Effects of a One-Week Research Program on the Graduate School Pipeline and Graduate Student Professional Development

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Sarah believes that every child deserves an excellent education. She has worked in inner-city public schools, both as a teacher and as an administrator, and in the admissions office of Amherst College, where she earned a B.A. in Chemistry. She holds a PhD from Yale University in chemical and environmental engineering, where her doctoral research produced a bio-based water purification system for removing arsenic from developing world water supplies.

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Arthur L.C. Antoine obtained a BSc. degree in Civil Engineering from The University of the West Indies, St. Augustine, Trinidad & Tobago in 2003 then moved on to practice his trade in the Caribbean engineering/construction industry. He graduated from Texas A&M University in 2009 with a MSc. degree in Ocean Engineering and subsequently, he returned to the Caribbean region to continue his career and professional development. Currently, he is pursuing a PhD in Construction Engineering and Management at The University of Colorado at Boulder. His research interests are in the areas of procurement, project delivery, alternative contracting methods and the use of incentive/disincentive strategies to encourage early project completion. In addition, he appreciates every opportunity to guide young Engineers through mentor-ship and he values the chance for his own professional development by learning from those mentor-ship experiences. Arthur is also Co-President of the Caribbean Student Alliance of Boulder; an independent student organization at CU.
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Abstract

During a one-week school break in 2015 at the University of Colorado Boulder, 20 undergraduate students, paired with 20 graduate student mentors, conducted engineering research. The goal of this program was to increase retention of undergraduates in engineering as well as to increase the pipeline of students, particularly underrepresented students, interested in pursuing graduate degrees in engineering. All students were selected through an application process, and all students were paid a stipend.

In addition to conducting research, undergraduate students were required to attend professional development events, including seminars on research etiquette, future research opportunities and the graduate school application process.

All participants completed a pre and post survey and are being subsequently tracked for retention, academic performance, and other research activities. In the first year of this program, the undergraduate cohort was 45% female and 25% underrepresented minority students, which is more diverse than the overall College of Engineering population at the University of Colorado Boulder, which is 24% female and 11.5% underrepresented minority students. The program was aimed at students who had no previous research experience. 60% of the cohort were first-year students, 20% were sophomores, and 20% were juniors.

Results showed that undergraduates who participated had a strong engineering identity and were interested in attending graduate school, but were uninformed about the financing and application process for graduate school. Thus, while undergraduates didn’t show significant changes in engineering identity or interest in research or graduate school from pre to post survey, they expressed an increased understanding of the graduate school application process as well as increased knowledge about financing for graduate school. 100% of the undergraduates who participated were enrolled in our College the following fall. Continued tracking of students will indicate whether these students matriculate in an engineering graduate program. Additionally, 100% of undergraduates said this research program was a positive experience, 95% would recommend the program, and 90% said their graduate student mentor was a good match.

Results also showed that graduate students felt this opportunity prepared them for future employment. Many expressed enthusiasm at the opportunity to practice and hone mentorship skills. 100% of the graduate mentors indicated that they would or might keep in touch personally with their undergraduates and 80% said they would or might keep in touch about their research. The graduate students also expressed gratitude for the contributions and assistance to their ongoing research activities which their mentees were able to provide.

This one-week research program increased access to graduate school for a diverse group of undergraduates and improved professional development skills for their graduate student mentors.
Moving forward, this research program will be replicated and improved upon for a one-week school break during 2016.

**Introduction**

The number and percentage of women and underrepresented minority students (URM) in Science, Technology, Engineering, and Math fields (STEM) diminishes at each step of the academic pathway, from BS to PhD to faculty\(^1\). On the other hand, participation in undergraduate research programs and a sense of engineering identity, especially early on in undergraduate study, have been linked to stronger retention of undergraduates in STEM fields\(^2\).

