

Neuroscience Vertically Integrated Projects Benefit STEM Student Self-Efficacy and Identity

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Abstract

Vertically integrated project courses (VIPs) are successful models for embedding long-term research participation into engineering curricula. Whether this model can be translated into gains for laboratory-based projects in biological sciences is unknown. Most biological sciences course-based undergraduate research experiences (CUREs) are a single semester, prohibiting longer-term assessment of student growth. A neuroscience VIP was designed in which students performed experiments to investigate the causality of genetic variants linked to amyotrophic lateral sclerosis (ALS). Students could enroll for up to three consecutive semesters. Through precourse and postcourse surveys and qualitative responses, strong gains were found in self-efficacy, science identity, and networking over multiple semesters of participation. The study shows that VIP courses in neuroscience are effective ways of promoting student gains in STEM.

Keywords: *biology, biomedicine, course-based undergraduate research (CURE), engineering, STEM*

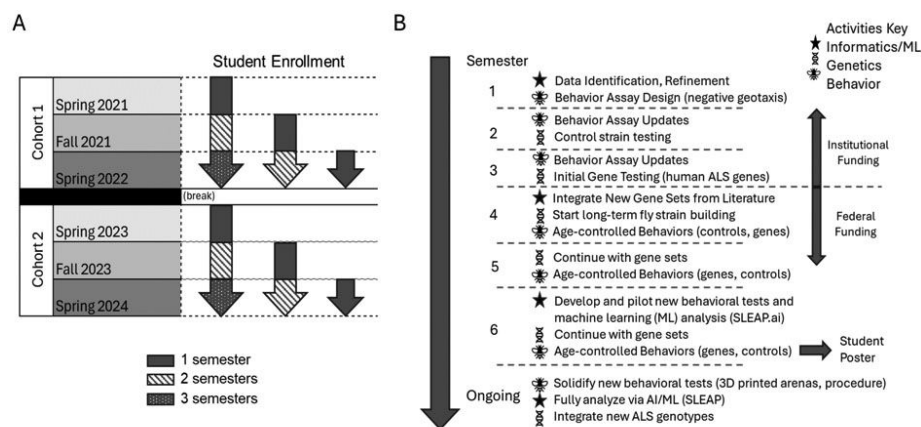
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Research experiences have extensive benefits for undergraduate students' academic and career success (National Academies of Sciences 2017; Russell, Hancock, and McCullough 2007). Although historically offered as one-on-one apprenticeships under the guidance of a faculty member, students now have many options for ways to gain research experience. Correspondingly, institutions have appreciated the impact on student engagement and

retention, and many have sought to create more centralized, institution-wide programs to support a larger number of students (Coyle et al. 2015; Rodenbusch et al. 2016). Course-based undergraduate research experiences (CUREs) are widely considered to be an outstanding model for scaling up academic year opportunities and for making them more inclusive (Bangera and Brownell 2014; Shaffer et al. 2010). CUREs allow students to gain team-based research experience and also earn credit toward their degree. However, they are generally limited to one semester of participation by the students.

Vertically integrated projects (VIPs) are multidisciplinary research and discovery teams embedded in curriculum that engage undergraduate and graduate students in faculty scholarship across multiple years. Unlike CUREs, VIPs involve the same students across multiple semesters of a continuous research project, which creates peer mentorship and leadership growth opportunities as students progress in the project. The VIP model originated in engineering and has been adopted into a formalized institutional-wide program at some colleges and universities with great success (Coyle et al. 2015; ElZomor et al. 2018). Students who return for additional semesters become peer mentors and leaders, and they develop significant topic expertise. A few studies have documented the positive effects of multisemester participation on students in VIP experiences (e.g., Sonnenberg-Klein and Coyle 2024), but to date these studies have not addressed students involved in laboratory-based research in biological or biomedical sciences.

