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NeuroStudies: A Model of an Interdisciplinary Neuroscience Studies Minor

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With nationwide demand for neuroscience programs increasing, faculty and administrators at a public institution with a liberal arts curriculum sought to develop a distinctive program building on existing strengths that would best fit our primarily undergraduate population. The creation of an interdisciplinary Neuroscience Studies minor was the result of collaborations with university stakeholders. Students taking Longwood University's Neuroscience Studies minor are trained to incorporate neuroscience into their areas of interest. Students take three core courses in neuroscience, including an introductory course, laboratory course, and interdisciplinary capstone experience. Additionally, students select three neuroscience-related courses from their major discipline. To gain broad support, the program was intentionally designed to support the university's mission, academic strategic plan, and several key university initiatives. Importantly for our smaller institution, the minor was implemented using existing university faculty, university resources, and a single hire. Since starting in 2015, the minor has quickly become the third largest on campus with increasing popularity among honors students. Program graduates have applied their training to careers paths as neuroscience Ph.D. candidates, master's degrees in a range of fields such as counseling, speech pathology, nursing, education, and neuropsychology, and others have benefited upon entering the workforce. Longwood's success developing an interdisciplinary Neuroscience Studies minor represents a blueprint for smaller institutions with limited resources, to provide students with an opportunity to learn about neuroscience and prepare for the future job market.

Key words: Neuroscience, Curriculum Development, Interdisciplinary

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It is an exciting time to be a neuroscientist! People with a wide variety of backgrounds are discovering our fascinating world through books, podcasts, television shows, scientific articles, and more (e.g., bestseller *Why We Sleep* by Matthew Walker, NPR's 'RadioLab' and 'Hidden Brain', "The Big Bang Theory" sitcom, "Psychology Today" magazines, and online forums like Reddit's r/psychology and r/neuroscience). Consumers are interested to learn that neuroscience can help them understand how to improve cognitive abilities, how to deal with everyday stress, mental illnesses, and why they desire to purchase the things that are advertised to them. Unfortunately, while interest in neuroscience-adjacent topics (e.g., dementia, psychedelics, and nootropics) are growing, neuroscience literacy in the public remains poor (Haynes and Jakobi 2021; Herculano-Houzel 2002; Smith and Seitz, 2019; Sperduti et al., 2012). Neuroscientists can leverage the great public interest in neuroscience to help improve scientific literacy and decrease misunderstanding or even distrust in science (Francken and Slors, 2018; Haynes and Jakobi 2021; Singh and Marusak, 2021).

The downstream effect of consumer demand for actionable neuroscience information is the need for more neuroscience-trained employees. Indeed, neuroscience-trained students are highly sought after in a wide variety of fields, including research and education, medical professions, engineering, business (especially marketing), law, and consulting (Olds, 2016). Not surprisingly, administrators at colleges and universities around the country are asking faculty to develop academic programs to train students in neuroscience (Akil et al., 2016). This has led to tremendous growth in undergraduate neuroscience programs in recent years, with the number of undergraduate institutions offering majors in neuroscience increasing from 90 in 2006 to 221 by the 2017-2018 academic year (Rochon et al., 2019). While some larger institutions have been able to develop programs on a grand scale (creating multiple majors and even entire schools within universities dedicated to neuroscience) smaller schools with fewer resources are working to provide valuable innovative opportunities for their students as well. At our institution, we sought to create a distinctive neuroscience program utilizing minimal additional resources to support undergraduates interested in applying neuroscientific concepts to their preferred majors.

Longwood University, a PUI located in central Virginia, is home to approximately 3,200 undergraduates and 1,500 graduate students (graduate programs are non-STEM disciplines). Approximately 95% of students are Virginia residents. Academically, Longwood follows the liberal arts approach; all students take classes in our general education curriculum even if they major in professional programs. Longwood's mission is to develop citizen leaders that can make positive contributions after graduation. At a school of our size and demographic makeup, creating an entirely new department or even staffing a typical neuroscience major was not feasible. Thus, we needed to explore novel approaches that would align with the university's mission and simultaneously provide a rigorous neuroscience foundation for students.

