Jump Starting Research: Preresearch STEM Programs

By Kimberly R. Schneider, David Bahr, Susan Burkett, John C. Lusth, Shelley Pressley, and Neyda VanBennekom

There are many benefits to getting students involved in research early in their career. However, first- and second-year students are often unaware of the research process and have no experience interacting with faculty, especially at large institutions. Three different course models devoted to preparing science and engineering students for successful research endeavors were offered at three research institutions. Goals of this work include (a) involving students early in their academic career so they can gain the most out of subsequent research experiences and (b) providing basic skills to make the transition into the research environment easier. These preresearch course models include a semester-long seminar, a 1-week faculty-led "boot camp," and an intense 3-day peer mentor led course. A pre- and posttest have been developed to help with the evaluation of the project. Results show similar gains in conceptual awareness between each course format and at each institution. This suggests that the educational models may be transferrable and easily adopted. Additionally, survey data indicate that students completing the program have a high placement into research experiences within 1 year of completing the course. Since 2011, over 500 science and engineering preresearch students have completed the courses through this collaboration.

Undergraduate engagement in research is one of several high-impact practices for enhancing student success (Boyer Commission, 2003; Kuh, 2008). The benefits are numerous; participants gain a deeper understanding of their field of study, critical thinking and communication skills, networking opportunities, and an increased probability of moving into graduate education (Hathaway, Nagda, & Gregerman, 2002; Kardash, 2000; Lopatto, 2007; Russell, Hancock, & McCullough, 2007). These benefits are enhanced when students move into research early in their undergraduate careers. Evidence supports the idea that early engagement in research can result in increased retention and GPA when paired to a matched control group (Craney et al., 2011; Nagda, Gregerman, Jonides, Von Hippel, & Lerner, 1998; Schneider, Bickel, & Morrison-Shetlar, 2015).

Many universities have early access research programs. For example, the Undergraduate Research Opportunity Program (UROP) at the University of Michigan (UM) has an extremely successful program for first-time-in-college (FTIC) and transfer students that was initiated in 1988. Students apply before their arrival on campus; the program moves hundreds of students directly into research as they matriculate to the university. The 2014–2015 academic year has approximately 1,300 students participating. Using the UM model, the Florida State University (FSU) UROP was developed in 2012. Two hundred students participated in 2014. On a smaller scale, the University of Central Florida (UCF) launched the L.E.A.R.N. in 2011, a FTIC undergraduate research living–learning program, to create a research science, technology, engineering, and mathematics (STEM) pipeline for 28 participants (Schneider et al., 2015). UM and FSU's UROP and UCF's L.E.A.R.N. are yearlong commitments, and students accept positions before coming to campus.

Programs that pipeline students into research early are beneficial, especially for students who are ready to make a commitment to research. However, some students may not be ready; they often lack confidence and understanding of the research process prior to arriving on campus. Once on campus, students' interests are often sparked when they talk to faculty, academic advisors, and/or peers about engagement in research. Offering programs that *introduce* students to research is one mechanism to help students make informed decisions about the level of engagement, if any, in terms of research commitment. Preresearch programs introduce students to academic research while teaching them general research skills.

This type of "research-oriented" approach (Healey, 2005; Healey & Jenkins, 2009) has students acquiring skills before becoming active research participants instead of acquiring them as they are conducting research (Elsen, Visser-Wijnveen, Van, & Van Driel, 2009). Programs like UROP and L.E.A.R.N. have one-credit courses that coincide with the research experience. Some content may be similar, but commitment levels for

the students and from the university are very different.

For many student populations (e.g., first generation, transfer, underrepresented) a preresearch program can be extremely beneficial. Student confidence in approaching faculty can be low, especially at large institutions (first author, personal observation), and preresearch instruction provides students with a safe place to explore the research process. Many undergraduate research programs are time-consuming and have high expectations (e.g., honors thesis, full-time summer program). Preresearch programs enable students to make an educated decision regarding their path into research. Some students may quickly determine that research is not what they thought it would be or that they do not have adequate time to devote to a position. This early decision can save the university, faculty, and students' valuable time and funds.

Undergraduates who complete a preresearch program should be better prepared for participating in research. Thus, this may decrease the training period for new researchers and allow faculty to invite additional students to their research team.

