OTHER FEATURE ARTICLE

Positive Affective and Behavioral Gains of First-Year Students in Course-Based Research across Disciplines

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Abstract

The Freshmen Research Initiative at Iowa State University promotes student interest and retention in science through introductory course-based undergraduate research experiences (CUREs). Successful strategies for the implementation of CUREs on a large scale in an affordable manner included the use of a postdoctoral coordinator and affiliation with student learning communities. Across multiple disciplines, students in single-semester introductory research courses reported personal gains related to research, to thinking and working like scientists, to attitudes and behaviors of a scientist, and to gains in skills as reported on the Undergraduate Research Student Self-Assessment. Key outcomes related to persistence in STEM, including self-efficacy and project ownership, were also suggested as early gains due to course-based research.

Keywords: *course-based research experiences, early undergraduate research, self-efficacy, sense of belonging, science identity*

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Numerous calls for increased undergraduate research experiences at the introductory level have been heard across science, technology, engineering, and math (STEM) disciplines over the past decade (Alberts 2011; President's Council of Advisors on Science and Technology 2012). These calls have been made in response to the high percentage of students who switch out of STEM majors during their first years of college (President's Council of Advisors on Science and Technology 2012). The reasons for switching are not limited to course difficulty but also include lack of interest in classes and little identification with the scientific community (Seymour and Hewitt 1997). Although inquiry and student-centered pedagogies promote engagement with the class material (Freeman et al. 2014), it is research experiences that can provide students with the opportunity to participate in the scientific process firsthand and begin to see themselves as scientists. However, currently only a small percentage of students participate in undergraduate research, and the majority of those experiences are limited to the upper level (Russell, Hancock, and McCullough 2007).

Course-based undergraduate research experiences (CUREs) for first-year students are one approach to providing more students with the opportunity to do science. By framing research within a credit-bearing course, these experiences are made accessible to a larger number and greater diversity of students (Auchincloss et al. 2014; Bangera and Brownell 2014). Further, introduction to research during a student's first year can help students decide whether they want to pursue majors and careers in science, potentially increasing retention. A number of introductory level CUREs have been implemented across STEM majors. For example, the Freshmen Research Initiative at the University of Texas at Austin recently published that retention in STEM majors significantly increased after participation in a three-semester sequence of research beginning in the fall semester of the first year (Rodenbusch et al. 2016). The Science Education Alliance program, Phage Hunters Advancing Genomics and Evolutionary Science (SEA-PHAGES), a one-year course implemented at a number of institutions across the United States, reported significantly improved GPA and retention in STEM majors (Jordan et al. 2014). A study at the University of California, Davis, found that participation in research (not necessarily CUREs) during the first two years of college was just as effective as research during the third or fourth years for increasing biology graduation rates (Jones, Barlow, and Villarejo 2010). Combined, these results indicate that early research experiences may be an effective strategy for retaining students in STEM majors.

Models describing the mechanisms by which CUREs promote persistence in science currently rely on the constructs of student aptitude, self-efficacy, sense of belonging in the scientific community, and science identity (Estrada-Hollenbeck et al. 2011; Graham et al. 2013). The first theoretical model applied to CUREs and persistence in science was presented by Corwin, Graham, and Dolan (2015). In this model, increased self-efficacy, sense of belonging to a larger community, and enhanced science identity are hubs connecting CURE activities to short-, medium-, and long-term outcomes leading to persistence in science (see Figure 1). In this article, gains in self-efficacy, sense of belonging, and science identity due to a one-semester, first-year CURE experience are examined, illustrating a significantly shorter and less expensive implementation of introductory research than has been reported elsewhere.

In addition to persistence, science literacy is a desirable outcome for college graduates, particularly STEM majors. Science literacy is defined as "the capacity to use scientific knowledge to identify questions and to draw evidence-based conclusions in order to understand and help make decisions about the natural world and the changes made to it through human activity" (Organisation for Economic Cooperation and Development 2004). Undergraduate research has been proposed as an effective method for increasing students' science literacy skills and is a goal of many course-based research experiences (Gasper and Gardner 2013; Hensel and Cejda 2014; Murray, Obare, and Hageman 2016; National Academies of Sciences, Engineering, and Medicine 2015; Ross and Bonner 2012; Seymour et al. 2004; Ward and Dixon 2008). Direct measures of scientific literacy skills are only just being established; examples are the Test of Scientific Literacy Skills (TOSLS) (Gormally, Brickman, and Lutz 2012) and the Science Literacy Concept Inventory (Nuhfer et al. 2016). In this work, the TOSLS was used to examine the impact that freshmen CUREs have on science literacy skills.

