Exploring Biology: A *Vision and Change* Disciplinary First-Year Seminar Improves Academic Performance in Introductory Biology

Caroline J. Wienhold[†] and Janet Branchaw[†‡*]
[†]Wisconsin Institute for Science Education and Community Engagement and [‡]Department of Kinesiology, University of Wisconsin–Madison, Madison, WI 53706

ABSTRACT

The transition to college is challenging for most students, especially those who aspire to major in the science, technology, engineering, or mathematics disciplines, in which introductory courses can be large and instruction less than optimal. This paper describes a novel, disciplinary first-year seminar (FYS) course, Exploring Biology, designed to address many of the challenges facing aspiring biology students beginning their academic careers at a large public research university. The course addresses typical FYS goals, such as community building, introduction to resources, and academic skill development, and introduces students to the core concepts of biology defined in the 2011 *Vision and Change* report. Relative to a matched comparison group of students, Exploring Biology alumni were retained at higher rates and had higher levels of academic performance in a subsequent introductory biology course, suggesting Exploring Biology has a positive impact on future academic performance in the discipline. Results from course evaluations and an alumni survey show that, overall, students valued both the FYS components and biology components of the course. These results provide evidence that the Exploring Biology disciplinary FYS model is an intervention that may increase academic success and retention in biology.

INTRODUCTION

The transition to college is challenging for all students (Tinto, 1993). These challenges can be exacerbated for those who aspire to major in the science, technology, engineering, or mathematics (STEM) fields, as these disciplines traditionally include difficult introductory courses taught in large-lecture formats, especially at large institutions. Nationally, less than 40% of students entering college interested in STEM complete a major in the field (President's Council of Advisors on Science and Technology, 2012), and attrition rates as high as 67% have been reported specifically in biology (Shaw and Barbuti, 2010). To address the challenges associated with the transition to college and the pursuit of a degree in biology, we developed, implemented, and evaluated a disciplinary first-year seminar (FYS) course, Exploring Biology.

The positive impacts of FYS courses on student success are well documented (Fidler and Godwin, 1994; Starke *et al*., 2001; Schnell and Doetkott, 2003; Keup and Barefoot, 2005; Pascarella and Terenzini, 2005; Tobolowsky and Associates, 2008; Jamelske, 2009). Nearly 80% of colleges and universities offer a FYS course (Tobolowsky and Associates, 2008), indicating that this type of high-impact intervention is sustainable across a wide variety of institutions. Studies show that participants in FYS courses earn higher grade point averages (GPAs) and are retained at higher rates (Starke *et al*., 2001; Schnell and Doetkott, 2003; Pascarella and Terenzini, 2005; Tobolowsky and Associates, 2008; Jamelske, 2009). In addition, students who participate in FYS courses are more engaged with their peers and faculty members and

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*Address correspondence to: Janet Branchaw (branchaw@wisc.edu).

participate in extracurricular activities and use campus resources, such as academic support services, at higher rates (Fidler and Godwin, 1994; Starke *et al*., 2001; Keup and Barefoot, 2005).

There are four general types of FYS courses, all of which use small student-centered classes and aim to improve retention of students into the second year: 1) extended orientation, 2) academic, 3) disciplinary, and 4) remedial (Tobolowsky and Associates, 2008). Of these four types, the disciplinary FYS model emphasizes the opportunities within and expectations of a discipline (Porter and Swing, 2006; Tobolowsky and Associates, 2008) and, importantly, facilitates the formation of a disciplinary community (Rogerson and Poock, 2014). However, there are few studies evaluating disciplinary FYS courses and, specifically, their impact on participants' persistence and success in the discipline. Studies report student gains in areas such as selecting majors, understanding opportunities within the discipline, developing academic skills and high overall GPA, and retention into the second year (Soulsby, 1999; Montgomery *et al*., 2003; Erickson and Stone, 2012; Birol *et al*., 2014; Black *et al*., 2016), but only one reported disciplinary FYS students' academic outcomes and persistence in subsequent disciplinary courses. Minchella *et al*. (2002) reported participants had higher levels of satisfaction in introductory biology than nonparticipants, earned higher grades, and were more likely to be retained within the major after three semesters. Their course served 20–25 students per semester, was offered concurrently with introductory biology, and included specific content tutoring and homework review. By contrast, Exploring Biology, the FYS course described here, serves ~200 students per semester, is taught before students take introductory biology, and generally introduces core biology concepts, not specific content.

THE EXPLORING BIOLOGY INTERVENTION MODEL

The Exploring Biology intervention was designed to welcome first-year students from various backgrounds to the discipline of biology, ease students' transition and integration into college life, and introduce students to a disciplinary conceptual learning framework. The course uses evidence-based FYS best practices, including 1) developing academic and study skills (e.g., critical thinking and writing), 2) developing support networks through faculty and peer interactions, 3) introducing extracurricular activities and campus resources, 4) introducing a discipline, and 5) guided individual self-exploration (Porter and Swing, 2006; Tobolowsky and Associates, 2008). These practices develop students' navigation and networking skills and support the exploration of personal interests and career aspirations. The addition of the disciplinary conceptual learning framework as outlined in the American Association for the Advancement of Science's *Vision and Change* report (AAAS, 2011), supports the development of college-level biology conceptual-learning skills. In practice, the biology and FYS course components are integrated through the use of active-learning pedagogies in lecture and discussion and two multi-assignment semester-long projects, the Discovery Poster and BioMap projects. However, for clarity and evaluation purposes, we present the course components separately in Table 1.

