The impact of multiple research experiences on undergraduate students

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ABSTRACT

For many years, studies have shown that undergraduate research experiences have numerous positive effects on students. This study seeks to determine if students get more benefit from having multiple undergraduate research experiences. Specifically, this study considered how students' self-efficacy and STEM belonging changed as a result of multiple experiences and how students' perceptions of the mentoring they receive related to the growth in their self-efficacy. In-depth interviews produced several case studies that outline specific benefits students gained from having multiple undergraduate research experiences. Faculty interviews enlightened the research related to the types of undergraduate research offered in various colleges and universities. Results indicate that students do benefit greatly from having multiple undergraduate research experiences. Self-efficacy and STEM belonging are significantly higher for students who have had multiple experiences versus those students who only had one experience. There is also a correlation between the instrumental mentoring students receive and the development of their self-efficacy. Students shared the excellent benefits they gained from having multiple undergraduate research experiences and the life-altering consequences of instrumental mentoring.

Keywords: STEM, Self-efficacy, Belonging, Undergraduate research, Instrumental mentoring, Social cognitive career theory

INTRODUCTION

Many higher education institutions offer undergraduate research experiences (URE) of some type. These experiences are an emerging and integral part of many science, technology, engineering and mathematics (STEM) undergraduate programs. Among the most obvious reasons for providing these experiences for students include recruitment, retention, and preparing students for careers and graduate school (Adedokun & Burgess, 2011; Adedokun et al., 2012; Nagda et al. 1998). There are also studies that explore the underlying factors, like self-efficacy and STEM belonging, that lead to these more tangible outcomes.

Bandura's social cognitive theory (Bandura, 2001) conjectures that a student's self-efficacy (belief in their ability to control their functioning and events that affect their lives) affects both their academic and career choices, as well as their performance results. Consequently, a student's self-efficacy evolves over time in reaction to their experiences. Lent et al. (1994) expanded upon Bandura's social cognitive career theory by focusing specifically on the theory's tenants in relation to career development in early adulthood. The three main interlinked concepts identified by Lent et al. (1994) include self-efficacy, outcome expectations, and future goals, all of which influence career development. Providing opportunities that increase a student's self-efficacy can lead to retention and progress toward a STEM career. Several studies have shown that specifically that URE can increase a student's self-efficacy. Omolola et al. (2013) studied the relationship between student's desire to persist in science and their research skills and how this affected their research self-efficacy. Their results showed that a students' self-efficacy in research along with their research skills can predict the student's persistence and aspiration for a research career.

STEM belonging refers to "the sense of inclusion, acceptance, and identity that individuals experience within the fields of STEM." (Hurtado et al., 2013) This idea brings together feelings of connection, ownership, and membership within the STEM community and also pertains to perceptions a person has in their ability to meaningfully contribute to the STEM discipline. It seems likely that having URE could increase STEM belonging for students. Maintaining feelings of belongingness within one's STEM discipline is important to avoid impacts on self-efficacy (Walton and Cohen, 2007). Additional research conducted by Hausmann, Schofield, and Woods (2007) provides evidence that sense of belonging is linked to initial intentions to persist. The study found that both white and African American students had similar survey results, indicating that sense of belonging affects persistence across many different groups.

One important aspect of URE is the idea of mentoring. Faculty may mentor or may assign a graduate student to mentor undergraduate students. This mentoring can take on many forms, from frequent meetings and careful guidance to assignment of tasks with little or no oversight. When the mentor provides guidance, support, and resources to help the student develop the practical tools and knowledge necessary to succeed in their chosen field, then these actions constitute instrumental mentoring. (Kram, 1988; Eby et al., 2008) Instrumental mentoring is a type of mentoring that focuses on achieving specific goals, acquiring skills, and advancing in a particular area of expertise. This form of mentoring differs from socioemotional mentoring, another common form of mentoring, by emphasizing less on the facilitation of social and emotional skills important for success in a STEM field and more on the practical laboratory skills to be utilized in a future career (Syed et al., 2018; Olsen et al., 2021). Syed et al. (2018) found instrumental mentoring to be a significant predictor of commitment to a STEM career in undergraduate students across gender and ethnicity. Their research also supported the idea that

instrumental mentoring affects STEM career commitment through mediation by factors such as STEM identity and self-efficacy. Instrumental mentoring has also been linked to increased STEM career optimism in graduate students (Olsen et al., 2021).

Background for the Study

This study focuses on the research experiences of students who have been involved in a state-wide network designed to help students who declare STEM majors to succeed in college. The network is a collection of people from K–12, higher education, government, and industry who have come together to help students of West Virginia. This network project was funded by the National Science Foundation and includes many features, such as conferences of members, working groups, a summer immersive research experience for entering college freshmen, and a student ambassador program, among other things. This paper focuses on the students who took part in the summer immersive research experiences as incoming freshmen and seek to determine how these experiences changed them and may have led to other undergraduate research experiences.

The state of West Virginia is committed to undergraduate research from the state level down to the state colleges and universities. The West Virginia Higher Education Policy Commission (HEPC) provides substantive funding each year for the state institutions to provide Summer Undergraduate Research Experiences (SURE) in science, technology, engineering, and mathematics (STEM) fields. The state also had the West Virginia Idea Network for Biomedical Research Experiences where undergraduates from smaller state institutions can engage in nine weeks of graduate level research in the field of biomedical sciences. Many institutions within the state receive the HEPC SURE funding to distribute to students, however there are also various other programs and opportunities throughout the state that encourage undergraduates to engage in research. During the study, faculty from five institutions within the state were interviewed to provide examples of what large and small institutions were doing to encourage research at the undergraduate level.

The universities in the state provide many opportunities to conduct undergraduate research. For some larger research institutions this is easier to do than for smaller liberal arts colleges with limited resources, however, all the colleges and universities interviewed had some URE to offer. Each of the universities mentioned below are part of the state-wide network and offered the two-week summer research immersion experience for incoming freshmen. Faculty at the universities told us a little more about the other programs that were offered at their organizations.

