

Creating a Successful Pathway to Graduate Studies: The Student Integrated Intern Research Experience (SIIRE)

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Abstract

For the health of the engineering profession and the nation, increasing the number and diversity of engineering students going on to graduate studies is imperative. The Student Integrated Intern Research Experience (SIIRE) is successfully addressing this situation, supporting students from undergraduate through graduate school. SIIRE recruits a diverse group of first-year students to begin in SIIRE in their sophomore year and provides enrichment activities geared toward creating awareness plus developing interest and providing logistical information about graduate school. For example, workshops include topics on developing research skills, general graduate school information, the Graduate Record Examination (GRE), research ethics and professionalism, and communicating research. Additional workshops are geared toward undergraduate student retention for expanding the pool of potential graduate students. Faculty mentor the students in developing graduate school applications their senior year. Students are also provided tools to help them obtain internships and undergraduate research experiences. All SIIRE students have financial need, and scholarships are provided through an NSF S-STEM grant.

SIIRE is extremely successful. Of the SIIRE B.S. graduates to date, over 90% attributed SIIRE for increasing their awareness of graduate school. 85% attributed SIIRE with increasing their awareness of the importance of completing their engineering degree, and half said it was an important factor in actually completing their degree. 92% responded that after participating in SIIRE they are more likely to encourage others to attend graduate school. Of SIIRE B.S. graduates, 45% continued with graduate school compared to the College of Engineering (COE) average of 17%. SIIRE is successful in creating a diverse pool of participants with 49% from minority populations and females making up 42% of the applicants, which is approximately double the rate for each group in the College of Engineering. Of those SIIRE graduates continuing on to graduate school, 29% are minority and 36% are female. SIIRE had success with students participating in internships (48%) and undergraduate research (74%), and 39% have both internship and research experience.

This paper will provide details about the SIIRE program and activities, share a program evaluation, discuss lessons learned and examine the future of the program.

Introduction

The Student Integrated Intern Research Experience (SIIRE) program at the University of Arkansas is funded via the NSF S-STEM program. The NSF S-STEM program provides student scholarship funds to encourage and enable academically talented but financially needy students to complete STEM degrees and enter the workforce. The SIIRE project addresses NSF's programmatic goal by integrating external (industry supported) intern or co-op experiences of students with ongoing on-campus engineering research activities to provide a guided pathway to a graduate engineering degree. Scholarship funds defray student educational costs during their

sophomore, junior, and senior years of undergraduate study and during 1.5 years of their graduate studies.

The goal the SIIRE project is to increase the number of students that complete a B.S. degree in engineering and then pursue and complete an M.S. degree within engineering by providing a structured pathway to graduate studies through integrated industry-based work experiences and university-based research partnerships [1]. In support of this overall goal, the following objectives are addressed:

1. To provide underrepresented and financially needy undergraduate students with information on the benefits and opportunities associated with graduate education
2. To provide underrepresented and financially needy undergraduate students with enhanced financial support and career experiences to improve the likelihood of completing both a B.S. and an M.S. in engineering
3. To provide personalized integrated industry and academic mentoring and professional development that results in increased enrollment and completion of graduate engineering degrees involving industry beneficial research
4. To increase the number of highly skilled employees in engineering fields ready to directly apply engineering research
5. To develop an innovative program that integrates industry-based student experiences with on campus research experiences that result in benefits to industry, faculty, and students

This overall goal is achieved through leveraged scholarship support for a cohort of students with financial need to participate in industry motivated graduate research topics that ideally allow for work in industry with the participation of practicing engineers in industry. Increasing the number and diversity of engineering students going on to graduate studies is imperative for the health of the engineering profession in our state, in our nation and across the globe.

In the next section, we present a summary of the SIIRE program in order to review its background, purpose, and structure. This provides the context for understanding where this program fits in with other programs and related literature as discussed in the third section. Then, because the program is still on-going, we present results on the effectiveness of the program over the first three years of the project. Finally, we summarize our key findings and ideas for future work.

Brief Overview of SIIRE and its Components

The SIIRE program was initiated at the University of Arkansas in 2013. As was noted earlier, the program was designed to provide financial support, as well as personalized and integrated industry and academic mentoring and professional development, to a cohort of underrepresented and financially needy undergraduate students to improve their chances of completing both B.S. and M.S. degrees in engineering prior to entering the workforce [1]. Simply stated, the SIIRE program recruits students from the university's first-year engineering program and the Engineering Career Awareness Program [2]. SIIRE then helps the selected students develop professionally throughout their academic careers by providing financial aid and encouraging participation in SIIRE's strong mentoring program that emphasizes engineering internships, professional development, and attending graduate school at least through the M.S. degree.

