

Outcomes of a Peer-Taught Course to Lower Barriers to Undergraduate Research Experiences

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Grace Ford recently graduated with a degree in Biomedical Engineering from the University of Virginia and has a strong interest in undergraduate research accessibility. She has taught and helped develop the peer-led course Starting an Undergraduate Research Experience (SURE), focused on supporting first-year students in building confidence and navigating the process of joining research labs. Her current research focuses on identifying and modeling key factors that enable students to successfully access and engage in undergraduate research.

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Introduction

Undergraduate research is a high impact experiential learning opportunity that allows students to work on real-world problems. Through this experience, students gain academic skills including lab techniques, experimental design, how to read and write scientific literature, and data analysis strategies [1]. Students also gain interpersonal skills including communication, problem solving, and critical thinking [2]. Finally, undergraduate research opportunities provide students with mentorship that helps students make future career choices and increases their sense of professional belonging [2].

Although the benefits of undergraduate research are well defined, students experience multiple barriers to entry. First, one of the major barriers to undergraduate research is a lack of belonging, both within research and at the university [3]. A lack of research belonging manifests as a barrier to research participation because students who lack a sense of belonging are less likely to seek out opportunities, ask for help, or advocate for themselves [4]. Another barrier to entry is a lack of self-confidence in research, which encompasses feelings of inadequacy, “I don’t feel qualified”, and “research sounds too difficult” [3], [5]. Self-confidence in research is critical for students’ engagement in undergraduate research opportunities, as students must believe they are capable of doing research in order to seek out and secure research positions. A third barrier to entry is a lack of research awareness, which manifests as “not knowing where to begin”, being unaware of undergraduate research opportunities, and being unaware of the benefits of undergraduate research. Unfortunately, students who are not aware of research opportunities are unable to seek out those positions and, therefore, are unable to participate. Furthermore, limited awareness of the personal and academic benefits of research can reduce students’ motivation to get involved [3]. These barriers are especially prevalent for first-year students, first-generation students, and members of underrepresented groups [3].

To address these barriers, we designed a one-credit, peer-taught introduction to research course titled, “SURE (Starting an Undergraduate Research Experience)”, to help students overcome barriers to entry into undergraduate research. As described previously [6], this course is designed primarily for first-year engineering students; however, any engineering student is able to enroll in the course. The typical class size in the fall semester is around 40 students. The course combines specifications grading and active learning opportunities to help students develop the skills necessary to successfully join a research lab. Previous results suggested that most students gained an understanding and appreciation of research and learned skills associated with finding and joining a research lab. However, multiple factors could contribute to these learning gains, including students’ experiences in other first-year introductory engineering courses. This possibility led us to ask, “Do students in the introductory research course perceive an increased sense of belonging in research, self-confidence in research, and research awareness compared to students who did not take the course?”

Methods

To evaluate whether the introductory research course reduced barriers to entry into undergraduate research, we compared students who completed the course to students enrolled in sections of the required first-year engineering course. Students enrolled in the introductory research course will be referred to as the Intervention group, and the students enrolled in the first-year engineering course will be referred to as the Control group. Students were excluded from the study if they were under 18 years of age, if their primary academic major was not in the engineering school, and if they had not yet enrolled in an introduction to engineering course. These exclusion criteria ensured that participants in the study were engineering students, and all participants had similar baseline experience in engineering. This study was approved by University of Virginia Institutional Review Board (IRB) under protocol number 7743.

We administered a survey through Qualtrics to both groups of students at the beginning and the end of the fall semester. The survey was designed to assess students' perceptions of their research belonging, research awareness, and self-confidence in research.

To measure research belonging, we adapted Mellinger's sense of belonging scale, which measures general sense of belonging and can be easily adapted to specific contexts [7]. To adapt the Mellinger instrument for identity-specific belongingness, we followed the provided example, "Overall, I feel valued by other scientists," by adding "by other researchers" or "in research" to the end of the applicable sentence stems. The original sense of belonging scale was validated as an 8- and 16- item survey. We chose to adapt the 8-item survey to keep our full survey as short as possible. We used the original five-level Likert scale of the instrument. The final instrument we used can be found in Appendix A.

