. Although faculty members may, at times, work with their entire cohort in a team lab meeting, these projects are conducted and written independently, necessitating individual conversations. As is the case in most research labs, students work alongside peers on similar topics, often with the same methods and equipment, and sometimes on different portions of the same research question, especially when it is linked to a faculty member's research area. Often seniors have at least some experience with their chosen research technique from previous course work, though there remains a great deal of needed training and oversight with laboratory work. Funding for independent study projects is provided minimally through department and/or program budgets, although seniors may apply for competitive funding to enhance their project through a campus-wide endowed fund.

A completed neuroscience independent study culminates in a full, manuscript-length research paper with a thorough primary literature review, including at least 20 sources, due half-way through spring semester. Additionally, students have an oral defense with one other faculty reader and present their work at a campus-wide research symposium in talk or poster format, and some at regional spring meetings. The entire process is assessed by taking into consideration all of the steps: hypothesis development, experimental design, data collection, data interpretation and presentation, independence of thought and process, and most substantially, effective written and oral communication.

HONORS THESES

Honors Theses are a common mechanism to support senior-level research and often follow a research apprentice model. Although there may be similarities across programs (e.g., they require a written thesis), models differ across and within institutions. Students in STEM departments at Lycoming College have the option of conducting individual Honors Thesis research as part of the college-wide Honors program, and/or applying for Haberberger Research Fellowships (described below). The college-wide Honors program requires students to do a total of two semesters of research under the supervision of a faculty mentor. The research must be truly collaborative in nature, not just part of a course-based research experience. These two semesters take place during the student's junior or senior year, depending on how early the student became engaged in an individual faculty member's lab. For biology and neuroscience students, projects completed in prior research methods courses (e.g., Research Methods in Cell and Molecular Biology) can count as the first semester of the Honors process (Morrison et al., 2020). The students must submit an Honors Thesis application to a campus-wide committee that includes faculty members within and outside STEM, so students must communicate their plans clearly to non-specialists, while also providing sufficient technical detail for the STEM committee members. The committee may ask for revisions to the proposals until both of these goals are met; however, most applications for STEM projects are ultimately approved.

Upon approval, Honors students spend a full semester completing their research project in a specific faculty member's lab. This time commitment varies from six to twelve hours per week, with a third or more of this time working directly with the faculty member. The student writes a formal multi-chapter Honors Thesis and presents it in a one-hour seminar to the Honors Thesis committee, made up of five faculty members. They can suggest modifications to the written thesis, which must be made before they indicate successful completion of the Honors Project, or the Committee can downgrade the experience to an Independent Study (a rare occurrence). The student earns the equivalent of one course credit for the Research Methods course and another for the Honors project semester. The faculty member earns no contact hours for supervising Honors Thesis work; however, thesis work is almost always presented at regional and national meetings, and forms the basis for the faculty members' grant applications and published research. So, it contributes to the faculty member's professional development and requirements for promotion.

In a slightly different model, Honors Theses at Miami University fall into one of two tracks: University Honors and Departmental Honors. For students to complete University Honors, they must already be accepted into the University Honors Program, which generally happens on acceptance to the University or during the first year. During the senior year, students in this program can elect to complete Honors with Distinction, which entails the completion of an individual research or creative project and maintenance of GPA >3.5, in addition to the standard course requirements of the University Honors program. Students completing this program must identify a faculty member to supervise their project and approve its completion, but there are no formal requirements regarding publication, presentation, or the scope/magnitude of the project. Moreover, no required courses or formal training in research skills are required, although student-faculty teams typically develop individual training plans similar to those used in research apprenticeship models. The flexibility of this program likely relates to participation by students in a wide array of departments, from Creative Arts to Neuroscience. This flexibility, however, also creates opportunities for students to develop a custom research experience (with appropriate faculty mentorship).

Students who are not a part of the University Honors Program at Miami University, but who still wish to graduate with Honors, can opt for the second path: Departmental Honors. Students must apply to this program during their junior year, and generally have substantial research experience prior to enrolling (often with their faculty supervisor). Enrolling in the junior year maximizes the potential for research productivity during the students' senior year, but has a negative impact on the accessibility of the program. Requirements vary by department, but generally include specific courses both semesters of their senior year, completion of a major research project under the mentorship of a faculty supervisor, and presentation of a written thesis approved by the mentor and other faculty members (the number varies by department). Some departments also require students to present their project at local, regional, or national conferences. Honors courses meet one hour per week to provide basic training in scientific literacy, statistics, and data interpretation, forming a scaffolded framework to help students progress. Additionally, the courses provide a structured peer support system to keep students on track and facilitate peer review of writing and presentations.