We developed the Exploring Biology course using an iterative process of design, implementation, evaluation, and revision over four semesters. The format is a two-credit FYS course that serves ~200 incoming first-year students each Fall semester (see the Supplemental Material for a sample syllabus). At this institution, students take Exploring Biology in the first semester of their first year and introductory biology in the second semester of their first year or the first semester of their second year. This prepares them for success before they enter the discipline and potentially alleviates academic or climate challenges that might otherwise cause a student to leave the discipline. Many of the elements of Exploring Biology, however, could readily be incorporated into a standard first-year, first-semester introductory biology course (see *Discussion* for implementation ideas).

Exploring Biology follows a cohorts-in-large-course design (Shapiro and Levine, 1999), allowing for the known benefits of a small student–teacher ratio and small-group learning (Springer *et al*., 1999), while still offering the capacity to serve large numbers of students. All students meet together in a large lecture setting during the first hour of class and then split into small discussion sections of ~20 students for the second hour. This creates communities of students with common interests,

TABLE 1. Exploring Biology course goals and corresponding course components

	Course learning goals	Course components
	Students will	
Disciplinary content goals	L1: adopt and use the five core concept cognitive framework as a learning strategy. L2: integrate scale and subdisciplinary perspectives into the cognitive framework. L3: write and speak in a disciplinarily appropriate manner. L4: recognize the interdisciplinary nature of biology across subdisciplines and other STEM fields.	Biology learning activities • Scale vs. concept framework Discovery Poster project • Research explorations • Library orientation
FYS transition goals	L5: identify and engage in biology cocurricular learning opportunities and link to classroom learning. L6: identify classes and majors that contribute to career preparation and consult with advisors to create an integrated academic plan. L7: explore opportunities to engage with campus biology learning communities and meet others interested in biology. L8: explore the social relevance of biology. L9: explore careers and majors in biology. L10: clarify or solidify commitment to majoring in biology.	BioMap project • Career explorations • Involvement explorations • Biology advisor meetings • Résumés and cover letters

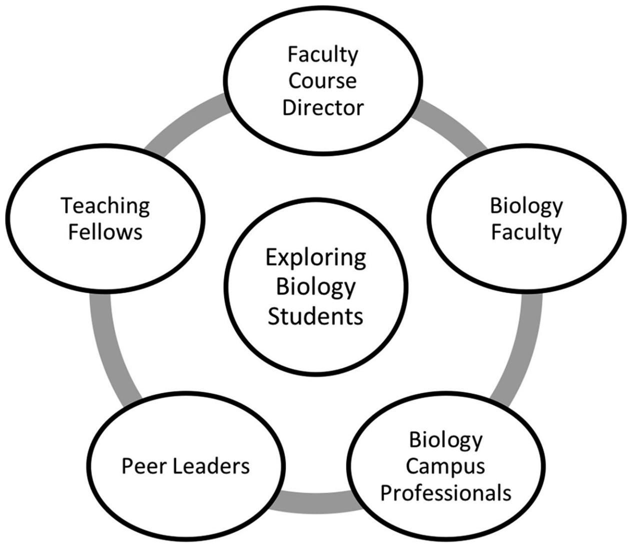

FIGURE 1. The Exploring Biology teaching team provides a network of support for students and includes instructors from across the biological sciences campus community. The faculty course director leads the team.

which enhances opportunities for networking among peers and informal interactions with faculty, and promotes retention in the discipline through an increased sense of belonging (Rogerson and Poock, 2014).

A faculty member leads the instructional team for the course, which includes biologists across career stages, from undergraduate peer leaders to graduate student and postdoctoral teaching fellows (Miller *et al.*, 2008) to other tenured faculty members, and other key campus professionals (e.g., librarians and academic advisors), all of whom are part of the biological sciences community (Figure 1). The diversity of the team creates opportunities for students to begin to build a network of support, a factor directly linked to undergraduate student retention (Pascarella and Terenzini, 1976).

Exploring Biology uses the five biology core concepts (henceforth referred to simply as "core concepts") in the AAAS *Vision and Change* report (AAAS, 2011) to develop students' abilities to think about and learn biology conceptually (1) evolution; 2) information flow, exchange, and storage; 3) pathways and transformations of energy and matter; 4) structure and function; and 5) systems). Frameworks, or mental models, lead to greater and faster learning gains (Ausubel, 1960; Smith *et al.*, 1978; Bradshaw and Anderson, 1982; Ambrose *et al.*, 2010) by "facilitating the acquisition of knowledge or skill" (Derry and Murphy, 1986) through developing students' abilities to organize, connect, and relate concepts. Students use the core concepts as a framework both to understand individual topics and to make connections between them.

The students in the course also use a scale versus concept framework (Table 2) as a visual tool to organize knowledge about each new topic and support their efforts to identify relationships, similarities, differences, contradictions, and other patterns across topics and concepts. We explore each topic through multiple core concept lenses and at multiple scales. The ultimate goal is to better prepare students for success in college biology courses by familiarizing them with the core concepts to increase their biology learning self-efficacy and, therefore, the probability that they are retained in the discipline. The eight topics presented in Table 2 are examples of the variety of topics used to teach the core concepts in Exploring Biology and are listed in the boxes representing the scale(s) and concept(s) each address. Typically, five or six topics are taught each semester based on the expertise of the instructional team, but the core concept learning goals remain the same from semester to semester.