One large university has an Office of Undergraduate Research which assists students in getting involved in many types of paid research experiences. They offer the state funded SURE program and supplement these funds with university and grant funds to support up to 50 students in the summer for an 8-week, 40 hour a week program. Along with this, the university typically has three or four NSF-funded Research Experiences for Undergraduate (REU) sites, an NIH-funded Vision Research Fellowship program, and an undergraduate research program at the Cancer Institute in the summers. The Office of Undergraduate Research also provides several opportunities for students to present research through poster presentations at bi-annual events and helps to fund some students to go to conferences to present. During the academic year, students can sign up for the Research Apprenticeship Program (RAP) to get paid or to receive college course credit for up to two semesters of research with a mentor. As a follow on to this,

students can sign up for a major specific research undergraduate course for one to three credits. The First2 Network project also funds academic year research for all scholars in their program who want to engage. Most STEM majors also have a senior capstone course in which students do research with a mentor as part of the requirements for graduation.

Another large university in the state also has numerous undergraduate research experiences. They require every undergraduate student to perform research for at least one semester. However, students may conduct research for as many semesters as they like. They have students prepare an undergraduate thesis and present them in the department or at conferences. In one department, donations have been given to fund around 20 students yearly to go to conferences. There are also several paid research opportunities on their campus. One such opportunity is the summer SURE program mentioned above, this university has funds for around 12 students for a 10-week summer experience. There are also grant-funded positions including NSF EPSCoR program and around 10 positions related to Neuroscience.

At a smaller branch campus of the large university, students have other research opportunities. Some students are funded by the First2 Network project to do research with individual mentors. There are several STEM faculty members that offer research projects in their various labs. At this institution, there are also for-credit courses that provide research experiences. These can start as early as the freshman year with a 1-credit course doing background research on a topic which can lead to further research in subsequent semesters and some have led to students coauthoring publications with their mentors.

At a small university, all students are required to complete a senior capstone course where they engage in guided research for one to two semesters. As a follow-up to the summer immersion program (mentioned above), students could continue their summer research into the fall semester by taking a general education course that provided students with real-world environmental science and ecology research related to their state. This course and research was grant-funded. The university also has paid and unpaid experiences in individual faculty labs that provides the opportunity for students to do research through another NSF project. Faculty also encourage students to apply for paid summer positions at other institutions. The faculty actively coach students in the application process, which leads to many students being placed in research positions outside the university.

Another small state university provides a variety of ways for undergraduates to engage in research which vary among disciplines. Several STEM professors have specific projects that have been going on for many years that students can join. There are projects related to botany, wildlife and forestry, physics (cancer research), forensics, bioarcheology, epidemiology, organic chemistry, and water quality. Students can sign up to get involved in research through the First2 Network project or sign up for an independent research class.

Research Questions

This research seeks to determine how students change as they have more research experiences as an undergraduate. The focus for this research is on three main ideas, students' sense of STEM belonging, students' self-efficacy, and students' perceptions of the mentoring they received. The research questions that guide this study are as follows:

1) Is the sense of belonging in their STEM major higher in students that have participated in more undergraduate research experiences?

2) Is self-efficacy higher in students that have participated in more undergraduate research experiences?

3) Is high self-efficacy linked with a high level of instrumental mentoring from their research mentor?

METHODS

Upon approval from the Institutional Review Board, participants were recruited from students who were part of the First2 Network. Two hundred seventy-seven students were sent an on-line survey and 41 responded and agreed to participate in the study, for a participation rate of 15%. Of these 41, five also agreed to be interviewed. Many of the survey respondents (68.3%) were white. African American or Black participants made up 9.8% (n = 4) of the study population, 9.8% (n = 4) identified as Latino/Hispanic, 9.8% (n = 4) identified as Asian/Pacific Islander, and 12.2% (n = 5) indicated other (primarily multiple races). Participants were split between the academic years with 14 (34.1%) freshmen, 14 (34.1%) sophomores, six (14.6%) juniors, and seven (17.1%) seniors or graduates. Most of the sample consisted of STEM majors (n =39, 95.1%). There were two who had switched to a non-STEM major.

Table 1 (Appendix) demonstrates the breakdown of the number of research experiences and class reported by the students who completed the survey (n=41). Fifty-six percent of the respondents reported participation in one experience in their undergraduate career, 29.3% of respondents reported participation in two experiences, 9.8% of respondents reported three experiences, while 4.9% reported participation in four experiences.

Measures

A survey was developed internally by the research team for this study. The survey was assessed for its face validity by the research team and several student leaders. This led to revisions before distribution to the targeted student population. Demographic information was collected and then in the second part of the survey students were asked questions related to self-efficacy, belonging, and mentoring. This second part of the survey was repeated for each research experience the student reported.

The design of the second part of the survey was a retrospective pre/post (RPP) used for multiple measures. In this design, respondents are asked to rate survey items several times during the same post survey from multiple specific frames of reference. In this survey, respondents were asked to report their attitudes or beliefs following their first research experience (which all respondents had) and then they are prompted to do this again for any additional subsequent research experiences. This design was able to capture changes over time as students can think back to these experiences and how their perceptions of efficacy and belonging changed. Little et al. (2020) discuss the merits of the RPP for repeated-measures research. They state that “A significant and growing body of empirical evidence supports the advantages of using the RPP design over the traditional pre/post design (TPP) (pg. 177).” These authors provided an extensive literature review and presented evidence from two original evaluation data sets to show that the RPP method is both psychometrically and practically a strong alternative to the TPP. Little et al. (2020) also point out that the RPP design can address many validity concerns that can come up when measuring non-cognitive constructs. One argument for using an RPP approach is that the design allows participants to estimate the degree of change that they experienced with greater

awareness and accuracy. Respondents were asked to rate their mentoring after each experience as well.

The questions for the survey were drawn from the following surveys:

- Self-Efficacy for Learning and Performance Subscale (SELPS) from the Motivated Strategies for Learning Questionnaire (MSLQ) for college students (adapted from Pintrich & De Groot, 1991)
- STEM Belonging (adapted from Good et al., 2012 and Goodenow, 1993)
- Instrumental Mentoring Scale (Syed et al., 2018; adapted from Tenenbaum et al. (2001) and Dreher and Ash (1990)

Student Interviews were conducted as a follow-up with five students who had completed the survey and agreed to be interviewed. Each student had completed multiple research experiences. The interviews were held using an online platform and recorded for later review. Students were asked how their URE influenced their persistence in STEM and what they found most beneficial. Student interviewees also shared how these URE shaped their plans for the future.

