



Three Training Programs for Preparing Undergraduates to Conduct Research

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Abstract

Three instructional formats devoted to preparing STEM students for successful research endeavors is the forum for this project. All formats are intended to reach undergraduate students early in their academic careers. The three formats include: a semester long seminar, a one week faculty led “boot camp”, and a 2½ day peer mentor led short course. The investigators attempt to keep the main topics in each format the same, although time constraints do not allow thorough review of each topic in the latter two formats. The topical content and activities cover the following areas: resume building, finding a faculty mentor, reading and analyzing journal articles, understanding the different types of literature available, using campus library resources, performing a literature review, discussion of intellectual property, tips on effective presentations, and career guidance. This project is motivated by the need for students to acquire appropriate skills in order to be effective in conducting research under faculty supervision. This project is a collaborative effort between three institutions with experience in teaching preparatory research skills in the different formats. The investigators are teaching each of the course formats at their institution. Working together to develop the appropriate course modules for dissemination to interested institutions, the team is preparing a set of best practices and evaluating the costs associated with each format. A pre- and post-test, in the style of a concept inventory, has been developed that can be used to assess improvements in student understanding of research skills and concepts. Initial results show similar gains in conceptual awareness at each institution. This suggests that the educational models may be transferrable and easily adopted by other institutions. Focus group discussions indicate that students are pleased with the programs and consider them useful, especially for students preparing to conduct research. To date, the team has impacted over 250 students and a web site is under development for disseminating project information.

I. Introduction

In this collaborative project, team members are developing educational materials for teaching research preparatory skills in three different approaches: a week-long faculty led boot camp, a 2½ day peer led short course, and a semester long seminar. The course syllabi, materials, assignments, and assessment test will be disseminated widely to STEM educators. The research preparatory content varies depending on educational approach but broadly includes the following topics: finding an advisor and creating a resume geared towards research, searching library databases, understanding the difference between popular, textbook, and peer reviewed literature, reading and analyzing scholarly articles, laboratory notebooks, responsible conduct of research, intellectual property rights, effective presentations, writing a literature review, and career opportunities.

The semester long seminar (SLS) is adapted from work done by The University of Wisconsin [1] as part of their Materials Research Science and Engineering Center (MRSEC) activities while the week-long faculty led boot camp (FLBC) was developed at Washington State University (WSU) [2] and the 2½ day peer mentor led short course (PMSC) was developed at the University of Central Florida (UCF). To date, each of the collaborating partners has taught the SLS (spring 2012) while two of the partners have additionally offered the FLBC and PMSC. Investigators

from two of the institutions observed both the FLBC and PMSC at the third partner institution during the summer 2012 as preparation for offering both of these programs in summer 2013. Each course type is summarized below.

Semester Long Seminar (SLS) - Each university offered this course as a 1 credit hour graded course in spring 2012. The classes met for 50 minutes each week in a 15-week semester. Students were expected to work two hours per week, outside of class, on assignments. Each institution handled recruitment for the seminar in varied ways. Both UCF and WSU have a centralized office of undergraduate research so they have a more extensive network of students to reach out to. At The University of Alabama (UA), a centralized office does not exist. The project team at UA was able to recruit 15 students from engineering disciplines and computer science. In the future, they will work with the UA Emerging Scholars program, a popular program intended to engage freshmen in research, to increase the number of STEM students. WSU had an enrollment of 27 students in their course. UCF developed a short application for the 30 seats in the class. They received 140 applications from a wide-variety of STEM majors. UCF students received the course credit at no-cost, WSU and UA had students take the course as part of their full time academic course load (no cost beyond full time enrollment costs). Faculty led the weekly instruction with various guest speakers from the Technology Transfer office, Library, and Writing Center as examples. Because of the overall length of this course format, a focus of the SLS has been the literature review. There is enough time for students to prepare a literature review on a topic that interests them and get feedback on the review. This review is something they can share with a potential faculty mentor as a way of showing their initiative and interest. In addition to the literature review, typical homework assignments for this course include: 1) preparing a CV, 2) investigating various faculty members and briefly summarizing their research interests, 3) drafting an email to a faculty member indicating one's interest in their area of research, 4) completing a library skills "game" and 5) attending research seminars across campus and answering short questions about the experience.