The instructional team develops new topics each year, but those that are particularly successful are refined and used again. As topics are tested across multiple semesters, instructional team members will submit them for publication in CourseSource (www.coursesource.org). Two course components that do not vary from semester to semester, the Discovery Poster and BioMap projects, allow students to learn about and present a scientific discovery of interest to them and to create a comprehensive academic plan that includes curricular and extracurricular components. Instructional materials for these projects have already been submitted to CourseSource.

TABLE 2. Scale vs. concept framework: Eight topic examples address multiple scales and/or core concepts[a]

	E	IFES	PTEM	SF	S
Molecular and Cellular	1. HIV	1. HIV 3. chemical signals	2. Cheese fermentation	1. HIV 6. Stem cells	6. Stem cells
Organismal	2. Cellular respiration	3. Chemical signals 5. Vaccines 6. Stem cells	7. Cellular respiration	4. Insects and climate 7. Cellular respiration 8. Forests and wood	5. Vaccines
Ecological	4. Insects and climate	3. Chemical signals	2. Cheese fermentation	8. Forests and wood	2. Cheese fermentation 4. Insects and climate

[a]E, evolution; IFES, information flow, exchange, and storage; PTEM, pathways and transformations of energy and matter; SF, structure and function; S, systems.

METHODS

Qualitative and quantitative methods were used to evaluate whether the Exploring Biology intervention achieved the goals for which it was designed. This included a cross-sectional analysis of data from course evaluations, an alumni survey, and institutional data on student academic performance in an introductory biology course. Human subjects research approval was obtained for all data-collection and analysis activities (IRB protocol #2014-0438).

Course evaluations and alumni surveys provided data about the impact of the course on students immediately after completing it (course evaluations) and 1 to 3 years later (alumni surveys). Institutional data were used to track and assess student academic outcomes in an introductory biology course taken after Exploring Biology. Two overarching evaluation research questions guided data collection:

1. What do students value and remember from their learning experience in Exploring Biology?
2. Does participation in Exploring Biology affect academic success in a future introductory biology course?

Course Evaluation Data

During the development of the Exploring Biology intervention, semester course evaluations were used to refine the course (formative evaluation). Once the course structure was stabilized, the evaluation data collected in two subsequent semesters were used to determine whether the model was successful (summative evaluation). Summative data are presented here.

We collected anonymous student evaluation data from two offerings of Exploring Biology at the end of the semester. The response rate was 98.5% (400/406). Data were analyzed to evaluate whether students perceived they had achieved the course learning goals and whether they thought the course components were helpful to their learning. Likert-type items on the evaluation survey were analyzed using Excel and SPSS (IBM, Armonk, NY). Results are presented as a percentage of responses recorded for each question.

Alumni Survey Data

The Exploring Biology alumni survey asked students to 1) reflect generally on their experience in Exploring Biology and 2) report on their subsequent extracurricular activities, ongoing engagement with Exploring Biology peers, and career aspirations. We sent the survey to all students, 1 to 3 years after completion of the course. We recruited participants through email solicitation and incentivized them with a raffle for an online retailer. The response rate was 19% (183/936). Because we were primarily interested in the impact of Exploring Biology on students majoring or intending to major in biology, we limited data analysis to responses from students who reported biology as their academic major or intended major (https://biosci.advising.wisc.edu/majors), reducing the response rate to 13% (125/936).

Alumni survey items were either Likert-type questions on a five-point scale (not at all; a little; somewhat; very; extremely) or open-ended response questions. We used Excel and SPSS to analyze the Likert-type items and present the results as a percentage of responses recorded for each question. We also included two open-ended questions in the analysis.

We coded responses to the first open-ended question, "Write five words or phrases that describe your experience in Exploring Biology," to generate themes by three raters with intimate knowledge of Exploring Biology (Creswell, 2014). We reviewed, revised, and refined the themes as a group to generate a codebook. Five raters, also with intimate knowledge of Exploring Biology, then coded the responses (intraclass correlation coefficient = 0.862, two-way random model with absolute agreement). We assigned final themes to each response by taking the most commonly coded theme among the five raters. Responses in which fewer than three raters were in agreement were labeled as "unassigned" (10.8% of total responses). Theme definitions are reported in Table 3. The eight themes outlined in Table 3 were identified from 494 words and phrases collected from the 116 students who responded to this question.

We categorized responses to the second open-ended question, "The most valuable thing I took from Exploring Biology was…" based on the course learning objectives that each addressed (Table 4). Ninety-six students answered this question. Several answers were complex and were therefore categorized as addressing multiple learning objectives, yielding an average of 1.5 learning objectives addressed per response. Approximately 3% ($n = 3$) of the responses could not be categorized and 7% ($n = 7$) of respondents indicated that they found nothing valuable.

Institutional Data

We used a matched-pairs design (Schnell and Doetkott, 2003; Rubin, 2006) to control for background characteristics that might influence academic outcomes in introductory biology. Each Exploring Biology student was matched to a "comparison" student who did not participate in Exploring Biology. The matched-pairs design generated comparable Exploring Biology and comparison group sample sizes from a starting comparison pool that had nearly 10 times the number of students.

We accessed institutional data records for all students who had matriculated between Fall 2011 and Fall 2014 as full-time, first-year students between the ages of 17 and 21 and had completed Exploring Biology or the first semester of the two-semester comprehensive introductory biology course for majors. The Exploring Biology group was further filtered to include only students who completed Exploring Biology with a "C" or better to ensure that they had participated fully in the intervention.