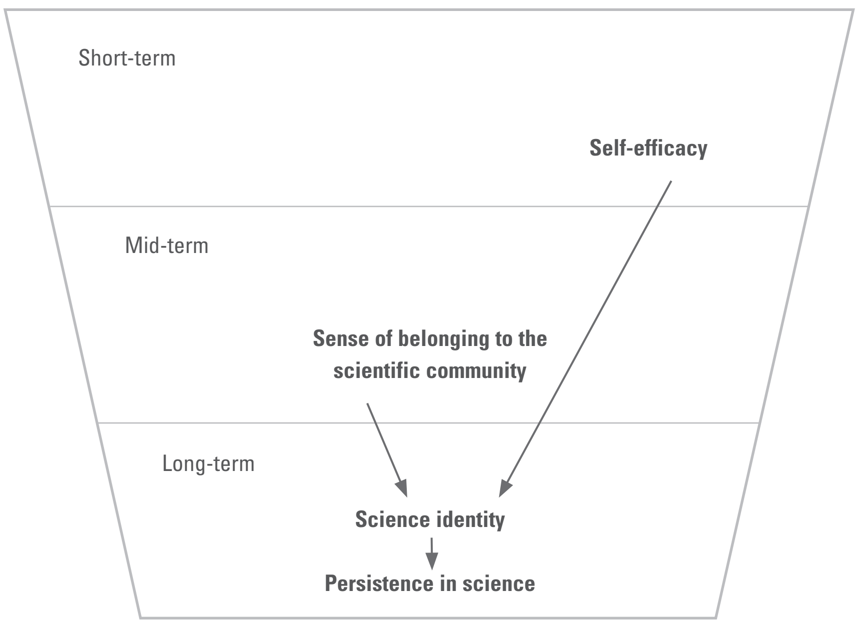
Implementation of CUREs on a large scale within an institution remains a challenge. Staffing, research costs, and curricular integration are hurdles that may arise; the solutions to these issues are often discipline- and departmental-specific. The grass-roots approach at ISU revealed several successful strategies for affordable and sustainable CUREs for a variety of disciplines. This article summarizes those strategies.

Methods

Program Structure

Iowa State University (ISU) is a research-intensive, land-grant university with close to 36,000 students and a strong

FIGURE 1. Model of CURE Outcomes Leading to Persistence in Science (adapted from Corwin, Graham and Dolan [2015] and categorized by development over time)



emphasis on STEM. As part of an extensive project, funded by the Howard Hughes Medical Institute (HHMI), to transform science education, authentic research experiences have been incorporated into more than 30 courses across different disciplines with the support of a faculty learning community (Cervato et al. 2015). In the past few years, this faculty learning community has focused specifically on first-year CUREs by implementing the Freshmen Research Initiative (FRI) at ISU.

The FRI is a multidisciplinary program that, as of spring 2017, has created 13 courses, or research streams, within multiple colleges, including liberal arts and sciences, engineering, and human sciences (see Table 1). The FRI was directed by the principal investigator of its supporting grant and coordinated by a grant-funded postdoctoral fellow. Fifty percent of the postdoctoral fellow's time was directed toward support of the FRI program, with the remainder of her time available for research in her discipline supervised by a faculty member at Iowa State University.

Responsibilities of this coordinator position included creation and distribution of a call for proposals for new first-year CUREs in the program and meetings one-on-one with instructors to discuss course design. The postdoctoral coordinator met monthly with the program director to report on the progress of the FRI. With her support, faculty designed the courses centered around their research interests or topics that would be appealing to students, using guidelines described by Auchincloss and colleagues (Auchincloss et al. 2014). These guidelines define the following characteristics of course-based research: scientific practices, discovery, relevance, collaboration, and iteration.

TABLE 1. Freshman Research Initiative across Three Colleges

Course	Semester[a]	Class size 2016	Gender (M/F)[b]	Class size 2017	Gender (M/F)	Learning community
College of Liberal Arts and Sciences						
Stem Cells for Neuroregeneration	S	10	1/9	12	1/11	
Insect BioBlitz	S	–	–	10	5/5	
IOWATER	S	16	10/6	22	15/7	X
Antibacterial Agents	S	–	–	8	5/3	
Sky's the Limit	S	6	1/5	4	2/2	X
College of Engineering						
Innovation Makers	S	15	12/3	9	5/4	
Safe and Efficient Transportation	F	–	–	34	29/5	X
Environmental Engineering	F	–	–	12	8/4	X
Biomaterials for Diabetes	S	–	–	10	5/5	
Engineering Education	S	–	–	4	2/2	
Biorenewable Resources[c]	S	11	7/4	15	9/6	
College of Human Sciences						
Dancing for Parkinson's	S	–	–	7	1/8	
Physical Activity Programs	S	–	–	3	0/3	
Total		58	31/27	150	87/65	

Note: [a]S = spring and F = fall
[b]M = male and F = female
[c]Co-listed in College of Engineering and College of Liberal Arts and Sciences

Instructors were encouraged to include as many of these CURE components as possible. Flexibility in course design and implementation into the curriculum were important features of the program. Each course was designed to fit the strengths and constraints of its discipline and departmental context, and to keep costs manageable so that it could be sustained using departmental operating funds.