This article describes a collaboration between multiple research institutions for development, strengthening, and adapting preresearch courses for STEM majors. There is a continued push to retain and train more STEM students for a competitive workforce (President's Council of Advisors on Science Technology, 2012), and research experience is an important tool to support training and retention (Hathaway et al., 2002, Nagda et al., 1998; Schneider et al., 2015). Three partnering institutions developed a program called Enhancing Undergraduate Research Opportunities (EURO). From 2012–2014, each institution implemented or expanded three STEM preresearch courses in different formats. This article describes (a) how to implement and/or expand courses at three different universities to provide framework and best practices for other institutions, (b) strengthening the course materials through student feedback and a multiuniversity partnership, and (c) documenting participants' success after leaving the program.

Preresearch course overview

Three existing course formats served as the program models and include (see Table 1): a peer-mentor short course (PMSC), a faculty-led boot camp (FLBC) and a semester-long seminar (SLS). Since 2004, UCF has offered the PMSC. The PMSC is a 3-day, one-credit course created to promote transfer and first-year student awareness about the possibility of research involvement as they move into a large research institution

TABLE 1

An overview of the three models of preresearch courses held at all three institutions.

	FLBC	PMSC	SLS
Originally developed	1 week: Washington State University (since 2007)	3 day: University of Central Florida (since 2004)	Full semester: University of Wisconsin–Madison (Cadwell et al., 2009)
Model overview	Paid experience, 40 hours in one week, workshop style	One pass/fail credit during the summer, 2.5 days, 20 hours (pre- and postclass assignments), roundtable style	One credit (fall or spring), weekly 60–90 minute, online lecture with in-class discussion
Unique features	Very close group, created a research poster, mock interview completed, invited research presenters	Lab and research visits, student research poster showcase, work in small groups with a peer mentor	Online modules in original version. For adaptation, focuses on creating a literature review through a step-by-step process, students attend research seminars around campus
Number of participants	20 (STEM only)	100 (50% STEM, 50% other disciplines)	30 (STEM only)
Taught by	One instructor with guest lectures	Peer mentors with small groups, lectures by guest speakers and the instructor	One instructor with guest lectures and video/internet lectures
Instructor comments	Week before fall or after spring classes seems ideal, busy week but over quickly, builds community	Ideal for transfer and nontraditional students, organizing is time-consuming, able to offer to high numbers of students, builds community	Fits into traditional schedules, easiest to implement with no centralized undergraduate research office

Note: FLBC = faculty-led boot camp; PMSC = peer-mentor short course; SLS = semester-long seminar.

FIGURE 1

Examples of the peer-mentor short course at Institution #1.

(see Figure 1), with 100 participants. Peer mentors who are advanced undergraduate researchers work with small discipline-specific groups in workshop-style sessions mixed with a series of short lectures. A similar style 1-week event, the FLBC, was created at Washington State University (WSU) in 2007. This program is geared toward rising sophomores and consists of 10 half-day modules with short faculty-led instruction, followed by activities or group assignments and a reporting back activity. The target size for FLBC is 20–30 students. The University of Wisconsin–Madison has a one-credit SLS, developed in Engineering Physics, with their Materials Research Science and Engineering Center faculty and staff providing research training (Cadwell, Zenner, Chesler, & Crone, 2009). A review of these three models can be found in Table 1 and are described in more detail in Burkett, Lusth, Bahr, Pressley, and Schneider, 2013.

In our work, STEM majors are the target audience. The goal is to attract students with diverse majors, early in their undergraduate careers, at a large research institution so that students can learn about research opportunities within their major and in other STEM disciplines and have time to fully participate before graduation.

The content in all three models fits into the following categories:

1. *Professional development and resources:* Creating strong academic resumes, developing e-mail etiquette, and learning about on- and off-campus research opportunities and general campus resources (e.g., career development, writing centers). Example assignments: drafting a resume, e-mail to a potential faculty mentor.
2. *Basic research skills and research etiquette:* Understanding the scientific method and research process, approaching faculty, interacting within a research group, understanding laboratory notebook protocols, and importance of lab safety. Example assignments: creating a professional timeline, design and implementation of a small group data collection project.
3. *Finding and using literature:* Understanding differences between information sources (e.g., primary sources vs. Wikipedia), using search engines and databases, and reading primary literature. Example assignments: using basic library resources, summarizing the research approach and findings from a peer-reviewed journal article.
4. *Dissemination—technical writing, posters, and presentations:* Providing an overview of discipline-specific technical writing and providing effective practices in the presentation of posters and oral talks. Example assignments: critiquing or creating a poster, writing a literature review.
5. *Intellectual property, technology transfer, and ethics:* Understanding differences between patents, copyright, and trademarks, providing an overview of authorship and the peer-review process, understanding responsible conduct of research, and understanding ethical issues within the research context. Example assignments: analyzing ethical dilemmas via case studies.