Research experiences in biological and biomedical sciences fields can be offered within introductory level courses

FIGURE 1. Diagram of Course Structure and Activities

Note: (A) Enrollment periods and cohorts of students who participated in the study. Students could enroll in any semester if space was available, but returning students had enrollment priority. (B) Detailed schedule of activities in all six semesters. Icons indicate categories of activities (informatics/machine learning [ML], genetics, behavior). On the right side, funding phases and student presentations are shown.

but are sometimes designed as inquiry-based experiences, in which the goals for students are to understand the scientific processes of developing testable hypotheses, experimental design, and iteration but do not yield new discoveries in their field. CUREs are a step beyond inquiry-based approaches, in which students participate in new knowledge generation but may require more content knowledge prior to entry. The VIP framework may offer a way to accelerate the pathways toward research competency in biological sciences by enabling students to enter as relative novices and contribute to a single project in different ways over time, rather than switching between different inquiry-based and CURE projects in different courses. This also may accelerate the process of socially reinforced scientific identity and belonging (Kim, Sinatra, and Seyranian 2018) as students become peer mentors in the project. However, these ideas have not been formally evaluated.

In this study the impact on student self-efficacy, science identity, and other metrics of student engagement across three semesters of participation in a neuroscience-focused VIP project was investigated. The validated Persistence in the Sciences (PITS) survey (Hanauer, Graham, and Hatfull 2016) as well as individual student responses to prompts during their enrollment were used to assess student outcomes. The study indicates strong positive effects on students with multisemester VIP participation by both quantitative and qualitative metrics.

Methods

Course

The course under study was titled Brain Communication Networks and was a hands-on, laboratory-based course.

Students worked in teams to identify a research question about genes linked to the neurodegenerative disease amyotrophic lateral sclerosis (ALS) and then tested their predictions using genetic manipulations of homologous genes in the fruit fly, *Drosophila melanogaster*. Students were expected to attend a one-hour full team meeting each week and two one-hour laboratory sessions designed to stagger team members across multiple days. Students enrolled each semester for up to three continuous semesters (Figure 1), and additional students could join in the second or third semester if space was available.

The neuroscience class was a VIP course because it allowed students to (a) work in teams on an aspect of the faculty member's research, (b) address a real-world problem, (c) earn academic credit, and (d) return for multiple semesters while taking on additional peer leadership. Students were generally first-, second- and third-year students by academic rank, and they came from many academic disciplines (a feature of VIPs). The instructor created subgroups which were mixtures of academic majors and academic years, facilitating learning and crossing disciplinary boundaries. Pairing students with different levels of experience also facilitated the development of peer leadership skills in returning students, who were told that they would have increasing mentorship roles as they continued on the projects.

The learning outcomes for this course centered around critical thinking, problem solving, engaging in discovery, and effective communication. These outcomes were assessed through regular research updates, reflections, precourse and postcourse surveys, and an end-of-semester presentation in either poster or wiki-page format.

TABLE 1. Participants in the Study

Total students	31
Sex	
Female	23
Male	6
Nonbinary	2
Semesters of participation	
1	23
2	17
3	3
Self-reported race	
White	15
Asian	6
American Indian or Alaskan Native	1
Black	0
Multiracial	4
Other	2
Not answered	3
Self-reported ethnicity	
Hispanic/Latino	6
Non-Hispanic/Latino	22
Not answered	3
First generation	5
LGBTQ+	4

Participants

Demographic information was ascertained through the precourse survey each semester. The class enrolled 95 students over six semesters. Of these, 31 unique students consented to data collection, and these students provided 82 scorable responses over up to three semesters of enrollment (Table 1). Three students did not provide demographic information and so were included in the class-wide analysis but excluded from analysis of effects by underrepresented student status. Of the 31 unique students who consented for inclusion in the study and submitted survey responses, 23 participated in at least one semester, 17 participated in at least two semesters, and 3 participated in all three consecutive semesters. Student attrition primarily was caused by scheduling conflicts, advancement into an individual research experience, or graduation.

Because of the small number of consented enrolled students from each demographic group considered underrepresented in scientific research, it was not possible to do individual analysis for certain demographics. Instead, as has been done for other analysis of VIPs (Sonnenberg-

Klein, Coyle, and Abler 2018b), a larger category of historically underrepresented minoritized (URM) students that included Hispanic/Latino students, non-White and non-Asian-identifying students, first-generation undergraduate students, and those in other minoritized groups such as LGBTQ+ students was created. This resulted in 30 total survey responses from URM students (some from the same student across multiple semesters), 49 responses from non-URM students, and 3 responses in which the student's characteristics were not reported.