SUMMER RESEARCH OPPORTUNITIES

In addition to these curricular, academic year experiences, undergraduates have an array of summer research experiences to which they can apply. The best-known example is the National Science Foundation Research Experience for Undergraduates (REU) program. Many colleges and universities have privately funded varieties, known as Summer Undergraduate Research Fellowships or similar names. These programs can incorporate many of the characteristics described above as authentic research experiences; however, the main difference is that large research and medical universities host the vast majority of summer REUs. Therefore, the training for the undergraduate can vary considerably. Some trainees work with the primary investigator, while others may work with a graduate student or postdoctoral fellow. Although some REU trainees have the opportunity to create their own small research project that they conduct, most work on the grant-related research of the lab. For this reason, selection into these programs is highly competitive, and often favors older students who already have some hands-on lab experience. This situation can disadvantage underrepresented students in STEM.

To overcome this shortcoming of the larger REU programs, one neuroscience summer research program hosted collaboratively by four regionally located PUIs, was designed to preferentially select younger and underrepresented trainees. Though initially funded by an institutional consortia grant (Yates and Stavnezer, 2014), this model was later awarded an NSF REU. Across the three-years of funding, the REU successfully trained 44 participants; 31% identifying as an underrepresented ethnic/racial minority, 38% as a first-generation college student, 56% were either first-year or sophomore level students, and 78% as female. Assessment data either matched or exceeded outcomes in comparison to the national REU averages on the Undergraduate Research Student Self-Assessment (URSSA). For example, students associated with this REU reported a higher level of "feeling responsible for the project", interacted with scientists outside of their school, and felt like a part of a scientific community.

Regardless of the program, summer research is normally an eight- to ten-week, full-time commitment, during which the trainee receives a stipend. Summer experiences are typically organized in programmatic ways. For instance, REUs offer professional development for the cohort of summer trainees, ethics training, opportunities to attend keynote lectures, and involvement in lab meetings. In addition, many of these programs support the development of underrepresented groups in STEM with strong recruitment and admission efforts, and a stipend can improve the odds that students needing to earn money in the summer can still participate in research. This immersive experience is very powerful, with trainees gaining extensive skill-based, methodological training, and many presenting posters at local end-of-summer symposia. REUs are, however, highly selective, limited by the number of openings, and dependent upon the applicant's ability to travel and live away from home for eight to ten weeks at a time.

FACULTY BENEFITS: GETTING PUBLISHABLE DATA

These year-long, upper level research experiences can be extremely costly in respect to faculty time; however, we have collectively learned that it is possible to obtain publication-quality data while working collaboratively with students (as discussed in Shortlidge et al., 2016). This consideration is particularly important for faculty members who are seeking external funding for their research programs and working at institutions where a significant level of research productivity is expected for tenure or promotion. In our experience, there are four important components to research projects that increase the likelihood that the project will yield results that are either publishable or useful as preliminary data for grant proposals: 1) careful sub-division of research projects into manageable mini-projects, 2) explicit communication of high expectations, 3) built-in mechanisms to increase student accountability, 4) planned activities to celebrate successes along the way. In addition, following these steps will lead to more successful group work and lab outcomes, even if publication is not the primary goal.

Although the structure of the research project can be quite different when working with a single student compared to a group of students, it is essential to take time to be intentional when designing the project and setting goals. It is particularly important to spend time before the semester begins to determine how to break the research project into small steps or mini-projects that are manageable for undergraduate students. A manuscript or proposal outline can be an important starting place for organizing the sub-projects, even though the final outcome may only loosely resemble your plan. Projects that are particularly amenable to such an approach are behavioral characterizations of novel animal models (or an assessment of the effect of a particular treatment on a host of animal behaviors). In this type of project, all of the students in the course could complete a particular behavioral assay each week. Throughout the semester, pairs of students can take three- to five-hour shifts testing animals in a particular behavior paradigm, so that over the course of a week 40-60 animals can be assessed. Molecular structure/function studies are also well suited for this type of course, in which individuals or pairs of students create unique mutations within a protein that they can assess for expression level, cellular localization, activity, etc. These aforementioned projects are just two examples, but with purposeful thinking, it is often possible to break down many research projects into smaller "mini-projects" that can either be distributed among different groups of students, or can be completed by the same groups of students during different weeks in the semester.