Our endeavors to meet the needs of our institution led us to create an interdisciplinary neuroscience studies program, similar to that described by Wiertelak and Ramirez in 2008, and Wiertelak et al. in 2018. Longwood's Neuroscience Studies program differs significantly from most institutions'

neuroscience programs that emphasize depth of knowledge to prepare future neuroscientists. Rather, our focus is on introducing students from a wide variety of majors to neuroscience with the goal of having them integrate neuroscience into their overall academic and personal lives.

Here we discuss the specific design of our program, as well as the rationale, process, and implementation of an interdisciplinary neuroscience studies minor to provide an example for faculty and administrators interested in developing their own programs.

MATERIALS AND METHODS

Initiating a new program at any institution has its challenges. At our smaller state institution in Virginia, creating an interdisciplinary program originating from faculty interest necessitated that there was adequate support from both faculty and administration across the university. To gain this support, we followed several steps. First, we brought together university stakeholders to discuss options for the new program. Second, we gained administrative support by aligning with university goals. Third, we designed the minor, and fourth, we advertised the finished product to students.

A Collaborative, Faculty-Initiated Program

Discussions began in the 2012-13 academic year to foster collaboration and discuss if/how a neuroscience program that would serve a large number of students might work at Longwood. Despite understanding the broad utility of neuroscience training for undergraduates, we were pleasantly surprised to find support from interested colleagues from the university's three academic colleges, Cook-Cole College of Arts and Sciences (Biology, Psychology), the College of Education and Human Services (Communication Sciences and Disorders, Kinesiology), and the College of Business and Economics (Management, Economics). Faculty shared evidence and anecdotes of books, recent graduates, and colleagues working in neuroscience and they wanted to be a part of our developing program.

To guide discussions of the ideal type of neuroscience program for our institution, the group of interested stakeholders read and discussed Wiertelak and Ramirez's 2008 paper on undergraduate curricula. Of the five types of undergraduate neuroscience programs presented in the paper (Wiertelak and Ramirez, 2008), the group selected an interdisciplinary neuroscience studies program. That approach has several benefits for a school Longwood's size. Functionally, creating an interdisciplinary program allowed the university to utilize diverse faculty, programs, and courses to create a neuroscience minor accessible to many students for a low investment of new resources by the university. Pedagogically, an interdisciplinary program fits the needs of our students. Rather than specifically training traditional neuroscientists, our stakeholders agreed that it would be most valuable to use the Neuroscience Studies minor to inform students' major disciplines, providing a competitive edge to Longwood graduates as they continue in their chosen fields. Of course, students desiring more rigorous training would be advised to supplement their Neuroscience Studies minor with appropriate coursework in Biology, Chemistry, Mathematics, and Psychology.

Gaining Administrative Support Through Alignment

Stakeholders were unanimous that the formation of this new minor should support Longwood's Mission to foster student learning, scholarship, and achievement that prepares students to make a positive contribution to society. Intentional alignment with broader university initiatives was an important part of securing necessary support and funding from university administration.

Longwood's Neuroscience Studies program was developed to support the university's broad goals and initiatives. Specifically, the program aligned with Longwood's mission to develop citizen leaders, to enhance student research, to support the general education curriculum that emphasizes understanding of issues or topics by considering them through multiple disciplinary lenses, and to increase student participation in STEM programs. Creating the program with these initiatives in mind helped obtain administrative buy in.

The first goal for the Neuroscience Studies minor was to create an interdisciplinary neuroscience program that best utilized the resources available on campus. For example, at Longwood (and other institutions of our size), there are only one or two faculty in each program that have disciplinary connections to neuroscience. This means that no one department had the resources to develop its own neuroscience program. Intentionally designing an interdisciplinary program allowed Longwood to bring together faculty from disparate departments. Likewise, whereas an individual department might not have the level of student interest necessary to support a new minor, our approach allowed us to attract students from across campus, including traditionally non-scientific majors, to increase the number of students graduating with a minor in a STEM discipline.