Of the three options students have to fulfill an introductory biology requirement at the university where this study took place, the two-semester comprehensive introductory biology sequence almost exclusively enrolls students intending to major in a biological science. We assumed that all students who began the two-semester introductory biology course for majors were similarly committed to completing a biology major. Therefore, we used outcome data only from the two-semester introductory biology course (from here on referred to only as "Introductory Biology") to mitigate the possibility of sample bias surrounding pre-existing differences in motivation and commitment to a biology major. In addition to grades in Introductory Biology, we accessed students' ACT scores, gender, race/ethnicity, first-generation status, enrollment in a curricular learning community (Shapiro and Levine, 1999; Tinto, 2000; Henscheid, 2004;

TABLE 3. Coding themes, definitions, and frequencies (n = 494 words from 116 survey respondents) in response to the prompt, "Write five words or phrases that describe your experience in Exploring Biology"

	Frequency	Themes	Definition of themes	Representative student responses
Course design (55.9%)	45.7%	Evaluation	Words describing student opinion, positive or negative connotation, of Exploring Biology	Interesting, fun, easy
	10.1%	Structure	Words about the structure, organization, implementation, or administration of Exploring Biology	Long, time-consuming, short
FYS transition (31.8%)	17.0%	Personal Growth	Words referencing acquiring new or modifying and reinforcing existing knowledge, behaviors, skills, values, or preferences; words reflecting a change in student intellect or mind-set	Eye opening, thought provoking, conceptual
	8.9%	Community	Words describing or eliciting images of relationships with people or commentary on commonalities, connections, classroom atmosphere or the learning environment in Exploring Biology	Lots of group work, cool guest speakers, encouraging, friendly
	4.3%	Navigation	Words describing or eliciting ideas about navigating the future, planning, or making choices about next steps, including academics, involvement in activities, or careers	Good for realizing lab life, what degree do I want, lots of options for majors
	1.6%	Transition	Words describing the transition to college; learning the ropes	Helpful—explaining the process, good introductory class, explorative
Disciplinary content (12.3%)	10.1%	Breadth	Words referring to the breadth of topics covered in Exploring Biology	Different fields, diverse fields, good overview of subject
	2.2%	Content	Words referencing the specific topics, assignments, or pedagogies used in Exploring Biology	Basic science, animals, poster making

Tampke and Durodoye, 2013), and participation in an academic support program (e.g., Federal TRIO Programs, www2.ed.gov/ope/trio) as factors that influence student success. Scholastic Aptitude Test (SAT) scores (2.6% of the matched-pairs data set, see Table 5) were converted to ACT equivalents using a standard conversion formula (www.act.org). Ethnicity was assigned according to the guidelines of the university and the U.S. Department of Education. Briefly, students were designated as minority if their race/ethnicity was Hispanic or Latino, Black or African American, Native Hawaiian, Pacific Islander, Native Alaskan, or Native Indian. Asian was categorized with white as majority. First-generation status was a voluntary, self-reported field. Students whose ACT/SAT, gender, race/ethnicity, or matriculation terms were not available were removed from the study before matching. Standard letter grades at this university are recorded as "A," "AB," "B," "BC," "C," "D," and "F." Students with grades other than "A–F," "drop," or "withdraw," in their first attempt in introductory biology (e.g. "incomplete"), were also removed before matching.

We used a two-tiered approach to create the matched-pairs data set. In the first tier of matching we created perfect categorical matches between the two pools. Perfect matches were made on: first-generation status, gender, minority status, ACT, and enrollment in Exploring Biology as part of a curricular learning community. Second-tier matching was used in cases in which multiple comparison matches were identified in order to increase compatibility and create a balanced sample size. These matching criteria were applied as follows until the comparison matches were reduced to the most appropriate match: the number of semesters after matriculation in which the student began Introductory Biology (beginning term), enrollment in an academic support services program, matriculation term, and the students' specific racial/ethnic group.

Using this procedure, we matched 94% of eligible Exploring Biology students with a comparison student. There were no statistically significant differences between the pools regarding the distribution of beginning terms, matriculation terms, and specific racial/ethnic group or the percent participating in an academic support program (χ^2, p = 0.34; p = 0.45; p = 0.46; p = 0.41, respectively). The final matched-pairs data set includes 698 students, with 349 in each pool (Table 5). We used Excel and SPSS (IBM) to do all analyses.

RESULTS

Students Value Exploring Biology

Immediately after the course, we asked students to complete an evaluation and provide an overall rating of their experience in Exploring Biology from poor to excellent. Fifty-seven percent of students indicated the course was average, good, or excellent. Students also reported the degree to which they thought they had achieved the course learning goals and provided feedback on specific components of the course. Self-reported learning goal achievement data are presented in Figures 2 and 3. From 54 to 83% of students reported that they were somewhat confident or confident in having achieved each of the course learning goals (Figure 2). Consistent with this, students evaluated specific course components and assignments positively overall, with 53–64% of students rating each as helpful or very helpful (Figure 3).