Setting high expectations and communicating them with students is an important component of a successful project. It is particularly important that students have an overview of the entire research project at the beginning of the semester, and understand how the work they are doing fits into the overall project objectives. When faculty members clearly describe how the students' work will lead to new knowledge in the field, it helps students develop ownership in and enthusiasm for their part of the project. It is also important to give students concrete examples of how previous classes contributed to published papers or grant proposals, so they set high expectations of themselves, and realize that producing publication-quality data is an attainable goal. Finally, if the class project is a subset of work going on in the research lab, it can be particularly effective to invite the independent research students to attend the related class/lab whenever possible, so that all students working on the project have an opportunity to interact and feel part of the same research team.

Students must also be held accountable for proper recording keeping and timely data collection. It is extremely important that students keep impeccable records of all of their lab work throughout the semester, and the tone must be set on day one. One strategy for encouraging good data collection habits is to provide students with examples of excellent lab notebooks so they have a clear understanding of the expectations. Equally important is to share examples of poor lab notebooks to emphasize that the consequence of not taking good notes is often time lost generating unpublishable data. Therefore, research mentors should plan for routine assessment of student lab books, and quickly address issues of incomplete record keeping. For projects requiring students to come in after hours to complete experiments, use of communication apps (Slack, Teams, GroupMe, etc.) help ensure students are completing experiments at the correct time. For example, students must log their testing hours and the animals tested to the whole class, and if no notification is received, there can be quick intervention by other students or the professor.

Finally, it is extremely important to celebrate successes along the way. Just like a sports team may celebrate a particularly meaningful win, it is important to celebrate the little things, such as finishing a challenging or time-consuming set of experiments, discovering a particularly exciting result, or learning of an important student achievement such as admittance to a summer research fellowship, medical school, or graduate school. Such team-building is essential to fostering a tight-knit, collaborative and supportive community of student researchers who are heavily invested in the success of the project and each other (Mickley et al., 2003).

SUCCESSES AND BENEFITS TO STUDENTS, FACULTY, AND PROGRAMS

Regardless of the format of the experience, authentic undergraduate research provides the student with knowledge of the entire research process, from idea generation through written final product. As they define their own research questions, students have a true sense of ownership of the project, which leads to high levels of buy-in and dedication to the effort that can take a significant amount of their already heavily scheduled time. Wooster President Howard Lowry was accurate in stating that the students would feel, “This, at last, is something of my own” when he instituted the required senior thesis (Lowry, 1965). Student researchers become facile with the primary literature as they consider interesting questions, understand the process of programmatic research and recognize how theories are often developed in incremental ways. They also become skilled at searching scientific databases and accessing resources as necessary. Following active experimentation, students deeply understand their research method(s) after having overcome skill or experience-based obstacles in data collection, and have a stronger appreciation for what the data actually are and what they mean. Students improve their statistical analysis and data presentation skills and, in either poster or paper format, present their holistic understanding of the project. Perhaps most importantly, these students develop their sense of self as a “real” scientist (Seymour et al., 2004; Lopatto, 2007). This confidence has been shown to improve retention in STEM, increase commitment to future scientific degrees, and positively alter perceptions of scientific identity (Seymour et al., 2004; Russell et al., 2007; Linn et al., 2015; Dolan, 2016; D’Arcy et al., 2019; Ramos et al., 2020). These outcomes tend to be even more pronounced among underrepresented groups in STEM, lending more impetus to the need to incorporate required curricular research experiences throughout the major (Bangera and Brownell, 2014; Dolan, 2017; Estrada et al., 2018; Theobald et al., 2020).

Students develop strong professional skill sets in the research process. Group research projects help students learn to work in the demands of an increasingly collaborative work environment; when structured properly, this can foster leadership skill development. Leadership and strong teamwork skills are certainly meaningful for those moving toward graduate study or research technician positions, as the team-based structure of scientific discovery is clearly the future of lab culture (Wuchty et al., 2007; Brewer and Smith, 2011). Learning to collaborate is also necessary for students entering non-STEM careers as many companies have transitioned to team-based cultures. In fact, a 2016 survey of 7000+ companies from 130 different countries indicated that changes to their organizational structure include a “network of teams” as their top priority (Bersin, 2016). Students who move through independent research projects, and those who collect data in small groups, develop a sense of personal accomplishment, an evolution in grit and self-esteem as they overcome obstacles, and produce a final project, perhaps the largest of their academic career (Dolan, 2016). They learn many aspects of what graduate school might be like, with research and article presentations mirroring graduate journal clubs, balancing competing demands on their time and interests, and opportunities to present their research project at local, regional and sometimes national conferences. In addition, the faculty mentors become more fully aware of the student’s strengths and weaknesses than may be possible in a classroom, not only to provide feedback for growth, but to provide strong and deeply informed letters of recommendation and job referrals (Ramirez, 2012).