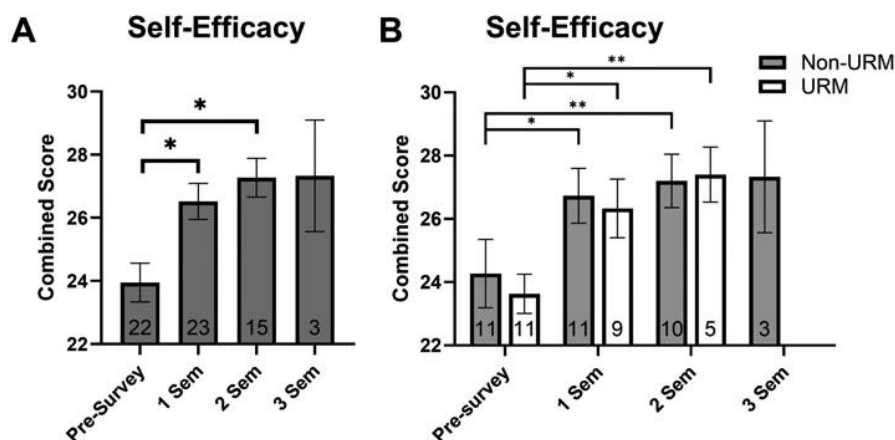
Students in the course were enrolled in a wide variety of majors, which is common for vertically integrated projects. Students in the Brain Communication Networks course were from the following majors: neuroscience and cognitive science, biology, molecular and cellular biology, biochemistry, physiology, medicine, bioengineering, and computer science.

Surveys

The Persistence in the Sciences (PITS) survey instrument to collect data about self-efficacy and science identity (Hanauer et al. 2016) was employed. Questions employed a Likert scale (1–5, with 5 being the highest) or similar text analysis (“highly likely” to “not at all likely,” with five possible rankings) as in the original PITS survey. Text responses were gathered from entries in student individual notebooks during the enrolled semester. Surveys were administered according to institutional IRB protocol. Briefly, students were given the opportunity to consent in the first two weeks of the semester, and consents were received by a party other than the instructor. After final grades were given at the end of the semester, the list of consented students was revealed to the instructor, who then collected survey responses and notebook responses from class surveys and materials of the consented students.

Data Analysis

Likert scale values were analyzed directly as numerical values. Categorical choices were converted to numerical values (for example, 1–5 for a five-choice ordered ranking) during analysis. Analysis of categorical and quantitative data used custom scripts in Python. Multiple comparisons testing used two-way analysis of variance (ANOVA) with an alpha of 0.05 and two variables: semesters enrolled and URM identity. Sidak's post hoc test was utilized to determine significant pairwise differences across multiple groups. Comparisons across semesters included all pairwise comparisons (e.g., precourse survey to one, two, or three semesters; one semester to two and three semesters, etc.). Comparisons when analyzing URM students included comparisons of URM or non-URM students to their respective precourse survey data and to semester-matched non-URM students. Analysis of student text responses used provisional coding to identify salient statements that demonstrated the impact of participants' engagement in the VIP course on

FIGURE 2. PITS Survey Findings on Self-Efficacy

Note: (A) Overall (summed) scores for self-efficacy questions and the effect of continued enrollment. (B) Scores by both semesters enrolled and underrepresented student status. All data show mean $\pm$ SEM, with N shown in each bar. *, $p < 0.05$, **, $p < 0.01$ (two-way ANOVA with Sidak's post hoc test). PITS, Persistence in the Sciences; URM, underrepresented minoritized students.

their self-efficacy, science identity, networking, and community building (Saldana 2021). This approach guided initial exploration of the data but allowed investigators to remain open to refining and adapting codes as directed by the data (Charmaz 2014). The qualitative data were then analyzed thematically, using constant comparison in MAX-QDA. One researcher initially coded the responses, and a second researcher reviewed the codes, themes, and selected quotations. Throughout the coding process, peer debriefing was employed to ensure trustworthiness.

