

The Explorations Program: Benefits of Single-Session, Research-Focused Classes for Students and Postdoctoral Instructors

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We present an update to Explorations, a program at Stanford University that allows undergraduates in an introductory biology course to explore specialized topics in the biological sciences while providing graduate students and postdoctoral scholars the unique opportunity to develop and teach single-session, research-focused classes. We provide an assessment of eight iterations of the program, using program attendance, student and instructor evaluations, senior exit surveys, course grades, and completion of undergraduate honors theses to assess the impact of our program on students and instructors. Students rated their experiences highly, and most reported that the program had a positive impact on their undergraduate careers and positively influenced their decision to participate in scientific research. Correspondingly, we found that undergraduates who participated in Explorations were more likely to complete an honors thesis. Instructors reported that the program provided a valuable opportunity to develop their teaching skills. Our work demonstrates the potential impact that one-time, research-focused classes can have on promoting undergraduate participation in authentic research experiences and in providing teaching experiences for graduate students and postdoctoral scholars, and we urge other universities to consider implementing such programs.

The benefits of undergraduate participation in authentic research experiences have been well documented, with numerous studies demonstrating that participating students positively respond to such experiences and garner enhanced scientific and critical-thinking skills (Lopatto, 2007; Seymour, Hunter, Laursen, & DeAntoni, 2004; Thiry, Laursen & Hunter, 2011). However, there are limited numbers of independent research positions available, and

this restricts the number of students who might gain from these experiences (Bangera & Brownell, 2014). One solution to this problem is the development of course-based undergraduate research experiences (CUREs). CUREs deviate from traditional “cookbook” labs by having students in a formal lab course work on research projects with unknown answers and thus an element of discovery, which is of interest to the broader scientific community (Auchincloss et al., 2014; Brownell

& Kloser, 2015). CUREs have led to improvements in student conceptions of scientific thinking and ability to interpret data, similar gains as observed in independent research experiences (Brownell et al., 2015; Kloser, Brownell, Shavelson, & Fukami, 2013; Lopatto, 2007).

However, challenges remain in getting undergraduates involved in either independent research or CUREs. In addition to there being a limited number of research positions available, structural characteristics of how undergraduates get access to independent research experiences may be barriers for undergraduate participation (Bangera & Brownell, 2014). Some students may feel overwhelmed and do not know where to begin finding research opportunities; others may lack awareness of what to say in e-mails or initial interviews. Still others may not know that undergraduate research can be a tremendous opportunity for them. A survey of undergraduates participating in independent research experiences found that the majority only became involved because a caring mentor reached out to them personally, more than twice the number of students who participated in research through their own inquiries (Mabrouk & Peters, 2000). There are also challenges for

involving students in research through CUREs. Even though students can enroll in a CURE like any other class, there are logistical hurdles associated with developing and incorporating CUREs in the curriculum (Benvenuto, 2002), with greater time investment needed from faculty to develop and teach CUREs (Shortlidge, Bangera, & Brownell, 2016). Thus, there is a need for opportunities for students to get exposure to research that is not as time intensive or costly as CUREs or independent research experiences.

Research-intensive universities must also balance the education of undergraduates with research productivity, which is often perceived as the primary role of graduate students and postdoctoral scholars (Brownell & Tanner, 2012; Schussler et al., 2008). Although graduate students may have opportunities to serve as teaching assistants, the training of graduate students as teachers is often neglected because of emphasis on research. A high percentage of teaching assistants receive little to no training (Luft, Kurdziel, Roehrig, & Turner, 2004), and many such teaching assistant positions are designed to serve institutional needs rather than the teaching development of instructors (Austin, 2002). In addition, there are few opportunities for graduate students and postdoctoral scholars to design and teach their own courses, despite the fact that many will be expected to do so if they become faculty at academic institutions.