Students who participate in undergraduate research programs are more likely to persist in their fields and enroll in graduate school\(^3,4\) as well as experience other benefits\(^5\). In particular, research experiences that occur early within a student’s undergraduate career are a common factor in successful intervention programs for retention of URM in STEM\(^6\) and lead to higher likelihood of persistence in STEM majors and pursuit of graduate school\(^7\). Undergraduates who participate in summer or semester-long research experiences report positive effects such as: “thinking and working like a scientist”, clarification/confirmation of career plans (including graduate school), and enhanced career/graduate preparation\(^5\).

Despite these benefits, however, becoming involved with research early in their undergraduate program can be difficult for students\(^8\). One study suggests that compared to upperclassmen, a much lower percentage of first-year students consider themselves to be engineers, and the discrepancy between males and females who consider themselves engineers is the largest among first-years\(^9\). In addition, faculty members are reluctant to include new undergraduates in their research laboratories due to lack of experience\(^6\). Meanwhile, for many students, particularly those who are the first in their family to attend college, research is often unfamiliar, and a summer or semester may feel inaccessible or overwhelming.

In order to create academic institutions that reflect our nation’s diversity, we must seal holes along the leaky pathway from undergraduate degree programs to professional jobs in STEM. An important step is retaining students once they have enrolled in undergraduate degree programs and supporting those students as they explore and continue along the academic pathway.

The research program we report on here, titled “Spring Break for Research (SB4R)”, was designed at the University of Colorado Boulder College of Engineering and Applied Science to address both retention of students within engineering and also support of student progress along the academic pipeline by providing a one-week mentored research experience to occur during spring break of 2015. We hypothesized that, similar to summer or semester-long research programs, a week-long research experience would improve engineering identity, increase undergraduate retention and increase the likelihood of attending graduate school.
In addition to the outcomes described for undergraduates, this program was also designed to ameliorate the issue that graduate students are most often not given sufficient training on critical professional skills to prepare them for the professoriate. The SB4R program addressed this deficit in the graduate experience by providing graduate students with an opportunity to hone their mentoring skills, boost communication skills and interact with other students to discuss research in an informal context. To participate, graduate students apply and propose a research project. Upon acceptance, they are paired with an undergraduate mentee and are responsible for teaching them and leading them through the research experience.

The development team piloted the 2015 SB4R program during CU Boulder’s spring break week in late March 2015. The development team collected pre and post survey data from undergraduate and graduate student participants. This program was repeated over spring break 2016 to continue to address retention of undergraduate students within engineering, support undergraduate students’ progress along the academic pipeline and, to provide graduate students with opportunities to develop critical professional skills to prepare them for the professoriate.

The goal of this paper is to present the program details, assessment results, and implications for future programs and adaptations.

Program Details

The 2015 SB4R team included two executive-level employees in the College of Engineering and Applied Science at CU Boulder and two engineering graduate student “leads”. The team was responsible for applying for funding for the program, advertising the program, developing pre- and post-surveys for evaluating the program, selecting and matching students to participate in the program, paying the students a stipend for their participation, leading information sessions and workshops about the program, and coordinating logistics for the week. We paired 20 undergraduate students with 20 graduate mentors for the pilot 2015 SB4R program.

Recruitment and Selection

Although this program was open to all students in our College of Engineering, it was primarily marketed to students in the BOLD (Broadening Opportunity through Leadership and Diversity) Center, a support center for women and URM engineering students. Underrepresented minority students at the University of Colorado Boulder have an average 6-year graduation rate that is 20% lower than the majority population. This research experience was designed to be a persistence strategy since students who engage in research in their first two years of college are more likely to persist in STEM majors. We sought to recruit a larger number of first and second year students who are more at risk for leaving engineering and were less likely to have previous research experience. Given that this was a one-week program, we felt that it was more likely to have an
impact on the students who had not yet done research but were eager to have such an opportunity. Since faculty are also more likely to hire students who have already had some experience, this experience will hopefully serve as a springboard for future research opportunities for these students.