Table 1 summarizes annual student participation in the SIIRE program since its inception, including underrepresented minority (URM) and female participation. Three cohorts of SIIRE students entered the program from fall 2013 to fall 2015, totaling 45 students. Students came from all eight departments in the College of Engineering including biomedical, biological, chemical, civil, computer science/computer, electrical, industrial and mechanical engineering. Caucasians comprise 51% of this SIIRE population and underrepresented minorities comprise the other 49%, with 24% Black or African American, and 18% Hispanic, 7% Asian American, and 0% American Indian or Alaska Native. The percentage of Black or African American and Hispanic students in the SIIRE population exceeds the College of Engineering populations for these ethnic categories, currently 3% and 10%, respectively. Across gender lines, 58% are male and 42% are female. The percentage of undergraduate women in the College of Engineering is currently 24%, the highest ever recorded, so results show that we are attracting a greater population of women into the SIIRE program. The SIIRE program has successfully increased the diversity of engineering students on the pathway to graduate studies.

Table 1. Summary of Student Participants in the SIIRE Program

Cohort	Participants	URM	Women
2013	15	3	7
2014	7	6	3
2015	23	13	9
Total	45	22 (49%)	19 (42%)

A major feature of the SIIRE program is student enrichment through the participation in professional development programs [3, 4]. SIIRE students are encouraged to participate in research and co-op or internship opportunities throughout their academic tenure to better prepare for graduate school or employment. Faculty, local engineers from industry and peers have volunteered to serve as formal or informal mentors for SIIRE students, either individually or in small groups.

Professional development workshops are regularly hosted for the SIIRE students on a variety of topics, including [3]:

- Resume Writing and Job Search Skills (primarily aimed at sophomores and seniors)
- Creating Your Unique Personal Development Plan: Explore Your Options (primarily for sophomores)
- How to be an Effective Sophomore (primarily for sophomores)
- Effective Oral/Written Communication (primarily aimed at juniors)
- Developing Research Skills in Engineering and Science (primarily for juniors)
- Writing and Presenting an Engineering-Based Business Case (primarily aimed at juniors)
- “Good Enough for Government Work?” Ethics and Professionalism in Research (primarily aimed at juniors)
- General Graduate School Information and Where to Find It (primarily for juniors/seniors)
- Seven Habits of Highly Effective People (primarily aimed at seniors)
- Presenting and Communicating Research (primarily for M.S. students)
- Transition from Student to Employee (primarily for M.S. students)

- Excelling on the GRE (primarily for seniors)

These workshops have been very well received by the students and have been cited as being instrumental in preparing the students for their careers. Several of the SIIRE workshops invited students from the general population of engineering students. In opening the GRE workshop to all engineering students, a majority of participants (at least 70%) indicated that studying for the GRE, the GRE overall, and graduate school were important or very important [4].

For further information about SIIRE, [Author] et al. [1] provides a detailed description of the SIIRE program describing the background and motivation for the program and its structure. A description of activities designed to mentor and enrich the professional development of the SIIRE students including summer work experience, research experience, professional development, faculty mentoring and peer mentoring is described in [Author] [3]. As the undergraduate SIIRE students began to approach graduate studies, it became important to incorporate a GRE workshop to increase awareness and preparation of graduate school bound SIIRE students. This work is described in Weishaar et al. [4].

As noted in the introduction, a key goal for the SIIRE program is to increase the number of U. S. citizens graduating with engineering degrees. The following section reviews similar programs and research related to this and other goals to show where SIIRE fits within this context.

Background

Prior research has called for increasing U.S. citizen participation in advanced engineering degrees. For example, the National Academy of Engineering's Educating the Engineer of 2020 report recommended that "U.S. engineering schools must develop programs to encourage/reward domestic engineering students to aspire to the M.S. and/or Ph.D. degree" [5]. These calls have made an impact in improving the numbers of awarded degrees nationally within engineering [6-8]. Despite those increases, the National Center for Science and Engineering Statistics [9] reported in 2017 that the proportion of U.S. graduate students has been declining since 2009.

The situation within the State of Arkansas has been exceptionally bleak because of historical lag, where according to the U.S. Census Bureau's 2005-2009 American Community Survey (ACS) 5-Year estimates, the national mean percentage of full-time employed workers (age > 16) working within the Architecture and Engineering (A&E) sector in Arkansas is 1.44%, last in the nation. According to the U.S. Census Bureau, the percentage of [people in state] 25 and older that hold a bachelors degree is only 18%, with the US average being 27.5%. The University of Arkansas, and specifically the College of Engineering (COE), has averaged 84.7 engineering master degrees awarded per year from 2002-11. Of this amount, only 35.7% went to [people in state], which makes it very difficult for these awarded degrees to make an impact within the state. This is especially true given that masters degrees have been projected to make up an increasing need within STEM fields [10, 11]. SIIRE attempts to improve on this situation by mitigating financial barriers to students completing undergraduate and graduate degrees in engineering and by creating an environment that helps engineering students perceive advanced graduate studies as a potential career option.