Data Analysis Methods

To analyze Likert scale data to measure perceived gains in student's sense of belonging and self-efficacy between students with one experience and those with multiple, a one-tailed, two-sample equal variance t-test was utilized. To analyze the Likert scale data to compare sense of belonging scores for students with two research experiences, a one-tailed, paired t-test was used. To analyze the Likert scale data to compare sense of belonging scores for students with three or more research experiences a one-tailed, paired t-test that compared the first experience score to the most recent experience scores was used. To determine if there was a correlation between self-efficacy and instrumental mentoring, a Spearman's rank correlation test was used. To analyze the interview data, the recorded interviews were reviewed and notes were made of the responses to the questions. The interviews were written up as case studies.

RESULTS

Student's Perceived Gains: One Experience Versus Multiple Experiences

A one-tailed, two-sample equal variance t-test was utilized to measure perceived gains in student's sense of belonging between students with one experience and those with multiple. The results are shown in Figure 1 (Appendix). A comparison of each item's average score reported by students who participated in one experience (M=4.04) and the average of the most recent score reported by students with multiple experiences (M=4.61) revealed a significantly higher score between the two groups for the item "I feel I fit in when I am in science or mathematics classes." ($p=0.03$). While it can be observed in the figure that group averages were different for all other questions, these differences were not significant.

Student's Perceived Gains: Two Experiences Comparing First Experience to Second Experience

A one-tailed, paired t-test was used to compare sense of belonging scores for students with two research experiences. The 12 students that reported having two research experiences were found to have a significant difference in average rating between their first and second experience for several of the sense of belonging items as noted with an asterisk in the Table 2 (Appendix). One important question where the students reported a significant increase between their first (M=3.67) and second (M=4.33) experience was the item "I feel comfortable when I am in science or mathematics classes." ($p<0.01$). Also, the average total sense of belonging for all items reported after their second experience (M=21.17) was significantly higher than their sense of belonging after their first research experience (M=19.35, p=0.03).

A one-tailed, paired t-test was used to compare self-efficacy scores for students with two research experiences as displayed in Table 2 (Appendix). The 12 students that reported having two research experiences in their undergraduate career were found to have a significant difference in average scores for the items "I'm confident I can understand the basic concepts taught in the other mathematics." (M1=3.92, M2= 4.5, p=0.01), "I'm confident I can understand the most complex material presented in the other mathematics and science classes required for my major." (M1=3.83, M2=4.25, p=0.05), "I'm confident I can do an excellent job on assignments and tests in the other mathematics and science classes required for my major." (M1= 4, M2= 4.42, p=0.03), and "I believe I will receive excellent grades in the other mathematics and science classes required for my major." (M1= 3.92, M2= 4.33, p=0.05). The overall total self-efficacy difference was not significant.

Student's Perceived Gains: More Than Two Experiences Comparing First Experience to Most Recent Experience

A one-tailed, paired t-test was used to compare sense of belonging scores for students with three or more research experiences in Table 3 (Appendix). Responses from their first experience were compared to responses from their most recent experience. The six students reporting three or more experiences (four students with three experiences and two with four experiences) reported significantly higher ratings for all five items in the sense of belonging portion of the survey. The average reported total sense of belonging for all items significantly increased from their first experience (M=21.67) to their most recent experience (M= 24.5, p=0.02).

A one-tailed, paired t-test was used to compare self-efficacy scores for students with three or more research experiences in Table 3 (Appendix). The six students reported a significantly higher score for the items "I'm confident I can understand the basic concepts taught in the other mathematics and science classes required for my major." (M1= 4.33, M2=4.83, p=0.04), "I'm confident I can understand the most complex material presented in the other mathematics and science classes required for my major." (M1=4.00, M2=4.67, p=0.05), "I'm confident I can do an excellent job on assignments and tests in the other mathematics and science classes required for my major." (M1=4.00, M2= 4.67, p=0.05). The overall total self-efficacy was higher, but not significantly higher.

Student's Perceived Gains: Students with One Experience Compared to Students with Multiple Experiences

A one-tailed, two-sample equal variance t-test was utilized to measure perceived gains in student's self-efficacy between students with one experience and those with multiple. The results are displayed in Figure 2 (Appendix). A comparison of each item's average score reported by the 23 students that participation in one experience and the average of the most recent score reported by the 18 students with multiple experiences revealed that all statements were higher for the group with multiple experiences and significantly higher for three of the statements: "I'm confident I can understand the most complex material presented in the other mathematics and science classes required for my major." ($p=0.01$); "I'm confident I can do an excellent job on assignments and tests in the other mathematics and science classes required for my major." ($p=0.01$); "I believe I will receive excellent grades in the other mathematics and science classes required for my major." ($p=0.02$). The average total self-efficacy for all items reported by students with multiple experiences was significantly higher ($M=26.83$) than the average reported by students with one experience ($M=23.74$, $p=0.02$).

Link Between Self-Efficacy and Instrumental Mentoring

A spearman's rank correlation test was completed to identify whether there was evidence for a correlation between reported self-efficacy and instrumental mentoring. The Spearman's rank correlation test yielded a $r=0.51$ ($p<0.01$) as displayed in Figure 3 (Appendix). This indicates that there is a significant moderate correlation between students' reported self-efficacy and a level of instrumental mentoring received. The t-statistic was calculated to be 3.66 and $df=39$.

Qualitative Data: Case Studies of Five Students

Five students with multiple research experiences that completed the survey were interviewed to learn more about the research experiences they participated in as well as the benefits they perceived to derive from participating in undergraduate research. The findings from the interviews for each student are summarized below.

Student 1

Alysa was a sophomore at a large public university. She was originally a mechanical and aerospace engineering major and then changed to a physics and computer science double major. She participated in four undergraduate research experiences starting with a two-week experience in the summer, a research apprenticeship program that lasted two semesters, an NSF grant funded academic year program for two semesters and a summer undergraduate research experience that spanned eight weeks for 40 hours per week.

Her research progressed through these experiences. The first short experience allowed her to get hands-on experience assisting with improvements for a new receiver on a radio telescope. This experience took place the summer before she entered college. She was able to conduct a small research experiment, get results and present them to peers and other researchers. Her second experience was during the academic year where she had a research apprenticeship for two semesters. She engaged often with her mentor in weekly meetings and worked on improving computer code for the project. From this experience, she was able to present her findings multiple times at student research symposiums and a large research meeting. She received grant funding for the third research experience and was able to continue in the same lab under a new

project involving pulsar nulling. She experienced a similar work environment and meeting schedule as with the second experience. She was integrated into a research team. During her fourth research experience, she continued working on pulsar nulling and worked an eight-week 40 hour a week schedule and was able to gain additional experience in the field and contribute to scientific research.

