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Structuring equity and inclusion into access to undergraduate research opportunities

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Introduction

Research skills are central to many aspects of engineering, but are sometimes stereotyped as being for people who are "clever, bright, reserved, socially clumsy" or unlike ordinary people [1], and incompatible with non-masculine identities [1]. Undergraduate students without much exposure to alternatives to these stereotypes may not envision themselves as being able to or wanting to do research. At the same time, research experiences may be the most accessible during an undergraduate degree at a research institution. Explicitly exposing students to research, especially students who feel they do not fit the cultural stereotype, may be a step to ultimately increase diversity among graduate students and faculty members in engineering. In addition, many positions in industry require research thinking – exposing students to research may strengthen their professional abilities and, ultimately, the engineering sector of the economy.

Undergraduate research experience in particular is important because it develops key complementary skills needed for further research, alongside technical competencies. Experiencing research at the undergraduate level is correlated with positive post-graduation outcomes, including effective speaking, understanding scientific findings, analyzing literature, and having clear career goals [2]. It also promotes three key graduate attributes required of all Canadian engineering students: communication, teamwork, and leadership [3]. Undergraduate researchers are also more likely to intend to pursue a graduate or professional program in science, technology, engineering or mathematics by approximately 14 to 17 percentage points [4].

In terms of career ambitions, Social Cognitive Career Theory [5] suggests experiences like undergraduate research can impact career ambitions and student occupational self-efficacy. Students completing undergraduate research experiences often identify gains in self-efficacy when asked to describe the impact of those experiences, with women being more likely to express gains in confidence [6].

Pierszalowski et al. [7] suggest thirteen barriers to the undergraduate research experience, ranging from physical resource issues (frequently cited) to lack of faculty diversity (less often cited). Frequently cited barriers that are also a concern for our department include lack of time, lack of faculty incentives, student and faculty perceptions of student readiness, student interest and motivation, and financial concerns.

Past research has suggested that GPA, standardized tests, and other commonly used metrics may not be successful at differentiating between the highest- and lowest-ranked graduate students [8], and can replicate bias against under-represented groups of students [9]. For example, gender has been shown as a factor in grade decreases in first-year university [10].

Supporting institutional strategic goals to broaden access to undergraduate student research [11], our department created a cohort-based, course-supported summer research program, with goals to:

1. Interest students in research.

2. Create an equitable application and acceptance process based on skills important to research, de-emphasizing or eliminating aspects like GPA, experience, or reference letters that may have a disproportionate impact on some groups of students.
3. Support students by providing summer research skill courses, training their mentors, and providing cross-cohort social/learning opportunities.

In this paper, we will focus on the evaluation of program aspects outside of the two summer courses.

Context

Institution

At our large, research-intensive institution, undergraduate research experiences were prioritized as part of the latest overall institutional strategic plan [11]. In concert with this strategic plan, a fund was created by the Office of the Vice President Academic and Provost to support expanding undergraduate research experiences, called Program for Undergraduate Research Experiences (PURE). This one-time, proposal-based, competitive program was open to applications from any academic unit, with $1 million total funding available.

Funding and Drivers

Our department's summer research program was formed within the mechanical engineering department at our institution in response to two primary drivers: first, a desire at the department level to increase the quality of undergraduate research experiences and, second, the availability of the one-time funding program associated with the strategic plan mentioned above.

Currently, there are three primary avenues for our mechanical engineering undergraduate students to participate in research. The first is through the NSERC Undergraduate Student Research Award (USRA) program. The department received eight total NSERC USRA positions in 2018, and six were filled with students from our department. In our department, selection into this program is primarily based on GPA. The second is through co-op positions with research faculty in the department. This requires individual faculty to fund the student's entire salary. There were two further Mech students hired via this avenue in 2018. Finally, students can enroll in a one or two term upper-year credit course where they complete a research project under a faculty member (students are not paid). Enrollments in this course tend to be low: fourteen students in 2018, three in 2017, seven in 2016.

Considering that our total departmental undergraduate enrollment (excluding the common first year) is 543 students, the number of our students participating in research at the undergraduate level represent a very small percentage of our total student body. As part of preliminary exploration into the reasons for this low involvement, the department ran a focus group with undergraduate students. It was determined that students (1) generally do not understand what research is, (2) associate research only with academia and not with industrial "R&D," and (3) believe that research opportunities are only accessible to top academic students.

At the department level, there had been growing recognition that utilizing undergraduates in research was a possible way to improve overall engagement in research in the department, and to encourage our students to consider both academic research and research careers after graduation. By bringing research into focus at the undergraduate level, we create a recruitment funnel, train

prospective graduate students for the general research community, and raise awareness among our students - our future alumni community - about what research is and how research serves the engineering profession. Mentoring younger students also enhances the skills of our graduate students and brings new ideas and perspectives to their work. Also, by engaging students in research in their undergraduate years, they develop a stronger sense of what research offers their careers and the engineering community, and we hope makes it more likely they may consider graduate school or industrial research, perhaps in partnership with the university.