The courses last a single semester, range from one to two credits, and were typically taught by tenured faculty assisted by graduate students from their research labs and undergraduate peer mentors. Almost all research streams included undergraduate peer mentors, either paid or earning research credit for their involvement in the course. These courses contributed to first-year students' set of electives (that is, the courses were not required and did not replace required introductory science labs).

Four research streams were affiliated with first-year learning communities. Learning communities at ISU vary in structure and can include linked courses, learning clusters, first-year interest groups, and shared residence halls (Cervato and Flory 2015). For students of similar academic majors, the learning communities facilitate the building of relationships, exploring of careers, and learning about university resources; they also provide peer mentoring. The learning communities that implemented course-based research either repurposed existing fall courses or created new research courses in the spring semester. Learning community coordinators co-taught these courses.

Most research streams were an open lab format with mandatory weekly or biweekly meetings. Classes at the beginning of the semester introduced the research topic and allowed students to learn experimental techniques. All students worked on a research project that investigated novel questions and generated new data. Research experiences in the FRI included wet bench, fieldwork, or big-data analysis. Many courses included lessons on reading scientific literature and experimental design. Midway through the semester, students were often placed in groups to research their topic and conduct experiments. Having students design experiments themselves was not a component of all courses. The group format continued through the last half of the semester, during which students collected and analyzed data. At the end of the semester, streams were invited to have their teams of students present their work at the FRI Symposium in poster format. Ten of the thirteen courses had students present their work at the symposium.

Learning Goals

Although the learning goals in relation to course content varied across courses, goals for gains in students' science skills that were common to all courses included building quantitative reasoning, enhancing scientific literacy, keeping a lab notebook, and preparing a scientific poster. Instructors all sought to provide students with opportunities to engage in novel research, feel like scientists, and explore scientific careers.

Faculty were supported in reaching their course and program goals by meetings with the postdoctoral coordinator and the opportunity to participate in an HHMI-funded faculty learning community that met regularly. Topics of this community included best practices for integrating the CURE goals of scientific practices, discovery, relevance, collaboration, and iteration, along with the use of big data in research courses. Graduate student teaching assistants were also offered participation in a FRI teaching assistant learning community facilitated by the postdoctoral coordinator, with similar themes. At the end of each semester, faculty met with the coordinator to review the results of student assessment for their class and to discuss sustainability approaches.

Student Population

Students were recruited to the FRI program by undergraduate advisers and through short presentations at introductory science classes, learning communities, or student organizations. Students enrolling in FRI courses were mainly first-year students, with a small percentage transferring to ISU from other institutions. During the 2015–2016 academic year, 58 students participated in the program. For the 2016–2017 academic year, 150 students enrolled in a FRI course. Majors included were biology, chemical engineering, electrical engineering, genetics, geology, kinesiology, and meteorology. The number of male and female students was about equal for both iterations (see Table 1). Underrepresented minority students represented 12 percent and 5 percent of those enrolled during the first and second year, respectively. First-generation college students were 21 percent and 29 percent of those enrolled during the first and second year, respectively.

The goal number of students for each research stream was equivalent to the size of a lab section, typically 20–35 students; not all courses reached this capacity. Many research streams began with a smaller size for the first year with intentions to expand in future iterations. Across 2015–2016 and 2016–2017, 207 students participated in the FRI program.

Assessment

The impacts of participation in the FRI were measured using the Undergraduate Research Student Self-Assessment (URSSA) during the 2015–2016 and 2016–2017 years (Weston and Laursen 2015). This tool measures student self-reported gains in several constructs: "Thinking and Working Like a Scientist," "Personal Gains Related to Research Work," "Gains in Skills," and "Attitudes and Behaviors of a Researcher." The questions for the constructs of “Personal Gains Related to Research Work,” “Thinking and Working Like a Scientist,” and “Gains in Skills” were on a Likert-style scale. The scale ranged from 1 = no gains to 5 = great gain. The items for the construct “Attitudes and Behaviors of a Researcher” were also on a Likert-style scale. Students responded with 1 = none, 2 = a little, 3 = some, 4 = a fair amount, and 5 = a great deal. Satisfaction items were also included in the URSSA to provide instructors with feedback about mentoring, facilities, and the overall experience. The instrument was administered online through Qualtrics at the end of the semester. Items relating to stipend and visiting researchers were removed from the original survey instrument, as they were not relevant to this FRI implementation. Questions were added to gather student identification numbers and research stream participation so that individual responses to different streams and student demographics could be matched. Items were also added relating to participation in learning communities. The modified survey is available by request. Survey participation was facilitated by course instructors at their discretion, either for extra credit (four courses) or voluntarily (nine courses), and students were given the choice to opt out of the survey.