Alysa benefited greatly from all these experiences. Firstly, she was able to get an idea of what was involved in research and how to contribute to scientific discovery. She mentioned that the first experience was "getting used to the idea of academic research". This led to the second experience where she said she was "able to go more in-depth into the specific field I am interested in going into and learning how to actually do cool things and contribute to science more broadly". In the third and fourth experiences she had continuity in a lab and on a topic and was able to gain additional experience in the field and contribute to the scientific research as the previous two programs had.

Alysa's participation in these four research experiences influenced her to change from her original major of mechanical and aerospace engineering to a physics and computer science double major. She began feeling disinterested in her original major during her freshman year of college but remembered feeling interested in the astronomy work during her first research experience, which influenced her decision to switch to a physics major. Then she decided to also declare a computer science major due to the amount of computer coding involved in astronomy.

Alysa gained opportunities to interact with researchers in her chosen field of study. In her last three research experiences, she was integrated into a team and interacted with graduate students and postdoctoral researchers who influenced her perception of researchers in a positive manner. She was also able to attend an international conference and found "it was very helpful to, sort of, go to one of the big international conferences and meet everyone and get to interact with the grad students and the postdocs and realize that people in the very specific, niche field I want to go into are really, really, nice and helpful and I want to work with those people".

Alysa said that her participation in research experiences helped in their academic studies by giving her more problem-solving skills and practice in advanced coding techniques. The experiences also helped instill a sense of self-efficacy that she was contributing to science and affirmed their confidence in their capability of doing graduate school level work. Ultimately, she expressed overall a feeling of confidence gained from research experience saying "the fact that I'm even remotely in the same league as them [graduate students] tells me that I am pretty good at STEM". Alysa also reported that her research experiences had a positive effect on their sense of belonging and attributed this to having the opportunity to meet others involved in the field outside of the people in their lab. She was also able to identify similarities between herself and other professionals within the field. The only downside mentioned was that she reported at times experiencing imposter syndrome that manifested after interactions with advanced graduate students, which at times contributed to insecurity because she could not yet do what the graduate students were doing.

Another positive that came from the experiences is the good relationships with her faculty mentors that provided opportunities for growth she would have not otherwise had. She felt closer to her first research mentor due to the casual research environment and longer researching hours of the short summer immersion program. Her second research mentor provided her with many opportunities that affected her ability to achieve academic and professional goals. Alsa said "the project I'm working on now, she wants to result in a paper and it would be a first author paper for me which would be really big for grad school…. She sent me

to the Nanograv meeting in New York City and then she funded me to go to Australia [for a conference] for two weeks".

In summary, Alysa expressed the belief that participation in research is essential for all STEM students. She said, "if you are not going to do research you need to do, … a hands-on project of some sort because, just learning the skills and in a more realistic environment than the classroom is pretty essential for all STEM".

Student 2

Emily graduated from a large, public university. She majored in biochemistry as an undergraduate student and now attends graduate school. She participated in four undergraduate research experiences starting with a two-week experience in the summer, shadowing multiple labs during her first two years of college, a three month NSF REU site, and taking a research based course for her last two years of college.

Her first experience involved building a radio telescope with common store-bought materials while also working on open-source coding. This experience took place the summer before she entered college. She presented her telescope to researchers and other interns. Her second experience involved shadowing a soil science and a plant science lab where she assisted with tasks like data entry and standardizing equipment. Her third experience allowed her to get hands-on experience studying molecular signaling pathways in soil bacteria. She participated in weekly meetings with the graduate student she worked with and presented her findings at the university's summer symposium. Her fourth research experience was a research based upper-level chemistry course that she took for two years. She initially studied mercury methylation in soil bacteria near sites of acid mine drainage but switched over to join a plant pathology lab studying a fungal pathogen of multiple magnolia species when their mentor for their first project left the university. For both of these projects in this course, she completed a literature review, engaged in weekly meetings with her mentor, and wrote up her findings at the conclusion of each semester

Emily cited multiple benefits from these experiences. She reported that her first research experience helped her better understand the process of research saying "I didn't really know what research entailed or how you would even draft up an experiment…I learned a lot of those components". For her third experience, she stated that the experience helped her gain independence as a researcher because she was "figuring out how to do a lot of these techniques for the first time without much guidance". In her fourth research experience, she reported that she continued to get more independent as a researcher while also gaining a lot of presentation and public speaking skills.

Emily credited her participation in research with helping her figure out what she wanted to do with her STEM career. "I had no idea that…all these different fields existed, and so I think just like, hopping around and working with really enthusiastic scientists in particular has helped me figure out what I want to do with my STEM career."

Emily reported that her experiences helped in her academic studies by introducing her to lab techniques that were later covered in her coursework. She also reported that because of how positive her experiences were, she decided to continue onto a master's program. She mentioned that her participation in research helped her increase her STEM self-efficacy and work through her impostor syndrome, saying "the more I worked in research labs the more I realized…I'm really capable of being a researcher and understanding what it takes". She also reported that she

feels more respected in professional settings such as conferences as a graduate student due to her extensive undergraduate research background.

Emily's relationships with her research mentors throughout her experiences greatly helped her reach her academic and professional goals. Although she reported having positive experiences with all of her research mentors, she mentioned that the best relationship she had was with her last research mentor for the research-based course. This research mentor influenced Emily to return to their lab for the master's program. The mentor also assisted her in starting the NSF Graduate Research Fellowship Program (GRFP) application, which she ended up getting awarded. She maintained that this mentor continuously tries to find her awards to apply for and experiences to participate in to facilitate professional development.

Overall, Emily agreed that participation in research was important for STEM students, especially for students that do not attend R1 institutions. She said, "I had no idea what I'm doing even existed…and so I've learned a lot of other skills and fields of science I otherwise wouldn't know about."

Student 3

Kaitlyn was a junior at a small, public university. She originally majored in Psychology but then switched to Mathematics. She participated in three undergraduate research experiences beginning with a two-week summer experience, a ten-week program aimed at measuring and enhancing NSF funded student success, and an eight-week NSF REU site.