There was also a recognition that undergraduates often lack certain skills or knowledge when they first join a research lab, and that a bridge or training program would be advantageous. There has also been discussion of which identities are most often excluded from research opportunities, and how to provide equitable access and meaningful support to have our research undergraduates better reflect our overall student demographics.

Our program was awarded $91,405 (~9%) of the overall university-wide pool in a competition with a 22.7% acceptance rate. The funding was partially matched by departmental and faculty member contributions. The award covered partial costs for the first year of the program, including developing and piloting the courses, project management and program evaluation costs, program coordination, graduate student mentor honorariums, and the majority of student stipends. Funding support for future years was committed by the department, including continuing to subsidize student stipends.

Program Structure

Our summer research program, *Combining Research Experience and Technical Electives for Undergraduates* (CREATE-U), is an immersive, cohort-based research education experience. The comprehensive program is designed to educate students about research and create an accessible, welcoming opportunity for undergraduate research in Mechanical Engineering.

CREATE-U has six major components:

1. Generating interest in research;
2. A pooled application process with an emphasis on diversity;
3. Course 1 (MECH 497, 3 credits): Research Skills in Engineering
4. Course 2 (MECH 498, 3 credits): Research Communication;
5. A research project work term within a mechanical engineering research lab, with support from graduate student mentors;
6. A supportive structure, including a welcome event and networking lunches.

CREATE-U is unique as it integrates and coordinates coursework with individualized, authentic research lab experiences. A supportive structure and courses with modern pedagogical practices help students bring together technical skills and knowledge with communication skills, interpersonal skills, discussions of ethics, and other key competencies. Classroom topics can be immediately applied, and course learning outcomes (including a research poster presentation) encourage students to disseminate their work. In addition to the regular faculty supervisor, CREATE-U students were also assigned a graduate student mentor in their lab.

In this paper, we intend to present our evaluation of the aspects of the program outside of the two courses. Our research questions were:

1. How effective were course-based interventions to increase undergraduate engineering student understanding of and interest in research?
2. How effective were attempts to create equitable and broad-based admissions into an undergraduate research experience for under-represented groups?
3. How effective was the overall program (excluding credit courses) in supporting students in learning to do research?

Methods

We addressed the goal of the program in several ways. The research aspects of this work received institutional ethics approval [certificates H19-01147 and H22-00269]. The program evaluation aspects of this work (completed as part of the funding requirements) did not require ethics approval at our institution, but were conducted in adherence to ethical research guidelines.

Increasing Interest in Research

Several approaches were used to increase understanding of and interest in research among undergraduate mechanical engineering students. We targeted core courses in second- and third-year, as those students would be eligible for the program.

Our integrated second-year program organizes guest speakers as a regular element of teaching. Typically, the guest speakers represent a range of possible career paths. The CREATE-U team coordinated with the second-year program to arrange a talk about research in the fall of 2019 and again in the fall of 2020, by one of the regular second-year course instructors. This was done with the explicit goal of exposing them to the idea and the reach of research, prior to the application period for CREATE-U. In 2019-20, we arranged pre- and post-surveys of the class related to research attitudes and belonging. In 2020-21, as part of regular course practices, students were asked to complete a short (1-2 sentence) reflection on the talk, with the prompt "What did you learn from this talk?". The student reflections were coded for content, with the aim of determining if students knew more about research and/or were more aware of whether they were interested in it.

In addition, the third-year lab course was restructured to introduce experimental design, then challenge students to design their own experiments to answer their own research questions. In 2019-20, we arranged the same pre- and post-surveys of the class related to research attitudes and belonging deployed in second-year.

We also held an information session for potential applicants to the CREATE-U program, which attracted approximately fifty students. This session was not separately evaluated, but many of the students who applied likely attended. Presented by the Associate Head of Teaching, supported by the course instructors and staff coordinator of the program, it discussed why one might pursue research, explained the program structure and activities, and explained the information process. We also reviewed a range of example CREATE-U positions, so students could envision themselves in the job. Slides were then distributed to all undergraduates and posted on the website. Additionally, posters and social media posts were created to advertise the program.

Selection of Students

Two aspects of the selection process were meant to increase the equity of the student selection process. The first was to de-emphasize grades and emphasize critical skills or attributes for research. This would mean that students were not screened for grades (as long as they met the minimum). A minimum GPA of 76% was required for consideration, which is the minimum for entry into a graduate program in our department. Students were told during information sessions and on advertisements that GPA would not be the deciding factor, which may have encouraged a broader range of students to apply. This was intended to attract students who had strong potential but were not captured through NSERC USRA or other programs. The second was to have applications scored by a blinded adjudication committee composed of faculty members involved in the program creation. Each application was scored by a minimum of three faculty, and Z-scores were used to calculate an overall score. Blinded assessment has been shown to reduce implicit bias against women and other underrepresented groups [12], [13].