To measure self-confidence in research, we used the Self-Efficacy for Research instrument [8]. We selected this instrument because it was specifically designed to assess undergraduate students' general research self-efficacy rather than self-efficacy for specific tasks. This broader scope allowed us to capture a wide range of undergraduate research experiences and include students at different stages in their research careers. We adapted the questions to shift the focus from mathematical biology to general research. To do this, we changed question 1, "I have appropriate background knowledge to conduct research in mathematical biology", by removing "in mathematical biology". We also changed question 3, "I can use mathematical software to conduct research", by removing "mathematical". Finally, we used the original six-level Likert scale of the instrument. The final instrument we used can be found in Appendix B.

To capture students' awareness of research, we designed an instrument that assesses students' perceptions of their knowledge of important aspects of research and getting involved in research. The instrument starts by assessing students' perception of their ability to understand how and why research is conducted at the university level. Next, it assesses the students' perception of their ability to identify the role of an undergraduate in a research lab and the benefits associated with doing undergraduate research. Third, it assesses students' perception of their ability to identify and describe undergraduate research opportunities available to them, the process of joining a lab, and resources available to help them get involved. These prompts were informed by the DRIEM model component of "Knowledge of Research and Researchers" that consists of who a researcher is, what a researcher does, and how research works [9]. Finally, the instrument

addresses the barriers to entry of not being aware of research opportunities, not being aware of the benefits of research, and not knowing where to begin [3], [5], [10]. We used a five-level Likert scale for the instrument. The final instrument we used can be found in Appendix C.

Finally, we included an open-ended question on both the pre- and post-course survey. In the pre-course survey, students were asked, “What do you feel is the biggest barrier preventing you from participating in undergraduate research, and why is it the biggest barrier?” In the post course survey, students were asked, “How have your perceptions of the barriers to participating in research changed from the beginning to the end of the semester?” The answers to these questions were used anecdotally to give context to the quantitative findings.

Students’ responses to the quantitative questions were coded on either a five-level Likert scale (Strongly disagree, Disagree, Neither agree or disagree, Agree, Strongly agree), or a six-level Likert scale (Strongly disagree, Disagree, Somewhat disagree, Somewhat agree, Agree, Strongly agree), as indicated above. Some questions were negatively expressed, and answers were adjusted appropriately before computing a student’s average score for each scale. Each student responder was de-identified and given a unique identification code. This allowed us to compare individual students’ pre- and post-course average scores for each scale using paired t-tests with a significance level of 0.05. Effect size of the Intervention group was calculated using Hedges’ g for low sample size ($n < 20$). Effect size for the Control group was calculated using Cohen’s d because the sample size was larger than 20.

Results

Research Belonging

Comparison of the pre- and post-course data revealed that the average research belonging score did not significantly change in the Intervention group but significantly increased in the Control group (Fig. 1). The Intervention student’s average research belonging score decreased from 3.21 ± 0.57 to 3.15 ± 0.55 (mean $\pm$ SD, $n = 16$, $p = 0.36$), with a small effect size (Hedges’ $g = 0.09$). The Control student’s average research belonging score statistically increased from 3.12 ± 0.51 to 3.23 ± 0.55 (mean $\pm$ SD, $n = 102$, $p = 0.01$), with a small effect size (Cohen’s $d = 0.20$).

Self-confidence in Research

Both the Intervention group and Control groups had significant increases in average self-confidence in research over the semester (Fig. 2). For the Intervention group, the average self-confidence in research score significantly increased from 3.31 ± 0.62 to 3.99 ± 0.49 (mean $\pm$ SD, $n = 16$, $p = 0.0001$), corresponding with a large effect size (Hedges’ $g = 1.16$). Similarly, for the Control group, the average self-confidence in research score significantly increased from 3.59 ± 0.73 to 3.86 ± 0.70 (mean $\pm$ SD, $n = 101$, $p = 1.49 \times 10^{-6}$), with a small effect size (Cohen’s $d = 0.38$).