Student gains in scientific literacy were measured using the Test of Scientific Literacy Skills (TOSLS) (Gormally, Brickman, and Lutz 2012) during the 2016–2017 year, using a pretest and posttest format. The complete instrument contains 30 multiple-choice questions measuring nine constructs related to student understanding of methods of inquiry leading to scientific knowledge and the ability to organize, analyze, and interpret quantitative data and scientific information. In previous local usage of TOSLS, students took an average of 44 minutes to complete TOSLS at the start of the semester and an average of 15 minutes at the end of the semester. The decrease in completion time is consistent with students rushing through the instrument. This led to the decision to reduce the number of constructs but keep all the questions within the retained constructs. The five selected constructs included (1) create graphical representations of data; (2) read and interpret graphical representations of data; (3) solve problems using quantitative skills, including probability and statistics; 4) understand and interpret basic statistics; and (5) justify inferences, predictions, and conclusions based on quantitative data. A test of attention was inserted partway through the survey to identify students who were completing the items without reading them. The question read, “Researchers found that chronically stressed individuals have significantly higher blood pressure compared to individuals with little stress. It is important to read questions carefully. The answer to this test question is B.” The first sentence of this question is exactly the same as the first sentence of an earlier question on the survey. Students who did not answer B to this item were excluded from analysis. The modified TOSLS survey is available by request.

Student identification numbers were used to match pretest and posttest results for each individual, as well as to match student information collected from other assessments. A question was also added to determine the research stream in which the students participated. The TOSLS survey was administered via Qualtrics during the first week and again the last week of the semester. Due to the small sample size of some newly formed courses, survey data from the TOSLS were combined from all courses in the FRI during the 2016–2017 academic year to strengthen statistical results. As with the URSSA, instructors were given the option to provide extra credit for completing the survey. Students were given the option to complete the survey for extra credit while excusing themselves from the study. This research was reviewed by the Iowa State University Institutional Review Board and declared exempt from full review (IRB ID: 15-712).

Results

Program Structure

Association with learning communities was found to facilitate enrollment and instruction of CUREs at ISU (see Table 1). The centralized support for learning communities at this institution provides advisers and peer mentors who promote a sense of belonging for first-year students from various disciplines and interests. Advisers who coordinated the learning communities co-taught the courses to reduce faculty load. Peer mentors who also have established relationships with the students support course instruction. Learning community courses are traditionally held in the fall semester and provide students with the resources to build relationships, discover the college campus, and explore career options. However, few activities are held during the spring semester. Several FRI courses developed in association with a learning community were held in the spring semester, which allowed a natural transition for students to this experience.

STEM Persistence

Persistence in STEM of the 58 students who were STEM majors and who participated in the spring 2016 FRI was determined in fall 2017, over one year later, to be 83 percent (see Table 2). In comparison, retention at ISU and with a STEM major over the same time period was 75 percent for the general population. One-year retention was comparable for male and female students. Persistence in STEM was lower at 71 percent for the small number of underrepresented minority students (African American, Hispanic, Native American, and Pacific Islanders) and for first-generation students at 69 percent.

Persistence in STEM of 101 students who participated in the spring 2017 FRI was determined one year later to be 90 percent (see Table 2). In this cohort of the FRI program, the retention of females in STEM majors was

TABLE 2. One-Year Retention in STEM Majors of Spring 2016 and 2017 Participants, Freshman Research Initiative

	Total		Male		Female		URM		First generation	
2016 retention	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**
STEM major	48	83	29	83	19	83	5	71	11	69
Non-STEM	3	5	2	6	1	4	0	0	1	6
Left ISU	7	12	4	11	3	13	2	29	4	25
Total	58		35		23		7		16	
2017 retention	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**
STEM major	91	90	41	85	50	94	5	71	8	89
Non-STEM	4	4	2	4	2	4	1	14	1	11
Left ISU	6	6	5	10	1	2	1	14	0	0
Total	101		48		53		7		9	

Note: URM = underrepresented minority

higher than that of males (94 percent versus 85 percent). Seventy-one percent of underrepresented minority students remained at ISU with STEM majors. Persistence in STEM of first-generation students was comparable to other groups at 89 percent.