Determining the critical skills or attributes for research that would be the basis of the candidate assessment was a multi-step process. First, we completed a literature review to assess what factors are associated with success in graduate school (as a proxy for research success). This revealed a very limited range of factors used in graduate school admission and research – typically GPA, standardized test scores, and reference letters. All of these factors can be impacted by systemic inequity: for example, some students may not feel as comfortable approaching referees because of the impacts of neurodiversity or because caregiving responsibilities limited their opportunity to interact with faculty members outside of class time.

Next a group of faculty, staff, and graduate students brainstormed possible skills or attributes that could be strong indicators of potential research ability. These ideas were grouped into themes, and included curiosity, navigating uncertainty, intrinsic motivation, perseverance, patterns and thinking broadly, and articulating ideas.

At a departmental faculty retreat, the committee presented on “Identifying Diverse Students” and shared the problem statement “We want to be able to select high quality students for research positions, but we want to minimize the use of GPA for selection (provide opportunities for more students). What factors make a good research student?” The committee also recommended that a rubric be developed for CREATE-U admission in order to provide a consistent reference point for identifying good students. The stated anticipated benefits included: (1) more objective assessment of students; (2) reduced likelihood of “self-replication” (homosocial reproduction) leads to greater diversity [14]; and (3) widening the candidate pool by reducing focus on GPA.

Retreat participants, consisting of faculty of all ranks, then worked in groups of four to six to brainstorm additional factors, and present their ideas to the group. Concepts were summarized, and multi-dot voting was utilized to determine which areas had the most support. Almost universally supported, and ranked far above the others, the strongest factors were perseverance, intrinsic motivation (from Self-Determination Theory [15]), and curiosity. Navigating uncertainty, research-group specific skills and articulating ideas were a second tier, receiving support from one third to half of participants. Research-group specific skills were removed from the final factors, as the program was using pooled admission. GPA served as a sixth, equally-

weighted criteria. Discarded factors included patterns and thinking broadly, practical skills, lifelong learning, networking skills, and social skills.

The final factors were defined as follows:

- Perseverance: Applicants demonstrate persistence despite difficulties, failure, or opposition. Applicants may have overcome substantial obstacles, including systemic barriers to education.
- Intrinsic Motivation: Applicants demonstrate that they choose to engage in activities because they find them satisfying, not due to external factors. Applicants are excited about the process of learning and are enthusiastic about research.
- Curiosity: Applicants demonstrate a strong desire to know, learn, or explore something and have a tendency to ask questions, pursue answers, and "play" with concepts. Applicants may demonstrate this through personal projects.
- Navigating Uncertainty: Applicants are comfortable with a high level of uncertainty, and are flexible and adaptable. They can look at a problem and see many solutions, and make decisions on what path to pursue. They are willing to take intellectual risks and are able to work without detailed guidance.
- Articulating Ideas: Applicants can express themselves and their ideas through writing and/or engineering drawing. They are able to curate their thoughts for an audience.
- GPA: UBC average, year 2 and up (except for applicants in second year, when year 1 is included) (76% minimum cutoff).

Rubric level descriptions were created for each of the factors, and students were asked short essay-style questions to draw out examples. The adjudication committee was explicitly asked to consider the attributes from a broad range of possible situations or examples, and not just from academic situations. If an applicant wrote about their sustained interest in a culture different from their own, which led them to learn a new language and how to cook dishes from that culture, for example, this could be rated highly in the curiosity category of the rubric. We chose to consider non-academic examples because we wanted to reduce bias for students with many past opportunities to participate in a wide range of academic activities, particularly past research, because these past opportunities may have only been available to more privileged students. Instead of direct academic or research experience, we were trying to identify personal attributes that departmental faculty believed would lead to success at research.

After the committee finished ranking students, the top ranked students were selected and matched with supervisors/projects based on student preference. Admitted students then participate in an informational interview to ensure students, mentors, and supervisors are comfortable working together. If it became clear that the match is not a good fit, the student would be matched to a different project and a new informational interview would be held.

COVID impacted the first round, as the university did not allow undergraduate students access to campus in 2020, leading to the program start to be postponed for one year. The application and adjudication processes were therefore repeated in 2021, and only the second list of selected students participated in the program.

Students in both CREATE-U and other summer research positions in summer 2021 were surveyed to capture changes in belonging [16] and self-efficacy [17] related to research (Appendix A).

Program supports

One of the central pillars of the CREATE-U program is the cohort model. By advertising, recruiting, and working as a cohort, it is possible to provide program-level supports to faculty supervisors, mentors, and participants.

Support to faculty began first, with the distribution of an information package that included both practical information about the program and a handout with curated information on communal and agentic language, with words and phrases to consider using and avoiding [18], along with a list of resource people at the departmental and faculty level. When posting, faculty were also asked to nominate a graduate student or postdoctoral mentor for the student, who would work with them day-to-day in the laboratory.

For many mentors, CREATE-U was their first experience in supervising students. To support them in this transition, we offered a mentor training afternoon that included a reflection on values and why the department values mentoring, and sections on diversity as a strength, acknowledging bias, the six facilitative conditions [19], facilitative condition response [20], and tools for mentoring.