To promote both teaching and research, we have developed and taught a program called Explorations that allows universities to provide an avenue for graduate students and postdoctoral scholars to hone teaching skills and promotes undergraduate involvement in independent research

experiences. In this program at Stanford University, graduate students and postdoctoral scholars (hereafter referred to as *instructors*) develop and teach single-session, research-focused seminars that typically meet only once and relate to the instructor's own research (Brownell, Khalfan, Bergmann, & Simoni, 2013). Some classes feature experiments that do not have predetermined answers, and in most classes students learn specific laboratory techniques and use advanced instrumentation, elements of authentic research experiences (Weaver, Russell, & Wink, 2008). These experiences provide undergraduates with a unique opportunity to explore a specialized topic within the biosciences and to experience aspects of scientific research early on in their undergraduate education. Here, we assess the effectiveness of the Explorations program, analyzing the impacts of eight iterations of the program from 2008 to 2014 as well as the introduction of a grade incentive for participating in Explorations.

Program summary and history

The Explorations program (<https://web.stanford.edu/class/bio41/Webpages/explorations.html>) was initiated in 2008 and is offered through the first course in the introductory undergraduate biology sequence, which typically enrolls 250–300 students and is taught in traditional lecture format. This course is the first required undergraduate biology course taken by students and is comprised mostly of sophomores. In addition, most students in this course have not taken (and are not concurrently taking) an undergraduate biology lab course because most students start the lab sequence the

following term. The Explorations program is held annually in the fall and is student run by graduate students who coordinate the organization of the program in conjunction with the introductory biology course faculty and staff. Graduate students and postdoctoral scholars interested in serving as instructors are recruited through communications sent to departments and targeted e-mail lists. Instructors submit a brief class summary that highlights the interactive, hands-on nature of the class (dubbed an “Exploration”), as well as the research components of the Exploration. An Exploration can be on any topic relevant to bioscience; past classes include topics in molecular and cellular biology, genetics, cancer biology, ecology and evolution, and more (see Brownell et al., 2013, for examples). Explorations are single-session classes, meeting only once for 3 to 4 hours, and have between five to 20 students each. Classes that involve a field trip (e.g., those that travel to our university's marine station or field sites) may last longer. Similarly, some classes require overnight experiments and thus may meet twice but for approximately the same total amount of contact time with students. Instructors are provided written guidelines for designing single-session classes but are not required to undergo any formal training. Starting in 2012, an optional hour-long orientation has been held where former Explorations instructors share their experiences and graduate teaching consultants provide general advice. The program typically offers 15–20 Explorations each year, each taught by a different instructor. These classes are scheduled in afternoons, evenings, or weekends throughout the first month

of the term. The Biology Department funds class-related expenses (e.g., lab consumables), and instructors receive a small honorarium for teaching. The program is introduced to students in the first week of term. Students sign up for a single Explorations class on a first-come, first-served basis through the university's online course portal.

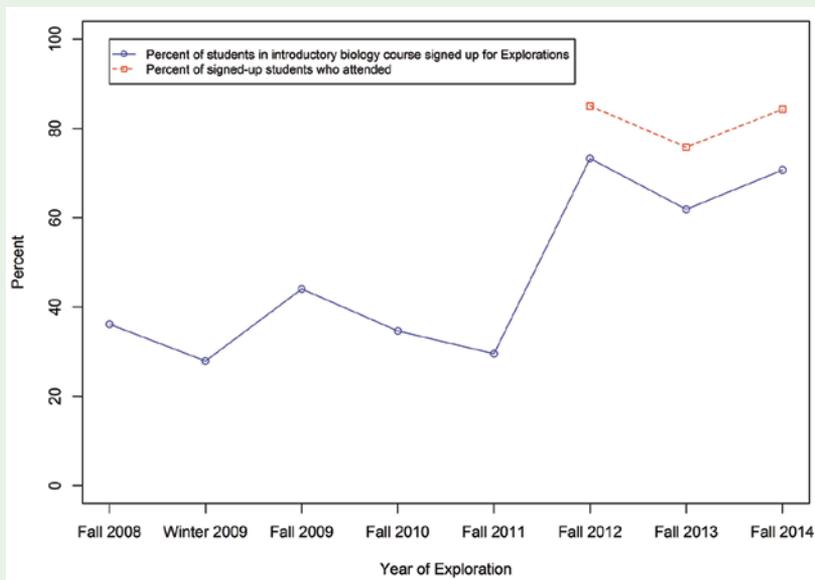
The program operates as part of the introductory biology course but is completely voluntary. Starting in fall 2012, students were provided with a small grade incentive; students who participated in Explorations could drop their lowest problem set score in the course. Because the course offers eight problem sets, collectively worth 10% of the overall grade, this grade incentive has at most a 1.25% impact in the grades of participating students. Before this incentive was added, instructors would often report a significant percentage of students who signed up would not show up, forcing instructors to adjust to smaller-than-expected classes. As a result, this incentive was added with the goal of increasing the percentage of students who attend Explorations after signing up.