Other topics, such as laboratory techniques, experimental design, and data analysis that would be valuable to preresearchers, have not been included to date primarily because of time constraints and the discipline-specific nature of these topics.

Faculty involved in this collaboration taught courses in the three formats at each institution: UCF, WSU, and University of Alabama (UA)—a new institution not yet involved in preresearch coursework.

Assessment and results

From 2012 to 2014, 605 students participated in preresearch courses offered at the three institutions; 540

students were STEM majors. These students came from diverse backgrounds and majors. Life science and engineering were the strongest subgroups with 45% and 41% of the STEM participants, respectively. Many students were first-year or transfer students. At I#1, approximately 50% were transfer students.

To evaluate the course offerings, formal assessment consisted of:

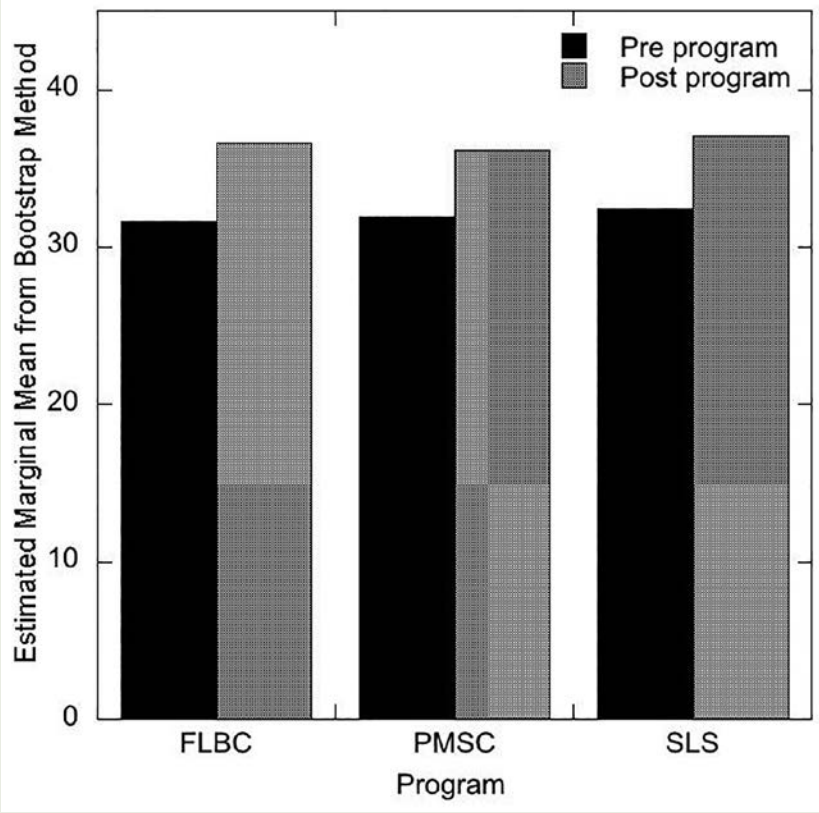
- pre- and posttests to document gains in student knowledge,
- focus groups as a way to determine the alignment of student experience with instructor vision, and
- follow-up surveys after 1 and 2 years to determine student pursuit of research experiences after completing the preresearch course.

Pre- and posttest

Because the programs are basic skill-building opportunities, the team was interested in knowledge gains regarding topics from the previously mentioned content categories. In the summer of 2012, a multiple-choice test bank was developed in the style of a concept inventory to assess learning gains within a program. For testing purposes, 50 questions were chosen from the test bank and used to assess the courses (i.e., fall 2012 to summer 2014). Using a simple Bootstrap method, a three-way mixed factorial analysis of variance was conducted to evaluate the effects of program type, institution, and the pre- and posttest on scores. Regardless of institution or program, there were significant gains from pretest to posttest, $F(1, 349) = 286.11$, $p < .000$. Figure 2 illustrates the nonsignificant interaction between program and pre- and posttest, $F(2, 349) = 0.61$, $p = .546$. There were no differences in prescores across programs, indicating that students were not differentially selected into programs. There were no differences in postscores across programs, indicating that each program is equally effective. All programs are effective in terms of increasing students' scores on the 50-question concept inventory. There does appear to be a significant interaction between institution and pre- and posttest, $F(2, 349) = 8.86$, $p < .000$. There were no significant differences between institutions at pretest. There were statistically significant differences between all three institutions at posttest, with WSU having the lowest posttest score ($M = 34.82$), followed by UCF ($M = 36.45$) and then UA ($M = 38.54$). In summary, all institutions are seeing positive outcomes from these programs, and where the program is taught, the instructor, and the student participants, may make a small difference.