The undergraduate student program started with a welcome day, including introductions and administrative matters, a paired introduction icebreaker, a keynote address by a department alum who was involved in undergraduate research and is now a senior leader in industry, a self-introduction by the graduate mentors, and lunch. The intention was for lunch to be a group activity for networking, but COVID restrictions changed it into each student and mentor pairing meeting to share a meal and become better acquainted.

The summer also included networking sessions. These were envisioned to be lunch meetings for mentors and mentees, but were held as online sessions due to COVID. At each session, a faculty member led a discussion on a topic related to research. Topics included:

- Day in the life of a graduate student
- Industrial collaborations in research
- Non-academic career options
- Spinning off research & innovation
- Roundtable panel of current graduate students
- What's next between now and grad school?

To bookend the summer, a closing session included a thank you and lunch between mentor and mentee pairs. In future years, this will be a poster session of all participants.

Results

Interest in Research

Out of 126 students enrolled, 100 students completed both pre- and post-surveys in second-year in 2019-20. Paired t-tests were completed to compare student results between pre- and post-surveys. Students rated their agreement with each statement on a 5-point scale (Table 1). Using the Bonferroni correction for six multiple comparisons, the significance level was $\alpha = 0.00833$. There was a statistically significant increase in agreement that students had been exposed to how research is done.

When asked an open-ended question about where they have been exposed to research, 12 students explicitly mentioned the guest lectures and another 5 listed venues that may have been the guest lectures (e.g. "class", "through presentations") when they had no similar venue listed in the pre-survey. One student also explicitly mentioned the CREATE-U information sessions. The item "I know what research is" did not quite reach statistical significance, but showed a marked increase (Table 1).

Table 1: Results from surveys of second-year class in 2019-20 (n=100). Five-point agreement scale (1 = Strongly disagree, 5 = Strongly agree).

	Pre-survey mean	Post-survey mean	Paired difference mean	p-value
I know what research is	3.99	4.15	0.16	0.0107
I think research is interesting	4.11	4.09	-0.02	0.7593
I think research is relevant to me	4.11	3.95	-0.16	0.0808
I want to learn more about research	4.09	3.99	-0.1	0.2657
I would like to participate in research opportunities	4.13	4.02	-0.11	0.1737
I have been exposed to how research is done	3.03	3.37	0.37	**0.0023***

For the 2020-21 second-year class, 111 of 125 enrolled students completed reflections (Table 2).

Table 2: Coded reflections to second-year research lecture (n=111). Note that reflections could include more than one aspect, so totals are >100%. (UG = undergraduate)

	Number of reflections	Percentage of reflections
Who can do research	6	5.4
Personal attributes that are good for research (e.g. curiosity)	3	2.7
I don't want to do research	3	2.7
I want to learn more about research	13	11.7
I can/want to/plan to do research	20	18.0
UG research is good for grad school applications	6	5.4
Research leads to many career options	41	36.9
There are opportunities to do research as an UG student/how to get involved in research	59	53.2
CREATE-U mentioned specifically	20	18.0

What research is like (goals/motivations, how researchers spend their time, funding)	47	42.3
Research crosses disciplines	15	13.5
How what I am learning now relates to research	13	11.7
Research leads to gaining many skills	5	4.5
Specific projects/types of projects	27	24.3
Career path of speaker	18	16.2
Personal connection (to topic of research discussed, family in research, personal experience in research)	4	3.6

Over half of the reflections mentioned learning about opportunities for undergraduates to participate in research, and 18% mentioned the CREATE-U program specifically. Many students also reported learning that research can lead to a range of careers in academia or industry (including entrepreneurial ventures). A few students talked about being surprised that undergraduates had enough background to be able to contribute to research, and more expressed surprise that concepts they were learning in second-year are used in research. A number of students indicated that they were now considering research as a career (while a few mentioned that they were now more certain that research was something they did not want to engage in).

For the 2019-20 third-year laboratory course, 18 students completed both pre- and post-surveys (Table 3). Again, we used paired t-tests with Bonferroni correction and a significance level of $\alpha = 0.00833$. While there were no statistically-significant changes, the magnitude of the increases in agreement with the statements "I know what research is" and "I have been exposed to how research is done" was similar between the two cohorts.

Table 3: Results from surveys of second-year class in 2019-20 (n=18). Five-point agreement scale (1 = Strongly disagree, 5 = Strongly agree).

	Pre-survey mean	Post-survey mean	Paired difference mean	p-value
I know what research is	3.94	4.11	0.17	0.0827
I think research is interesting	4.00	4.06	0.06	0.8260
I think research is relevant to me	4.00	3.83	-0.17	0.3313
I want to learn more about research	4.06	4.06	0.00	1.0000
I would like to participate in research opportunities	3.89	4.00	0.11	0.5425
I have been exposed to how research is done	3.06	3.44	0.39	0.1100

Applicants and Selection of Students

In 2021, thirty-eight students applied, and thirteen were accepted (GPAs: 79.5% to 90.9%; one withdrew for family reasons). Gender and international/domestic ratios matched the overall departmental undergraduate population better in the CREATE-U program than in the group of summer research students hired through other mechanisms.