Kaitlyn's first experience was a short experience where she investigates the water quality of springs the summer before her freshman year of college. In this experience, she engaged in daily meetings with her research mentor and then presented her results to her peers and other researchers. Her second experience involved determining ways to support several computing, math, and engineering students at their university over the course of ten weeks. For this experience, she took part in weekly meetings with their mentor and presented her findings at a conference. Kailtyn's third research experience was an 8-week NSF REU site where she studied discrete hypergeometric series and complex analysis. This experience consisted of daily meetings with her research mentor and a presentation at a symposium.

Kaitlyn took away multiple benefits from her research experiences. She found that her first experience fostered community building in STEM. Kaitlyn reported that "learning to be professional and communication skills" was the most beneficial takeaway from her second experience. Her third research experience furthered her development of professional and communication skills. Kaitlyn highlighted that her first and third experiences helped increase interest in her STEM major but was unsure of the influence her second experience had in their interest. She attributes the raised interest to the community building she felt occurred during her first experience.

Kaitlyn mentioned that her first two research experiences helped her academic studies "in terms of relationships with professors and peers", while her third experience helped enhance her math skills. Two of her experiences helped increase her self-efficacy, with the first making her "a little more confident in presentations" while the third made her feel "more confident in my ability to do math". Her sense of belonging increased as a result of all three experiences. The first experience helped her build community with her peers. Her second and third experiences helped her feel more confident talking to professors and other people in the field who are interested in math.

Kaitlyn described her relationships with her various research mentors as professional, helpful, and friendly. Her first mentor encouraged her to join a program they thought would be beneficial for her where she could network with a professor at the college they planned on attending. She joined the program for a period of time and assisted with presentations on science related topics. Of her third research mentor, Kaitlyn mentioned that they helped her "with algebra and also constructive criticism on presentations".

In short, Kaitlyn expressed that participation in research is beneficial when it pertains to specifically what a student wants to do because it "definitely helps with knowing what is in your field and self-efficacy too."

Student 4

Tom was a sophomore at a mid-size, public university. His major was computer science. He participated in two research experiences starting with a two-week experience in the summer and an NSF grant funded academic year program for two years.

The first experience lasting two weeks involved Tom investigating the effect of machine learning on the copyright process in the music industry. This experience allowed him to present his results to other interns and researchers. His second experience allowed him to engage in cyber security research where he created attribute-based access control policies to avoid escalation of privileges within networks. In this experience, Tom participated in weekly meetings with his research mentor to communicate project progress.

Tom reported many benefits from his two experiences. He stated that the final presentation of the first experience was beneficial because it aided in the development of his public speaking skills. For the second experience, the development of the relationship with his research mentor was the most beneficial takeaway from the experience.

Tom's participation in his first experience influenced his interest in the STEM major by increasing his interest in the topic of machine learning while his second experience led him to pursue an area of emphasis in cybersecurity within his major. Both of these experiences greatly influenced what he wanted his future STEM career to be. Tom expressed that in his current job search, he is seeking jobs that "merge the two … using machine learning to develop cybersecurity principles and practices".

Tom said that his participation in research experiences helped his academic studies by connecting him with research mentors that guided him and put him on the right path his freshman year. His second research experience exposed him to attribute based access control policies as a freshman which he later encountered in coursework his sophomore year. The second experience also led him to learn the python coding language. In terms of improved self-efficacy, Tom reported that his first experience "made me feel more comfortable with the college environment" while his second experience improved his STEM self-efficacy because "having that project…being able to showcase that to the people in the industry and peers…definitely made me feel more confident about my abilities". His sense of belonging on campus was improved by both experiences by connecting him with professors that allowed him "to go and talk to that person, I feel comfortable talking to that person, definitely made me feel better with being on campus."

Expanding on his relationships with his research mentors, Tom stated that his relationships with both mentors were positive. He credits his first research mentor with helping him immerse himself into the college atmosphere. Regarding his second mentor, he said that this

mentor "cares a lot about student's learning and students focusing on their education". Tom communicates with this professor very frequently and mentioned that this professor helped with his academic and professional goals by selecting him for awards within the computer science department at his university. This mentor also notified Tom of opportunities associated with his research and served as a resource that he could go to for computer science topics and writing letters of recommendation.

To summarize, Tom expressed the belief that participation in research is important for STEM students. He stated "I think that it is instrumental to student success…I think that the ability to have a project, to get hands-on in what you're doing rather than just go through the classes and go home is 100% instrumental to success in college."

Student 5

Ethan was a senior at a large, public university. His major was originally forensics but was later changed to a multi-disciplinary major. A multidisciplinary major is a major that allows for students to customize their education by allowing them to pick three minors to pursue to go towards one degree. He participated in two research experiences beginning with a two-week experience in the summer and a research apprenticeship program that lasted one semester.

The first experience exposed Ethan to research about water quality and microorganisms in various water samples. At the end of this short experience, he presented the results to a group consisting of interns and researchers. Ethan's second experience engaged him in a forensics project that investigated picture quality of different types of samples such as blood splatter. For this experience, he participated in a poster presentation at his institution's symposium.

Ethan found several benefits from his research experiences. First, he found it helpful "actually going out into the field and kind of having that opportunity to collect data and see how it can be used in scientific research." This experience took place during the SARS-CoV-2 pandemic, which led Ethan to realize that "regardless of circumstances, research can be done anywhere or any place". His second experience was beneficial because it provided him an opportunity to work "with an individual [their research mentor] who is more knowledgeable in the field…helping me get that experience that I would need to feel comfortable in that kind of atmosphere when it comes to research". Ethan's participation in his first experience increased his comfort conducting research. His second experience improved his comfort in his major as he reported feeling more uncomfortable than most in his STEM originally.

Ethan reported that participation in research helped him in his academic studies. He stated, "I think that it [his first experience] may have helped in a couple of specifically the earlier biology classes. Some of those procedures were similar…especially for the second experience [the research apprenticeship program] it kind of helped me get more comfortable with a lab setting in general like using pipettes and using specimens, tubes, and slides, those kinds of things". The experiences helped him believe in his ability to do research and improved his confidence pursuing a STEM major in general. However, he mentioned that his experiences only increased his sense of belonging in his major and not his future STEM field since he felt that his second research project was too broad.

Ethan reported not having a close relationship with his first research mentor because he did not meet frequently with this mentor over the short first experience. He additionally did not report a positive relationship with his second mentor, who he felt did not understand the requirements associated with the research program he was in. He had a better relationship with a graduate student he was working under in their mentor's lab. While Ethan felt more comfortable

in his major after his experiences, he does not attribute the increased confidence to his mentors but rather the experiences themselves.