FIGURE 2

Pre- and posttest scores by program. Estimated marginal means determined using a simple Bootstrap method.



Focus group

One goal of the project was to balance broad, but extensive, content with an overall positive student experience. It is a challenge to communicate the important and serious nature of academic research yet also encourage enthusiasm about opportunities. At the end of each course, an assessment team, external to the faculty developing and delivering courses, conducted a focus group. This team used Skype to conduct the focus groups at the partnering institutions. Using one evaluation team allowed for consistency in the focus-group style of questions and discussion. This approach allowed evaluators the opportunity to truly understand the nature of preresearch courses and their impact on students from diverse majors. Focus groups were comprised of a subset

of the total participants, typically 5–25 students that agreed to attend a 30–60 minute session. Focus group feedback was used to continuously strengthen the courses (see Table 2).

One year later survey data (preliminary data)

To monitor placement into research experiences and student involvement after completing a preresearch course, surveys were administered 1 year and 2 years after completion. The survey had specific questions about student level of participation in research as well as questions regarding their major, when they were enrolled in the preresearch course, etc. Students who had matriculated into research positions were asked to describe their involvement in detail, whereas students not yet involved in research were asked about the reasons for not becoming involved.

All participants received the voluntary survey with two additional reminders in 2013 and 2014. A total of 101 completed surveys were received from STEM students from a possible 350 program graduates. Eighty-four of the respondents had completed the course 1 year prior, 17 had completed it 2 years prior. From the survey data, a few important observations were noted:

- 54.8% of the students were involved in undergraduate research 1 year later;
- 57% of the students involved in research had secured paid research positions;
- 35.1% of the students not involved in research, one year later, report they realized that (a) they were not interested in research, or (b) they had insufficient time for research;
- 76.5% of the students were involved in undergraduate research 2 years later;
- 80% of the students involved in research, including both 1 year and 2 years later, reported that the course prepared them for involvement in research; and
- 74% of the students involved in

TABLE 2

Overview of focus group findings: Highlights for individual focus groups.

Mode	Strengths	Suggested improvements
All	- Overall students described extremely high levels of satisfaction with their learning experiences.	NA
SLS	- Students detailed that the course "expanded the whole research process," "broadened their skills," and gave them the opportunity to do "the act of doing research." All agreed that the assignments were engaging and comprehensive. (UCF) - All agreed that the assignments helped them learn more about research. (WSU)	- Students asked that the class presenters post or e-mail their PowerPoint presentations. They also suggested virtual lab tours. (UCF) - Some students were surprised about the amount of work for a one-credit class. Others commented that attending research seminars conflicted with their schedule. (WSU)
FLBC	- All agreed that the assignments helped them learn more about research and gain confidence engaging in undergraduate research. (UCF) - Content reported as most valuable included resume writing, speakers, writing an abstract and the general structure of the class—"present, observe, manage, record and work in groups." (WSU) - Content reported as most valuable included resumes, career center feedback, mock interviews, literature review, approaching a faculty member, abstract writing, posters, group work, and lab tours. (AU)	- Students learned library content in prior courses. Students asked for speakers from their disciplines. Students thought it was important to reflect the actual schedule during registration. (UCF) - Some students expressed frustration about using the library to find and reference articles. Students asked for lab tours and suggested groups could be split based on their disciplines. (WSU) - Students wanted to learn more about how writing the literature review fits into the research process. Students also expressed a preference for choosing the research lab to visit. (AU)
PMSC	- Content reported as most valuable included lab tours, workshops, resumes, learning about other disciplines and etiquette, guest speakers, and group work. (UCF) - Content reported as most valuable included resumes, e-mails, lab tours, meeting professors, and library activities—physical library and using online databases. (WSU) - Content reported as most valuable included resumes, speakers, research initiatives, mock interview, designing experiment and poster, and lab tours. (AU)	- Students observed that lab tours were less valuable when the lab had not structured the visit. They asked for additional activities related to graduate school. (UCF) - Students asked for lab tours geared toward their major. Some preferred a 4–5 day course. Students also asked for additional feedback on resumes. (WSU) - "The amount of time allotted for each exercise was excessive." Students wanted more time to conceptualize the experiment. They also asked for class time to start the literature review and receive feedback on a draft. (AU)

Note: From Lancey (2012–2014). FLBC = faculty-led boot camp; PMSC = peer-mentor short course; SLS = semester-long seminar. UCF = University of Central Florida, WSU = Washington State University, AU = University of Alabama.

research reported that the course made them a better candidate for research.