The distribution of domestic (citizens and permanent residents) and international students in CREATE-U was more representative of the department overall (Figure 1). The distribution of male and minority gender students was similar between CREATE-U and other mechanisms (Figure 2). However, when we considered only the other competitive mechanisms (e.g. NSERC) all the summer students identified as male.

Competitive mechanisms (including NSERC USRA) typically require GPAs of >85%. Faculty members select specific students to add to the applicant pool, which means that the mechanism is very open to bias and homosocial replication.

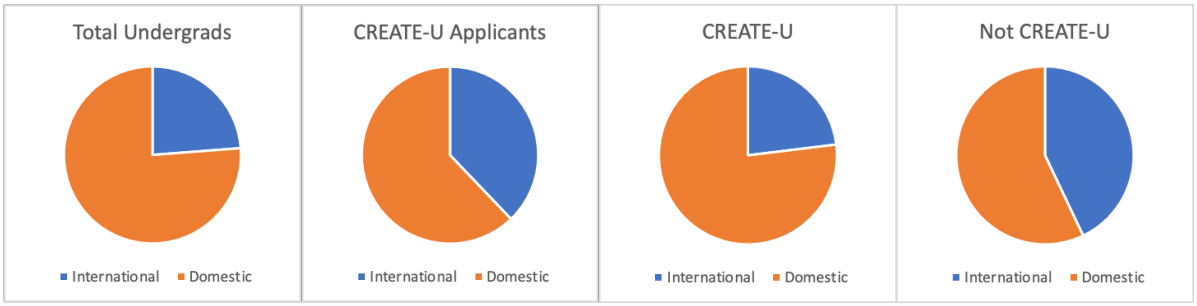

Figure 1: Distribution of international and domestic students in the total undergraduate population (left), the CREATE-U applicant pool (centre left), the accepted CREATE-U students (centre right) and the summer research students from other venues (right).

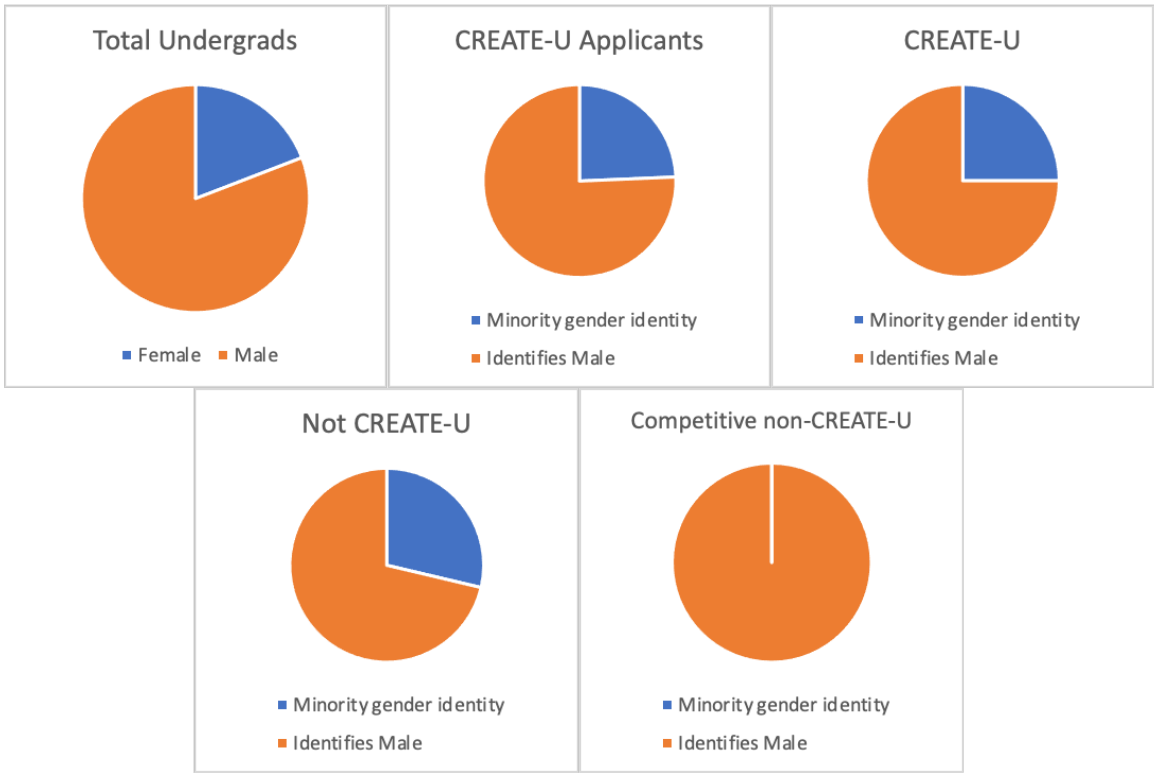

Figure 2: Distribution of student gender in the department (top left; note that our institution did not collect other minority gender information), in the CREATE-U applicant pool (top centre), the accepted CREATE-U students (top right), the summer research students from other venues (bottom left), and the summer students from competitive programs (bottom right).