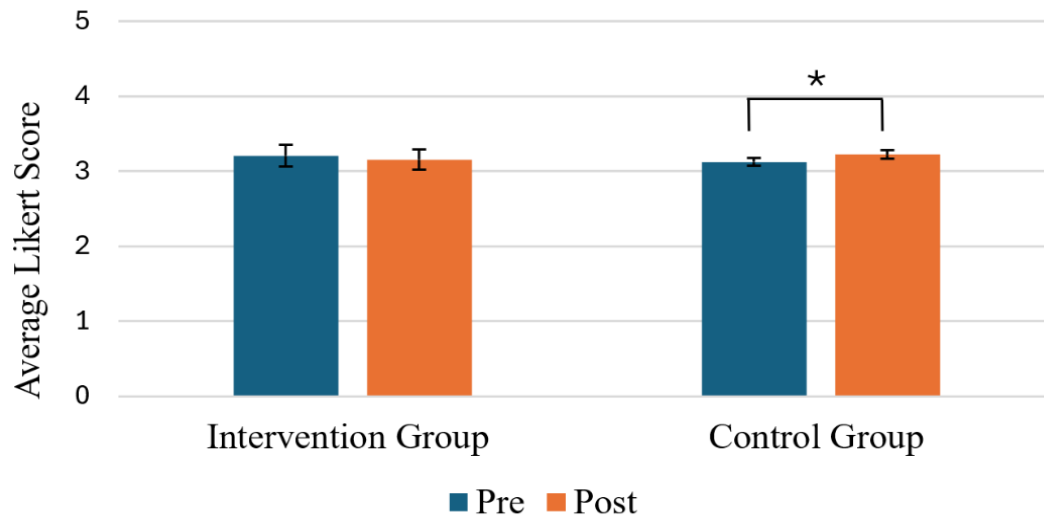


Figure 1: Research Belonging. Comparison of pre- and post-course average research belonging scores for the Intervention and Control groups. *Significant increase in score from pre- to post-course (paired t-test, $p < 0.05$).

Research Awareness

Students in both the Intervention and Control groups experienced significant increases in research awareness during the semester (Fig. 3). For the Intervention group, the average research awareness score significantly increased from 2.89 ± 0.44 to 3.80 ± 0.49 (mean $\pm$ SD, $n = 16$, $p = 1.02 \times 10^{-6}$), with a large effect size (Hedges' $g = 1.86$). Similarly, for the Control group, the average research awareness score significantly increased from 3.00 ± 0.57 to 3.26 ± 0.60 (mean $\pm$ SD, $n = 103$, $p = 3.09 \times 10^{-6}$), with a small effect size (Cohen's $d = 0.45$).

Discussion

Our introductory research course was designed as an intervention to help students join undergraduate research by lowering the barriers to entry into undergraduate research. To evaluate the impact of the intervention, we compared perceptions from students enrolled in our introductory research course to perceptions from students enrolled in a first-year engineering course. To assess whether the intervention lowered the barriers of entry into undergraduate research, we compared students' pre- and post-semester perceptions of their research belonging, self-confidence in research, and research awareness. Overall, both the Intervention group and Control group reported lower barriers to entry after the semester as demonstrated by greater self-confidence in research and research awareness. Although both groups had statistically significant differences in pre/post scores, the Intervention group had greater average scores for both self-confidence in research and research awareness. To provide context to the quantitative data, students were asked whether their perceptions of barriers to participating in research had changed over the semester. In the Intervention group, out of the 13 responses, 77% of students reported that the barriers decreased, 15% of students reported that the barriers had not changed,