Undergraduate Research Student Self-Assessment (URSSA)

Four courses offered extra credit for survey completion, with an average response rate of 71 percent. Of the remaining courses, 36 percent of students responded to the URSSA survey. All the courses have been combined for presentation of the URSSA results, which will be discussed in the context of its constructs. Students were asked to self-report their gains after the end of the FRI experience. Positive gains were high among all constructs: “Personal Gains,” “Thinking and Working Like a Scientist,” “Attitudes and Behaviors of a Researcher,” and “Gains in Skills.” The greatest gains were observed in the “Personal Gains” and “Thinking and Working Like a Scientist” constructs (see Tables 3 and 4, respectively), which were significantly higher than those of “Attitudes and Behaviors of a Researcher” and “Gains in Skills.”

The “Personal Gains” construct measures affective gains related to confidence, comfort, and self-efficacy (see Table 3) in students’ ability to conduct scientific research, comfort performing research in a collaborative environment, and confidence to work independently in the lab. As a whole, participants indicated moderate to good “Personal Gains.” Of note, comfort working collaboratively and communicating science were outcomes that scored highly among “Personal Gains.”

The “Thinking and Working Like a Scientist” construct also showed high gains (see Table 4). This construct measures reported gains in understanding the process of scientific research, the nature of science, and scientific practices. Items ask students to report their gains in identifying the limitations of scientific research, how knowledge and skills are applied in research, and how research questions are designed. Overall, students indicated good gains in “Thinking and Working like a Scientist.” Experimental design and problem solving were some of the highest reported gains within this category.

The construct “Attitudes and Behaviors of a Researcher” asked students about gains associated with working in a scientific community, including thinking creatively about the research, performing research independently, and sense of responsibility for the project (see Table 5). This construct contained items related to a sense of belonging to the scientific community and science identity (i.e., some of the measures included in the model of student benefits derive from conducting authentic research versus “cookbook” lab experiences). Participants indicated that their experience in the FRI led to some to a fair amount of gains in “Attitudes and Behaviors of a Researcher.” Project ownership was apparent as a major gain within this category.

The “Gains in Skills” construct measured student gains in skills relating to science labwork, including scientific

TABLE 3. Personal Gains Related to Research Work

Personal gains	2015–2016			2016–2017			All years		
	Mean	SD	N	Mean	SD	N	Mean	SD	N
Comfort in working collaboratively with others	3.76	1.09	49	4.26	0.91	80	4.07	1.01	129
Comfort in discussing scientific concepts with others	3.71	1.26	49	4.20	0.78	81	4.02	1.01	130
Taking greater care in conducting procedures in the lab or field	3.73	1.30	49	4.15	0.98	79	3.99	1.13	128
Confidence in my ability to do well in future science courses	3.47	1.36	49	4.17	1.02	82	3.91	1.20	131
Understanding what everyday research work is like	3.65	1.44	49	4.06	1.05	81	3.91	1.22	130
Ability to work independently	3.76	1.27	49	3.99	1.03	81	3.90	1.13	130
Confidence in my ability to contribute to science	3.48	1.34	48	4.09	0.92	82	3.86	1.13	130
Developing patience with the slow pace of research	3.71	1.30	48	3.91	0.99	79	3.84	1.12	127
Total	29.87	8.44	47	32.96	6.14	47	31.75	7.25	120

Note: Student responses to the prompt, "How much did you GAIN in the following areas as a result of your most recent research experience?", with 1 = no gains, 2 = a little gain, 3 = moderate gain, 4 = good gain, 5 = great gain. Total score out of 40. SD = standard deviation.

TABLE 4. Thinking and Working Like a Scientist: Application of Knowledge to Research Work

Thinking and working like a scientist	2015–2016			2016–2017			All years		
	Mean	SD	N	Mean	SD	N	Mean	SD	N
Figuring out the next step in a research project	3.82	0.99	49	4.20	0.94	82	4.05	0.98	130
Formulating a research question that could be answered with data	3.84	1.28	49	4.14	0.96	80	4.02	1.10	129
Problem-solving in general	3.76	1.18	49	4.11	1.05	82	3.98	1.11	131
Understanding the theory and concepts guiding my research project	3.82	1.22	49	4.06	0.99	81	3.97	1.09	130
Identifying limitations of research methods and designs	3.63	1.18	49	4.15	0.92	80	3.95	1.05	129
Understanding the relevance of research to my coursework	3.57	1.49	49	4.11	1.16	81	3.91	1.31	130
Understanding the connections among scientific disciplines	3.69	1.19	49	3.89	1.12	82	3.82	1.15	131
Analyzing data for patterns	3.47	1.14	49	3.73	1.11	80	3.63	1.12	128
Total	29.59	8.33	49	32.25	6.52	76	31.21	7.37	125

Note: Student responses to the prompt, "How much did you GAIN in the following areas as a result of your most recent research experience?", with 1 = no gains, 2 = a little gain, 3 = moderate gain, 4 = good gain, 5 = great gain. Total score out of 40. SD: standard deviation.