All courses and research opportunities described here, with the exceptions of the NSF REU and the Lycoming College Honors Thesis, provide both the student and the faculty member with credit. This associated credit benefits the students by ensuring that they are gaining course credit toward graduation, and not needing to pay additional tuition or fees to access this transformative experience, increasing the total number and the diversity of students that participate in undergraduate research. These benefits are certainly enhanced for programs/institutions in which research (whether conducted independently or as a part of a course) is a requirement for graduation. Teaching credit is of great benefit to the faculty members mentoring the research students, as it is a tangible statement of institutional support for the importance of research activity. As a result of this increased focused time for scholarship, faculty members can work effectively with more students than they might be able to if they were only mentoring students within the apprentice model in their research lab. Faculty members are also able to collaborate with more students to produce preliminary data for grant proposals or publication-quality data. Rotating teaching credit through different faculty members for group-based research courses can give more of them opportunities to obtain credit for student/faculty collaborative research. If responsibilities are well-coordinated among members, it allows for faculty members to opt in and out of the course as it fits their scholarly needs (e.g., opting out in years when they need to focus on writing manuscripts or grants).

CHALLENGES AND LESSONS LEARNED

The examples presented here are not without their challenges. Research can be expensive, in dollars and in time. All of these example programs have had to strike a balance to achieve success despite these challenges. In terms of budgetary expenses, group projects can reduce costs by using fewer consumable supplies, animals, or reagents. In addition, the opportunity to create programmatic research, rather than one-off experiments, makes the use of those funds more fiscally responsible. Some institutions have endowed funds to support some or all of a student's research expenses, although these are often allocated through competitive applications. Other institutions have departmental budgets with allocations for each laboratory course, and others charge (or could charge) lab fees.

Student time management can create challenges in these programs. Some experiments require commitments outside of scheduled class time, in addition to a full schedule of regular courses, co- and extracurricular activities, and the demands of college life in general. Setting a strict schedule, clear group and mentor expectations, and developing regular routines can alleviate these concerns. The more difficult issue to overcome may be faculty teaching time and teaching credit. As faculty members receive teaching credit for each of these research experiences, be it a group, class, or individual version of mentorship, at least one traditional content-driven course is essentially removed from that semester's offerings. Limiting offerings can be a challenge for departments with fewer faculty members and can also limit student choices, but research experiences clearly offer students a depth of knowledge and skill development unmatched in a typical content-driven course. The institutional commitment to faculty teaching credit for these courses is a key to ensuring the ability to maintain offerings, supporting large enough sections and opportunities for as many students as possible. Rotating faculty members through these courses is also key to equity within the department.

All of these examples, except the REU and Honors Thesis, are required or elective components of the student's major, contributing credits toward each institution's graduation requirements. The opportunity to register for these research opportunities provides equity for all students, including underrepresented students in STEM. The Honors programs, however, can risk excluding students who are not familiar with the hidden curriculum of academe (Bangera and Brownell, 2014; Martinez-Acosta and Favero, 2018), and may privilege applications demonstrating more experience or a stronger resume. Obvious solutions to these concerns are available. Many programs include letters of support from faculty mentors, intentionally invite applications from students who show promise in lab experiences even if they are not achieving the highest grades, and provide active assistance from faculty members in developing application materials. A less obvious but incredibly powerful solution would be to provide fellowships to underrepresented students, so that they receive a stipend for their independent research project, alleviating a conflicting demand to earn money while on campus (Bangera and Brownell, 2014; Martinez-Acosta and Favero, 2018). For example, Lycoming College's Haberberger Research Fellowships recognize and fund up to six of the most advanced student research projects in STEM annually. Students apply through the same committee that approves Honors Project applications, working with a faculty member on their proposal, and awardees receive $1,000 stipends, a small supply budget, and recognition at the Honors Convocation. The stipend allows students of all means to take time away from other paying jobs to do research. This funding mechanism has enhanced the diversity of the student population engaged in research at Lycoming, and may serve as a model for other institutions with similar goals.