Modes of program assessment

To holistically evaluate the impact of Explorations, we analyzed undergraduate and instructor post-class surveys, introductory biology course grades, senior exit surveys, and data on undergraduate thesis writers. Questions on the survey instruments for assessment remained consistent throughout the period evaluated, and responses were largely consistent from year to year as well. We also used these data and program attendance to assess

FIGURE 1

Percentage of students signed up for Explorations and percentage of signed-up students who attended an Explorations class. This latter value is only available from 2012 to 2014.



the impact of the grade incentive on program enrollment and student perceptions of the program.

Program attendance

To assess any changes in student enrollment in Explorations after the introduction of the grade incentive, we tracked the percentage of students enrolled in the introductory biology course who signed up for Explorations each year. The percentage of students who signed up for Explorations increased after the grade incentive was introduced in 2012 (Figure 1). In the five iterations of Explorations prior to 2012, between 27.9% and 44.1% of students in the introductory course signed up each year; after the grade incentive was introduced, between 61.9% and 73.3% of students signed up each year.

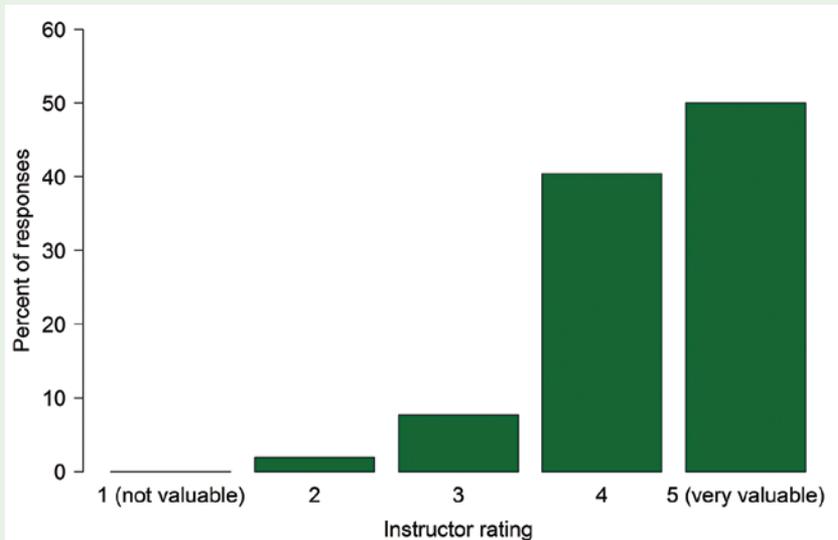
Starting in 2012, instructors were required to take attendance at each Exploration. We found that from 2012 to 2014, between 75% and 85% of students who signed up to participate in Explorations actually attended the Exploration (Figure 1). Although we do not have comprehensive attendance records for Explorations before 2012, we infer an increase in the percentage of students who sign up and attend Explorations after the introduction of this grade incentive on the basis of an in-class survey conducted in 2010 and feedback from Explorations instructors.

Student evaluations of Explorations

At the end of each Exploration, instructors distributed standardized evaluation surveys for students to

FIGURE 2

Instructor ratings for how valuable Explorations was for developing as a teacher, ranging from 5 (very valuable) to 1 (not valuable).



provide feedback on the class and instruction. Surveys were done anonymously in hard copy to facilitate the highest response rate among participants. The survey included both closed and open-ended questions that asked students about their experience in the Exploration. Open-ended questions were coded using grounded theory as per Brownell et al. (2013). Seven hundred fifty-two evaluations were collected across eight iterations of Explorations, 269 from the first five iterations where the program did not offer grade incentive and 483 from three iterations with the grade incentive.