Overall, Ethan stated of undergraduate research, "I think that it can be important for STEM students…just because especially doing earlier research also lets them know what opportunities are available in the field." Ethan clarified that his cause for leaving STEM were not due to the experiences, but rather "attitudes towards searching for support [in STEM] was what drove me away from a STEM major."

DISCUSSION

This section will discuss how the results answer the research questions posed.

Research Question 1: Is the sense of belonging in their STEM major higher in students that have participated in more research experiences?

The findings of this study suggest that participation in multiple research experiences leads to an increased reported sense of belonging in a STEM major. When comparing students that reported participation in one research experience to students who participated in multiple experiences, those with multiple research experiences reported a higher mean rating for each sense of belonging item in the survey. Most notably, students with multiple research experiences reported a significantly higher mean for the item "I feel I fit in when I am in science or mathematics classes."

When examining the changes in sense of belonging scores of students reporting two research experiences, it was found that there was a significant increase in means reported after their second experience when compared to their first experience for the items "I feel I fit in when I am in science or mathematics classes." and "I feel comfortable when I am in science or mathematics classes." Although not every item had a significant increase in mean, the mean reported after students' second experience was higher for every statement. Additionally, the mean across all sense of belonging items for their second experience was significantly higher than the mean for all items after their first research experience.

An examination of students reporting three or more research experiences revealed significantly higher means for every sense of belonging item when comparing students' first experience and their most recent experience. Not surprisingly, students with three or more experiences were found to have a significantly higher overall sense of belonging.

These findings support the idea that undergraduate STEM research experiences assist students specifically in developing feelings of belonging in their STEM coursework. Undergraduate research experiences were also found to increase comfort in students with multiple research experiences. The students reporting three or more experiences were found to have the most significant increases across the most items which provides support for the idea that participating in more research experiences leads to a higher sense of belonging within a STEM major. This is also observed within the student interviews, where several students expressed that their experiences had a positive impact on their sense of belonging. Alysa (Student 1) described her research experiences as helping her meet established researchers in the field while Kaitlyn (Student 3) reported her experiences helping her establish relationships with her peers. In summary, students generally reported a greater sense of belonging in their major for most sense of belonging items in the survey the more experiences they participated in.

Research Question 2: Is self-efficacy higher in students that have participated in more undergraduate research experiences?

The results from the survey suggest that reported self-efficacy is increased in students with more research experiences. A comparison of the means of students that reported involvement in multiple undergraduate research experiences yielded significantly higher means for the self-efficacy items "I'm confident I can understand the most complex material presented in the other mathematics and science classes required for my major.", "I'm confident I can do an excellent job on assignments and tests in the other mathematics and science classes required for my major.", and "I believe I will receive excellent grades in the other mathematics and science classes required for my major." than those who only reported participation in one URE. Additionally, a significant increase was observed for overall self-efficacy scores between students with multiple experiences and those with one. All the self-efficacy item means reported from the students with multiple experiences compared to those with one experience are higher, however not all the differences were significant. This offers evidence that students that participate in multiple experiences perceive themselves as having a higher STEM self-efficacy than those that only participated in one experience. The results from the survey suggest that this increased self-efficacy leads to a greater belief within students that they can perform well in their STEM courses, an important aspect of succeeding in STEM.

Students reporting participation in two experiences have a significantly higher rating for their second experience for the following self-efficacy statements: "I'm confident I can understand the basic concepts taught in the other mathematics and science classes required for my major.", "I'm confident I can understand the most complex material presented in the other mathematics and science classes required for my major.", "I'm confident I can do an excellent job on assignments and tests in the other mathematics and science classes required for my major.", and "I believe I will receive excellent grades in the other mathematics and science classes required for my major." Although not all item differences were significant, all items in the self-efficacy section of the survey were found to have a higher mean after students' second experience. Similar to previous findings, students with two experiences reported a higher confidence in items relating to success in STEM courses.

Students in three or more experiences reported a higher average rating for the statements "I'm confident I can understand the basic concepts taught in the other mathematics and science classes required for my major.", "I'm confident I can understand the most complex material presented in the other mathematics and science classes required for my major.", and "I'm confident I can do an excellent job on assignments and tests in the other mathematics and science classes required for my major." There was an increase in mean for all other statement from the first to the final experience but they were not found to be significant. Student interviews provided additional context for these answers, with Tom (Student 4) expressing that participation in research increased his confidence about his research abilities. Alysa (Student 1) and Emily (Student 2) both reported their research experiences helped them work through their imposter syndrome within STEM research. In summary, the data from the surveys and interviews helps support the notion that more participation in undergraduate research helps develop more self-efficacy and increases a student's belief in their ability to successfully navigate their STEM coursework through development of their self-efficacy.

Research Question 3: Is high self-efficacy linked with a high level of instrumental mentoring from their research mentor?

The survey data suggests that there is a moderate positive correlation between a high level of self-efficacy and a perceived high level of instrumental mentoring from research mentors. This is consistent with what several of the faculty interviewed from various universities envisioned students would get out of the program. A faculty member from a mid-size public university in explained that their faculty members intentionally try to provide instrumental mentoring to their undergraduate research students by "building up their technical and analytical skills". Another faculty member from a large university mentioned that their faculty members perceive their institution's research opportunities as allowing students to practice "critical analysis, performing research in the literature and working on a project" which in turn helps students build their self-efficacy.

The sentiment of a link between instrumental mentoring received and perceived self-efficacy was echoed in the student interviews. Alysa (Student 1) who had a higher than average score for the items in the self-efficacy section for her most recent experience, reported that her UREs helped her instill a high level of self-efficacy by assisting with the development of her problem-solving skills. Kaitlyn (Student 3) similarly reported higher than average self-efficacy scores for her most recent experience in the survey, while also mentioning that her experiences contributed to the honing of her math and presentation skills in the interview. Several students reported in the interviews that their research mentors assisted in the development of their self-efficacy skills. Alysa (Student 1) said notably of her mentor that she played a big role in assisting Alysa in connecting with other academics in her field as well as directly providing an opportunity for a publication. Tom (Student 4) mentioned the instrumental mentoring that he received from his research mentor helped him be able to speak about his project to others in the field increased his confidence within research. In short, STEM self-efficacy is linked to the level of instrumental mentoring received by a student's research mentor.