Although there are significant benefits of research to students as described above, there can also be individual frustrations related to the research topic that must be alleviated, and group dynamics that must be remedied. When research projects are focused on a faculty member's research area, students do not have as much ownership over the experimental design, leading to less buy-in and dedication to the project. In most projects, however, even within such constraints, students are permitted to think creatively about research methods, design appropriate dependent measures, and maintain autonomy in actually conducting the experiment. These topic-based frustrations are often mitigated as students explore an area more deeply, becoming more engrossed in the question and methodology, and recognizing the role that they can play in an active and on-going research project. As in any group experience, there will be differences in personality, work ethic, engagement levels, and ability to meet expectations. Working with groups from the start, with clear statements on course syllabi, clearly articulated group contracts and expectations (Oakley et al., 2004), and frequent check-ins can facilitate equitable group participation. For most of these projects, at least a component of each student's grade assessment is individual, which can help to assuage students' anxieties about group work. Assessment, however, can be a challenge, as it can be difficult to evaluate a student's actual lab ability. Therefore, a larger portion of the grade often depends on the written product or final oral presentation (Wilson et al., 2016). These deliverables can be illustrative of the student's experimental expertise, but they are not measures of timeliness, team work, problem solving, or increased aptitude.

Students who complete meaningful research projects near the end of the spring semester (when seniors will soon leave campus), are not always able to take their research to regional or national conferences, such as the annual Society for Neuroscience meeting. The few juniors able to participate in these experiences often present their work at national or regional conferences the following year, but this is a very small percentage of the total number of students. Most students, therefore, present their work locally at institution-wide research events or at late spring/early summer regional conferences, such as Midwest Psychological Association or regional SFN meetings (see Appendix 2 for a listing of potential undergraduate-focused conferences).

Lastly, identifying a course assessment tool is a challenge with research-focused courses, as there are numerous instruments available for measuring different aspects of student learning and growth. Although we recognize that a comparison of assessment results from the programs described above would be valuable, we deliberately refrained from such analysis, because each institution uses different assessment tools, making meaningful comparisons among programs difficult. This situation is not uncommon. Dolan (2017) notes that most studies of the efficacy of course-based research experiences are often focused solely on a particular program or course, utilizing a specific assessment tool, rather than taking a comparative approach. Widespread adoption of a standardized assessment tool could benefit the neuroscience education community as we work to understand the specific components of research experiences that are most effective for delivering desired outcomes. Assessment instruments such as the Classroom Undergraduate Research Experience (CURE) survey (Lopatto and Tobias, 2010), have been used extensively to assess many course-based research experiences across disciplines, and were instrumental in designing some of the solutions provided here. This survey includes pre- and post-tests to measure student-reported gains in course/research elements and student attitudes toward science. Other assessment tools, such as the AAC&U Value rubrics and URSSA (used by the NSF REU), are also available (Rhodes, 2010; Weston and Laursen, 2015). As valuable as these tools have been to assess student reported learning gains and attitudes, most criticisms of these types of assessment tools point to the fact that these surveys measure student subjective responses, and not outcome variables of learning gains and research capabilities (Deslauriers et al., 2019). A review by Shortlidge and Brownell (2016) offers a comprehensive description of available assessment tools and a thoughtful discussion of important considerations to make when evaluating research experiences.

CONCLUDING REMARKS

Although the benefits of undergraduate research training are clearly significant, developing course-based solutions to the unique challenges faced by each institution can be difficult, especially when considering programs for students who are late in their academic training. Every program and institution is unique, and there is not a one-size-fits-all course or research experience that should be universally implemented. A newly designed program or course may incorporate individual components of the programs described above for upper-level students, and may also try to adopt some of the early (Buffalari et al., 2020) or transitional experiences (Morrison et al., 2020). Also, it is important to realize that many of these programs evolve over time to adapt to changing resources, new curriculum requirements, changing numbers of majors, or students' needs. The solutions presented here highlight important considerations before implementing a new program or course-based research experience: 1) the specific objectives/learning gains desired for the research experience; 2) the skills and prior experiences that students will bring to the program, often developed in earlier coursework; 3) the benefits of individual research experiences vs. group-based solutions; 4) financial and staffing limitations; 5) how to design the experience to incentivize faculty buy-in (tangible benefits to instructors). Obviously significant time and effort are needed to create a successful curricular research experience for all students, but the process pays dividends. The students, faculty, program, and institution all benefit, while improving equity in training and research opportunities. Thus, finding creative ways to incorporate upper-level research opportunities into the curriculum is well worth the investment.

REFERENCES

Aguanno A, Mertz P, Martin D, Bell, E (2015) A national comparison of biochemistry and molecular biology capstone experiences. Biochem Mol Biol Educ 43:223-32.

Brewer CA, Smith D (2011) Vision and Change in Undergraduate Biology Education: A call to action. Washington, DC: American Association for the Advancement of Science. Available at www.visionandchange.org.

Bangera G, Brownell SE (2014) Course-based undergraduate research experiences can make scientific research more inclusive. CBE Life Sci Educ 13:602–06.