We hosted information sessions in late October 2014 to promote 2015 SB4R and to recruit both undergraduate and graduate applicants. The program was promoted through flyers, emails, newsletters, and posts on Facebook groups affiliated with our College of Engineering. Undergraduate students filled out an online Qualtrics application and were selected based on the following factors:

- Interest in program and future research
- Level of research experience, where we sought students with little or none
- Ability to match general research interests with graduate mentor research project
- Availability over spring break week

Prospective graduate mentors completed a Qualtrics application and were selected based on the following factors:

- Interest in mentoring
- Ability to give undergraduate meaningful work in one-week project related to graduate’s ongoing research
- Availability over spring break week

**Activities Prior to Spring Break for Research 2015**

Prior to the Spring Break week, each pair (graduate mentor and undergraduate researcher) was required to meet. The pairs were given complimentary coffee cards for the local café on campus as an incentive for the meeting. During these meetings, we encouraged the students to get to know one another on a personal level and to discuss their research project. Graduate students also had the opportunity to assign their mentee some background reading at this time. Additionally, both graduate student mentors and undergraduate researchers were assigned separate pre-surveys via Qualtrics, which we used as a metric for evaluating our program. More details about this survey are explained in the Assessment Section.

**Schedule for the Spring Break week**

In addition to the research component of our program, the agenda for the one-week research program included three professional development workshops and a reception where students had the opportunity to meet one another and learn about each other’s research experiences. These workshops were each 60 to 90 minutes in length on the Monday, Tuesday and Wednesday during the break week. The first workshop was about lab safety and was presented by a representative from our campus Environmental Health and Safety Office. This session was helpful because most
of the students in our program had no lab experience and some would be interacting with chemicals. The second workshop, titled “Research 101,” was led by a graduate student lead for the program. The format was an oral presentation that discussed the following topics:

- How to conduct a scientific literature review
- Types of research questions and research methods
- Laboratory hierarchy and terminology (from undergraduates all the way up to PI)
- Culmination of research (journal publications, theses, presentations, etc.)
- Research Experiences for Undergraduates (REUs) sponsored by the National Science Foundation
- Other research programs at the University of Colorado Boulder

The third workshop, titled “Grad School 101,” was also led by a graduate student lead of the program. The format was an oral presentation that discussed the following topics:

- Types of graduate programs (Masters, PhD, professional, etc.)
- Reasons to pursue a graduate degree
- Costs of a PhD program compared to other graduate programs – including tuition, student loans, fellowships, salary via teaching or research assistantships
- How to choose a PhD program
- Timeline for applying to graduate programs
- How to be a strong applicant for a PhD program

At the end of both the second and third workshops, undergraduates had the opportunity to ask questions of a panel of 5 graduate students conducting research in various engineering departments.

As all three workshops were scheduled in the morning, 8:30am to 10:00am, respectively, on the Monday, Tuesday and Wednesday of spring break, the rest of the day was open for the students to conduct research. The graduate student mentor and undergraduate researcher agreed upon the particular schedule for the research component of the program, but we required the students to work full time for the week (i.e. 40 hours over the week). We also encouraged graduate students to invite the undergraduate to research events, such as lab group meetings or talks within their department, so that the undergraduate could witness the lifestyle of a graduate student researcher.

In addition to the professional development workshops, the undergraduate students were required to complete a research “nugget”, one slide – one slide that showcased something the student learned, achieved, enjoyed, etc. They were given until the end of the week to submit the research nugget. The week following Spring Break a reception was held, with faculty and staff invited, where the undergraduate researcher slides were displayed using a projector. Graduate mentors were able to assign additional deliverables if appropriate for their project.
Activities after Spring Break for Research 2015

After the undergraduate and graduate students had completed the week, they were required to complete a post-survey in Qualtrics about the program. More details about this survey are explained in the Assessment Section. Additionally, stipends were contingent upon completion of all program components, so these were awarded after the program. Undergraduate students received $500, graduate students received $250, and their faculty research advisors received $100.

Assessment

Demographics

The pilot Spring Break for Research program attracted 25 applications for the pilot program. From these applications, a diverse group of 20 undergraduates and 20 graduate mentors were selected as seen in Table 1.