CONCLUSION

This study investigated how involvement in UREs affected sense of belonging, self-efficacy, and the link between perceived level of instrumental mentoring received and self-efficacy for undergraduate STEM students. Sense of belonging was found to be significantly higher for students from their first research experience to their most recent experiences. This is especially important when combined with the findings from Hausmann et al. (2007) that indicate that sense of belonging plays an important role in persistence. In this study, self-efficacy was also reported to be significantly higher in students from their first research experience to their most recent experience. Again, this is significant when combined with the findings of Omolola et al. (2013) that show that self-efficacy is also a predictor of persistence. This study additionally found that a perceived high level of instrumental mentoring from a research mentor was correlated with high reported levels of self-efficacy. Syed et al. (2018) found similar results in their study where they surveyed both undergraduate students who had participated in a STEM support program and students who did not and found that instrumental mentoring leads to increased commitment to a STEM career which was mediated by self-efficacy.

Some limitations of this study include the number of participants in the study. Several survey responses were unusable due to incorrect responses to the survey, such respondents grouping multiple UREs together instead of answering the statements for each separate experience. Although enough usable responses were received, it would have strengthened the validity and applicability of these findings if there was additional data to analyze. Another limitation of the study is that many survey respondents reported their race as being white which

makes the applicability of the findings to non-white students difficult. One way this research could be expanded upon in the future is by investigating how factors such as gender, race and ethnicity, and first-generation status influence sense of belonging and self-efficacy after participation in UREs. Another point of interest would be to survey undergraduate students again about their perceived level of instrumental mentoring received and their self-efficacy while simultaneously surveying their research mentors about the level of instrumental mentoring they perceive to be providing. Examining the similarities and differences between how students' perceive the mentoring they received and how faculty perceive their own mentoring could offer insight into any discrepancies that undermine the effectiveness of the mentoring received. This research could be useful for informing more effective mentoring practices.

An important takeaway from this research is that participation in UREs is invaluable for the development of STEM students in many aspects including but not limited to improving their sense of belonging and self-efficacy in STEM with the potential to lead to persistence in the STEM pathway. Universities and colleges of all sizes should consider making the investment to promote undergraduate STEM research as a way to retain students and assist them in developing into valuable members of the STEM workforce. These experiences not only benefit students in their academic career but serve to assist them in finding career paths and prepare them for a future in a STEM career.

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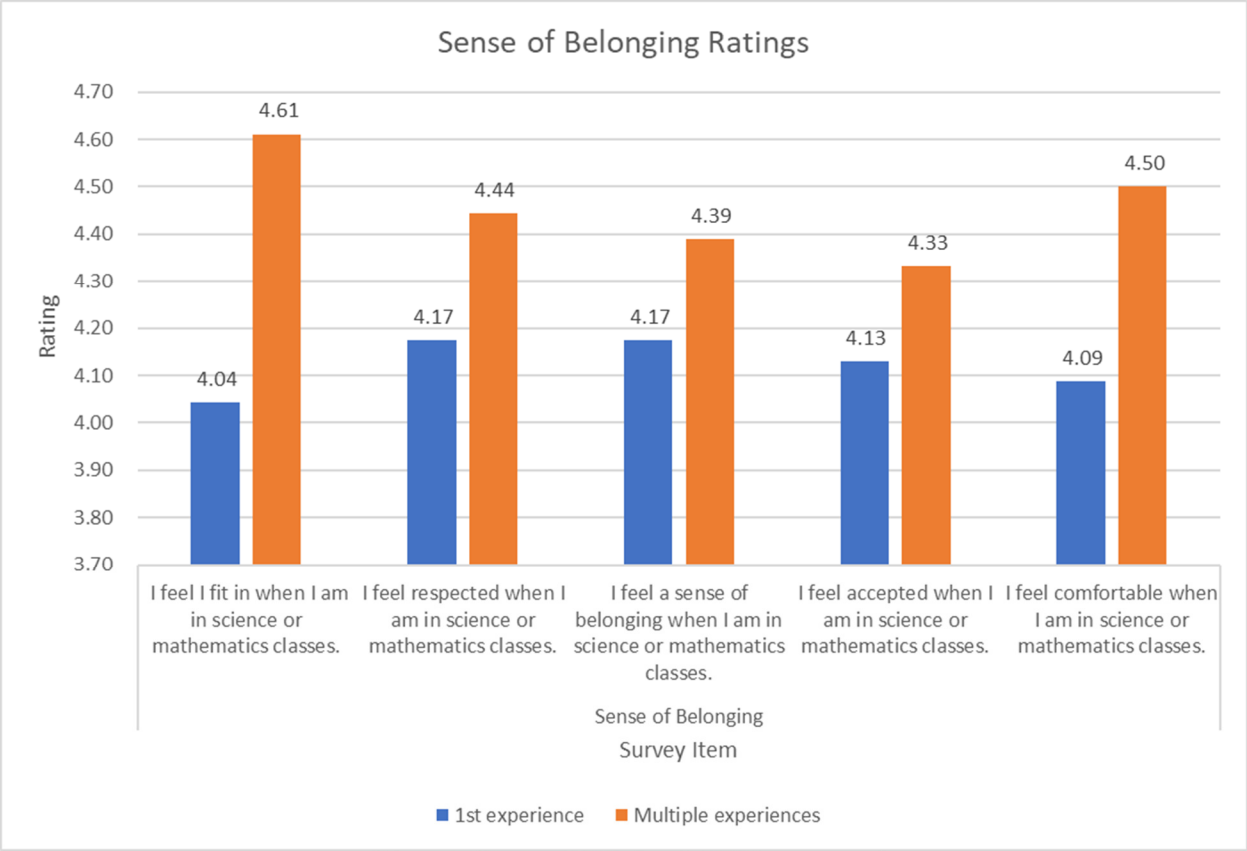
APPENDIX

Table 1. Characteristics of Survey Participants

Number of Research Experiences	Total	Class	Number
1 Experience	23	Freshmen Sophomore Junior Senior/Graduate	9 8 3 3
2 Experiences	12	Freshmen Sophomore Junior Senior/Graduate	4 4 1 3
3 Experiences	4	Freshmen Sophomore Junior Senior/Graduate	1 1 1 1
4 Experiences	2	Freshmen Sophomore Junior Senior/Graduate	0 0 1 1

Note: n=41

Fig. 1 Sense of Belonging Comparison Between Undergraduate Students with One Experience and Students with Multiple Experiences (Good et al., 2012; Goodenow, 1993)



Note: n= 41. Participants rated each item in the survey using a five-point scale: (1) Strongly Disagree and (5) Strongly Agree.