Bersin J (2016) New research shows why focus on teams, not just leaders, is key to business performance. Forbes Magazine, March 6, Available at https://www.forbes.com/sites/joshbersin/2016/03/03/why-a-focus-on-teams-not-just-leaders-is-the-secret-to-business-performance/#13ae608024d5.

Boyette-Davis J (2018) A report on the qualities, skills, and characteristics desired by top neuroscience graduate programs. J Undergrad Neurosci Educ 17:A54-A58.

Buffalari D, Fernandes JJ, Chase L, Lom B, McMurray MS, Morrison ME, Stavnezer AJ (2020) Integrating Research into the Undergraduate Curriculum: 1. Early Research Experiences and Training. J Undergrad Neurosci Educ 19(1):A52-A62.

Cooper KM, Gin LE, Akeeh B, Clark CE, Hunter JS, Roderick TB, Elliott DB, Gutierrez LA, Mello RM, Pfeiffer LD, Scott RA, Arellano D, Ramirez D, Valdez EM, Vargas C, Velarde K, Zheng Y, Brownell SE (2019) Factors that predict life sciences student persistence in undergraduate research experiences. PLoS ONE 14(8):e0220186.

D'Arcy CE, Martinez A, Khan AM, Olimpo JT (2019) Cognitive and Non-Cognitive Outcomes Associated with Student Engagement in a Novel Brain Chemoarchitecture Mapping Course-Based Undergraduate Research Experience. J Undergrad Neurosci Educ. 18(1):A15-A43.

Deslauriers L, McCarty LS, Miller K, Callaghan K, Kestin G (2019) Measuring actual learning versus feeling of learning in response to being actively engaged in the classroom. PNAS 116:19251-57.

Dewsbury B (2020) Deep teaching in a college STEM classroom. Cult Studies Sci Educ 15:169–91.

Dolan E (2016) Course-based undergraduate research experiences: Current knowledge and future directions. Committee on Strengthening Research Experiences for Undergraduate STEM Students (National Science Foundation). Available at https://sites.nationalacademies.org/cs/groups/dbassesite/documents/webpage/dbasse_177288.pdf.

Dolan EL (2017) Undergraduate research as curriculum. Biochem Mol Biol Educ 45:293-98.

Estrada M Hernandez PR Schultz PW (2018) A longitudinal study of how quality mentorship and research experience integrate underrepresented minorities into STEM careers. CBE Life Sciences Educ 17:1-13.

Fernandes JJ (2020) Course models for integrating research into the curriculum. Available at https://neuronline.sfn.org/training/course-models-for-integrating- research-into-the-curriculum.

Finley A, McNair (2013) Assessing underserved students' engagement in high-impact practices. Washington, DC: Association of American College and Universities.

Fromherz S, Whitaker-Fornek JR, Sharp AA (2018) Classroom-Based Research Experiences to Support Underserved STEM Student Success: From Introductory Inquiry to Optogenetics in the Embryonic Chicken. J Undergrad Neurosci Educ 17(1):A97-A110.

Jones M, Barlow AEL, Villarejo M (2010) Importance of undergraduate research for minority persistence and achievement in biology. J Higher Educ 8:82-115.

Karazsia BT, Stavnezer AJ, Reeves JW (2013) Graduate admissions in clinical neuropsychology: The importance of undergraduate training. Arch Clin Neuropsych 28:711–20.

Kinzie J (2013). Taking stock of capstones and integrative learning. Peer Rev 15(4).

Kuh GD (2008) High-impact educational practices: what they are, who has access to them, and why they matter. Washington, DC: Association of American College and Universities.

Linn MC, Palmer E, Baranger A, Gerard E, Stone E (2015). Undergraduate research experiences: Impacts and opportunities. Science 347: 628-33.

Lopatto D (2004) Survey of undergraduate research experiences (SURE): First findings. Cell Bio Edu 3:270-77.

Lopatto D (2007) Undergraduate research experiences support science career decisions and active learning. CBE Life Sci Edu 6:297-306.

Lopatto D (2010) Undergraduate research as a high-impact student practice. Peer Rev 12 (2).

Lopatto D, Tobias S (2010). Science in Solution: The Impact of Undergraduate Research on Student Learning, Washington, DC: Council on Undergraduate Research.

Lowry H (1965) Adventures in Education. Wooster, OH: The College of Wooster Bulletin. Retrieved July 11, 2020 from http://cdm15963.contentdm.oclc.org/cdm/singleitem/collection/p15963coll17/id/51/rec/4.