TABLE 4. Each response to the prompt "The most valuable thing I took from Exploring Biology was…" was categorized according to the course learning goal that it addressed (n = 96)[a]

	Course learning goals	Representative student responses
	Disciplinary content goals	
7%	L1: adopt and use the five core concept cognitive framework as a learning strategy	• Learning to understand general principles • A general overview of biology before I took introductory biology
18%	L2: integrate scale and subdisciplinary perspectives into the cognitive framework	• The ENORMOUS [*sic*] diversity in biology • Microscopic biology is much more interesting than macroscopic biology
6%	L3: write and speak in a disciplinarily appropriate manner	• Learning how to properly make a résumé and cover letter • Learning how to make and present posters
9%	L4: recognize the interdisciplinary nature of biology across subdisciplines and other STEM fields	• Getting excited about applied biology • Learning about all the different options that I could use my knowledge gained in biology in
	FYS transition goals	
19%	L5: identify and engage in biology co-curricular learning opportunities and link to classroom learning	• How to seek out independent research • Taking advantage of the resources available to me whether it be research, volunteering, or attending seminars
30%	L6: identify classes and majors that contribute to career preparation and consult with advisors to create an integrated academic plan	• The four-year college plan, which helped me figure out what I wanted to do and how to get there • Planning ahead in college and beyond
15%	L7: explore opportunities to engage with campus biology learning communities and meet other biology interested individuals	• The introductions to people in my field • Meeting my teaching fellow, who got me involved in research
4%	L8: explore the social relevance of biology	• Learning about the current research being done and how it applies to our lives • The information you obtain in biology can be applied to daily life.
34%	L9: explore careers and majors in biology	• By finding areas I really found interesting I discovered my major • The career fair where they brought in people from different professions to talk to us
8%	L10: clarify or solidify commitment to majoring in biology	• Finding my major. I came in thinking biology and found that I could accomplish the same goals and enjoy a different major more. • That I definitely wanted to pursue a biological major/career
3%	Not able to map onto learning objectives	• Satisfying the first-year seminar requirement • Learning how a college course worked

[a]Several responses addressed more than one learning goal.

TABLE 5. Data set matching scheme and characteristics (n = 698)

			Pool characteristics[a]	
Matching scheme	Match categories	% of pairs matched	Exploring Biology (n = 349)	Comparison (n = 349)
Perfect match tier I	FGCS[b]	100	18.6%	18.6%
	Minority[c]	100	9.5%	9.5%
	Female	100	63.3%	63.3%
	Curricular LC[d]	100	41%	41%
	ACT	100	28 (range = 19–35, SD = 2.7)	
Match when possible tier II	Beginning term[e]	88.8	2.88	2.91
	Support program[f]	96.6	2.9%	4.0%
	Matriculation term	75.6	Fall 2011–Fall 2014	
	Specific race/ethnicity	90.0	Majority white	

[a]No statistically significant differences found between pools.
[b]First-generation college student.
[c]Defined as Hispanic or Latino, Black or African American, Native Hawaiian, Pacific Islander, Native Alaskan. or Native Indian.
[d]Enrolled in a curricular learning community.
[e]Average semester postmatriculation to begin Introductory Biology course.
[f]Enrolled in an academic support program.

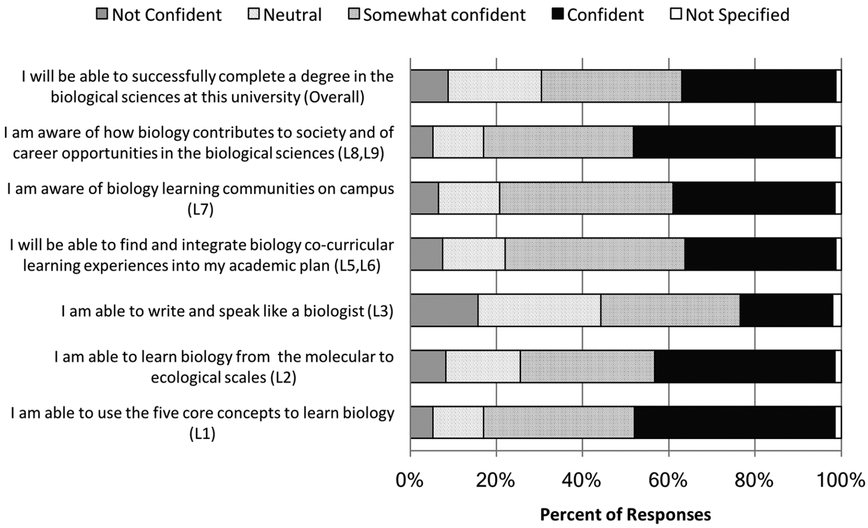

FIGURE 2. Exploring Biology student confidence in achieving learning objectives. Students from two semesters of Exploring Biology were asked at the end of their semesters to rank their confidence in having achieved the stated learning objectives based on their experiences in the course (*n* = 400).

Beyond the evaluation data collected from students immediately after the course, we also investigated the impact of Exploring Biology on students 1 to 3 years later using a separate alumni survey. We asked alumni students what they remembered about the course and what they found valuable. More specifically, we asked them whether the FYS components of the course had eased their transition to college.

To get a sense of what mattered most to alumni students in the course and before asking them about any specific course components, we asked them to "Write five words or phrases that describe your experience in Exploring Biology." This question was intentionally asked first to solicit responses that were not biased by subsequent questions. The emerging themes, definitions, and frequencies are presented in Table 3. More than half (55.9%) of the words and phrases referred to the design of the course, either by offering an evaluation of the course (45.7%) or by reflecting on the structure of the course (10.1%). The second most common set of codes (31.8%) referred to the FYS components of the course and align with FYS design principles and with factors that have been previously identified to contribute to college persistence (Porter and Swing, 2006; Tobolowsky and Associates, 2008). The third most common category of codes (12.3%) referred specifically to the disciplinary content of the course and reflected students' recollections of the biology topics and specific projects from the course.