The second goal for the new minor was to create a rigorous program that would attract excellent students from across campus, including Longwood's Cormier Honors College. Importantly, a high level of rigor allowed us to market the program as a prestigious option for students. Academic rigor beyond other programs was achieved by requiring students to earn a B- or better in all classes that count toward the minor. That is a significantly higher bar than the C- or better required for courses in most other programs on campus. To help attract excellent students from other majors, the minor's introductory course would also serve as a general education requirement, allowing students from any major to take the course without prerequisites and then continue in the Neuroscience Studies minor if they chose. An additional consideration during development was that creating an attractive, rigorous, and distinctive program within the state of Virginia was a prerequisite for approval from our institution's accreditation body.

The third goal for the program was to foster a community of interdisciplinary research. The formation of the Neuroscience Studies minor provided a unique opportunity to create an interdisciplinary community of faculty and students motivated to collaborate on scholarly research

projects while aligning with the university mission. This new community would open new opportunities for students to use neuroscience to support their major-specific research. Additionally, this research community of students and faculty would be well positioned to take advantage of both internal and external funding initiatives related to neurosciences. Beyond Longwood-based research, our goal was to support student and faculty engagement in neuroscience educational outreach with the local community.

Taken together, these approaches demonstrated to university administration that through thoughtful allocation of university resources, the interdisciplinary Neuroscience Studies minor would help achieve the university's broader initiatives.

Design of the Neuroscience Studies Minor

The specific design of the minor emerged from discussions with stakeholders, many of whom had been involved in the preliminary conversations in previous years. The group leaned heavily on the 2008 Wiertelak and Ramirez design of an interdisciplinary neuroscience studies program in the design of this program (more recently updated in the 2018 paper). Three required courses comprise an introduction to neuroscience, a mid-level depth course in neuroscience, and a capstone experience. Students are also required to take at least three courses from a selection of neuroscience-adjacent coursework. (Table 1).

Students are given two possible entry points into the minor. The first is a newly created *NEUR 105 Introduction to Neuroscience* course that was explicitly designed to both serve as an introduction to foundational neuroscience concepts and fit into Longwood's general education program. The other entry class is *PSYC 151 Biopsychology*. By modifying an existing course, we were able to provide students with foundational neuroscience knowledge. Both courses share similar student learning outcomes related to neuroscience. The second neuroscience course in the minor is *NEUR 321 Behavioral Neuroscience*. This lab course allows students to explore neuroscientific knowledge more deeply through hands-on experiences. To maximize resources, this course also serves as an elective option for psychology majors. To ensure that neuroscience and psychology objectives are fulfilled, faculty teaching the class meet regularly to discuss this course.

The capstone course of the minor is *NEUR 405 Interdisciplinary Neuroscience Applications*. This course is meant to reiterate key elements of neuroscientific principle and to facilitate professional development for all minors. Specifically, students use what they have learned through the Neuroscience Studies coursework to make connections between their major discipline and neuroscience. In addition to considering how their own careers might be related to neuroscience, they also practice communicating neuroscience principles and their relevance to audiences with no background experience.

In addition to the three core neuroscience courses, students must complete at least three elective courses from the list (Table 1; usually from their major). This design is intended to allow students to take higher-level courses in their major that intersect with neuroscience or add knowledge to a study of neuroscience. For instance, student might learn about brain development and synapse formation