Table 1. Demographics of the participants of the Spring Break for Research program as compared to the demographics of the College of Engineering and Applied Sciences

Compared to the College of Engineering demographics at CU Boulder, the SB4R program had a much higher percentage of female undergraduate researchers. Additionally, the percentage of underrepresented minorities in our program is over two times larger for undergraduate participants and approximately five times larger for graduate mentors than the overall College of Engineering demographics. Of the five students who applied but were not selected, three of them had significant research experience and were not a good fit for a short-term introductory program.

Hypotheses
We hypothesized the following about our SB4R undergraduate participants:

1. Undergraduate students who participate in this program will be more likely to think of themselves as engineers (improved engineering identity).
2. Undergraduate participants will indicate a greater likelihood of pursuing graduate school after this experience compared to prior.
3. Undergraduate participants will indicate a greater likelihood of pursuing future research opportunities after this experience compared to prior.
4. Through SB4R, undergraduate participants will feel more prepared for the graduate school application process.
5. Undergraduates are unaware about how engineering PhD programs are financed.
6. Students who participate in SB4R are more likely to be retained and graduate in Engineering.

We hypothesized the following about our SB4R graduate mentor participants:
1. Graduate students who participate in this program will feel more confident in their mentoring skills.
2. Graduate students who participate in this program will improve their engineering identity.
3. Through Spring Break for Research, graduate students perceive they can help influence/encourage undergraduate students establish engineering identity.
4. Through Spring Break for Research, graduate students perceive they can influence/encourage undergraduate students to pursue research and/or graduate school.
5. This experience will help prepare graduate students for future employment.
6. Graduate students believe mentoring undergraduates through Spring Break for Research is more difficult than it actually is.
7. Graduate students who participate in this program will feel more confident in their mentoring skills.

Pre and post surveys for undergraduates and graduate students were developed to address our hypotheses. The following are sample questions from those surveys.

Sample Questions from Undergraduate participant Pre-Survey

- Ordinal scale rating of the extent the respondent agrees with the following statements:
  - I consider myself to be an engineer
  - I feel like I belong in engineering
- Ordinal scale rating of the likelihood of the respondent to pursue the following:
  - Future research opportunities after spring break
  - Graduate degree in engineering
- How prepared do you feel for the graduate school application process?
Sample Questions from the Undergraduate participant Post Survey

- Ordinal scale rating of the extent the respondent agrees with the following statements:
  - I consider myself to be an engineer
  - I feel like I belong in engineering
- Ordinal scale rating of the likelihood of the respondent to pursue the following:
  - Future research opportunities after spring break
  - Graduate degree in engineering
- Was Spring Break for Research a positive experience?
- Would you recommend this program to other students?
- Was your mentor a good match?
- What was the best part of this program?
- What would have made this experience better?

Sample Questions from Graduate Mentor Pre-Survey

- Ordinal scale rating of the extent the respondent agrees with the following statements:
  - I think of myself as an engineer
  - I feel like I belong in the engineering community
  - I am confident in my abilities to teach engineering content to another person
  - I am comfortable communicating with my undergraduate mentee
- Ordinal scale rating of the extent the respondent believes she/he can have influence on the following:
  - Helping your undergraduate student establish their engineering identity
  - Encouraging your undergraduate student to pursue research
  - Encouraging your undergraduate to pursue graduate school

Sample Questions from Graduate Mentor Post-Survey

- Ordinal scale rating of the extent the respondent agrees with the following statements:
  - I think of myself as an engineer
  - I feel like I belong in the engineering community
  - I am confident in my abilities to teach engineering content to another person
  - I am comfortable communicating with my undergraduate mentee
- Ordinal scale rating of the extent the respondent believes she/he can have influence on the following:
  - Helping your undergraduate student establish their engineering identity
  - Encouraging your undergraduate student to pursue research
  - Encouraging your undergraduate to pursue graduate school
- Do you think you and your mentee will keep in touch?
Do you think you and your mentee will continue to communicate about research?

What was the best part of the Spring Break for Research program?

What would have made this experience better?