At the end of the alumni survey, after students had been reminded of the various components of the Exploring Biology course by answering several specific questions, we asked them to complete the following statement: "The most valuable thing I took from Exploring Biology was…" To determine the extent to which student answers addressed the course learning objectives, we categorized the answers by learning goal(s) (Table 4). The most frequently valued learning goals addressed FYS transition goals (L5, 19%; L6, 30%; L9, 34%). Only one learning goal that addressed disciplinary content was mentioned more than 10% of the time (L2, 18%). Together, these qualitative data from the first and last questions on the alumni survey suggest that students value the FYS components but also find the exploration of the diversity of biology valuable.

In addition to the open-ended questions, we asked students to reflect on specific course components known to positively impact the transition to college. These included whether they had continued engagement with those in the Exploring Biology community, their engagement in extracurricular activities, and whether Exploring Biology influenced their biology career aspirations. In response to asking whether they had stayed connected to the Exploring Biology community, many reported they had engaged with someone from their Exploring Biology community within the last two semesters through discussions of potential classes (33%) or potential careers (35%) or simply because they studied together in groups (35%). When we asked alumni about their participation in extracurricular activities, the majority reported they participated in or were planning to participate in two or three extracurricular activities, most frequently

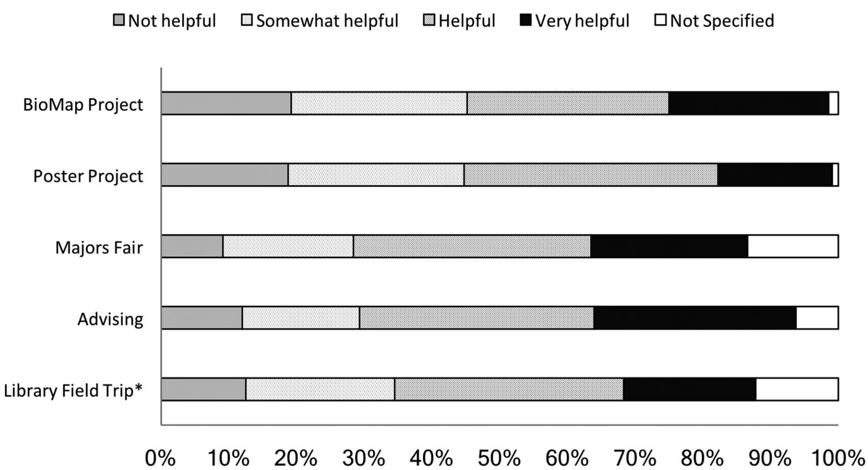

FIGURE 3. Students rate helpfulness of Exploring Biology course components to their learning. Students were asked to rank how helpful each of the course components was to their learning in Exploring Biology. Students from two semesters were asked to rank the library field trip (denoted with an asterisk; *n* = 400), while data for the other components were collected from only one semester (*n* = 208).

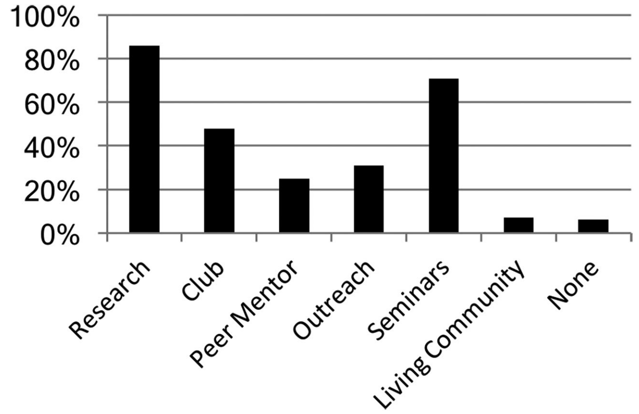

FIGURE 4. Exploring Biology alumni engagement in extracurricular activities. Alumni were asked to report their involvement or planned involvement in extracurricular activities. Individual alumni may be represented in multiple categories ($n = 113$).

undergraduate research and attending campus research seminars (Figure 4). Thirty to forty percent of the students credited Exploring Biology with being the place where they "learned about this activity for the first time" or with "showing me how to get involved."

Alumni survey results also showed Exploring Biology had minimal influence on students' selection of major or career pathway (Figure 5). Because recruitment to the course focused on intended or declared biology majors, we were not surprised by this result. However, several students provided comments about how the course introduced and helped them to understand and choose from the more than 30 undergraduate majors in the biological sciences offered at the university.

Exploring Biology Students Experience Increased Academic Success in Introductory Biology

Using a matched-pairs design, we compared the rates of adverse ("D," "F," "drop") and passing ("A" to "C") outcomes in Introductory Biology between students who had participated in Exploring Biology and those who had not (comparison). Data in Table 6 show that, in the first semester of Introductory Biology, Exploring Biology students had significantly fewer adverse outcomes than comparison students: 4.6 and 8.3%, respectively (χ^2, $p = 0.045$).

Beyond their significantly better academic outcomes in the first semester of Introductory Biology relative to comparison students, a greater percentage of Exploring Biology students continued on to enroll in the second semester of Introductory Biology (88.3 vs. 82.5%, χ^2, $p = 0.032$), and a greater percentage of Exploring Biology students completed the full two-semester sequence by the end of their second year (93.2 vs. 88.2%, χ^2, $p = 0.036$). Of the initial 698 students who completed the first semester, 592 had a grade recorded for the second semester at the time of data collection (Exploring Biology, $n = 306$; comparison, $n = 286$). An analysis of adverse versus passing outcomes in this second semester indicated that Exploring Biology students continued to pass the second semester more often than comparison students (χ^2, $p = 0.0046$). Furthermore, the frequency of students repeating or improving their grade versus those who did worse from the first semester to the second was statistically significant only for students who earned a "C" in the first semester (Table 7). Exploring Biology students who received a "C" in the first semester of Introductory Biology more often passed the second semester than comparison students who earned a "C" in the first semester (χ^2, $p = 0.021$). We did not detect statistically significant shifts for students who passed the first semester with a grade of "B" or better (see the Supplemental Material for grade frequencies). These results suggest that Exploring Biology differentially benefits students most at risk for adverse outcomes in Introductory Biology and prevents students from faltering in subsequent courses.