Martinez-Acosta VG, Favero CB (2018) A Discussion of Diversity and Inclusivity at the Institutional Level: The Need for a Strategic Plan. J Undergrad Neurosci Educ 16(3):A252-A260.

Morris JK, Peppers K, Mickley GA (2015) Intentional Excellence in the Baldwin Wallace University Neuroscience Program. J Undergrad Neurosci Educ. 13(3):A146-9.

Mickley GA, Kenmuir C, Remmers-Roeber D. (2003) Mentoring undergraduate students in neuroscience research: a model system at Baldwin-Wallace college. J Undergrad Neurosci Educ. 2003 Jun 15;1(2):A28-35.

Morrison ME, Lom B, Buffalari D, Chase C, Fernandes JJ, McMurray MS, Stavnezer AJ (2020) Integrating Research into the undergraduate curriculum: 2. Scaffolding research skills and transitioning toward independent research. J Undergrad Neurosci Educ 19(1):A63-A73.

Nagda BA, Gregerman SR, Jonides, J, von Hippel W, Lerner JS (1998) Undergraduate student-faculty research partnerships affect student retention. Rev Higher Edu 22:55-72.

National Research Council (2003) BIO2010: Transforming Undergraduate Education for Future Research Biologists. Washington, DC: The National Academies Press.

National Survey of Student Engagement (2020) Engagement Insights: Survey Findings on the Quality of Undergraduate Education– Annual Results 2019. Bloomington, IN: Indiana University Center for Postsecondary Research.

Oakley B, Felder RM, Brent B, Elhajj I (2004) Turning student groups into effective teams. J Student Cent Learn 2:9-34.

Quinn JJ, Oswald BB. (2016). A strategy for broadening undergraduate research participation in behavioral neuroscience. Annual meeting of the National Institute on the Teaching of Psychology.

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. Int J STEM Educ 5:10.

Ramirez JJ (2012) The intentional mentor: effective mentorship of undergraduate science students. J Undergrad Neurosci Educ 11(1):A55-63.

Ramos RL, Comiskey M, Dowling J, McFarlane HG, Betz AJ (2020) Undergraduate Participation in the Society for Neuroscience. J Undergrad Neurosci Educ 18(2):A129-A133.

Rhodes, T (2010). Assessing outcomes and improving achievement: Tips and tools for using rubrics. Washington, DC: Association of American Colleges and Universities.

Russell SH, Mancock MP, McCullough J (2007) Benefits of undergraduate research experiences. Science 316:548-49.

Seymour E, Hunter AB, Laursen SL, DeAntoni T (2004) Establishing the benefits of research experiences for undergraduates in the sciences: First findings from a three-year study. Sci Ed 88:493-534.

Shortlidge EE, Bangera G, Brownell SE (2016) Faculty perspectives on developing and teaching course-based undergraduate research experiences. BioScience 66:54–62.

Shortlidge EE, Brownell SE. (2016) How to assess our CURE: A practical Guide for instructors of course-based undergraduate research experiences. J Microbiol Biol Educ 7:399-408.

Theobald EJ et al. (2020) Active learning narrows achievement gaps for underrepresented students in science, technology, engineering, and math. PNAS 117:6476-83.

Weekes NY (2012) Diversity in neuroscience. We know the problem. Are we really still debating the solutions? J Undergrad

Neurosci Educ 11(1):A52-4.
Weston TJ, Laursen, SL (2015) The undergraduate research student self-assessment (URSSA): Validation for use in program evaluation. CBE Life Sci Educ 14:ar33.
Wiertelak E, Hardwick J, Kerchner M, Parfitt K, Ramirez J (2018) The new blueprints: undergraduate neuroscience education in the twenty-first century. J Undergrad Neurosci Educ 16:A244-51.
Wilson A, Howitt S, Higgins D (2016) A fundamental misalignment: intended learning and assessment practices in undergraduate science research projects. Asses Eval Higher Educ 41:869-84.
Wuchty S, Jones BF, Uzzi B (2007) The increasing dominance of teams in production of knowledge. Science 316:1036-39.
Yates, JR, Stavnezer AJ (2014) Engaging undergraduate summer research students and faculty in a regional neuroscience network. J Undergrad Neurosci Educ 13:A45-A51.