TABLE 5. Attitudes and Behaviors of a Researcher

Attitudes and behaviors	2015–2016			2016–2017			All years		
	Mean	SD	N	Mean	SD	N	Mean	SD	N
Feel responsible for the project	4.14	1.14	49	4.38	0.82	79	4.29	0.96	128
Think creatively about the project	3.86	1.17	49	4.18	1.00	80	4.05	1.08	129
Engage in real-world science research	3.63	1.20	49	4.10	1.06	80	3.92	1.14	129
Feel like a scientist	3.63	1.42	49	3.91	1.26	81	3.81	1.32	130
Try out new ideas or procedures on your own	3.16	1.37	49	3.77	1.19	78	3.54	1.30	127
Work extra hours because you were excited about the research	3.20	1.53	49	3.74	1.17	81	3.54	1.34	130
Feel a part of a scientific community	3.25	1.33	48	3.51	1.27	79	3.41	1.29	127
Interact with scientists from outside your school	1.89	1.28	45	2.17	1.47	71	2.06	1.40	116
Total	26.64	8.246	44	29.81	6.68	68	28.56	7.46	112

Note: Student responses to the prompt, “During your research experience HOW MUCH did you:”, with 1 = none, 2 = a little, 3 = some, 4 = a fair amount, 5 = a great deal. Total score out of 40. SD = standard deviation.

writing, presenting orally, and conducting observations in the lab or field (see Table 6). Moderate gains in skills relating to research were reported, with the top items related to communicating science.

The URSSA also contains questions related to student career goals in STEM. Students were asked how well the FRI clarified their career goals and prepared them for futures in STEM. Eighty-eight percent of first-year students agreed or strongly agreed that the course confirmed interest in their fields of study (Mean = 3.1, SD = 0.8, N = 81), and 90 percent agreed or strongly agreed that it prepared them for advanced coursework (Mean = 3.14, SD = 0.61, N = 81). Seventy-nine percent agreed or strongly agreed that the research experience prepared them for a job (Mean = 3.01, SD = 0.77, N = 81). Another set of questions examined how much more likely students were to pursue education and careers in STEM. First-year students were slightly more likely to be interested in a master’s program in science, mathematics, or engineering (Mean = 2.9, SD = 1.35, N = 78) and work in a science lab (Mean = 2.82, SD = 1.4, N = 78). Almost 50 percent of students indicated a previous intention of pursuing advanced degrees in science, and 35 percent said they were more likely to pursue advanced degrees (N = 40).

Open-ended questions allowed students to provide feedback on the FRI program. The most frequently mentioned feature was the length of the course, with students requesting more time to perform research. They also suggested greater publicity for the program, indicating that more students should learn about this opportunity. When asked about any additional gains not listed in the survey, the most common theme was related to working with others.

URSSA data were also analyzed according to gender and underrepresented minority status, with few to no significant differences observed on the URSSA. Among the areas that showed differences, female students were significantly less likely to pursue certification as a teacher ($p = 0.0013$, N = 66 males, 56 females, Mann-Whitney test) and underrepresented minority (URM) students indicated that they felt like a scientist during their research experience significantly more than non-URM students ($p = 0.0499$, N = 10 URM, 120 non-URM, Mann-Whitney test), although the number of URM students in this analysis was quite low.

Test of Scientific Literacy Skills (TOSLS)

TOSLS asks students to directly demonstrate their understanding of methods of inquiry leading to scientific knowledge and to organize, analyze, and interpret quantitative data and scientific information. The response rate for both the pre- and post-TOSLS was 18 percent. Seventy-three percent of students answered the test of attention on the pre-TOSLS, and 96 percent answered correctly on the posttest. Students answering the test of attention incorrectly were removed from future analysis.