Students rated Explorations highly: 92.3% ranked their class as “excellent” or “good,” whereas only 6.3% ranked the class as “OK” or “poor.” We compared student evaluations of Explorations from before and after the introduction of the grade incentive to see if students had differ-

ent motivations (which would likely lead to different ratings) for participating in Explorations. There was no significant change in the percentage of students who rated their Explorations as “excellent” or “good” during the five iterations offered without grade incentive (94.1%) compared with the three iterations where the grade incentive was offered (92%; two population Z-test, $p = .18$, $Z = 1.35$). However, the percentage of students rating their experience as “excellent” decreased from 62.08% to 50% after the introduction of the grade incentive (two population Z-test, $p = .001$, $Z = 3.27$). Students were also asked if they would be interested in participating in another Explorations class; the vast majority of respondents (94.3%) responded affirmatively, and there was no significant difference between the proportion of favorable responses before and after the introduction of

grade incentive (two population Z-test, $p = .075$, $Z = 1.78$).

Students were asked to describe the best part about the Exploration that they attended. Nearly half (47.4%) of students across all eight iterations wrote that conducting experiments or learning specific techniques in the lab were the best part of the class, the most common response. Students also cited the specialized topic of the classes (32.3%), the hands-on learning aspects (17.1%), and having the opportunity to be in a research laboratory or field site setting (16.1%). Students were also asked an open-ended question about areas of improvement for their Explorations class. Although responses varied, the most common were that the instructors could have done a better job preparing class components such as providing videos, handouts, or PowerPoint presentations (35.9%), followed by requests for greater amounts of background information or reading (17.4%), more hands-on components (13.3%), and more discussion and greater amounts of general information (12.2%). Students were also asked to evaluate their instructor’s overall teaching and how well prepared their instructors were; these data were only available for the period 2011 to 2014 ($n = 752$). A majority (61.7%) rated their instructors’ teaching as excellent, with 36.5% rating their instructors’ teaching as good. Only 1.8% rated their instructors’ teaching as OK or poor. Similarly, the vast majority (74%) thought that their instructors had excellent preparation, with 23% indicating that the instructors’ preparations met their expectations. A small percentage (2.9%) circled that the instructor could have been more prepared, and only one student

(0.2%) indicated that their instructor was not prepared at all.

Instructor evaluations

Instructors were given a survey, distributed electronically, to assess their experiences with Explorations. Although evaluations were collected from 2008 to 2011, these evaluations were not standardized and suffered from a low response rate. Starting in 2012, instructors were required to complete the survey, leading to greater yield; we focus here on these iterations of the program. Between 2012 and 2014, 56.8% of instructors ($n = 74$) were graduate students and 43.2% were postdoctoral scholars, consistent with the ratio in previous years (Brownell et al., 2013). Fifty-two instructor evaluations were collected. Of these, 67.3% rated their experience teaching with the program as excellent, and 28.9% as good. Only two instructors (3.9%) rated their experience as OK, and none rated the program as poor. Instructors self-assessed how valuable the program was for developing as a teacher, choosing a number from 1 (*not valuable*) to 5 (*excellent/very valuable*; Figure 2). All but five instructors (90.4%) rated the program as a five (50%) or four

(40.4%). Four instructors (7.7%) gave the program a three and one instructor (1.9%) gave the program a two, with no instructors giving the program a one. Instructors also indicated that they would be willing to teach again with a similar program, with more than half (53.9%) indicating that they would be highly likely to teach a similar program again, and 36.5% likely to teach again. Only five instructors (9.7%) indicated that they would be neutral or slightly unlikely to teach a similar program again. Instructors also self-reported their previous teaching experience, with 52.9% previously serving as a teaching assistant for more than one course. Approximately 20% had served as a teaching assistant for only one course. Similarly, 19.6% of instructors had not served as a teaching assistant or instructor in any official capacity before, but had taught or mentored in other contexts. Four instructors (7.8%) indicated that they had never taught or mentored before.