Past experience in research was substantially different between CREATE-U students and summer research students from other venues (Figure 3). This seems to indicate that the CREATE-U mechanism may be offering opportunities to do research to undergraduates who have not had access to such opportunities before.

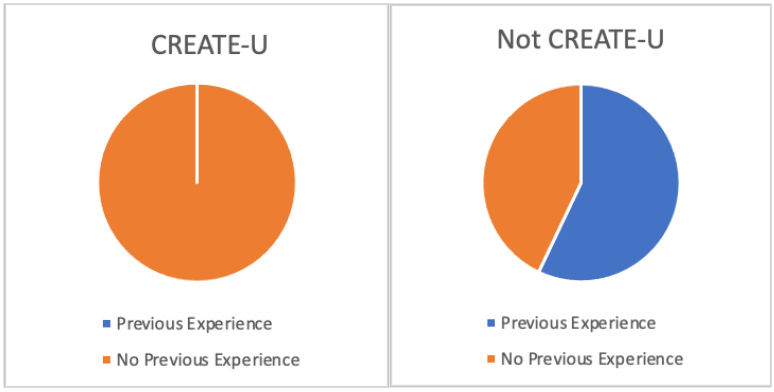

Figure 3: Self-reported previous research experience for CREATE-U students (left) and non-CREATE-U summer research students (right).

Supervising faculty were asked to evaluate the students they we matched with during the program. Responses to the open-ended question "Were the students selected through the placement process high quality?" were coded for ratings. Of the 9 responses, 8 supervisors felt their students were excellent, and 1 indicated their student was good. Some supervisor quotes:

> *"Yes, after having working with him, I can say I would hire him without the CREATE-U funding. He is an exceptional student"*
>
> *"I don't think I have ever had a student work with me after 2nd year (the CREATE-U student working with me just completed year 2). He appeared to be at par or better prepared than a student after 3rd year."*
>
> *"The student assigned to my project was excellent."*

Some of the supervisor responses indicate that they might not have considered the particular student they were matched with if they had not been in the CREATE-U program. It is possible that the preparatory research skills course also enhanced the effectiveness of the students by giving them basic training that supervisors would otherwise need to provide. All supervisors said they would participate in the program again.

Program supports

While we intended to measure any changes in self-efficacy and belonging in research between the CREATE-U and non-CREATE U students, few summer research students completed both pre- and post-surveys. There were similar changes in research self-efficacy between the two groups, but a larger range of change in research belonging (Figure 4). This could possibly be influenced by CREATE-U students being different from the more common identities in their lab placement in ways that affected their experience of belonging (e.g. gender, cultural background).

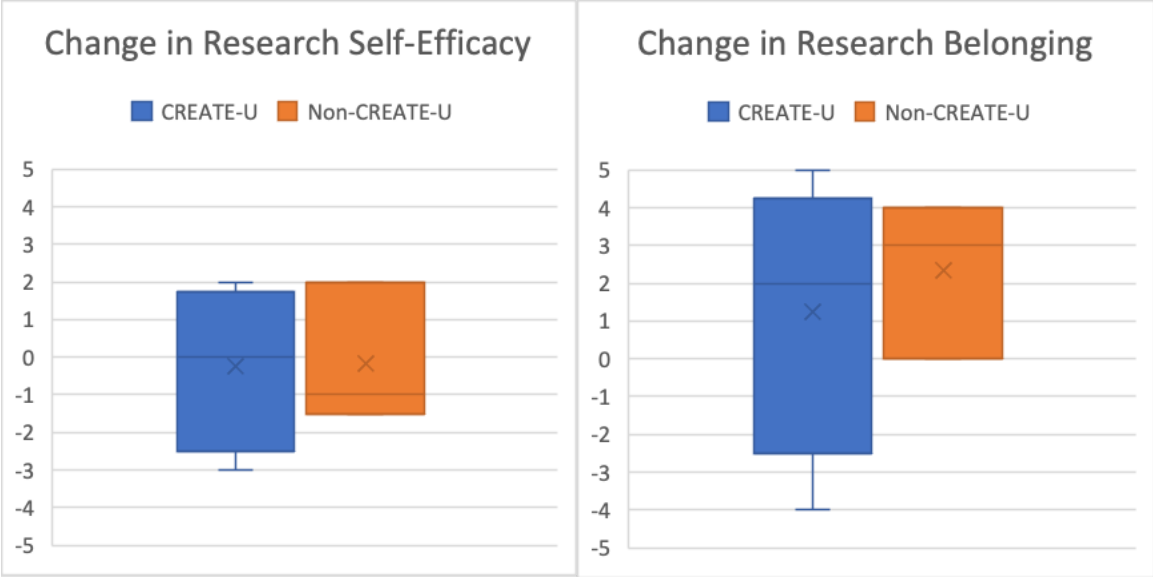

Figure 4: Pre-post survey results on self-efficacy in research and belonging in research from CREATE-U (n=4) and non-CREATE-U (n=3) summer research students.