TABLE 6. Gains in Skills

Gains in skills	2015–2016			2016–2017			All years		
	Mean	SD	N	Mean	SD	N	Mean	SD	N
Preparing a scientific poster	3.96	1.19	49	4.14	1.07	71	4.07	1.12	120
Explaining my project to people outside my field	3.67	1.17	46	4.04	0.93	78	3.90	1.04	124
Conducting observations in the lab or field	3.57	1.25	47	3.75	1.09	77	3.69	1.15	124
Conducting database or internet searches	3.38	1.21	47	3.80	1.12	76	3.64	1.17	123
Managing my time	3.35	1.28	49	3.78	1.16	80	3.61	1.22	129
Making oral presentations	3.17	1.19	48	3.78	1.18	80	3.55	1.22	128
Writing scientific reports or papers	3.10	1.37	48	3.79	1.04	78	3.53	1.22	126
Understanding journal articles	3.24	1.48	45	3.68	1.09	74	3.51	1.26	119
Using statistics to analyze data	3.07	1.31	46	3.68	1.27	74	3.44	1.31	120
Keeping a detailed lab notebook	3.39	1.51	46	3.40	1.30	73	3.40	1.38	119
Calibrating instruments needed for measurement	2.93	1.21	44	3.67	1.32	72	3.39	1.32	116
Working with computers	2.79	1.32	48	3.68	1.24	79	3.35	1.34	127
Defending an argument when asked questions	3.10	1.01	49	3.49	1.06	74	3.33	1.05	123
Total	42.42	12.84	38	49.2	11.02	59	46.55	12.17	97

Note: Student responses to the prompt, “How much did you GAIN in the following areas as a result of your most recent research experience?”, with 1 = no gains, 2 = a little gain, 3 = moderate gain, 4 = good gain, 5 = great gain. Total score out of 65.

The mean pre-TOSLS score for 2016/17 was 8.74 (out of 13 possible, removing the test of attention item), with SD = 2.88 and N = 50. The mean post-TOSLS score was 8.78 (SD = 3.08, N = 46), which is not significantly different from the pre-TOSLS mean score. No significant difference was observed using an unpaired or paired *t*-test, and no significant changes were observed for the individual constructs within TOSLS. Disaggregating the data by either gender or research stream also did not reveal significant changes in pretest to posttest scores for these groups of students. The TOSLS is not discipline-specific, so it may be that instruments within each discipline represented in the FRI must be used to achieve an accurate representation of student gains in these skills.

Discussion

Support of the FRI program by a postdoctoral coordinator was found to be a successful, affordable strategy, with the program expanding from three to 13 courses within three years. One-on-one discussions with faculty on course design and sustainability allowed for flexible implementation of the FRI along with identification and distribution of best practices. Course development in association with learning communities also provided essential instructional assistance through advisers and peer mentors. Future topics of research could include gains achieved by the peer mentors and graduate teaching assistants participating in the program. Also, many participating students expressed their appreciation of the experience as a way to better understand the subject studied and to enhance their laboratory skills.

Retention of STEM Majors

The one-year retention of first-year STEM majors participating in the spring 2016 FRI was 83 percent and 90 percent for participants in the spring 2017 FRI. Both are larger returns compared to the overall baseline STEM one-year retention of 78 percent for 2016 at Iowa State University. Self-selection is likely a contributing factor to the larger retention. With more data in future years, the retention of a matched sample will be compared. Analysis of the reasons why students leave STEM following participation in the FRI program would also be a useful goal in the future.

URSSA

In general, students indicated good gains across all areas assessed by the URSSA instrument, with the constructs "Personal Gains" and "Thinking and Working Like a Scientist" with the highest reported outcomes. The key factors (Figure 1) that are modeled for persistence from CURE participation are distributed across a few constructs in the URSSA. The paragraphs that follow discuss students' self-reported gains for those specific questions in the URSSA that relate to self-efficacy, sense of belonging, and science identity (see Figure 1).

Self-Efficacy

The URSSA construct on "Personal Gains Relating to Research Work" contained the most items relevant to science self-efficacy, with students indicating good gains in "confidence in my ability to do well in future science courses" and "confidence in my ability to contribute to science" (see Table 3). Items relating to academic and career preparation are also indicative of confidence, with students agreeing that their research experience prepared them for advanced coursework or thesis work. Additional items asking whether the research experience prepared them for graduate school or a job did not score as high, likely because not all first-year STEM majors are thinking yet about graduate school, and career plans after graduation can seem a long way off to a first-year college student.

These gains in confidence are a positive outcome for a single-semester FRI program. Similar results have been observed in other single-semester research courses at both the introductory and upper levels (Baumler et al. 2012; Kloser et al. 2013; Olimpo, Fisher, and DeChenne-Peters 2016; Shanle, Tsun, and Strahl 2016; Siritunga et al. 2011; Unrau and Grinnell 2005; Wang et al. 2015). Self-efficacy is also expected as a first positive outcome from an undergraduate research experience (Corwin, Graham, and Dolan 2015). Structural equation modeling of participants in an undergraduate research program (not a research course) showed that the effects of research skills on persistence in science are mediated by self-efficacy beliefs (Adedokun et al. 2013).