Program Requirements 19-20 Credits
In order to complete a minor in Neuroscience Studies, students must: 1. File a form of intention to pursue the Minor at the Registrar's Office 2. Earn a grade of "B-" or better in PSYC 151 or NEUR 105, NEUR 321/PSYC 321, NEUR 405. Earn a grade point average of 2.0 in all additional courses chosen to meet the minor requirements.
Required Courses 10-11 Credits
NEUR 105 - Introduction to Neuroscience 4 credits or PSYC 151 - Introduction to Biopsychology 3 credits NEUR 321 - Behavioral Neuroscience 4 credits NEUR 405 - Interdisciplinary Neuroscience Applications 3 credits
Choose 9 Credits from the following Courses
BIOL 206 - Human Anatomy and Physiology I 4 credits BIOL 306 - Vertebrate Physiology 4 credits BIOL 313 - Hormones and Behavior 3 credits BIOL 326 - Cell Biology 4 credits BIOL 360 - Developmental Biology 4 credits BIOL 412 - Biochemistry I 4 credits BIOL 475 - Animal Behavior 4 credits CHEM 351 - Instrumental Analysis 3 credits CHEM 371 - Advanced Organic Chemistry 3 credits CHEM 412 - Biochemistry I 4 credits CSDS 455 - Neurology in Human Communications 3 credits CSDS 460 - Special Populations in Communication Disorders 3 credits CMSC 389 - Artificial Intelligence 3 credits KINS 215 - Exercise Is Medicine 3 credits KINS 461 - Kinesiology Seminar 3 credits KINS 386 - Biomechanics 4 credits KINS 387 - Physiology of Exercise 4 credits MANG 362 - Organizational Behavior 3 credits NEUR 210 - Decision Making 3 credits NEUR 390 - Directed or Independent Study in Neuroscience 1- 6 credits. NEUR 490 - Independent Research in Neuroscience 1-6 credits. NEUR 495 - Special Topics 1-4 credits NEUR 498 - Honors Research in Neuroscience 3 credits. PHIL 355 - Philosophy of Mind 3 credits. PHYS 300 - Mathematical Physics 3 credits PHYS 326 - Optics 4 credits PHYS 331 - AC/DC Circuits 4 credits PHYS 341 - Electronics 4 credits PSYC 300 - Sensation and Perception 4 credits. PSYC 301 - Psychobiology of Stress 3 credits PSYC 313 - Hormones and Behavior 3 credits PSYC 324 - Learning 4 credits. PSYC 315 - Comparative Animal Behavior 3 credits PSYC 452 - Psychopharmacology 3 credits RECR 320 - Facilitation Techniques/Interventions I in Therapeutic Recreation 3 credits RECR 321 - Facilitation Techniques/Interventions II in Therapeutic Recreation 3 credits

Table 1. Longwood's Neuroscience Studies Minor Requirements.

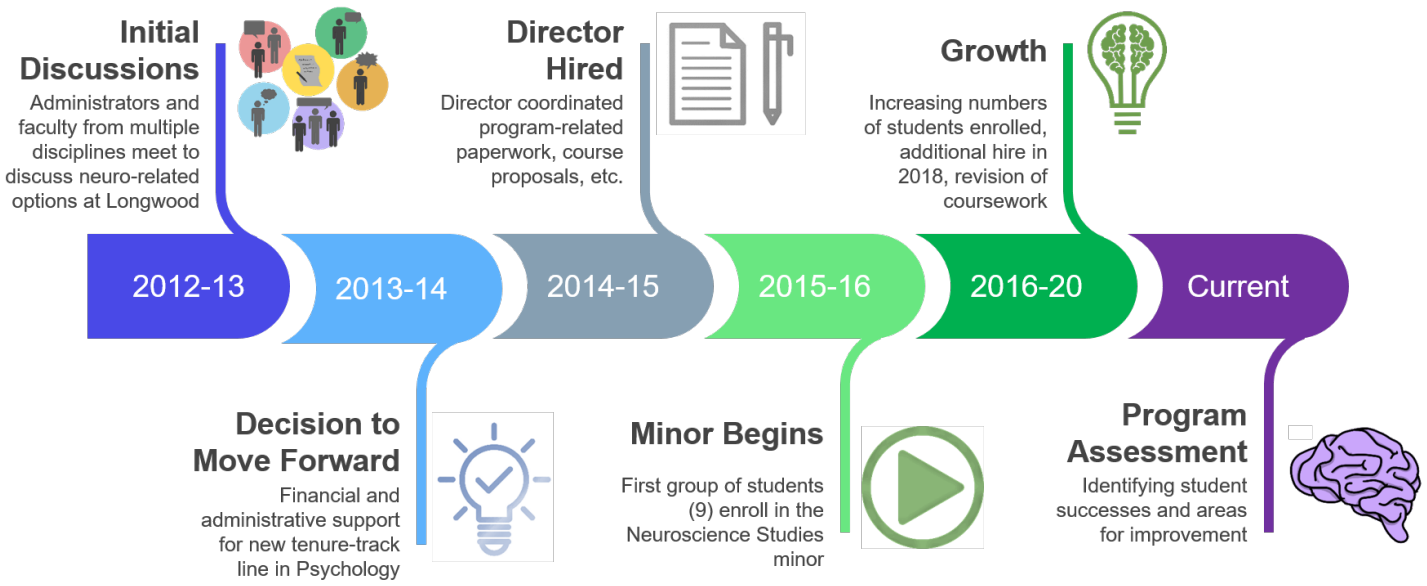

Figure 1. Neuroscience studies minor creation timeline and process.