Did you feel adequately prepared to serve as a mentor? What would have helped you to feel more prepared?

Were there any difficulties or issues that came up in mentoring your undergraduate?

Did this experience help to prepare you for future job opportunities? How so?

Have you had any prior mentoring experience?

Would you recommend this program to other graduate students in the future?

Results

Undergraduate

Engineering Identity - Based on the survey results we concluded that there was no statistically significant change in the perceived engineering identity of the undergraduates after their participation in the program. 85% of the undergraduate researchers considered themselves to be engineers both before and after the program. 80% of the undergraduates felt like they belong in engineering both before and after the program. We did not see a significant shift, and we suspect this is because the program attracted students who already had a strong engineering identity.

Future Research Plans - Based on the survey results we concluded that there was no statistically significant change in the undergraduate’s plans to pursue future research opportunities after their participation in the program. The median rating between pre and post surveys remained a rating of “highly likely”. We did not see a significant shift, and we believe this is because the program attracted students who indicated a strong interest in pursuing future research opportunities before the program.

Future Graduate School plans - Based on the survey results we concluded that there was no difference in the rating of students who intend to pursue a graduate degree in engineering before and after the Spring Break for Research program. In both pre and post the participants indicated a rating of “highly likely” to pursue a graduate degree in engineering.

Understanding of the Graduate School Application Process and Financing - Based on the survey results we concluded that after the Spring Break for Research program the undergraduate participants had an improved understanding of the process for applying to graduate school and an improved understanding of how engineering graduate school is funded. This change was a result of the learning that occurred during morning workshops (which specifically addressed these topics) and discussions between undergraduates and their mentors.

Retention – 100% of the undergraduate participants were retained in our College of Engineering the subsequent fall.
Graduate Engineering Identity - Survey results from the graduate mentors indicated that there was no statistically significant change from pre to post program in the graduate student’s engineering identity.

Mentoring - Survey results from the graduate mentors indicated that there was no statistically significant change from pre to post program in the confidence of the mentors in their mentoring skills. Results also indicated that the graduate mentors did not increase in their belief that they could influence or encourage undergraduates in establishing their engineering identity. Graduate mentors did show an increase in comfort communicating with their undergraduate mentee after the program.

Participant Feedback

Feedback from the pilot Spring Break for Research Program was overwhelmingly positive, with the following highlights:

- 100% of undergraduates reported that the program was a positive experience
- 95% of undergraduates reported that they would recommend the program to others
- 75% of graduate mentors said that they would definitely recommend the experience, 25% of graduate mentors that they might recommend
- 100% of graduate mentors said they thought they would or might stay in touch with their undergraduate mentee overall and 80% said they would or might keep in touch about their research in particular

Testimonials from Undergraduate Researcher Surveys

“I discovered the wide range of experiences in a research project: cleaning, running experiments, collecting samples, and analyzing data. My mentor has an NSF grant, so I've realized how affordable and fun grad school can be. Talking to other students about their experiences helped me see the diversity in studying research.”

“I got a taste of what it would be like to do research. I acquired experience using Abaqus, a program that I might use in my academic and professional career. I learned that if I decided to pursue a PhD, I have a lot of resources for obtaining funding. I also got to see how the research advisor interacted with my mentor. As far as choosing a specific research topic, I would need exposure to other options before honing in on what interests me most. However, after this experience, I feel more comfortable with the topic of Photonics and would highly consider it for more long term research.”

“From this experience, I not only learned a lot about research, but also about what graduate school is all about. I learned many of the important aspects of research, such as the importance of patience,
studying, and good lab skills. Furthermore, I learned that research is a very rewarding experience and that it is definitely an option for me in the future. In addition, I learned some very important lab skills that will help me in the future. Also, I learned about the process of applying to grad school. Overall, I learned much from this experience.”

“I gained a valuable look into the world of research, which is something I've been considering, but haven't entirely decided on going into. This experience was a good look at what working in a research lab would be like without having to worry about over committing myself during the semester.”