Results

Self-Efficacy Gains

Students showed significant increases in self-efficacy after only one semester of enrollment (Figure 2). The average student score trended upward with additional semesters, but these differences were not statistically significant with the current cohort (Figure 2A). The effect sizes for self-efficacy (precourse survey vs each semester) as measured by Cohen's d were large, ranging from 0.89 to 1.21. Both URM and non-URM students benefited equally well and showed the largest gains after one semester of participation (Figure 2B). Because only 3 students consented for the study that participated for three continuous semesters, the significance of the third semester could not be evaluated here; however, overall responses to the third semester were similar to the second semester responses.

Science Identity

The survey showed a strong increase in the science identity of participating students after one semester (Figure 3A). In the second and third semesters, the average score

was similar to the first semester but had a larger range, so these were not assessed as statistically significant. The effect sizes for science identity were medium (0.6–0.8, Cohen's d). Gains were seen equally in underrepresented and non-underrepresented students (Figure 3B). Survey questions in this category also inquired about students' sense of belonging in STEM, which was closely associated with scientific identity.

Science Community Values

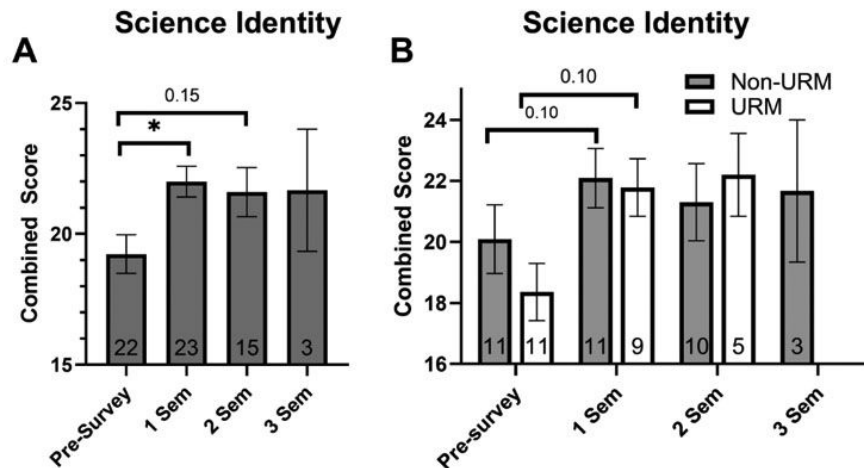
The portion of the PITS survey containing questions about science community values, or how a student aligns with the values system of scientists, had a maximum score of 24. Students on the precourse survey already scored quite highly on this metric (Figure 4) and did not show additional growth, suggesting that the majority of incoming students already valued scientific inquiry and discovery. As expected, effect sizes for this category were low (0.08–0.47).

Science Networking

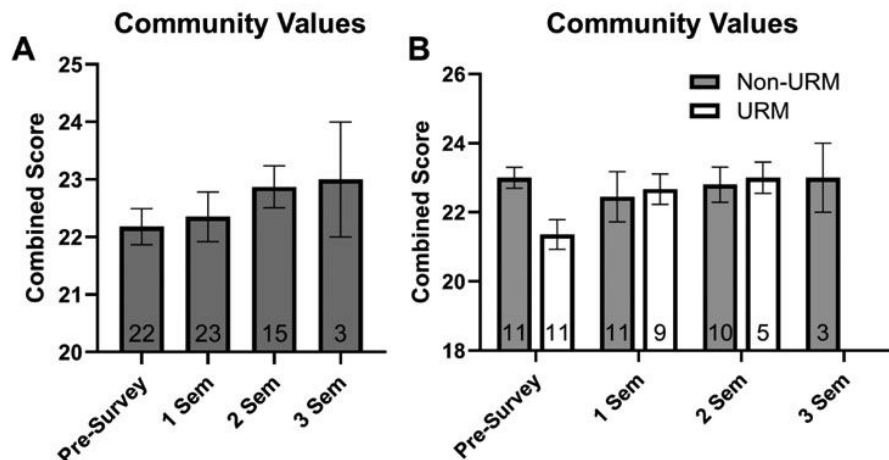
Student networking questions on the PITS survey asked about whether students had communicated about their research beyond other students in the course (friends, family members, other faculty, or to other members of the public, for example at a poster session). The strong trend toward communicating their work beyond the classroom seen in the surveys (Figure 5) indicated that increasing participation influenced this metric. Effect sizes were medium to high (0.67–1.16, Cohen's d).