in BIOL 360 Developmental Biology, how to use our understanding of how our brains work to improve workplace efficiency in MANG 362 Organizational Behavior, and application of neuroscience to creating circuits (and vice versa!) in PHYS 341 Electronics. These elective courses were selected and audited regularly through small group discussions between the director and representatives of each individual department.

Program learning outcomes were developed to ensure cohesiveness within the program, including the neuroscience-adjacent electives. After completing the Neuroscience Studies curriculum, we expect that students are able to: (1) explain basic neuroscience principles *to a general audience*; (2) recognize the neuroscience underlying common diseases, disorders, drugs, and everyday behaviors; (3) defend or debate ongoing neuroscientific research efforts; (4) discuss how ongoing neuroscientific research efforts are relevant to one's daily life; (5) use the scientific method to investigate and explain common human behaviors and the neuroscience responsible for them; (6) communicate clearly and specifically the connections between specific disciplinary courses and the field of neuroscience; (7) communicate clearly and specifically how the field of neuroscience relates to potential careers both in and outside of explicitly neuroscience careers.

Advertising and Student Recruitment

Once approved, it was necessary to advertise the program to students. To do this, the director adopted the motto "Neuroscience for Everyone!" when sharing information about the new, interdisciplinary minor. The director communicated directly with students as well as faculty and staff who served as advisors and mentors. The director also collaborated with University Admissions and Marketing to advertise the program externally. Internally, we created flyers, banners, and other on-campus advertisements. The director also visited department meetings for all relevant programs to deliver a short presentation and answer questions ahead of peak student advising times. In sum, these efforts increased awareness of the minor prior to its first semester, during the first few years, and have continued to attract prospective students to both the university and minor.

Word of mouth and student advocacy quickly became a key recruiting method, which led to growth within specific departments. As a result, ongoing relationships with faculty in other departments was critical to generating new student engagement. Clear communication about the minor has been particularly important with programs that do not traditionally identify themselves as connected to neuroscience.

RESULTS

Goal 1: Create a new, interdisciplinary STEM program that supports existing majors and minors.

The process from first discussions in 2012 to graduating the first class of minors took only five years (Figure 1). Based on an executive summary of the proposed program developed by initial stakeholders, university administrators created a new tenure-track line specifically for the hire of a faculty member to develop and direct the new program (in addition to disciplinary teaching responsibilities). Upon starting the role in the fall of 2014, the new hire (CLF, one of the authors) worked quickly to design and implement the Neuroscience Studies minor. Longwood's Interdisciplinary Neuroscience Studies minor, often referred to as NeuroStudies in marketing materials, launched in Fall 2015 and leverages existing faculty, research labs, and resources to meet student needs.

Longwood's Neuroscience Studies minor is intentionally interdisciplinary, a novel approach to neuroscience education within the state of Virginia (Table 2). Longwood's program provides a diverse range of students a unique

Public Virginia Colleges and Universities Neuro Programs	
School	**Program Type**
College of William and Mary	Neuroscience Major
George Mason University	Neuroscience Minor Neuroscience Major
James Madison University	Neuroscience Concentration; Biology
Longwood University	**Neuroscience Studies Minor; Interdisciplinary**
University of Mary Washington	Neuroscience Minor; Biology and Psychology
University of Virginia	Neuroscience Major
Virginia Tech	Clinical Neuroscience Major Cognitive Behavioral Neuroscience Major Experimental Neuroscience Major Computational and Systems Neuroscience Major

Table 2. Comparison of Neuroscience Programs within Virginia.