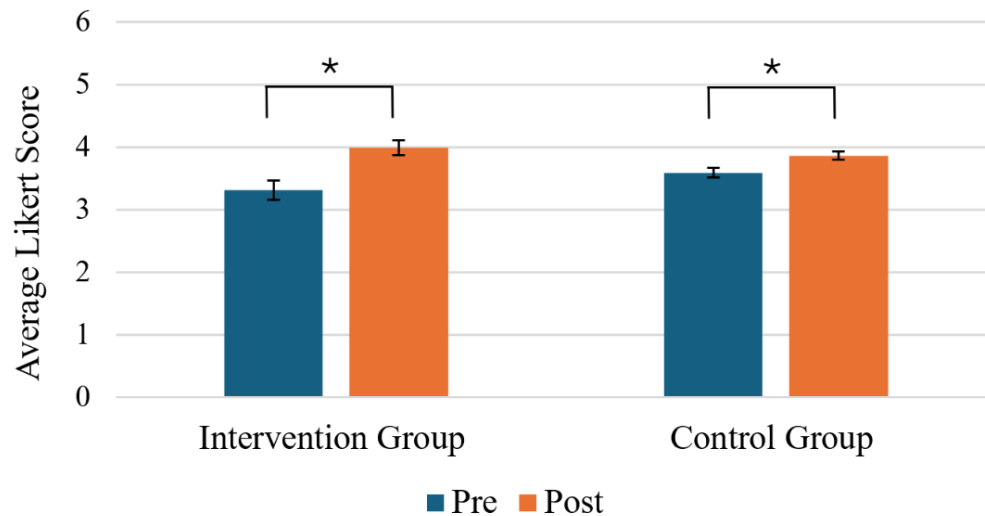


Figure 2: Self-Confidence in Research. Comparison of pre- and post-course average self-confidence in research scores for the Intervention and Control groups. *Significant increase in score from pre- to post-course (paired t-test, $p < 0.05$).

and 8% of students reported that the barriers worsened. In the Control group, out of the 36 responses, 36% of students reported that the barriers decreased, 53% of students reported that the barriers had not changed, and 11% of students reported that the barriers worsened. Overall, these responses suggest students in the Intervention group experienced a greater reduction in barriers compared to students in the Control group.

Belonging

The quantitative data show that the average research belonging score did not change significantly in the Intervention group but significantly increased in the Control group. However, the significant increase in average research belonging scores experienced in the Control group had a small effect size.

Qualitative data suggest that at the beginning of the semester students in both the Intervention and Control groups felt a lack of belonging in research. Students in the Intervention group felt that they did not have the proper connections to join a research lab. A student in the Intervention group said they “[did] not [have] enough connections”, and a different student in the Intervention group said, “I don’t know any of my professors or anyone conducting research right now.” Students in the Control group indicated that they need more time to find their place in college before getting involved in research. A student in the Control group stated, “I want to settle into college before starting research,” and another student in the Control group said, “I just started college, so I want to get adjusted first before I take on other responsibilities.” Additionally, a student in the Control group suggested that they did not belong in undergraduate research because they were a first-year student: “I feel like research is meant for upperclassmen and I am only a first year.”