Course grades

We analyzed the introductory biology course grades, taken at the end of the term, to see if there were any differences between students who signed

up for Explorations and those who did not. Using unpaired t -tests, we found that there were no significant differences between the mean introductory biology grade of those who signed up for Explorations and those who did not sign up for Explorations in 6 of the 7 years that we tracked (Table 1). For one of the years (fall 2012), students who signed up for Explorations had a higher mean grade than those who did not sign up (unpaired t -test, $p = .0426$).

Senior exit surveys

For biology majors, we further tracked the impact of the program with numerical and open-ended questions in the senior exit survey, given to students immediately prior to graduation, approximately 2.5 years after most students participated in Explorations. Although senior exit surveys can represent a skewed subset of students because they only reach those who fulfill graduation requirements, such a bias is unlikely given that our university has an extremely high undergraduate graduation rate with 96% of students graduating after 6 years. A total of 98 senior exit survey evaluations from 2011 to 2014 were collected from biology majors who

TABLE 1

Mean introductory biology course grades of students who signed up for Explorations versus those who did not.

| | Fall 2008 | Fall 2009 | Fall 2010 | Fall 2011 | Fall 2012 | Fall 2013 | Fall 2014 |
|--|-------------------------|-------------------------|-------------------------|-------------------------|--------------------------|-------------------------|-------------------------|
| Mean grades of students who signed up for Explorations | 83.76% ($n = 116$) | 83.86% ($n = 137$) | 81.84% ($n = 114$) | 82.10% ($n = 96$) | 82.88%* ($n = 214$) | 83.07% ($n = 190$) | 84.98% ($n = 176$) |
| Mean grades of students who did not sign up for Explorations | 82.67% ($n = 205$) | 81.98% ($n = 174$) | 82.09% ($n = 215$) | 82.30% ($n = 229$) | 80.14%* ($n = 78$) | 82.98% ($n = 117$) | 82.94% ($n = 73$) |

*Indicates significance at the $p < .05$ level (unpaired t -test).

FIGURE 3

Selected responses from senior survey open-ended question: “Please describe in your own words what positive impact, if any, Explorations had on your undergraduate experience,” with responses grouped into four categories.

1. Access to potential research mentor

- “It was nice to talk to a graduate student who was interested in teaching undergraduate students.”
- “It paired me up with a postdoc who was doing some really amazing research. Although I didn’t end up going in that route the experience helped me realize that [the university] is a very open community and people want to share knowledge and help each other learn. The guy leading it was very friendly and eager to answer questions and explain everything.”
- “It helped me gain connections to find a PI in the field I was interested in. I currently now work with a Prof. who was introduced through the exploration.”
- “The leader on my Exploration advised me on which lab to choose and I have worked in that lab since sophomore year, and did my honors thesis in this lab. My work in this lab also helped me to choose my career path as an MD/PhD.”

2. First exposure to scientific technique, lab equipment, or research location

- “It was my first introduction to [the university’s marine station], where I later decided to participate in undergraduate research.”
- “Gave an early introduction to a real biology lab and see actual research going on.”
- “My first interaction with a pipette. It did not go well, but at least I didn’t make this mistake when I joined a real lab.”
- “Interesting stuff! Showed me what goes on in one of the labs on campus.”
- “I just thought it was cool to see the lab setting and I got some outside of [the introductory biology course] knowledge on the immunology associated with organ transplant.”

3. Interest in specialized topic

- “It gave me a brief insight into the vast world of cancer biology. It gave me more confidence in learning about an intimidatingly large subject field, and helped me understand the big picture slightly better.”
- “It was fun and allowed me to meet other students who were interested in the same topics that I was. It also allowed me a chance to ask questions about topics I wasn’t very familiar with in a small and intimate setting.”
- “Showed me I really like stem cell research.”