A premise behind SIIRE is that financial barriers not only make it difficult for some undergraduate students to complete an undergraduate degree in engineering but also impact their perception of continuing within graduate school. Thus, first and foremost, SIIRE is a scholarship program. This is very important within the State of Arkansas where workers within the state with a bachelor's degree can expect to earn over \$25K more annually over those with a high school diploma and those with a graduate degree increasing that amount by over \$13K [12]. Thus, getting the students to complete their undergraduate degree is of utmost importance. Other programs [13] also recognize that the financial aid element is an important component to impacting degree completion. See also the work of Weller [14]. Alon [15] discusses these influences, which disproportionately impact under-represented groups within STEM. For example, Anderson-Rowland [13] describes how their scholarship components are integrated with motivating students for graduate school. Numbere and Riordan [16] describe a program similar to SIIRE that focused on supporting undergraduate research that included stipends for students throughout the academic year. They reported that "27% of the SURE participants enrolled in graduate school in engineering within two years of their graduation." Stipend support for students is an integral component of all undergraduate research experiences supported by the National Science Foundation's Research Experiences for Undergraduates program. However, in the case of SIIRE, the support is a scholarship, not a stipend. A stipend is provided for work as an undergraduate researcher, while a scholarship cannot have a work expectation.

Besides mitigating financial barriers, SIIRE works on helping the students see an advanced degree as a viable option. The choice of whether or not to go into engineering has been shown to be a very complex decision process with many competing factors such as those discussed in Matusovich et al. [17]. The choice of attending graduate school has similar complexities. Gibbs et al. [18] examined qualitative factors that influenced undergraduate engineering students in their decisions to attend graduate school. Based on a survey of 256 undergraduate students and 220 graduate students across four universities, Gibbs et al. [18] performed a thematic analysis to identify barriers and supports associated with pursuing graduate school. One of the largest barriers was concerns about funding for graduate school. These concerns not only included getting funded but also the level of funding relative to quality of life during the reduced income associated with full-time graduate studies. Again, scholarships and assistantships are an important component of the decision. In this case, SIIRE also provides (limited) funding towards graduate studies by supplementing the base assistantship awards of SIIRE students.

Gibbs et al. [18] also reported that confusion about the graduate studies application process and a lack of knowledge of graduate school were barriers to the decision process. Educating students about graduate school is a key component of programs that attempt to increase graduate enrollments in STEM fields. For example, Anderson-Rowland [13] describes how awareness of graduate school was integrated into scholarship programs at Arizona State University. Oakes et al. [19] describe in detail the development of four seminars utilized at Purdue University that had the overall goals of increasing student knowledge about reasons to pursue graduate studies and enhancing their chances for admission and financial aid. The four seminars covered 1) whether or not to go to graduate school, 2) preparing for the Graduate Record Exam (GRE), 3) taking the GRE, and 4) applying for national fellowship programs. SIIRE's two workshops on graduate studies and the GRE, essentially cover the same concepts presented within Oakes et al [19].

Similar to the conclusions of Oakes et al. [19], the SIIRE workshops have indicated a significant increase in student's knowledge in this area.

The recognition that research experiences, interacting with professors, and professional growth and development are important factors in the decision to graduate school is discussed in Gibbs et al. [18]. Borrego et al. [20] summarized the major factors investigated in previous studies that influence the choice to attend graduate school and how educators may develop programs to increase graduate enrollment in engineering. For example, research experiences for undergraduates have been shown to be a critical factor in student choice to pursue graduate studies [18, 20]. Therefore, programs should attempt to promote research experiences for undergraduate students. Because SIIRE is a scholarship program, a research experience cannot be required, but it is encouraged. SIIRE workshops focus on performing research and on how to communicate research. In addition, SIIRE supports students as they perform their graduate studies, which often includes a thesis.