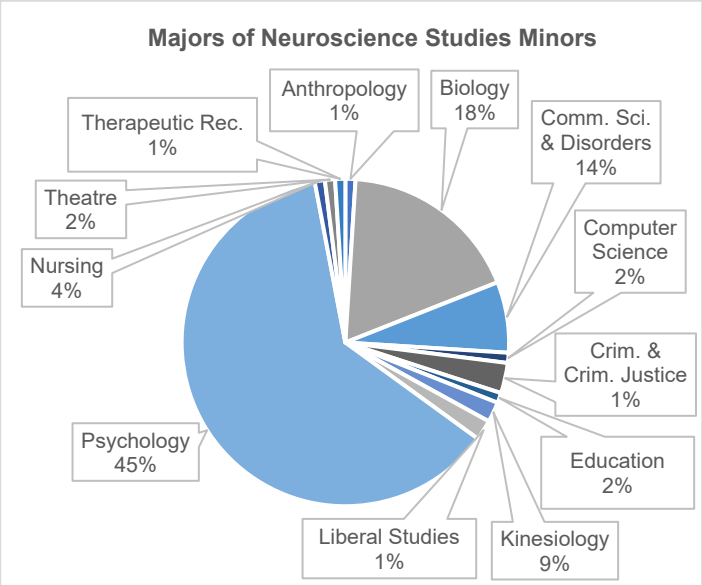

Figure 2. Majors of students choosing Longwood's Neuroscience Studies minor to complement their primary field of study.

opportunity to incorporate principles of neuroscience into their major area of study. The minor has indeed attracted students representing all four major undergraduate colleges and twelve different majors: Anthropology, Biology, Communication Sciences and Disorders, Computer Science, Criminology and Criminal Justice, Elementary and Middle School Education, Kinesiology, Liberal Studies, Psychology, Nursing, Theater, Therapeutic Recreation (Figure 2). Additionally, many students enrolled in the Neuroscience Studies minor also have a second minor, increasing the reach and integration of the program. These second minors include Art History, Coaching, Outdoor Education, and Special Education.

Goal 2: Create a Rigorous Program that is Attractive to Excellent Students from Across Campus.

In the first semester, Fall 2015, Longwood's Neuroscience Studies minor had 9 declared students. By Fall 2017, the number had risen to 66 declared minors. As of the Spring 2021, there were 50 minors, making it one of the top three largest minors on Longwood's campus. Concurrently, program graduation has increased from 4 students in Spring 2017, to 25 in Spring 2019, and 13 for Spring 2021. As a group, the overall GPA of minors is 3.30, which is higher than the overall GPA of Cook-Cole College of Arts and Sciences (3.03) as well as the College of Business and Economics (3.22). In the spring of 2021, of 166 honors students with at least one declared minor, the Neuroscience Studies minor was the second most popular minor, trailing the chemistry minor by only one student.

Goal 3: Foster a Community of Interdisciplinary Research.

The number of students and faculty members participating in undergraduate neuroscience research has not changed dramatically in the six years since the inception of the program. However, there are several indicators that the community of interdisciplinary research is forming. For instance, students conducting research have come from a wider variety of majors than in the past, including Biology, Chemistry, Communication Sciences and Disorders, Kinesiology, Music, and Psychology. Additionally, several collaborative projects between faculty members in different programs have taken place, such as Biology/Psychology and Psychology/Music collaborations.

In addition to building community, students and faculty actively engaged in neuroscience research have been quite successful. Many of these students have successfully completed Senior Honors Thesis research projects, written internal research grants, presented at national conferences, and been accepted into Longwood's competitive, REU-inspired summer research program.

The success of faculty and student neuroscience research has had broader consequences as well. For instance, motivated by the success of undergraduates conducting neuroscience research, the administration decided to build a state-of-the-art interdisciplinary behavioral neuroscience research lab in Longwood's new building, Allen Hall, which opened in Fall 2020.