Faculty Led Boot camp (FLBC) – This one-week (~40 hrs) intensive course, funded by a Type 1 NSF CCLI grant and established by WSU, targets rising sophomores. The program introduces students in STEM fields who have completed one year on campus to the process of working as an undergraduate researcher. The summer schedule rotates short lectures with active learning activities and has students reporting their activities back to the group. Two topics are covered each day, with small group activities after each lecture. A team of faculty and staff members, such as librarians and Technology Transfer personnel, act as instructors for the course. The topics covered during the FLBC are similar to those described in the SLS Section, however, students must complete all assignments or activities during the time permitted versus "homework" assignments in the SLS.

Using an intensive summer program has had several benefits. First, by positioning the program at the start of the summer, the students begin the summer or next semester ready to seek out research projects. Secondly, students experience the type of concentration and dedication required for carrying out research with faculty. Third, a short summer program does not interfere with off-campus summer jobs; an additional week after final exams has not been viewed as an impediment to students obtaining additional financial resources over the summer for the upcoming school year. Fourth, faculty participation is simplified as the timing just after

classes does not interfere with summer travel. In the first year of the grant, ___ ran their camp with 15 students in May 2012 immediately after the close of spring semester. Students are paid a small stipend (\$275) for participating. UCF ran the FLBC in August for 20 students, immediately before the beginning of the fall semester. The students received a graded one credit hour for participating in the course.

Peer Led Short Course (PLSC) – This 2½ day short course, established by UCF as the Summer Research Academy (SRA), was developed in 2004 to increase the number of transfer students involved in research. This was to help improve transfer student retention and engagement [3, 4, 5]. In 2005, the program was opened to rising sophomores and juniors who are current students. It is a 1-credit pass/fail course that enrolls 100 students each year. Currently the make-up of the course is 50% transfer students and 50% current students (over 50% of students are STEM majors). As with other formats, course content is similar. The educational model is similar to the boot camp with short lectures, collaborative activities, and mini-workshops; plus an afternoon is spent visiting 3-4 research laboratories. In this model, however, the bulk of the classroom activities is facilitated by peer mentors. Peer mentors are current undergraduate students that have experience doing research and are trained by staff personnel. The course consists of several pre- and post-assignments in addition to assignments that occur during the short course.

The primary benefit of this model is the large number of students that can participate. Typical numbers are approximately 100 compared to 20-30 in the other models. Guest lectures by faculty and other University personnel are included. However, the bulk of the discussions and the grading of assignments are conducted by the peer mentors. Another added benefit of this format is the leadership and mentoring experience gained by the mentors. In the first year of the grant, UCF ran their camp with 100 students in June 2012 in between summer sessions. WSU ran the PLSC in August 2012, in the week before fall semester begins, to 61 students but did not offer course credit.

II. Background

Undergraduate research programs around the country support activities for a wide range of students. Many of these students have had little or no prior experience working in a laboratory research environment. Consequently, many university undergraduate research directors and others involved in organizing college and campus-wide activities commonly comment on the challenge of integrating these students into undergraduate research (UGR) programs and providing them with fundamental information about the process of research. Many of the ideas and plans in place or in progress at the nation's research institutions are based on ideas laid out in the Boyer Commission report [6] that highlights an integrated education through undergraduate research opportunities.

Many of the larger public research schools struggle with low retention rates in STEM. For instance, at Washington State University freshman to senior retention in engineering is 48%. As noted in the literature [7], many STEM fields use undergraduate research as a capstone experience, held until the end of the curriculum as a culminating experience. However, it has been found that the retention rate of students in STEM increases with participation in undergraduate research [8, 9]. This type of participation may be the norm at private institutions

and used to help student cognitive development [10], with students being involved and mentored closely from the freshman year [11]. In contrast, the larger public institutions have challenges related to their mission and size, including issues of transfer students from community colleges, large freshmen classes and advising limitations. For example, survey data shows that transfer students are less engaged than “native” students on a college campus, but short courses and peer mentorship appear to improve engagement [12]. Thus, undergraduate research programs that incorporate coursework and/or peer mentorship should increase transfer student engagement and retention.

Programs to introduce students to the research process and community do exist at public research universities [13], but there currently is not a best-practices method established, or verified transferable models, for getting *large* numbers of students (hundreds per year) into research activities, beyond one-on-one mentoring (of the sort referred to as “A Mentor for Every Student” in the Boyer report). This is not a viable solution to significantly increase our pipeline of students entering STEM research careers. We do not mean to discount one-on-one mentoring and feel that indeed, this is probably one of the most high-impact transformative learning experiences at a university. However, we note that by definition that method will limit the total number of undergraduates participating in significant research experiences. Many public universities have student to faculty ratios well over 10:1 in STEM fields; most faculty we have informally polled suggest they would like to mentor one to three undergraduates in their laboratories. If the number of undergraduates involved in research in the STEM disciplines is to increase significantly at public research universities, programmatic, rather than individual, activities must be institutionalized.