Related to self-efficacy is ownership, here defined as students taking responsibility for their project. "Project ownership" was the top scoring item measured on the URSSA. Located within the "Attitudes and Behaviors of a Researcher" construct, students reported feeling responsible for the project (see Table 5). Other items relating to project ownership, such as working extra hours because they were excited about the project and trying out new ideas or procedures on their own, however, had only average self-reported gains (see Table 5).

Belonging to the Scientific Community

Several factors show that the FRI experience has a positive impact on students' belonging. The second highest-scoring item within the URSSA concerned comfort working collaboratively with others (see Table 3). The majority of FRI courses included some form of group work. In addition, when students were asked to list additional gains not included in the URSSA, teamwork skills were a common feature. The majority of FRI courses included undergraduate peer mentors and the amount of time spent interacting with graduate students and/or faculty varied among courses. Items on the URSSA relating to time spent with the research mentor are complicated by the fact that some courses were primarily led by graduate students and postdoctoral scholars, whereas others had more faculty involvement.

The URSSA contains a question that directly asks about a sense of belonging to the scientific community (see Table 5), found within the construct "Attitudes and Behaviors of a Researcher." Students somewhat agreed to feeling like they belonged in the scientific community. First-year students had some opportunity for external validation from members of the scientific community during the FRI Symposium, in which students presented posters summarizing their research. Faculty and students alike commented that preparing for the poster session greatly enhanced their understanding of their research project. However, further sources of external validation listed on the survey, such as authorship on a publication, conference attendance, or awards based upon their research, did not occur due to the short duration of the research experience.

The construct of belonging to a scientific community is a main hub within the Corwin model of STEM persistence, but it is not an immediate product of research activity (Corwin, Graham, and Dolan 2015). Rather, sense of community is developed over time due to collaborative experiences and external validation by the scientific community. The one-semester FRI experience may be too short to achieve more than a moderate sense of belonging. A sense of belonging to the scientific community is often a component within constructs of science identity (Estrada-Hollenbeck et al. 2011), which is not observed until after a whole year of research (Robnett, Chemers, and Zurbriggen 2015). This supports the possibility that students in the FRI had not yet achieved a significant sense of belonging in the scientific community after one semester of research.

Science Identity

The URSSA instrument contains one item on science identity, with students indicating that they felt like a scientist only a fair amount during the research experience (see Table 5). It is difficult to identify the degree to which sense of belonging is intertwined with identity. "Identification occurs when an individual accepts influence from another person or a group in order to establish or maintain a satisfying self-defining relationship to the other" (Kelman 2006, 3–4). The model proposed by Corwin, Graham, and Dolan (2015) posits science identity as a late outcome of course-based research, suggesting that a single semester of first-year research is insufficient to make significant gains in science identity.

Limitations

Curricular integration remains an area of growth for the FRI program. Some courses were affiliated with learning communities, whereas other courses were offered as advanced electives. Students traditionally enroll in such courses during the last years of their undergraduate education when their schedules are more open. Additionally, departments provide little instructional support for advanced electives, such as graduate teaching assistant lines. FRI courses that rely on graduate students are continuing to search for strategies to sustainably support teaching assistants.

Student self-selection is a limitation for assessment of the FRI program. In future iterations of the FRI, with broader curricular integration of the courses, student composition is likely to include a wider range of abilities and interest levels. This will allow for a better assessment of student gains due to introductory course-based research. Finally, the URSSA instrument is administered only at the end of the semester. Pre- and post-surveys would provide stronger evidence of student gains. Future assessment of outcomes relating to self-efficacy, sense of belonging to the scientific community and science identity would be better measured with instruments with multiple items addressing these constructs.

Among similar implementations at other universities, the Howard Hughes Medical Institute grant supported the initiation of first-year CUREs by providing funds for research supplies and equipment, graduate teaching assistants, and salary for the postdoctoral coordinator. Consequently, during the last year of grant support, a university committee was initiated by the associate provost for academic affairs to investigate the potential for an office of undergraduate research at ISU that would include continuation of the FRI.

Conclusion

The Freshmen Research Initiative at ISU has provided an opportunity for grassroots development of successful CURE implementation strategies. The implementation of first-year research experiences in association with learning communities was found to provide instructional support and build upon retention efforts ongoing in the communities. The FRI program also allowed for the first effort at investigating affective and behavioral gains after a CURE targeted to first-year students across a range of contexts and disciplines. After a single semester of research, students reported good gains relating to research, and thinking and working like scientists. Assessment data suggest that students experienced gains in self-efficacy and project ownership, outcomes that are predicted to support persistence in STEM.

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