Qualitative Findings

To complement the quantitative analysis, student text responses in surveys and notebooks also were analyzed.

FIGURE 3. PITS Survey Findings on Science Identity

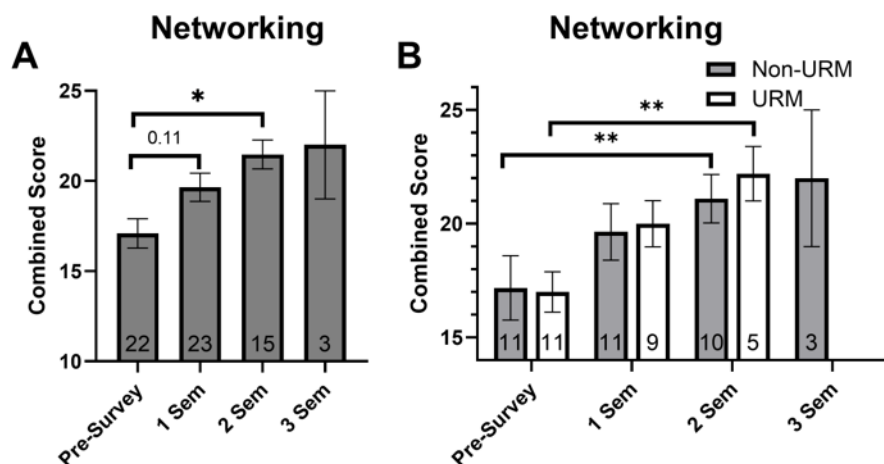
Note: (A) Overall (summed) scores for science identity questions and the effect of continued enrollment. (B) Scores by both semesters enrolled and underrepresented student status. All data show mean $\pm$ SEM, with N shown in each bar. *, $p < 0.05$ (two-way ANOVA with Sidak's post hoc test); p values just above alpha = 0.05 also are shown above groupings. PITS, Persistence in the Sciences; URM, underrepresented minoritized students.

FIGURE 4. PITS Survey Findings on Science Community Values

Note: (A) Overall (summed) scores for science community values questions and the effect of continued enrollment. (B) Scores by both semesters enrolled and underrepresented student status. All data show mean $\pm$ SEM, with N shown in each bar. PITS, Persistence in the Sciences; URM, underrepresented minoritized students.

These queries were more open-ended and therefore captured additional parameters of impact on student growth. Organized into themes, the responses showed common patterns related to key learning outcomes present in most undergraduate science curricula. Impressively, student comments overwhelmingly suggested that they benefited in many aspects from more than one semester of participation in the same project (Table 2).

Science Identity and Networking. Although initially some students felt they needed more experience, after the second semester the students reported that scientific identity had grown through their hands-on work, trial and error, and connecting with others. Qualitative responses related to networking (“broader impact”) indicated that students began to understand the value of science and learned the importance of sharing their work outside of the course.

FIGURE 5. PITS Survey Findings on Science Networking

Note: (A) Overall (summed) scores for science community values questions and the effect of continued enrollment. (B) Scores by both semesters enrolled and underrepresented student status. All data shows mean $\pm$ SEM, with N shown in each bar. *, $p < 0.05$, **, $p < 0.01$ (two-way ANOVA with Sidak's post hoc test). PITS, Persistence in the Sciences; URM, underrepresented minoritized students.

Research Process. The students demonstrated increasing understanding of the process of science through their narrative responses. At the end of the first semester, the students reported learning that science was more about inquiry and problem solving than memorizing information. Students who started a third semester reported being constantly surprised by outcomes and challenges. At the end of the third semester, most students said they had learned that science was constantly evolving.