One of the limiting factors with incorporating undergraduates in research laboratories is the “incubation period” that faculty anecdotally report. Many faculty note their reluctance to increase the number of undergraduates they support in their research teams is tied to the time it takes for the students to become “productive”. We feel it is in the best interests of both the faculty and students to provide students the skills needed prior to starting the mentoring process with individual faculty. If undergraduates are better prepared for participating in research, the “incubation period” will naturally decrease and it will be easier to incorporate more students into research mentorship activities in STEM disciplines.

This preparation step has been described as a “research oriented” approach [14, 15], where students are learning specific skills needed for becoming active research participants (i.e., learning to do research). This is distinguished from the “research based” [16] courses that involve research in a course [17] or more mentored and tutored methods. The “boot camp” approach has been especially popular in programs that focus on entrepreneurship with examples being BYU’s innovation boot camp [18], Carnegie Mellon’s summer Biotechnology entrepreneurship boot camp [19], and a partnership between UCSD, the University of Florida, and IIT in Chicago called Invention to Venture [20].

III. Findings

The activities to date have generated several findings that have been partially reported at the Council on Undergraduate Research (CUR) national meeting and have demonstrated formative

information that will impact subsequent years. They will be reported first by each program and then some summary comments will be noted.

Semester long seminar (SLS). The project team administered a pre- and post-test assessment in spring 2012 of student learning and understanding of the undergraduate research process to all participating students. Each institution used a common test with a mix of multiple choice, T/F, and open-ended questions to assess increased awareness and understanding of topics associated with research skills. The pre-test was given on the first day of class, while the post-test was given at the final exam time. The difficulty in scoring the tests led to a decision to modify the test to make it easier to score and to expand the number of questions associated with each concept covered by the test. The project team now has a concept inventory style test that can be used to look at knowledge gains when administered as a pre- and post-test. Nevertheless, from the first semester pre-post test results, there was a measurable increase in the understanding of undergraduate research in the students at all institutions. In general, the largest gains were seen from students with the lowest pre-test scores, as shown in Table 1 and Figure 1. Additionally, anecdotal evidence suggested that many (> 30%) of the students had already found a research position at the end of the semester.

Table 1. Pre-post test averages in the student body after SLS.

Institution	Pre	Post
UA	52.4 ± 18.4	64.6 ± 12.6
UCF	58 ± 11.5	72 ± 8.9
WSU	46.3 ± 17.6	60.8 ± 13.4

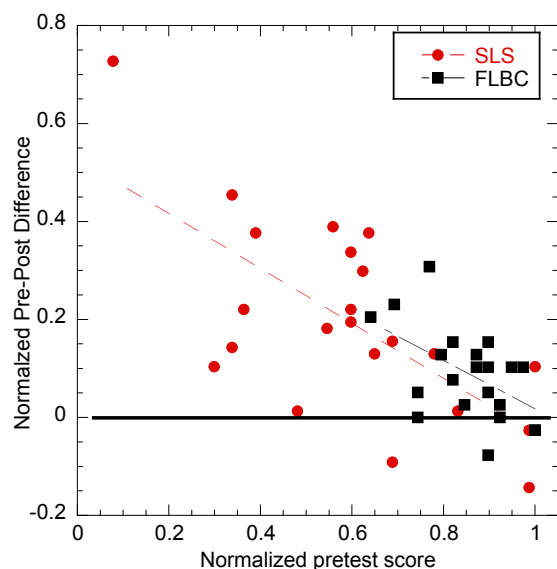


Figure 1. Normalized change in score (defined as Post-test score minus Pre-test score)/ (Pre-test maximum score) as a function of normalized pre-test score from students participating in SLS and FLBC activities. In general, gains were highest for the students that started weakest in performance. SLS data from WSU and UCF and FLBC from WSU.

The UCF office of Operational Excellence and Assessment Support carried out a uniform focus group for all three institutions at the end of the spring SLS course. Students at all three schools perceived the most useful segment in the course was the information about contacting faculty and finding research positions. Each school had other sections / topics reported as useful, but this topic was highlighted by all schools. Additionally, the literature review assignment was seen as onerous and more work than the other assignments, and generally was viewed as least positive. In response, the investigators have decided that future semesters will include a modification of the literature review assignment so that it pervades the entire semester and is revisited at multiple times to ensure students do not have one high stakes assignment. A significant number of students expressed the concern that they felt the work load was too high for a one credit course.