“I really enjoyed getting to see the real world applications of what I am learning in my classes. In addition, I also liked getting a deeper exposure to programs like Matlab and SolidWorks and to use them for actual applications.”

“The program basically taught me more about engineering than my classes have for the last semester and half; I now have a defined goal.”

*Testimonials from Graduate Mentor Surveys*

“Mentoring is a key skill in many industries, as a professional I had to mentor consultants and realized it is a complex task that requires lot of expertise. During this week I had the chance to improve my mentoring skills: communicating, delegating and time management among others. It has also been a very interesting experience to show a freshman what graduate school is like and give them a glimpse of what knowledge we developed and the work we do.”

“I learned how to explain my research in more simple ways so everybody can understand. I also learnt how to organize my time so my mentee could help out efficiently. Also, I learned that is not just about doing research, but also about having fun in the lab and connecting with the mentee to encourage him to succeed.”

“It was amazing, and I'm glad that my undergrad was able to be so independent. I was very hands-on at first, but let her take the lead the last two days. What did I get out of it? I re-learned how excited I am about this work, and also realized that I make a good mentor with the right students. I haven't always done great in the past, but I think that Vanika and I worked very well together.”

“The organization was great. And then having an interested mentee whom I was able to share experience in grad school with.”

“The student brought in fresh ideas. In the process of teaching the student about my research it forced me to put it in simpler terms and improved my communication on the topic. The student also had a few insights that were surprising and enlightening.”
“Teaching my mentee key concepts in engineering useful to treat data which I am sure will be useful for her studies as an engineer. Working in the lab can be very tedious and repetitive, having a motivated freshman around has boosted the number of experiments performed in the lab during this week.”

“I could see how this experience could make me more prepared for a position where I either train new employees or am managing a project.”

“I believe this mentoring opportunity helped me see what mentoring and advising in the lab really is. I loved it!”

Summary

The most significant change from the pre to post survey for the undergraduate participants was their understanding of the graduate school application and funding process. More significantly, the undergraduate comments and rating of the program indicates that these participants felt that the Spring Break for Research program was a worthwhile and beneficial experience that would help them in their future engineering careers. The undergraduate students who participated already had a strong engineering identity so we did not see a direct impact to identity from the program. We also found through our surveys that our program attracted undergraduates who were already planning to pursue future research opportunities and had an interest in graduate school so there was no significant change to these plans after the program. For future programs we will consider strategies for attracting students who do not already have a strong interesting in doing research and attending graduate school. 100% of the undergraduates who participated were retained in engineering the following fall semester and we will continue to track the persistence of this group. We are in the process of administering a survey to our 2015 cohort, both undergraduates and graduates, to learn how the experience has helped them longer-term and influenced their plans related to research, graduate school, and mentoring. The graduate mentor comments show that the program was worthwhile to graduate students and that they appreciated the opportunity to mentor and gain teaching experience. Graduate students also gained confidence from pre to post program in communicating with their students.

Lessons Learned & Future Plans

Based on the surveys from the 2015 program, in addition to discussions and feedback from past participants and prospective applicants, the SB4R program managers have obtained beneficial insight for improving the program going forward. Prospective graduate applicants in particular, tend to be most concerned with the workload involved by participating. Many of these graduate students believe that they would be inundated with supplemental work by participating. Organizers often have to dispel this belief by discussing past examples of projects and by explaining to the
graduate mentors that the undergraduate mentees are essentially assigned to assist the mentors on their ongoing academic/research projects.

Consequently, during Spring Break for Research 2016 the program’s organizers plan to obtain substantial marketing material such as video footage of the participants in action as well as testimonials. The 2016 Spring Break for Research program is in progress currently and we have already seen a significant increase in interest. Undergraduate applications were up by over 50% and graduate applications were up by over 100% by the application deadline. Per request, we have also added a professional development workshop for graduate students led by the Associate Dean for Graduate Programs in our College of Engineering and Applied Science.

We will continue to track participants over time to see whether the undergraduates who participated in our program have a higher retention rates, and whether graduate students continue on to academia or choose professions elsewhere.

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References