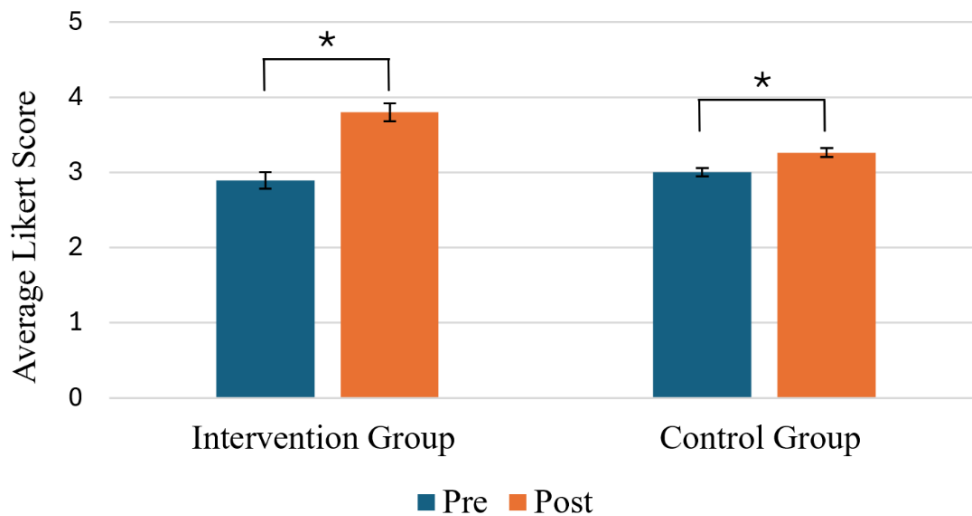


Figure 3: Research Awareness. Comparison of pre- and post-course average research awareness scores for the Intervention and Control groups. *Significant increase in score from pre- to post-course (paired t-test, $p < 0.05$).

At the end of the semester, only one student in the Intervention group mentioned that their research belonging had changed. The student said, “I feel more equipped to ... reach out to professors.” A student in the Control group suggested that during the semester they formed connections which lowered their barriers to research: “the barriers seem less difficult as connections are formed.” Another student in the Control group said, “I know students and professors I could talk to if I have questions or want to take the first few steps.” Finally, a student in the Control group said, “It is more accessible that what I thought it previously was.”

It is not entirely surprising that students in both groups did not experience large increases in research belonging because they have not yet participated in undergraduate research. During research experiences, students develop relationships with faculty, graduate students, and their peers that help them gain confidence and a sense of belonging [2]. Without developing these relationships within research, it is doubtful that students would greatly increase their sense of belonging in research. However, during the first-year engineering experience, students do form connections to faculty and peers that can help them join a research lab.

Self-confidence in research

Although both the Intervention and Control groups demonstrated a statistically significant increase in average research awareness scores, the Intervention group had a larger pre- to post-course increase than the Control group.

At the beginning of the semester both students in the Intervention group and students in the Control group did not feel they were good enough to join research labs and did not have enough background knowledge. A student in the Intervention group said, “I don't feel qualified, so I'm

hesitant to put myself out there and end up doing incorrect work and setting a project behind.” Similarly, a student in the Control group said that their biggest barrier was “qualification because I don't know how much I'll be able to contribute.” In terms of not having enough background knowledge, a student in the Intervention group said, “I don't know if I have undergone the required coursework to be in a lab,” and a different student in the Intervention group stated, “I have no notable experience or background to be considered for a research position.” Additionally, multiple students in the Control group mentioned that the biggest barrier to participating in research was not having enough time.

At the end of the semester, some students in the Intervention group said they felt qualified to participate in undergraduate research and had the necessary background knowledge. A student in the Intervention group said, “Research definitely feels more attainable in a sense of my understanding and ability to [do research].” Another student in the Intervention group said, “I assumed you needed to have a good understanding for a relevant field to start researching a certain topic, but the point is to explore and converge on what seems interesting and ideally most applicable to your desired field.” However, one student in the Intervention group said, “I do not have enough prerequisite knowledge to do the lab I want to do,” but this could be explained by the requirements of a specific lab.

In comparison, only one student in the Control group indicated that their perception of their qualifications had changed during the semester: “I've realized that participating in research might be possible even without research experience if you reach out to professors.” On the other hand, multiple students in the Control group said they still did not feel adequate or did not have enough background knowledge to participate in research. A student in the Control group said, “I still don't feel like I have adequate knowledge”, and another said, “I am waiting until I am further along in my coursework, and as such I have not engaged with research.” Additionally, a student in the Control group reported feeling “still not content in myself that I can do that.” Finally, multiple students indicated that time was still their biggest barrier. A student in the Control group stated, “I just have less time now than before,” and a different student said, “I feel like I have even less time now.”