Interest and Engagement. The VIP course impacted students' interest and engagement both in their subject area and in science in general. Many reported feeling more interested in science and engaged with their other science classes because they knew how to apply the knowledge. By the first semester's end, most students reported looking forward to applying findings in the following semester. As enrollment progressed, students were inspired to dive more deeply into unknown topics and explore new experimental approaches.

Peer Interactions. The students overwhelmingly had positive experiences with their peers in the lab. Students newer to the course saw group and peer interactions as influential in providing guidance on laboratory activities, and experienced students were driven to become peer mentors and leaders. During the second and third semesters, students highlighted the benefits of having more experienced group members to mentor less experienced students, with many students reporting they "wanted to help new students," and the newer students appreciating experienced peers who guided them throughout the class. By the third semester's end, most stu-

dents reported being able to connect with others who love science. Importantly, students reported that group support during challenges helped teams pull together to solve problems. Students reported that working with peers allowed for sharing knowledge, gaining different perspectives, and developing friendships to create new ideas and handle challenges encountered while conducting research.

Career Plans. Many students enrolled in the course to help them decide between medicine and research or needed it for their future goals. After two semesters, some students reported that they would be doing summer research; something they never thought would happen. Some students changed from planning to pursue an MD to planning to pursue a PhD or a combined MD/PhD, whereas some were still deciding. Regardless of future plans, by the third semester's end students said the class made graduate school seem more possible.

Discussion

This study provides insight into the benefits of a multisemester VIP research experience for students in the neurosciences and biological sciences. Experiences with research consistently produce increased student achievement, interest, retention, engagement, and persistence for underrepresented students (Hurtado et al. 2009; Rodenbusch et al. 2016; Russell et al. 2007), particularly in STEM (Chemers et al. 2011; Jones, Barlow, and Villarejo 2010). CUREs expand access to research experiences. It was hypothesized that the VIP model would provide similar benefits in many metrics but also might go beyond CUREs in improving student science identity and increasing

TABLE 2. Outcomes and Examples

Outcome	Example quotation
Research process	“In this class, I have learned more about the process of developing and conducting research on a topic than in the short time frames given in formal lab classes, where I act as more of a machine that follows the instructions without a true understanding of what I am doing and why.” “When I started working with the flies two semesters ago, I was a little intimidated. I had never worked in a research environment before, and I had some imposter syndrome. However, I was surprised by how quickly I had picked up on both the lab techniques and the scientific approaches. Now I have been taking this course for a year and feel like an expert on everything we do daily in the lab.”
Interest and engagement	“It has made me more interested in neuroscience.” “In taking this class, I have become more open to learning about science in my other classes, regardless of how monotonous they may feel, because I can then apply those lessons within our research.” “I am honestly really excited to continue to do this line of research because it is very rewarding to start from the beginning and work up to an end product.”
Peer interactions	“Last semester in this class was one of the first times I was put in a group where we all put in the same amount of work. We might not have all had the same set of skills, but we were all able to contribute and play to our strengths.” “One thing that I enjoyed about this class was that it connected me with other students who love science, and through those relationships I was able to become better at science even outside of the course . . . These relationships became extremely valuable to me.” “I am excited to use those skills I learned last semester to help the new students as they navigate their first time in the lab.” “I do really appreciate the ability to have knowledgeable people around me to bounce ideas off of and to ask questions, this has been quite helpful.” “Working with a group allows me to share my ideas while also getting help and feedback from students who have taken this class before.” “There were many challenges this semester . . . I do think that all these challenges made everyone work more as a team, because when someone was having problems with something it made it easier to ask another person about it. Then together we could brainstorm what was going wrong and how to fix it. Also, I think that it allowed us all to be on the same page more often. So, these challenges were definitely more growth or learning experiences rather than just frustrating.”
Scientific identity, broader impacts, and career plans	“Before, I felt like I was just studying science, but now I feel like I'm actively doing science.” “I thought the poster session was pretty cool. I didn't realize that there would be so many people actually listening to our poster!” “Communicating findings allows for more cooperation with interested individuals and potentially gives outside sources an outlet for ideas and information that can improve/expand the research.” “It's one of the responsibilities of a researcher to communicate your findings with the rest of the community.” “I went from wanting an MD degree to shooting for an MD/PhD now as I don't think I can leave research now that I'm in it!”