4. Different perspective of science

- “Super interesting and fun to do something different and hands on!”
- “It was a nice break from [lectures of the introductory biology course]. It was a friendly acknowledgement that bio exists outside of lecture halls.”
- “It was fun! It was nice to do something with other students that was purely out of interest in the subject matter—a reminder that what we learn is really cool, not just a stepping stone to med school or whatever else.”
- “Helped me realize that people in science had great senses of humor and had fun at their jobs—they were not just lab rats.”
- “I realized that graduate students were performing experiments that they were really passionate about, so I tried to do research that I can be excited and passionate about.”

self-reported that they had attended an Exploration. A majority (61.2%) indicated that the Explorations program had a positive impact on their undergraduate education, with the remaining 38.8% reporting a neutral impact. No students reported a negative impact. Of those who reported a positive impact, 8.3% further responded that the program had a large positive impact, “influencing [their] choice of major, classes, and participation in undergraduate research.” Students were asked to describe the positive impact Explorations had on their undergraduate experience; selected responses are found in Figure 3. Responses varied, ranging from students who wrote that Explorations offered their first opportunity to see a lab and work with scientific equipment, to others who indicated that the program inspired them to do research and that they found their thesis labs through Explorations. Others wrote that Explorations allowed them a chance to hear about active research or to learn about a new field, and others specifically mentioned enthusiastic instructors.

Completion of honors theses

We tracked students who graduated with honors in biology from 2012 to 2015 ($n = 202$) to determine if there was a correlation between participating in Explorations and completing an undergraduate thesis. Students do not typically submit a petition to become honors students until the fall of their senior year and are required to have a minimum GPA within the major and also complete a research-based honors thesis. We found that students who signed up for Explorations were more likely to complete an honors thesis (two population Z-test, $p = .0014$, $Z = 3.203$): 18.9% of

students who signed up for Explorations completed an honors thesis compared with 12.4% of those who did not sign up for Explorations. This trend was reflected in each year of the comparison (Table 2).

Discussion

Our results show that the Explorations program has positively impacted undergraduates, graduate students, and postdoctoral scholars. Evaluations from eight iterations of Explorations from participating undergraduates indicate that the vast majority of students viewed their experiences as beneficial and regarded their instructor's teaching as excellent or good. Students specifically cited experiments, learning of specific laboratory techniques, the specialized topic of the class, and hands-on learning as the best parts of their Exploration, consistent with some of the key aspects students have found most rewarding when participating in authentic research experiences (Lopatto, 2003). Similarly, instructors benefitted from developing and teaching these Explorations. The vast majority of instructors rated the experience as valuable to developing as a teacher and reported overall high satisfaction with the experience, consistent with studies that have demonstrated gains from teaching and mentoring undergraduates (Dolan & Johnson, 2009). Although most instructors indicated they had prior teaching experience, nearly one third of instructors had never taught or mentored before or served as a teaching assistant or instructor in an official capacity. This program allows the rare chance for graduate students and postdoctoral scholars to design and teach their own class, with rela-

TABLE 2
Percentage of students completing an honors thesis by year of introductory biology course compared between students who signed up for Explorations and those who did not.

| | Year of introductory biology course | | | |
|--|-------------------------------------|---------------------|--------------------|--------------------|
| | Fall 2009 | Fall 2010 | Fall 2011 | Fall 2012 |
| Percentage of students who signed up for Explorations that completed honors theses | 21.9%* (n = 137) | 21.9%* (n = 114) | 15.6% (n = 96) | 16.8% (n = 214) |
| Percentage of students who did not sign up for Explorations that completed honors theses | 10.9%* (n = 174) | 12.1%* (n = 215) | 14.0% (n = 229) | 11.5% (n = 78) |

Note. Sample sizes are provided for total number of students that signed up for Explorations (top row) and those that did not sign up for Explorations (bottom row).

*Indicates significance at the $p < .05$ level (two population Z-test).

tively low time commitment given the one-time nature of the Exploration, and receive feedback on their teaching from student evaluations. There is a demand for teaching opportunities for graduate students and postdoctoral scholars, especially for those who are considering careers that involve teaching. This demand is particularly acute at large research universities, such as our institution, where there is great emphasis on research rather than on teaching and pedagogical development (Brownell & Tanner, 2012). Explorations thus provides valuable opportunities for teaching and teacher development for graduate students and postdoctoral scholars.