The observed changes in research self-confidence scores likely reflect the combined influence of prior student experiences and course-specific interventions. First, the lower pre-course self-confidence in research score among students in the Intervention group could be explained by less confident students being more likely to enroll in the course. Additionally, during the first-year engineering course students learn technical skills that are applicable to undergraduate research including data analysis and problem solving. Although not mentioned in the qualitative responses, these experiences could explain the observed quantitative increase in self-confidence among the students in the Control group. Furthermore, the greater self-confidence in research scores observed in the Intervention group could be explained by additional mentorship provided in the Intervention course. During the Intervention course students participate in student panels, labs tours, and activities that re-enforce that they are qualified and more than “good enough” to do research. Specifically, the instructor guides students through an activity that helps students highlight transferable research skills from their prior experiences. These findings are consistent with the literature supporting the instrument we used to measure self-confidence in research. Antonou et al. showed that self-confidence increased for students who participated in a short-term three-day workshop [8]. This supports our findings that students in the Intervention group

could experience gains in self-confidence in research without participating in an undergraduate research experience. However, data from Antonou et al. also showed that students did not increase their confidence to do research independently during the workshop [8]. Antonou et al. suggests that it takes longer than a workshop, or an intervention, to develop self-confidence to do research independently [8]. This observation suggests an intervention can help support students' research self-confidence but cannot completely replace confidence gains experienced during research experiences. Together, these factors could explain the initial differences and the post-course gains in research self-confidence observed across groups.

Research Awareness

Similar to self-confidence in research, both the Intervention and Control groups showed a statistically significant increase in average research awareness scores, but the Intervention group had a larger pre- to post-course increase than the Control group.

At the beginning of the semester students in both the Intervention and Control groups most frequently said that their biggest barrier preventing them from participating in undergraduate research was not knowing where to find research opportunities or knowing how/where to start. A student in the Intervention group said, "I don't know where to get started, how to get involved, or how to reach out to get a research position." A student in the Control group said their biggest barrier was "reaching out to learn about how to get started because it seems separated from everything else at the university as a first year." Another student in the Control group said, "knowing how to get started, because it seems like an overwhelming and competitive process."

By the end of the semester, students in the Intervention group felt that they were more aware of how to join a research lab. A student in the Intervention group felt "more equipped to start research." A different student in the Intervention group said, "I've realized there's more positions and open-ness to undergraduates than I thought." Another important area of growth in the Intervention group was learning the roles of undergraduates in a research lab. A student in the Intervention group student shared, "My perceptions of the barriers to participating in research have changed from the beginning of the semester from believing that research would solely involve graduate students, where I now understand undergraduate students also play a role in the lab."

Some students in the Control group experienced an increase in research awareness while others did not. Students became more aware of "the benefits that come with conducting research" and "resources on grounds to start research." While another student in the Control group stated, "I mostly understand how I would get involved with research." However, barriers for students in the Control group still exist. A student in the Control group said, "there is still some difficulty involved with obtaining a research position," and another student said, "I have realized it is harder than I thought to find an opportunity."

These results suggest that students are gaining information about undergraduate research and how to get involved through both the Intervention course and other sources. It is unsurprising that students in the Intervention group have a higher research awareness score because students in the Intervention group received direct instruction on the roles of undergrads in research, the benefits of undergraduate research, and how to get involved. Wayment and Dickson found that

due to an informal communication system, usually word-of-mouth, there was unequal student awareness and access to research opportunities [10]. This suggests that students can become aware of the undergraduate research opportunities without participating in the intervention. However, the intervention provides a resource that makes information about undergraduate research more accessible for all students.

Limitations

A major limitation to this study is the small sample size of students enrolled in the introductory research class. Out of the 38 students enrolled in the class, only 16 students responded to both the pre- and post-course survey, which limited the number of pairwise comparisons and reduced the statistical power and ability to generalize our findings. Additionally, the small sample size limited our ability to compare other factors impacting students' experiences like socioeconomic or first-generation status. Furthermore, with the limited ability to generalize the data, it is possible that our findings are unique to this group of students and our institution.