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APPENDIX 1

Terminology used to describe upper-level research experiences	
Term	**Description**
Course-based Research Experience (also known as CUREs or CREs, typically in laboratory courses, but can be stand alone)	Lab-based, group research projects are common ways that students gain hands-on research experience. Group projects are usually constrained by the course content or the faculty member's research expertise, but students do have the ability to conduct a small, authentic research project throughout the semester. This experience typically culiminates in a short written report or poster presentation, and serves to develop skills in all aspects of a brief research endeavor.
Capstone Course	Most often a content-specific course taken in the junior or senior year, typically using primary literature, with a focus on integrative approaches to critical, reflective, and applied thinking. Students often work in small groups, serve as discussion leaders, and are expected to find connections between the particular course's content and holisitic academic experiences. Students may propose research questions, but may or may not carry out experimental research in such a course, depending on whether it includes a lab component. Capstone courses may also involve professional development opportunities, such as resume and cover letter writing, meetings with alumni, or career exploration.
Required Capstone Research Experience or Senior Indepdendent Study	Semester or year-long research experience, usually completed in the senior year. The student completes an authentic research project either of their own creation or by working independently within an area of a faculty mentor's research. It is intended to be a high-impact experience, allowing the student agency throughout the entire project, developing deep critical thinking, reasoning, independent laboratory skills, and facility with the literature, and culminating in a poster presentation and/or manuscript-style paper. This experience is usually a requirement for graduation, and counts as part of the student's course credit for graduation and/or their major.
Honors Thesis Project	Semester or year-long research experience, usually completed in the senior year. Candidates for Honors projects must meet particular college-wide GPA or other curricular requirements, and a research proposal must be approved by a departmental or campus-wide committee. After the proposal is approved, the student completes an authentic research project of their own creation or by working independently within an area of a faculty mentor's research. It is intended to be a high-impact experience culminating in a poster presentation and/or manuscript-style paper.
Research Apprentice	Students can work for course credit or for a small hourly wage to assist a faculty member in their research lab. Students usually do not have control or agency over the project, but learn basic methodological skills, gain a better appreciation for the research question, and can "try out" independent research for just a few hours each week. Some honors projects also follow the research apprentice model.
Summer Research Experience	Eight- to ten-week immersive research experience, sometimes away from the home institution. Students engage in full-time research in the lab of a research mentor, usually for a stipend and/or course credit. Nature of research project/training, presentation options, and professional development opportunities vary by location.
Research Experience for Undergraduates (REU)	National Science Foundation-funded summer programs all over the United States. Most, but not all, are affiliated with major research universities and acceptance is highly competitive. Trainees perform experiments to support the PI lab's existing grant-funded research, usually under the supervison of a postdoctoral fellow or graduate student, during a full-time 10-week experience. Trainees usually recieve a stipend and funds to travel to and from the sponsoring institution, and opportuniteis for professional development with the cohort in the program including poster presentations and graduate admissions coaching.

APPENDIX 2

A list of some conferences that support undergraduate research presentations

National meetings	American Chemical Society (ACS)
	American Psychological Association (APA)
	Association for Psychological Science (APS)
	Faculty for Undergraduate Neuroscience (FUN) Poster Session
	National Conference on Undergraduate Research (NCUR)
	Society for Developmental Biology (SDB)
	Society for Neuroscience (SfN)
Regional neuroscience-specific meetings	Advancing Cross-Disciplinary Outreach in Neuroscience (AXON; NY/NJ area)
	MidBrains (Midwest area)
	Midwest/Great Lakes Undergraduate Research Symposium (mGluRs)
	(NEURON)
	(SYNAPSE)
State/Regional society sponsored meetings	Academy of Sciences - State or City
	Eastern Psychological Association (EPA)
	Midwest Psychological Association (MPA)
	Society for Neuroscience (SfN) chapters
	Undergraduate Honor Society meetings (Tri-Beta)
Regional meetings	Arkansas Symposium of Psychology Students
	Eastern Colleges Science Conference (ECSC)
	Front Range Neuroscience Group based out of Colorado State University
	MidAmerica Undergraduate Psychology Research Conference
	Midwest Eye Research Symposium
	Colorado Anschutz Medical Campus
	Southern California Conferences for Undergraduate Research (SCCUR)
	St. Louis Area Undergraduate Research Symposium
	West Coast Biological Sciences Undergraduate Research Conference
Institutionally sponsored, but open meetings	Butler University Undergraduate Research Conference
	Harvard University National Collegiate Research Conference (NCRC)
	Sciences University of Maryland Baltimore County
Conferences specifically supporting diversity	Annual Biomedical Research Conference for Minority Students (ABRCMS)
	Science (SACNAS)
	Women of Color STEM Conference
Model organism meetings	Annual *Drosophila* Research Conference
	International *C. elegans* Conference
	International *Xenopus* Conference
	International Zebrafish Society Meeting (IZFS)
	The Allied Genetics Conference (TAGC)