Borrego et al. [20] apply social cognitive career theory to examine the underpinnings of why engineering students choose graduate school. They developed constructs aligned with social cognitive career theory such as self-efficacy, outcome expectations, supports, barriers and choice actions. These constructs present a more holistic view of the many factors involved in making the choice to attend graduate school. For example, Borrego et al. [20] used self-efficacy to represent "a person's beliefs about their ability to organize and execute the courses of action necessary to achieve a specific goal, is distinct from objective performance." In relation to choosing graduate school, self-efficacy relates to "belief in one's ability to learn relevant new skills, successfully conduct independent research, and complete a graduate degree." These findings suggest that programs like SIIRE can be effective if they reinforce these elements. SIIRE's design attempted to enhance understanding of student knowledge of graduate school process, research processes, professionalism, time management and career choices. In addition, SIIRE includes social interaction and mentoring. Creating an environment where students believe that they can be successful in graduate school is a key goal of the SIIRE program. One limitation of programs like SIIRE is that they cannot address all of the factors. For example, the results of Ro et al. [21] suggest that math proficiency and teamwork skill have strong predictive capability for graduate school choice. In the case of math proficiency, the higher the skill, the increased likelihood of attending graduate studies. However, higher perceptions of team work skills indicate a higher chance of choosing industry as the first choice after graduation. A comprehensive approach to addressing the underlying factors that are important to engineering students' decisions regarding attending graduate school should be the basis for programs that address this important problem.

As noted in this section, previous programs and research have investigated the effectiveness of such efforts. The following section presents preliminary results based on 3 of the 5 active years of the SIIRE program.

Program Results

Work on assessing the effectiveness of the SIIRE program is on-going; however, preliminary evaluation indicates some encouraging signs. We present these initial findings based on several

measures that were used to assess the success of the program, including the percentages of SIIRE students who:

- Continued on to engineering graduate school
- Received engineering related employment upon graduation
- Completed an engineering bachelor's degree
- Participated in a co-op, internship or undergraduate research program
- Completed the SIIRE program
- Represented diverse populations

In addition, students leaving the SIIRE program, whether due to graduation, failure to meet program milestones or other reasons, were asked to complete an exit survey to determine their opinions about the program, its components and the impact of SIIRE on their career choices.

A total of 45 SIIRE students comprised the 2013, 2014 and 2015 cohorts. Six students (13%) left SIIRE prior to B.S. graduation of which 2 graduated with an engineering degree and 4 left engineering. Five of the 6 students who dropped out had GPAs below the SIIRE required threshold of 3.0. Eight of the 45 SIIRE students (18%) are still active and enrolled in the College of Engineering.

As of Fall 2018, 31 SIIRE students (69%) graduated with an engineering bachelor's degree, of which 14 (45%) are from underrepresented minority populations and 14 (45%) are female. Of the SIIRE B.S. graduates, 48% participated in an engineering co-op or internship, 74% participated in an engineering undergraduate research experience, and 39% had both experiences. Only 13% of SIIRE B.S. graduates to date did not participate in either a co-op, internship or undergraduate research experience.

Of the 31 SIIRE engineering bachelor's degree graduates, 14 (45%) continued their studies in engineering graduate school, 7 of which stayed at the University of Arkansas. Of the 14 continuing on to graduate school, 4 (29%) are from underrepresented minority populations and 5 (36%) are female. One interesting fact is that 100% of the students continuing on to graduate studies had participated in undergraduate research, indicating the importance of engaging undergraduate students in research. Of these students, 67% also participated in a co-op or internship. Of the 17 (55%) SIIRE bachelor's degree graduates who did not continue with graduate studies, 100% were employed in engineering related positions.

As mentioned earlier, 45% of SIIRE students continued on to graduate school. Although a direct comparison cannot be made, the College of Engineering had an average of 17% of B.S. graduates over the last three years that continued on to graduate studies. Of SIIRE graduates not attending graduate school, 100% were employed in engineering related fields. An average of 75% of the College of Engineering's graduates were employed in engineering related fields over the last three years.

Table 2 on the next page provides a breakdown from each cohort of the number of students who graduated with their bachelor's degree and attended engineering graduate school, took an engineering related industry position, are still active in their bachelor's degree program or withdrew due to a change of major or low GPA. The table also provides the percentage of the total participants in each category.

Table 2. SIIRE Participant Status in Fall 2018

Cohort	Graduated				Total
	Enrolled to Grad School (%)	Engineering Job (%)	Still in B.S. Engineering Program (%)	Withdrew from SIIRE (%)	
2013	6 (40.0)	6 (40.0)	0 (0)	3 (20.0)	15
2014	2 (28.6)	3 (42.8)	1 (14.3)	1 (14.3)	7
2015	6 (26.1)	8 (34.8)	7 (30.4)	2 (8.7)	23
Total	14 (31.1)	17 (37.8)	8 (17.8)	6 (13.3)	45

Note: % indicates the row percentage which means % within each cohort

The SIIRE program was very successful in directing students to graduate school and in providing experiences that help them gain job in engineering related fields.