Students and graduate student mentors were also asked open-ended questions about the program supports, which generally went beyond typical summer research student supports. Graduate students reported appreciating the mentor sessions, while suggesting further professional development for mentors to allow them to learn how to support students they are supervising.

> *"Mentor training session was good. I prefer a more in-depth mentor training session (may be couple of sessions) to see in the future programs. May be professors from the department with lot of mentoring experience can train mentors. I previously followed [a program for PhD students on the path to becoming faculty], in that program, many professors from the faculty shared their experience with participants. Similarly, it will be a very nice experience if mentors can systematically learn more about mentoring (e.g., how to communicate with mentees, how to identify the skills that mentees lack, how to guide them, different approaches that one can do to guide a mentee, what can we do if a mentee is not following instructions, how to establish a good mentor-mentee relationship etc.) and to listen to their experiences."*

> *"The mentor training session helped mentors get prepared for the CREATE-U program by providing professional guidelines and insights."*

Students reported primarily positive responses to the regular lunch sessions and the support provided by the graduate student mentors.

> *"[Lunch sessions] were interesting. I think we covered so much in [the research skills course] and other sessions talking to different lecturers/professors that there was a lot of repeated information though."*

> *"These sessions were a great opportunity to ask questions and learn more about the field of research."*

"The lunch sessions were fun and interesting."

"The mentors have been amazing. I couldn't have achieved my end goals if not for their continuous support. Something that I did not really enjoy were the virtual sessions. After a year of zoom calls, I was excited to have an in-person conversation with all my mentors and guest speakers, but I understand that given the situation certain decisions had to be made. Social lunch events would have been really great to have!"

Discussion

As part of the CREATE-U program, we successfully

1. Generated interest in research within our undergraduate population.
2. Created a rubric that de-emphasized GPA and emphasized skills or attributes that we believe are critical for research.
3. Completed a blinded adjudication of applicants which resulted in better representation of our undergraduate population.
4. Supported students in the program with courses, mentorship, and other development opportunities.

We had limited data to determine if the interventions led to increased research self-efficacy or belonging when compared to summer research students outside the program.

Initial results suggest that students within the department have a better understanding of research and their potential interest in it following our interventions. From our earlier focus group, it is clear that students need specific information about research before some of them will be interested in exploring research. We also helped to address some of the barriers to undergraduate research. This includes those expressed by students in their reflections, such as lack of student awareness of opportunities and student perceptions of lack of student readiness to participate in undergraduate research [7].

The program was successful in selecting and training students that were highly-rated by their faculty supervisors. This suggests that a blinded, rubric-based evaluation of applicants that de-emphasized grades did not lead to a decrease in student quality. We had a wider range of GPAs than is typical in other summer research opportunities (which typically have a cut-off grade of >85%), indicating that undergraduate program GPA may not be the strongest indicator of success at research. This result is consistent with work examining factors related to success in graduate programs [8]. The selected applicants also better represent the larger undergraduate body in our program compared to other summer research programs.

None of the CREATE-U students had previous experience in research while over half of the other summer students had previous experience, which indicates that we may have partly tapped into a separate population of students who would have been less likely to engage in research for a variety of factors, including not knowing a faculty member who would put them forward via another mechanism. The lack of past experience may have led students to prefer the CREATE-U program due to the variety of curricular and programmatic supports in learning about research.

Limitations of the program include still having a small number of supported placements. As the institutional funding ended, supervisors now need to shoulder more of the student salary cost (although the department has continued to offer some subsidy). Supervisors also do not get to directly select the student they receive through the program (although they do get the opportunity to veto the student they have been assigned). We are optimistic that several factors within this program, including the equity aspects, the courses and cohort supports, the opportunity for graduate students to engage in the program, and the departmental subsidy, will continue to counter-balance this lack of choice for supervisors.

Strengths of this work include the development of a rubric using a broad range of sources to identify the factors that research faculty in engineering expect are important for success in research. We also used multiple venues to address the lack of knowledge about research and to generate student interest in trying research at the undergraduate level. Having students' regular instructors speak about research and encourage them to consider it may be important, as they can connect course content directly to research.

Limitations of this work include limited numbers of students in the cohort and limited numbers in the other summer research positions. We also do not yet have a long-term evaluation of the success of the students at research or the retention of students in research careers. This is a possible area of future research.

Overall, this program appears to be successful at increasing access for undergraduate students to try research, creating a more equitable process to select students, and supporting students in developing research skills.