Next steps

We will continue to use the 1 year and 2 years later survey to monitor students completing our courses to strengthen the longitudinal assessment. In addition, we will work with campus partners to document the students who are involved in research more systematically. For example, at I#1 all students involved in research are documented through a new database in development. Future plans include matching the students involved in these courses with the database to provide real data on student involvement after the courses.

Discussion

There are clear benefits to training students in the methods for conducting academic research so they can acquire the necessary skills to be productive. Results suggest that 1-year after a preresearch course, over 50% of students are conducting supervised research and over 50% of students in that particular group are being paid for those efforts. For large campuses, these are positive rates because the number of faculty mentors can be a limiting factor. Additionally, 2 years after a preresearch course, over 75% of the students are involved in research. However, one aspect to consider is that students involved in research might be more likely to respond to the survey, thus inflating our overall percentage. These numbers are much higher than the campus averages. For example, at I#1, the required 2013–2014 Graduating Senior Survey documented that 8.9% of students self-reported involvement in undergraduate research with a faculty mentor in all disciplines (N = 12,586). The I#1 2011 National Survey of Student Engagement (NSSE) data showed a higher average (24% STEM seniors) participating in research (N = 388). I#2 in 2010 had a 31% positive response from their STEM students (main campus). I#3 NSSE data from 2013 showed 40% STEM seniors had participated in supervised research.

Student focus group reports indicate that students have high levels of satisfaction with our preresearch programs, and this fact does not vary between or within institutions regardless of program model (see Table 2). Interestingly, evaluators found that favorite topics and assignments varied between institutions. We have improved our programs based on focus-group feedback. For example, early in the program, two assignments were found to be difficult for the students: creating an abstract from a journal article and writing a literature review. Improvements to these assignments were made by modifying the assignment details and, in the case of the literature review, breaking the assignment up into smaller subassignments done in multiple stages.

Monitoring student learning of research skills remains a challenge. Prior to development of the multiple-choice test, the team used a test with primarily open-ended questions, making it difficult to be consistent in grading. The multiple-choice test has provided a good solution to this problem. Moving forward, a more extensive and rigorous test bank is a task for the team that will help others in teaching and implementing preresearch courses.

Although students indeed benefit from these courses (with indirect benefit to faculty mentors and research programs), the courses do come at a cost to the institution. Several different models can be adapted depending on the university, the research culture at that university, and resource constraints. For example, costs for using a graduate student instructor at one of our institutions is approximately \$85 per student for the SLS. In the PMSC, each peer mentor is hired for a total of 40 hours to assist (training, course, and grading time included). Thus, instructor time, office support, and cost for peer mentors needs to be considered. We estimate costs in the range of \$75–\$400 per student for these courses. A cost of less than \$400 might be considered to be small compared with other research programs that often invest \$1,000–\$10,000 for each individual student. Tuition funds could help to offset these costs at some institutions.

These courses can be adapted for community college populations to help prepare students before they matriculate to a 4-year institution. The cost, however, may preclude some campuses from running a full course. Therefore, the preresearch courses described here could be adapted into a 1-day interactive workshop or a seminar series for interested students. For example, the PMSC has lab tours and a poster showcase that allow students to really visualize research. These components, with a general overview of research, could be adapted into a research awareness daylong event for students. Preresearch events could be conducted at a much lower cost to the institution. Universities and/or departments could host workshops, which students are required to attend prior to starting research, or institutions could take the approach of creating online modules.

Conclusions

Students, faculty, and the organization as a whole benefit from offerings of preresearch programs. This is especially true if universities are trying to raise awareness of the benefits of research to a diverse set of students. Multiple aspects of these programs vary, including the form of instruction (e.g., faculty vs. student-mentor led), the timing of the programs (e.g., academic year, summer, or in-between semesters), and the direct benefit to the student

(e.g., credit vs. stipend). Regardless of course format, all appear to be effective for student involvement in research and for increasing knowledge of research methods and terminology. The choice and long-term success of the format depends more on the culture of the institution.

By introducing students to the nuances of the research environment, we believe that preresearch courses reduce barriers to involvement and provide confidence and knowledge for all students who participate. Preresearch courses can motivate students to become engaged in research early in their academic career, which can help retain, train, and inspire future generations of scientists and engineers. ■

Acknowledgments

We appreciate the help and support from Patrice Lancey, Uday Nair, Divya Bhati, Nancy Lynch, Amy Bickel, Kathy Rovito, Kendra Pass, and Donelle Posey. This work was sponsored by a collaborative grant from the National Science Foundation (123068, 1123096, and 1123181).

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