TABLE 6. Exploring Biology students perform better than the comparison group in first-semester Introductory Biology course

	Pass[a]	Adverse[b]
Exploring Biology ($n = 349$)	95.4%	4.6%[c]
Comparison ($n = 349$)	91.7%	8.3%

[a]Defined as "A" through "C."
[b]Defined as "D," "F," or "drop."
[c]χ^2, $p = 0.045$.

TABLE 7. Frequency of grade shifts (repeat or improve; decrease) from the first to the second semester of Introductory Biology ($n = 592$)

	Exploring Biology ($n = 306$)	Comparison ($n = 286$)
= "A"	60.0%	68.2%
< "A"	40.0%	31.8%
> = "AB"	60.0%	42.2%
< "AB"	40.0%	57.6%
> = "B"	87.9%	86.3%
< "B"	12.1%	13.7%
> = "BC"	65.5%	68.2%
< "BC"	34.5%	31.8%
> = "C"	97.9%	84.4%
< "C"	2.1%	15.6%[a]
> Adverse	100.0%	72.7%
= Adverse	0.0%	27.3%

[a]χ^2, $p = 0.021$.

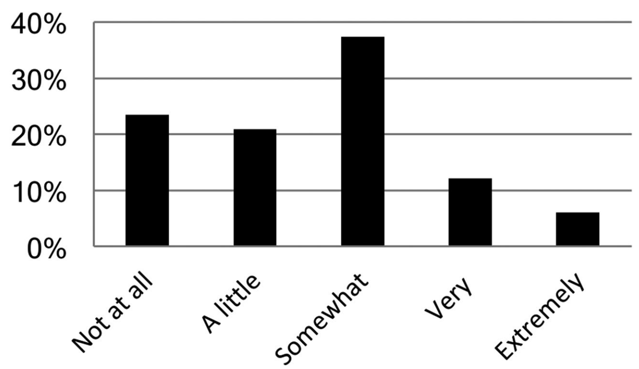

FIGURE 5. Exploring Biology impact on alumni career and major path. Alumni were asked to report how important their participation in Exploring Biology was in guiding their major or career path ($n = 115$).

In summary, course evaluation, alumni survey, and institutional academic performance data provide evidence for the effectiveness of the Exploring Biology FYS intervention. Most promising were the institutional data, which suggest that participation in Exploring Biology contributes to greater success in introductory biology, the gateway course for all biological sciences majors.

DISCUSSION

Overall, the data provide strong evidence that the Exploring Biology course effectively supports first-year biology students as they transition to college and increases their academic success in a subsequent introductory biology course. Though it is challenging, if not impossible, to attribute student outcomes to any one particular learning experience or intervention, the alumni survey, which specifically addressed the student experience in Exploring Biology, and the institutional data, which compared Exploring Biology students with a matched comparison group of students, suggest that the positive outcomes, at least in part, resulted from students' experiences in Exploring Biology. For example, even though students have multiple opportunities to learn about extracurricular activities in their first semester on campus, many attributed their later involvement in the activities to the Exploring Biology course (Figure 4).

The answer to one specific question on the alumni survey, "Write five words or phrases that describe your experience in Exploring Biology," provided strong evidence that Exploring Biology achieved the goals of a typical FYS. The identification of aligned themes, and specifically a "transition" theme, suggests that Exploring Biology supported students' transition to becoming valued members of the biological sciences university community and that the course effectively helped students build community and develop navigation skills. The themes also align well with the factors identified in Tinto's synthesis of the literature on student college transitions. In Tinto's theory, the integration of academic experiences, such as performance in courses and interactions with faculty, and social experiences, such as extracurricular activities and peer group interactions, are key factors that contribute to student persistence (Tinto, 1993), the ultimate goal of a FYS.

As a disciplinary FYS, a goal of Exploring Biology is to increase persistence in biology. We found evidence that this goal was achieved in students' improved academic outcomes in Introductory Biology compared with a matched comparison group of students who did not participate in Exploring Biology. The high rate of persistence through Introductory Biology course work along with the decreased "D"/"F"/"drop" rates by our alumni indicate that Exploring Biology contributed to student success in the gateway introductory biology course. Additionally, tracking students into the second semester of Introductory Biology provided evidence that Exploring Biology preferentially benefited at-risk students with midlevel performance (i.e., those with a "C" in the first semester), rather than supporting improved outcomes for students already at high levels of performance. These results suggest that Exploring Biology may have its greatest impact on students most at risk for leaving the discipline and therefore is an effective intervention for reducing attrition from biology.