leadership and collaborative skills. Although multisemester CURES in biological sciences have been implemented and studied before (Quick and Cisneros 2022), this course integrated multiple features characteristic of the VIP model (for example, multilevel students, multidisciplinary, and continuously evolving research tasks), which warranted an analysis of its specific impacts on students. In addition, biological sciences VIPs (including neuroscience) have been developed and deployed for undergraduates, but no evaluation of their outcomes has been reported to date. Therefore, this study provides a foundation and initial data about their impact that will help grow and refine assessment tools for VIPs in biological science fields. Through both qualitative and quantitative analysis, there was growth in indicators of student engagement with their science curriculum, teamwork and communication skills,

and confidence that they could contribute to new knowledge. Although the quantitative results identified effects primarily in the first semester of participation, qualitative analysis of student responses identified multiple beneficial effects for students who participated across at least two semesters.

As expected, continued participation in the VIP increased students' reported self-efficacy. Self-efficacy is influenced by achievement experiences (Bandura 2000), therefore becoming more proficient over time at using scientific practices continues to increase students' sense of self-efficacy. This VIP gave students an opportunity to practice the required skills of inquiry in biology, including research design, specialized lab techniques, and public poster presentations, a standard way for scientists to present data.

Likewise, it was found that participating in this VIP increased the students' scientific identity. Experiences with authentic research practices of a particular discipline incorporate students into that culture, which in turn increases their identification with that discipline (Singer et al. 2000). Scientific identity has been shown to be shaped by interest in the topic, confidence in scientific competencies, career aspirations, and perceived recognition as a scientist from relevant others, such as teachers (Cohen et al. 2021; Dou and Cian 2001; Vincent-Ruz and Schunn 2018).

In contrast, there were no significant increases in students' scientific community values. This is likely because the students entered the course with such high ratings that a significant finding was not possible (a "ceiling effect"). Ceiling effects have been seen across both formal and informal education settings and may falsely suggest that there is no effect of the course on this outcome (Staus, O'Connell, and Storksdieck 2021).

It was found that as students continued to participate in the VIP they discussed their findings more with others outside the class. They also were able to articulate the broader impact of their findings. Results that offer broad impact increase the meaningfulness of the pursuit, which increases the likelihood that a student continues to be engaged (Renninger 2009).

Qualitative responses demonstrate student interest and engagement. The PITS survey administered in this study was initially designed to assess whether new course-based research experiences aided student success and retention potential (Hanauer et al. 2016), which are common goals of all institutions of higher education. From a curricular perspective, students in the neuroscience VIP reported an increased engagement in the curriculum, stemming from a better understanding of why they were learning certain topics in their other coursework. Although this study did not explicitly address retention, of the 95 students enrolled over six semesters, 93 either were still majoring in a scientific field or had successfully graduated in a scientific field (representing a 97.9 percent retention rate). For comparison, the US undergraduate six-year graduation rate mean was 62 percent in 2023 (Lee and Shapiro 2023).

It was suspected that one of the factors that enabled these strong gains was the unique structure of VIP experiences, which places students together with teammates at different levels of their degree program (first-, second-, third-, and fourth-year) and from different majors on campus. This structure ensured collaboration across levels, enabled richer dialog about research topics, and brought diverse ideas to bear on challenges they faced. Discussing and creating together has been shown to foster discourse among students and the active construction of student

understanding (Singer et al. 2000). Doing so also fosters relatedness, crucial to encouraging engagement (Ryan and Deci 2020). In addition, group work reduces competition and increases cooperation (Linnenbrink-Garcia, Patall, and Messersmith 2013). Furthermore, the critical support provided by the relationships built with instructors and peers during the research process is especially salient for underrepresented students (Jones et al. 2010). Although this type of interaction also is possible to implement in single-semester CUREs, responses from the study students indicated that continued participation increased the impact of collaboration.