In the next phase of this work, we plan to compare the experiences of the first-year students to fourth year students to see how students' perceptions change overtime. Also, we are planning to conduct student interviews to further explore and highlight specific student experiences. Finally, we would like to conduct a similar study at a different institution to see how the results differ by university.

Conclusion

Undergraduate research positively influences student learning and enhances a student's overall educational experience [11]; however, barriers to entry prevent students from accessing undergraduate research opportunities. This paper explores the barriers of a lack of research belonging, self-confidence in research, and research awareness. To address these barriers to entry we previously designed a peer-taught introductory research course. Here we assess impact of the introductory research course by asking the question, "Do students in the introductory research course perceive an increased sense of belonging in research, self-confidence in research, and research awareness compared to students who did not take the course?" We found that students in both the Intervention and Control groups experienced lowered barriers to entry demonstrated by significant increases in average self-confidence in research and research awareness scores. Although the Intervention group had lower average scores for research belonging, the Intervention group had greater average scores for both self-confidence in research and research awareness. Furthermore, qualitative data suggests students in the Intervention group experienced a greater reduction in barriers compared to students in the Control group.

Qualitative data provided student anecdotes that gave some explanation and context to the quantitative data. The qualitative data indicate that some students in both the Intervention and Control group felt that at end of the semester they had gained connections that could help them join a research lab. However, most students in both groups did not experience large increases in research belonging. This finding is unsurprising, as students typically gain a sense of belonging in research through relationships formed during a research experience; therefore, students who have not yet participated in research are unlikely to show substantial increases in their research belonging.

Students in the Intervention group experienced increases in their self-confidence in research demonstrated by students in the Intervention group expressing they felt qualified to participate in undergraduate research and had the necessary background knowledge to do so. However, multiple students in the Control group said that they still did not feel adequate, had enough background knowledge, or enough time to participate in research. This is consistent with the literature that a program, like our Intervention course, can help students' research self-confidence but cannot completely replace confidence gains experienced during research experiences.

Finally, students in the Intervention group felt that they were more aware of how to join a research lab and the roles of undergraduates in a research lab. While some students in the Control group experienced an increase in research awareness, others did not. This suggests that students can gain research awareness without participating in the intervention, but there is unequal access to this information. So, the intervention provides a resource that makes information about undergraduate research more accessible for all students.

In summary, the introductory research course reduces the barriers to entry into undergraduate research by supporting students' confidence in their ability to do research and increasing their awareness of how and why to engage in undergraduate research.

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Appendix A. Research belonging instrument

To what extent do you agree or disagree with the following statements:

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly Agree
In general, I feel a sense of belonging in research.	☐	☐	☐	☐	☐
I don't really feel accepted in research	☐	☐	☐	☐	☐
Overall, I feel valued by other researchers.	☐	☐	☐	☐	☐
I feel disregarded by other researchers.	☐	☐	☐	☐	☐
I feel like I fit in, in research.	☐	☐	☐	☐	☐
I feel like I don't really fit in with other researchers.	☐	☐	☐	☐	☐
I feel connected with other researchers.	☐	☐	☐	☐	☐
I feel so distant from other researchers.	☐	☐	☐	☐	☐

Appendix B. Self-confidence in research instrument

To what extent do you agree or disagree with the following statements:

[illegible]

Appendix C. Research awareness instrument

To what extent do you agree or disagree with the following statements?	Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree
I can explain the purpose and goals of conducting research in general.	☐	☐	☐	☐	☐
I can describe how research is conducted at my university.	☐	☐	☐	☐	☐
I can describe the role and responsibilities of an undergraduate researcher.	☐	☐	☐	☐	☐
I can identify academic and professional benefits of participating in undergraduate research.	☐	☐	☐	☐	☐
I can identify undergraduate research opportunities available at my university.	☐	☐	☐	☐	☐
I can describe the process of obtaining a research position.	☐	☐	☐	☐	☐
I can identify campus resources to help me get involved in undergraduate research.	☐	☐	☐	☐	☐