Our analyses also suggest that the introduction of the grade incentive, which had at most a relatively minor 1.25% change in student grade, was beneficial by motivating more students to sign up and participate and allowing instructors to more effectively plan their class given greater certainty about the number of students who would be present.

Explorations reached nearly twice as many students per year after this change, which also increased the proportion of students who signed up for Explorations and attended. Despite the expanded audience, the grade incentive did not significantly impact student perceptions of the program. Although there were some differences in individual categorical ratings from before and after the change, the percentage of students who ranked their Exploration as excellent or good did not differ, nor did the percentage of students who indicated that they would be interested in attending a similar class in the future.

We also were interested in seeing if Explorations was differentially reaching certain populations of undergraduates enrolled in the introductory biology course. Although demographic data is not available to fully explore this question, we compared the average introductory biology course grades between undergraduates who signed up for Explorations with those who did not

sign up. We found no differences in general, consistent with expectations that students of all academic levels are participating in Explorations. Although our university's student body and those enrolled in the introductory biology course may not be representative of all undergraduates, our work demonstrates that single-session, research-focused programs embedded in a biology course can be attractive not only for the highest achieving students but also for students of different academic abilities.

Our work also suggests that Explorations may positively influence students to participate in independent research, with undergraduates who signed up for Explorations more likely to complete a biology honors thesis. Although our data only include students who majored in biology and completed an honors thesis, we see a correlation between Explorations and research participation, suggesting several possibilities: (a) students who attend Explorations are motivated to do research because of the program, (b) students who were likely to conduct research were more likely to sign up and participate in Explorations, (c) students who graduate with honors are more motivated to participate in extra activities, or (d) a combination of the above factors. Although likely a combination of factors, we infer that Explorations has had a positive impact on promoting undergraduate involvement in research. This assertion is supported by senior exit data from biology majors. Although the survey only represents a subset of students who participated in Explorations, a large majority (>60%) of students who participated reported that the program had a positive impact, with some reporting a large, significant impact that influenced

their choice of major, classes, and participation in research. Students explicitly wrote that the program helped inspire them to participate in research or assisted them in finding specific labs to join. These comments pinpoint two main avenues in which Explorations promotes undergraduate research involvement: (a) Explorations provides a chance for undergraduates to get a taste of research and learn about a specialized topic in the biosciences, and (b) the program facilitates undergraduates meeting prospective research mentors. Both of these avenues are critical for promoting undergraduate involvement in research. Most undergraduates only partake in research when already connected with a prospective mentor (Mabrouk & Peters, 2000), with the lack of awareness in finding research opportunities a significant barrier to undergraduate research involvement (Bangera & Brownell, 2014). Undergraduates also report that learning about a specialized topic in depth and learning lab techniques are two of the most significant objectives for them in participating in research (Lopatto, 2003); most Explorations showcase both a specialized topic and advanced lab techniques to the students, potentially increasing their awareness of research topics and their motivation to participate in such authentic research experiences.

In addition, single session research-focused classes may be easier to implement than course-based undergraduate research experiences. Unlike CUREs that require significant faculty time and sometimes high cost, Explorations provides a less time-intensive option that still could produce some of the same gains as observed in CUREs, such as student interest in independent research

(Kloser, Brownell, Chiariello, & Fukami, 2011), while also allowing for graduate student and postdoctoral scholar pedagogical development. Such a model can also be beneficial for smaller universities without graduate students or postdoctoral scholars because faculty or even advanced undergraduates could develop single-session, research-focused classes that would require less time to develop and teach than semester-long CUREs while still leading to significant gains in undergraduates. Similarly, we envision that such a model could also be applied to high school students, with advanced undergraduates, graduate students, or postdoctoral scholars as instructors. Thus, short, one-time research-focused classes may provide a valuable alternative or supplement to universities without the resources to implement CUREs, and we urge other universities to consider implementing such programs that could benefit undergraduates, graduate students, and postdoctoral scholars simultaneously. ■

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