Faculty Led Boot Camp (FLBC). The two courses conducted in 2012 served 15 and 20 students at WSU and UCF, respectively. For WSU, the one-week course was held immediately after the spring semester so the pre-post test was not used as it was being modified by the project team. However, WSU was able to continue to track its former FLBC students and has generated the following results from its ongoing 5-year program. The standard WSU engineering retention from freshmen to graduation is 48%. Of the 42 WSU FLBC students that “should have” graduated (i.e. their 4.5 year time after enrollment), 34 graduated in STEM, 1 in Psychology, 2 in Business, 2 are still enrolled in STEM, and 3 have dropped out. This is an 81%+ retention rate in STEM to graduation, almost double the standard graduation rate. The total retention of the previous 78 students (2011 and earlier) for those that are still pre-graduation time includes 3 that are non-STEM majors, 2 that are on academic probation, 3 that have dropped out, and 70 who are still majoring in STEM disciplines or graduated. This is an effective 90% retention rate in STEM. We recognize that students self-select for this extracurricular activity and therefore, we do expect the rates to be higher. These data will continue to be collected as the FLBC cohorts at all three schools move through their program. The historical performance shows that 61% of the students do find a research position after 1 year from the program.

At UCF, the one-week course was held in August with 20 students from a variety of STEM majors. All students were given a pre- and post- test. The change in score was previously shown in Figure 1; scores were normalized to account for different starting performance between the different student groups. The UCF office of Operational Excellence and Assessment Support carried out a focus group. Students reported high levels of satisfaction with the course. All agreed that the assignments helped them learn more about research and gain confidence engaging in undergraduate research. Assignments and experiences they reported as most valuable included working in groups, Google scholar search for literature review, UCF library activity, email the professor, simulation and mock interviews, guest speakers, conference presentation skills, and resume critique. The literature review was described as “worth it”.

The limited data collected so far is too preliminary to draw conclusions, but one interesting feature observed in Figure 1 is the total range of student performance in the pre-test is much smaller in the FLBC than the SLS. This may indicate that the SLS draws from a much broader

range of students (i.e. more typical of the total student population) while the FLBC may draw from a group of students with a more uniform understanding of the undergraduate research process. We will continue to track if this is the case throughout the programs; the implication being that different methods to deliver these skills may naturally reach different student populations, and hence may also have different levels of effectiveness.

Peer Led Short Course (PLSC). The two courses conducted in 2012 served 61 and 100 students, respectively at WSU and UCF. For UCF, the Summer Research Academy (SRA) was held in June and they continued to perform assessment of effectiveness in the program for it's historical base of students. They found that 60% of the students moved into research positions within two years of the program; 30% had spent 4+ semesters involved in research while 40% of the SRA participants were not involved 1+ years after the event. Of that 40% not involved in research, 30% realized they were not interested in doing research, 45% still plan to get involved, and 25% had trouble finding a mentor or didn't understand the process. This implies only 10% of the SRA participants had an unsuccessful impact by being involved in SRA, as we feel students that realize that undergraduate research "isn't for them" are making an informed decision that will positively impact their academic careers. Similar results were seen at WSU in the FLBC regarding a fraction of participants that realized it wasn't for them. At WSU, the short course was held for the first time in August just prior to classes starting in the fall. Participants provided feedback at the end of the program by ranking each session based on their perception of how it will affect their future research activities on a scale of 1-4, with 4 being "very valuable". 82% of the students ranked the laboratory research tours as "very valuable", followed by the resume critique (71% ranked it "very valuable") and scholarships and fellowship session (66% "very valuable"). Perceptions about research in science and engineering as a result of their experience in the program stayed the same for 15% of the participants, seemed more interesting for 84% and seemed less interesting for 2% of the participants. Follow-up surveys are planned in the spring semester of 2013 to measure how many students have obtained a research position, are still looking, or have decided that research is not for them.