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References
[1] A. Tintori and R. Palomba, "The most common stereotypes about science and scientists: what scholars know," in *Turn on the light on science: A research-based guide to break down popular stereotypes about science and scientists*, 2017, pp. 1–18.
[2] A. L. Zydney, J. S. Bennett, A. Shahid, and K. W. Bauer, "Impact of Undergraduate Research," *J. Eng. Educ.*, vol. 91(2), no. April, pp. 151–157, 2002.
[3] D. F. Carter, H. K. Ro, B. Alcott, and L. R. Lattuca, *Co-Curricular Connections: The Role of Undergraduate Research Experiences in Promoting Engineering Students' Communication, Teamwork, and Leadership Skills*, vol. 57, no. 3. Springer Netherlands, 2016.
[4] M. K. Eagan, S. Hurtado, M. J. Chang, G. A. Garcia, F. A. Herrera, and J. C. Garibay, *Making a Difference in Science Education: The Impact of Undergraduate Research*

Programs, vol. 50, no. 4. 2013.
[5] R. W. Lent, S. D. Brown, and G. Hackett, "Toward a Unifying Social Cognitive Theory of Career and Academic Interest, Choice, and Performance," *J. Vocat. Behav.*, vol. 45, no. 1, pp. 79–122, 1994.
[6] A. Carpi, D. M. Ronan, H. M. Falconer, and N. H. Lents, "Cultivating minority scientists: Undergraduate research increases self-efficacy and career ambitions for underrepresented students in STEM," *J. Res. Sci. Teach.*, vol. 54, no. 2, pp. 169–194, 2017.
[7] S. Pierszalowski, J. Bouwma-Gearhart, and L. Marlow, "A Systematic Review of Barriers to Accessing Undergraduate Research for STEM Students: Problematizing Under-Researched Factors for Students of Color," *Soc. Sci.*, vol. 10, no. 9, p. 328, 2021.
[8] O. D. Weiner, "How should we be selecting our graduate students?," *Mol. Biol. Cell*, vol. 25, no. 4, pp. 429–430, 2014.
[9] M. A. Wilson, M. A. Odem, T. Walters, A. L. DePass, and A. J. Bean, "A model for holistic review in graduate admissions that decouples the gre from race, ethnicity, and gender," *CBE Life Sci. Educ.*, vol. 18, no. 1, pp. 1–12, 2019.
[10] M. G. Wintre *et al.*, "Academic achievement in first-year university: Who maintains their high school average?," *High. Educ.*, vol. 62, no. 4, pp. 467–481, 2011.
[11] University of British Columbia, "Shaping UBC's Next Century: Strategic Plan 2018 - 2028," pp. 1–78, 2018.
[12] C. a Moss-Racusin, J. F. Dovidio, V. L. Brescoll, M. J. Graham, and J. Handelsman, "Science faculty's subtle gender biases favor male students.," *Proc. Natl. Acad. Sci. U. S. A.*, vol. 109, no. 41, pp. 16474–9, Oct. 2012.
[13] C. Goldin and C. Rouse, "Orchestrating impartiality: The impact of 'blind' auditions on female musicians," *Am. Econ. Rev.*, vol. 90, no. 4, pp. 715–741, 2000.
[14] S. Nielsen, "Why do top management teams look the way they do? A multilevel exploration of the antecedents of TMT heterogeneity," *Strateg. Organ.*, vol. 7, no. 3, pp. 277–305, 2009.
[15] E. L. Deci, R. J. Vallerand, L. G. Pelletier, and R. M. Ryan, "Motivation and Education: The Self-Determination Perspective," *Educ. Psychol.*, vol. 26, no. 3&4, pp. 325–346, 1991.
[16] D. Anderson-Butcher and D. E. Conroy, "Factorial and criterion validity of scores of a measure of belonging in youth development programs," *Educ. Psychol. Meas.*, vol. 62, no. 5, pp. 857–876, 2002.
[17] T. Rigotti, B. Schyns, and G. Mohr, "A short version of the occupational self-efficacy scale: Structural and construct validity across five countries," *J. Career Assess.*, vol. 16, no. 2, pp. 238–255, 2008.
[18] D. Gaucher, J. Friesen, and A. C. Kay, "Evidence that gendered wording in job advertisements exists and sustains gender inequality.," *J. Pers. Soc. Psychol.*, vol. 101, no. 1, pp. 109–28, Jul. 2011.
[19] R. D. Myrick, *Developmental Guidance and Counseling: A Practical Approach*. Educational Media Corporation, 1997.
[20] J. Wittmer and R. D. Myrick, *Facilitative Teaching: Theory and Practice*. Educational Media Corporation, 1980.

Appendix A – Research Belonging and Research Self-Efficacy Prompts

Students were asked for their agreement on a five-point scale (strongly disagree to strongly agree) with the statements below.

Research self-efficacy statements [17]
I feel I will remain calm when facing difficulties in my research because I can rely on my abilities.
When I am confronted with a problem in my research, I feel I will usually find several solutions.
Whatever comes my way in my research, I feel I will usually handle it.
My past experiences in my work have prepared me well for research.
I feel I will meet the goals that I set for myself in my research.
I feel prepared for most of the demands in my research.

Research belonging statements [16]
I feel comfortable with research activities.
I am part of the research community.
I am committed to research.
I am supported in the research community.
I am accepted in the research community.