Finally, it was found that VIP courses in biological sciences helped students achieve their short-term training goals and long-term career goals. For example, many students reported enrolling because they felt it would enhance their competitiveness for graduate or medical school applications. When informally asked, many students indicated that they were pursuing additional research opportunities through summer programs or individual research experiences, both on the students' home campus or in nationwide summer research programs. The instructor indicated that students with VIP experience had a high rate of success in gaining admission to these programs, likely because students could demonstrate an interest and understanding of research that strengthened their applications.

Implications

One challenge inherent to VIP deployment in "wet lab"-based environments is adequate space and supplies, the latter of which requires continuous funding from the institution, student fees, or another source of support. However, because of the impacts on retention, engagement, and success of students of all backgrounds, institutions are choosing to invest in growing VIP teams in many majors. Here data are provided to support this assertion for neuroscience curricula. The authors' experience was that small institutional seed funds provided a means for initiating the VIP experience and collecting early data on student success; these data ultimately enabled success in obtaining nationally competitive funding to support the VIP course and students.

Another challenge is ensuring that students who enroll in a VIP course earn credit within their major. Unlike engineering fields in which VIP courses originated (which are offered in a single College of Engineering at the study institution), students in the broad field of biological and biomedical sciences could be enrolled in any of 21 degree-granting programs across four colleges. Some students were not able to enroll in the VIP class described here because their major did not recognize the neuroscience course as fulfilling a degree requirement. Studies of the VIP model in engineering suggest a correlation between student research persistence and the ability to count the

VIP as credit for their major (Sonnenberg-Klein, Coyle, and Abler 2018a). Because biological and biomedical sciences fields share many similar learning and curricular goals, universities must help students break through false barriers in the curriculum and create smooth pathways for students to gain access to high-impact curricular research opportunities in multidisciplinary fields.

Limitations

One limitation of this study was that students submitted an application to the instructor instead of being able to directly enroll. This likely selects for students motivated to pursue a research experience. For most semesters except for the last one, all applicants were able to be accommodated, so no further selection bias was introduced (the final semester, approximately 80 percent of applicants were accepted).

Another limitation of the study was the small number of students who consented to data inclusion relative to the total number of enrolled students. This prevented an ability to draw significant conclusions about the effects on specific subsets of underrepresented students.

The PITS survey was designed to measure single-semester research participation in CUREs, and it therefore minimized or omitted some dimensions of the impact on students enrolled for longer periods. For example, the PITS survey does not assess project ownership, intellectual growth in the subject matter, or interest or aptitude in peer mentorship or leadership over multisection enrollment. These factors have been shown to be enhanced by VIP and CURE participation (Hanauer and Dolan 2014; Lopatto et al. 2008; Sonnenberg-Klein and Coyle 2024). In addition to the above shortcomings, the PITS survey also does not assess interdisciplinarity, the effects of working with students from different majors, or growth in teamwork and collaborative skills, features that are more characteristic of VIPs than CUREs. The authors hope to evaluate these metrics in future work across multiple types of CURE and VIP courses in the biological sciences.

Conclusion

Vertically integrated projects were originally launched as curriculum-embedded, long-term research experiences for students in engineering (Coyle et al. 2015). However, the model is generalizable across disciplines and therefore could provide benefits for physical and life sciences, social sciences, and humanities. In undertaking this study, the hope was to provide both a model for building VIP experiences in neuroscience and biological sciences, and an objective measurement of its impact on this student population.

This study shows the strong positive effects of VIP participation on students in neuroscience and related biological sciences majors, expanding the evidence for this model to

be deployed across scientific fields and beyond. As more schools implement the VIP model in modernized curricula, strong gains in student confidence, success, and retention are anticipated. Although it is acknowledged that developing and teaching a VIP requires a significant time commitment from faculty, the benefits to students are worth the investment by undergraduate institutions and should produce a better prepared workforce for the twenty-first century.

Data Availability Statement

The data underlying this study are not publicly available due to the presence of student identifiable information in many raw data files. Because of the small numbers of students in certain demographics, there is increased risk of students being identified in data files. Data distribution requests will be reviewed by the IRB before fulfillment and will be deidentified before distribution.

Institutional Review Board Statement

All activities received IRB approval in August 2021 by the University of Arizona. The IRB approval was #2108158383.

COI Statement

The authors have no conflicts of interest to declare.

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