During both of these courses, each institution used the revised pre-post test, or concept inventory, described earlier. The revised test is now a set of 50 multiple choice or T/F questions that represent each concept covered during each of the courses. Initial results indicate that the concept inventory developed was successful. At WSU, the mean score (out of 50 possible) \pm standard deviation for pre- versus post-test was 31.4 ± 4.2 and 33 ± 3.7 , respectively, which is statistically significant. Peer mentors were also given the test before the PLSC and results showed that there were significant differences in pre-test scores for mentors compared to the participants, with mentors scoring higher. Test results were also compared between the different mentor groups and there was no significant difference between pre-test or post-test scores among the different mentor groups.

Anecdotal Evidence

Below, in Table 2, we provide examples of how students were impacted by the course:

Table 2. Anecdotal Evidence: Unsolicited Emails from Graduates of the Training Program.

SLS	<p>Hi, this is STUDENT NAME from last spring's Research Skills class. I participated in an REU this summer, and I thought you might be interested in how well the class prepared me for it.</p> <p>Learning to use the library databases helped a lot. Other REU students in my office used Google Scholar to find papers, which works, but I found that using databases' filter functions made it easier to find papers relevant to what I working on. The paper-writing technique (organize by paragraph, write first and last sentence of each) has been really useful. I used it on a couple of assignments last semester, and I feel like it cut my writing time to about 2/3 of what it was before.</p> <p>Getting exposure to reading papers was good. My research group had a weekly journal club where the REU students had to give short talks (3-5 minutes) about a paper we had read. For the first few weeks, I actually used one of the assignments from the class to help read my papers. I can't find it now, but it was the one where we had to pick and read a paper and identify the hypothesis, the conclusions, etc. I completed that assignment for each paper and used the questions as talking points.</p> <p>So overall, the class definitely helped.</p> <p>I just wanted to let you know that I received an internship position about a week after the semester ended at a company called Earthrise Space Inc. and we are working on building a lunar rover to send to the moon for the Google X Lunar Prize! It is very exciting and I am very happy to be a part of this experience. During my interview they were very interested in the Research Academy and were pleased that I gained a professional outlook on research!</p>
SLS	<p>Boeing offered me an internship!!! I accepted the offer and passed the background and reference checks...! Yay, I am so excited! That was my first interview and nailed a job. I believe my research experience definitely gave me the upper hand! I'm so happy and feel stress free I don't have to worry about finding a summer internship. Everyone else is still scrambling... Anyways I'm doing another presenting my research at an LSAMP event. Exciting and good time, love the experience.</p>
PMSC	<p>After participating in SRA last summer I was able to meet Dr. X and I am now working with him and his Cholera research and continuing my research in the spring. I thought the academy was an amazing opportunity and it definitely kicked off my research experience for me. I am more than grateful. I was wondering who I can talk to about becoming a mentor this coming summer?</p>
PMSC	<p>The Research Skills Short Course was great! It helped me get a research position and I learned about techniques for reading scientific papers, which I have already used in class.</p>
PMSC	<p>It was highly informative and instilled confidence in me to get a research position.</p>
FLBC	<p>I just want to thank you for teaching the STEM Academy, I felt that is was very well structured and gave me knowledge into research and contacts to help along the way. I'm currently working now to try to coordinate a research topic with Drs. X and Y, that would work with my internship and my HIM thesis. If anything this course gave me the courage and tools to attempt this.</p>

The UCF office of Operational Excellence and Assessment Support carried out a focus group for participants in the PLSC at the two universities. Again students described high levels of

satisfaction with their learning experience. Both groups really enjoyed the lab tours and meeting students involved in research. Overall students had a positive experience working with the peer mentors. At the University of Central Florida, they specifically found the following useful: 1) Becoming more aware of career and internship opportunities and topics; 2) Changing their perspective about how research is conducted – they had thought it was done by one person and now know about the lab structure; 3) Understanding “the structure of research”; 4) Learning the expectations related to research; and 5) Realizing that fine arts and humanities areas conduct research.

IV. Summary

In summary, three educational approaches have been described for helping students prepare to conduct research. The efficacy appears similar between the FLBC and PLSC programs. The Semester long seminar is probably easiest to implement if a university does not have a centralized undergraduate research (UGR) office. Time intensive courses do not appear to have the issue of mixed expectations in content and workload as fewer students expressed uncertainty in what they were “getting into”. The SLS appears to be difficult to run for more than a class size of approximately 30 for one instructor. The activities for the FLBC or PLSC do not always translate well into take-home assignments for the SLS, some things need that block of time with faculty. Finally, the costs are probably very similar (if you consider faculty time, UGR director time, etc.); each appears to cost between \$200 - \$500 per student to get the programs up and running. Future years will continue to track retention and performance of all three groups at all three schools.

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