The differential positive impact of Exploring Biology on students who earned a "C" in the first semester of introductory biology may be explained by previously reported results from Hulleman and Harackiewicz (2009). They showed that encouraging students to make connections between science course material and their lives promoted performance for students in science. Importantly, the benefit was isolated to students who had low expectations of success, and no difference was seen in performance for students with high expectations for success. In this experiment, the authors combined the expectancy-value and utility-value models. The expectancy-value model of motivation states that an individual's expectancy to achieve success on a particular task is a predictor of eventual success and is influenced by perceptions of competence and personal goals, among other factors (Eccles and Wigfield, 2002). The utility-value model states that a student's performance is influenced by his or her perception of a topic's usefulness and relevancy to his or her life goals (Eccles *et al.*, 1983). The Hulleman and Harackiewicz experiment (2009) suggested that altering a student's perceived utility of a task influences his or her expectancy to accomplish the task, eventually leading to overall greater success. In addition, further experiments showed that reflecting on the personal relevance of course material is core to the utility-value intervention (Harackiewicz *et al.*, 2016).

Exploring Biology, which includes many activities designed to help students identify their career interests in biology, seek courses and extracurricular activities to support their goals, and reflect on course material to make personal connections, may produce positive outcomes in a similar way. On the basis of the expectancy-value model, a student who earned a "C" grade in the first semester of Introductory Biology would likely have a lower expectation for success in the second semester than a student who earned a "B" or better. Because of the lower expectation for success, the "C" student would be more likely to do poorly in the second semester than a higher-performing student. However, Exploring Biology students who earned a "C" grade in first-semester introductory biology had fewer adverse outcomes than comparison students, which suggests a mediating effect aligned with the expectancy-value model. Also aligned with Hulleman and Harackiewicz's report (2009), high-performing students in Introductory Biology were not impacted by the Exploring Biology intervention. Therefore, we hypothesize that activities completed in Exploring Biology may generate higher utility values for students in Introductory Biology, increasing their motivation and buffering the negative effects of a low-success expectancy value typically resulting from a "C" grade in the first semester.

Adaptation and Implementation of the Exploring Biology Intervention Model

Although Exploring Biology is designed and implemented as a FYS that students take before their introductory biology course, this course could easily be offered concurrently or linked through a first-year interest group with a traditional first-semester, introductory biology course. Alternatively, components of the curriculum could be incorporated directly into a traditional introductory biology course. The institutional context, including both opportunities and constraints, will be an important consideration for those deciding whether and how to use the Exploring Biology curricular materials.

The diverse teaching team in Exploring Biology provided the opportunity for students to interact with the broader scientific community, a key factor shown to contribute to academic integration and retention (Pascarella and Terenzini, 1976; Tinto, 1993). While the availability of a dedicated course director and team of teaching fellow instructors for a new stand-alone course may be limiting at other institutions, the community building in discussion sections could be maintained with regular teaching assistants who have had professional development training. In addition, to ensure students' access to the biological sciences network on a campus, a variety of faculty and professional staff could be invited to give guest lectures and presentations.

Including FYS activities in an introductory biology course may be viewed as competing with biology content and instructor time (Sommers, 1997). Therefore, those who choose to take this approach should aim to integrate, rather than add, the FYS content by refocusing disciplinary content and assignments to encourage orientation to the campus, interaction with the biology community, and exploration of personal interests. For example, instead of teaching students how to write citations, a literature search assignment could be developed in collaboration with library staff to teach students to write citations while simultaneously introducing them to the library as a campus resource and the librarians as members of the disciplinary community. Likewise, a final project could be restricted to research that is being conducted on campus to encourage networking with local faculty members and promote a sense of belonging as students learn about their institution. Beyond these specific suggestions, simply having the biology faculty member teach both the FYS and disciplinary components of the course, rather than inviting a student services professional to teach the FYS components, would maximize integration.

In addition to the impact of the FYS components, we postulate that the positive outcomes in the Introductory Biology course resulted, at least in part, from engagement with the core concepts of *Vision and Change* (AAAS, 2011). Students often identified conceptual examples as useful to their learning (e.g., subdisciplines or complex biological phenomena) when asked to reflect on the course, which suggests that they may have found using the core concepts as a framework to be useful in learning biology. Further studies are underway to assess whether students' conceptual understanding of biology improves after engaging with the framework and whether they adopt and use this framework in Introductory Biology. Regardless of the outcome of these studies, tools are available now to guide integration of the framework into courses. These include the BioCore Guide (Brownell *et al*., 2014) and the Conceptual Elements framework (Cary and Branchaw, 2017), which provide detailed articulations of the core concepts to support the development and organization of instructional materials in any course.

Limitations

Though the evidence that participation in Exploring Biology supports students' transitions to college is strong, the alumni survey response rate was relatively low, and there are factors that were either not examined or beyond our control in this study. For example, though we controlled for academic indicators and demographic factors, true random assignment of students to the Exploring Biology and comparison groups was not possible, and we did not measure student motivation. We addressed the possible impact of differential motivation by using data from the two-semester introductory biology course for majors. However, it still could be that Exploring Biology students are simply intrinsically more motivated, which could account for their increased success and persistence.

Also, we recognize first-year students' experiences are complex, and participation in support programs, such as residential learning communities and FYS courses, can vary considerably from student to student. This makes it very difficult to identify and consider all variables in the evaluation of one particular intervention. Consequently, although we matched students based on their participation in other programs, not all program participation could be accounted for, and some of the benefits measured may be partially attributed to participation in other programs.

CONCLUSION

The course evaluation, alumni survey, and institutional data presented here suggest that the Exploring Biology FYS course supports aspiring first-year biology students' transition to college and future success in an introductory biology course and may serve as a model intervention for other campuses. All of the Exploring Biology curricular materials will be available via CourseSource or upon request. In addition, the authors are available to consult on ways to implement and leverage the course materials and resources (e.g. teaching assistants, other first-year seminars on campus) on other campuses.

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