DISCUSSION

Developing a neuroscience-related program at a small primarily undergraduate institution can be time-intensive and requires collaboration from many college stakeholders. Our process has resulted in one of the most popular and fastest-growing programs on campus, attracting students from all four colleges. The Longwood Neuroscience Studies minor consists of six courses, including a three-course sequence of neuroscience-specific core courses and three neuroscience-adjacent elective courses. Importantly for a school of our size, we creatively leveraged existing

resources to develop a minor that differed from others available in our state with minimal new investment. Rather than strictly developing traditional neuroscience graduates, Longwood's Neuroscience Studies minor prepares students for a variety of careers with an appreciation of how diverse neuroscience perspectives can inform their lives.

Program Challenges

As with any new program, Longwood's Neuroscience Studies minor needs periodic evaluation. One concern that some of our students from majors other than Biology or Chemistry have shared is that the minor alone does not prepare them for traditional graduate programs in neuroscience. They do not have the biology/chemistry/math background necessary to compete with other graduate school applicants. These students usually pursue graduate programs in psychology or attempt to gain additional experience following graduation before applying to neuroscience programs. We can assist these students by making graduate program requirements clear so that students have time to add that training during their undergraduate curriculum. A second challenge is the rapid growth of the minor. To meet student needs, increased resources may be needed to help the program with advising loads, increased demands for course offerings, and requests for a major.

Program Successes

Program success can be measured in several ways. For instance, Longwood's administration appreciates that the academic rigor of the program adds prestige to the university. This has led to improved research facilities

Another measure of program success is the positive effects on students participating in and completing the minor. Enthusiastic students have created a Neuroscience Club on campus to show their pride at being a part of a selective minor. This sense of belonging may contribute to our high percentage of students in the minor who persist to graduation and achieve post-graduate goals (e.g., Davis et al., 2019).

Further, students graduating with a Neuroscience Studies minor have successfully integrated neuroscience into their careers. Some have gone on to earn their Ph.D. in neuroscience; many others have earned master's degrees in a range of fields such as counseling, speech pathology, nursing, education, and neuropsychology. Others have found success entering the workforce after obtaining their Bachelor's degree. Alumni are employed in a wide range of occupations including behavioral health technician, program coordinator for an information systems company, and assistant teacher in early education programs. Regardless of their path following graduation, our students have expressed appreciation for the Neuroscience Studies minor and have found value in the program whether directly related to their future career or enriching their education at Longwood University.

Future Program Directions and Assessment

Given the success of the minor, it is natural to envision continued growth. We have seen an increase in student enrollment in the minor over the past five years. Since Longwood's program is distinctive within Virginia (Table 2), we also anticipate an influx of first year students from Virginia or surrounding states that wish to incorporate neuroscience into their careers without committing to a traditional neuroscience program. As a consequence of these growth streams, it will be necessary to efficiently support students moving forward. As one mechanism to help students more effectively plan their time on campus, the director is developing a comprehensive advising guide for students that will clearly explain required coursework for a variety of neuroscience-related careers following graduation. We will also consider adding additional courses or programs to meet student demand. One example of the latter is the formation of a more traditional neuroscience minor that has greater emphasis on biology, chemistry, math, and physics. Another programmatic option being explored is the creation of a Neuroscience Studies major with distinct tracks that share common professional development and capstone experiences (e.g., Psychology, Natural Sciences, Business/Marketing, Communication Sciences and Disorders, etc.).

The future direction of the minor will be guided by assessment data. Over the years, we have collected both direct (e.g., capstone course presentations, quizzes, number of research grants awarded) and indirect data (e.g., course reflections, mentored research applications, placement after graduation, etc.) on student performance relative to the minor's seven student learning outcomes. Now that we have several years of data, our next major task will be identifying trends in student performance and post-graduate placement. We will then compare those data with post-pandemic enrollment and student demographic trends. Using this information, and through discussion with Neuroscience Studies minor stakeholders, we can determine what improvements should be made and where it makes sense to invest future resources.

Longwood's success developing an interdisciplinary Neuroscience Studies minor represents a blueprint for smaller institutions with limited resources to provide students with an opportunity to learn about neuroscience and prepare for the future job market. While there are certainly challenges, our results suggest that it is possible to implement a new student-centered program through campus-wide collaboration, a focus on meeting institutional initiatives, and creative use of available resources.

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