Exit Survey

Students who left the SIIRE program were asked to complete an exit survey. Students were considered as leaving the program if they 1) left involuntarily due to not meeting program renewal criteria such as GPA, change of major to one outside of engineering, or left the university prior to graduation; 2) decided to voluntarily leave the program for their own reasons; 3) graduated with a bachelor's degree and went to industry or to graduate school at another institution; or 4) completed their graduate program at the University of Arkansas. Basically, any reason that the student exited the SIIRE program at any point triggered the request for the student to fill out an exit survey. The survey focused on obtaining student perspectives on the program components and goals as stated in the introduction above. The survey included questions intended to gain insight into overall student satisfaction with program; how strongly the program increased student awareness of graduate school and its importance to their careers; how important SIIRE was to students in completing their engineering degrees; student desire to apply for and attend graduate school; and the likelihood that students would encourage others to attend graduate school.

The exit survey respondents provided the following insights:

- 100% of the students were satisfied/very satisfied with how SIIRE prepared them for graduate school
- 85% were satisfied/very satisfied with their overall experiences of the SIIRE program
- 77% of the students (100% of graduate school bound) said that SIIRE was an important factor in their desire to apply for graduate school
- 62% of the students (86% of graduate school bound) said that SIIRE was an important factor in their decision to attend graduate school

- 92% said that, after participating in SIIRE, they are more likely to encourage others to attend graduate school
- 85% attributed SIIRE with helping them understand the importance of completing their engineering bachelor's degree
- 46% said that SIIRE was an important factor in completing their engineering bachelor's degree

Summary and Future of SIIRE

Based on the analysis of our assessment data, we can conclude that SIIRE was successful in providing underrepresented and financially needy undergraduate students with 1) information on the benefits and opportunities associated with graduate education, 2) enhanced financial support and career experiences to improve the likelihood of completing both a B.S. and an M.S. in engineering, and 3) industry and academic mentoring and professional development that resulted in the increased enrollment and completion of graduate engineering degrees. As such, SIIRE represents the template for a program that can be adapted for use within other STEM programs, especially within engineering.

Since one of the key goals of the SIIRE program is to increase the likelihood that STEM students will choose to attend graduate school, we are very encouraged by these initial results. Naturally, since students selected to participate in SIIRE, this result may be due to self-selection bias. However, we have anecdotal evidence that indicates that the majority of students entering SIIRE did not have prior background and knowledge of graduate school options. We hypothesize that introducing the notion of graduate school earlier in the undergraduate's career could be a key factor in increasing the likelihood of attending graduate school. Other factors within the SIIRE program that we feel may encourage students to go to graduate school include:

- *Requiring students to prepare a preliminary graduate school application as juniors.* It is likely that this reduces their psychological and cultural barriers in considering graduate school as unattainable. At the conclusion of this exercise, the students realize that they can do it and it is not as hard as they may have thought.
- *Facilitating the taking of the GRE.* Since we decided to pay the GRE testing fee, this removes one transactional cost to students considering graduate school.
- *SIIRE's partial funding of graduate school.* We hypothesize that knowledge that at least some graduate school costs will be subsidized also decreases the students' consideration of this cost when evaluating whether or not to attend graduate school.

Based on these ideas, we believe that a program that has the following minimum set of elements could be very successful in increasing the likelihood that undergraduates apply for graduate school:

1. *Training and cost reimbursement for GRE testing as sophomores, junior, and seniors.* In other words, each year the undergraduate students should take the GRE (or GRE practice), which is similar to how high school college prep students prepare for and take the ACT as opposed to taking the GRE just once.
2. *Preparing a preliminary graduate school application as juniors.*

3. *A workshop similar to our implemented GRE preparation workshop.*

Our assumption is that if the undergraduates are more likely to apply to graduate school, this will increase the likelihood that they will **attend** and eventually complete graduate school. Beyond this minimal set of support elements, we feel that the professional development activities used by SIIRE were useful in that they created some social cohesion amongst the students and provided for interaction between professors and students outside of a classroom environment. Other research has indicated that creating this bond between students and advisors (especially research advisors) can have a significant impact on student's perceptions of their capabilities with respect to graduate studies. Regardless, the minimal set of elements appears to be a cost effective method for increasing the pipeline of U.S. citizens attending STEM graduate studies. Future work can examine the effectiveness of our recommended minimal set of support elements and exploring the analysis of our final cohort of students. This may include following up with their career paths a number of years after the SIIRE program. We are currently working on improving our evaluation methodologies in order to better evaluate the program and to investigate if our hypothesis about various underlying factors is significant.

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