Table 2 Sense of Belonging and Self-Efficacy Survey Results for Students with Two Experiences Comparing First and Second (Pintrich & De Groot, 1991; Good et al., 2012; Goodenow, 1993)

SENSE OF BELONGING - Averages				
Survey Item	1st Exp.	2nd Exp	Difference	p-value
I feel I fit in when I am in science or mathematics classes.	3.83	4.42	0.59	0.01*
I feel respected when I am in science or mathematics classes.	4.17	4.25	0.08	0.36
I feel a sense of belonging when I am in science or mathematics classes.	3.75	4.08	0.33	0.08
I feel accepted when I am in science or mathematics classes.	3.83	4.08	0.25	0.14
I feel comfortable when I am in science or mathematics classes.	3.67	4.33	0.66	<0.01*
Overall Sense of Belonging	19.25	21.17	1.92	0.03*
SELF EFFICACY - Averages				
Survey Item	1st Exp.	2nd Exp	Difference	p-value
I'm confident I can understand the basic concepts taught in the other mathematics and science classes required for my major.	3.92	4.50	0.58	0.01*
I'm confident I can understand the most complex material presented in the other mathematics and science classes required for my major.	3.83	4.25	0.42	0.05*
Considering the difficulty of the classes and my skills, I think I will do well in the other mathematics and science classes required for my major.	4.17	4.25	0.08	0.38
I'm confident I can do an excellent job on assignments and tests in the other mathematics and science classes required for my major.	4.00	4.42	0.42	0.03*
I believe I will receive excellent grades in the other mathematics and science classes required for my major.	3.92	4.33	0.41	0.05*
I'm certain I can master the skills being taught in the other mathematics and science classes required for my major.	4.00	4.33	0.33	0.08
Overall Self-Efficacy	24.83	26.08	1.25	0.13

Note: n=12. Participants rated each item in the survey using a five-point scale: (1) Strongly Disagree and (5) Strongly Agree.

*Significant at p<0.05.

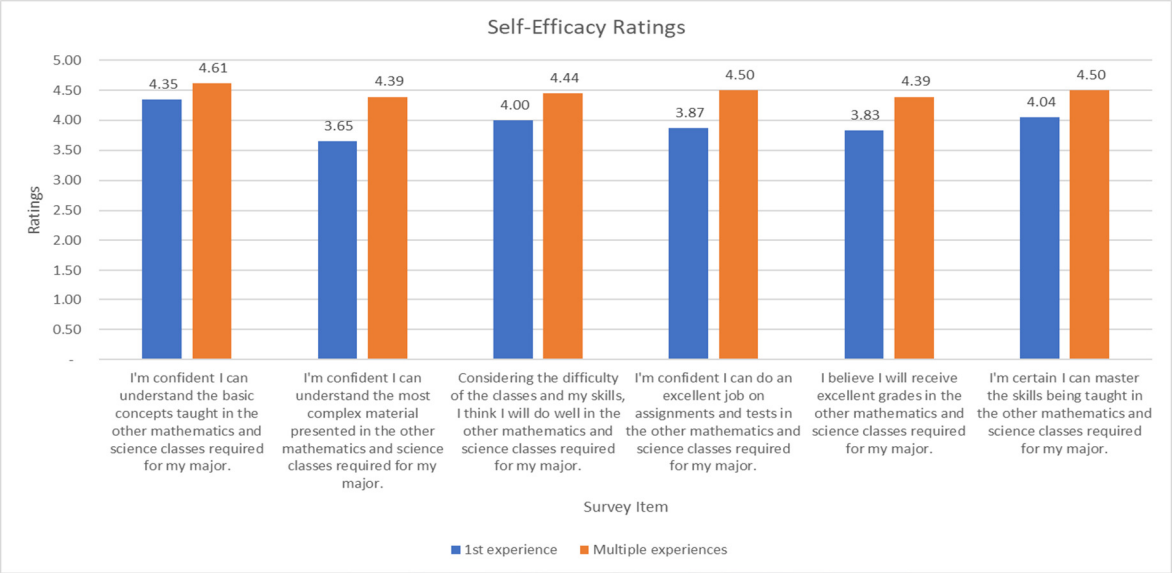
Table 3 Sense of Belonging and Self-Efficacy Survey Results for Students with 3+ Experiences (Pintrich & De Groot, 1991; Good et al., 2012; Goodenow, 1993)

SENSE OF BELONGING - Averages				
Survey Item	1st Exp.	Most Rec. Exp	Difference	p-value
I feel I fit in when I am in science or mathematics classes.	4.50	5.00	0.50	0.04*
I feel respected when I am in science or mathematics classes.	4.17	4.83	0.66	0.01*
I feel a sense of belonging when I am in science or mathematics classes.	4.50	5.00	0.50	0.04*
I feel accepted when I am in science or mathematics classes.	4.17	4.83	0.66	0.05*
I feel comfortable when I am in science or mathematics classes.	4.33	4.83	0.50	<0.01*
Overall Sense of Belonging	21.67	24.50	2.83	0.02*
SELF EFFICACY - Averages				
Survey Item	1st Exp.	Most Rec. Exp	Difference	p-value
I'm confident I can understand the basic concepts taught in the other mathematics and science classes required for my major.	4.33	4.83	0.50	0.04*
I'm confident I can understand the most complex material presented in the other mathematics and science classes required for my major.	4.00	4.67	0.67	0.05*
Considering the difficulty of the classes and my skills, I think I will do well in the other mathematics and science classes required for my major.	4.50	4.83	0.33	0.18
I'm confident I can do an excellent job on assignments and tests in the other mathematics and science classes required for my major.	4.00	4.67	0.67	0.05*
I believe I will receive excellent grades in the other mathematics and science classes required for my major.	4.33	4.50	0.17	0.18
I'm certain I can master the skills being taught in the other mathematics and science classes required for my major.	4.67	4.83	0.16	0.18
Overall Self-Efficacy	25.83	28.33	2.50	0.06

Note: n=6. Participants rated each item in the survey using a five-point scale: (1) Strongly Disagree and (5) Strongly Agree.

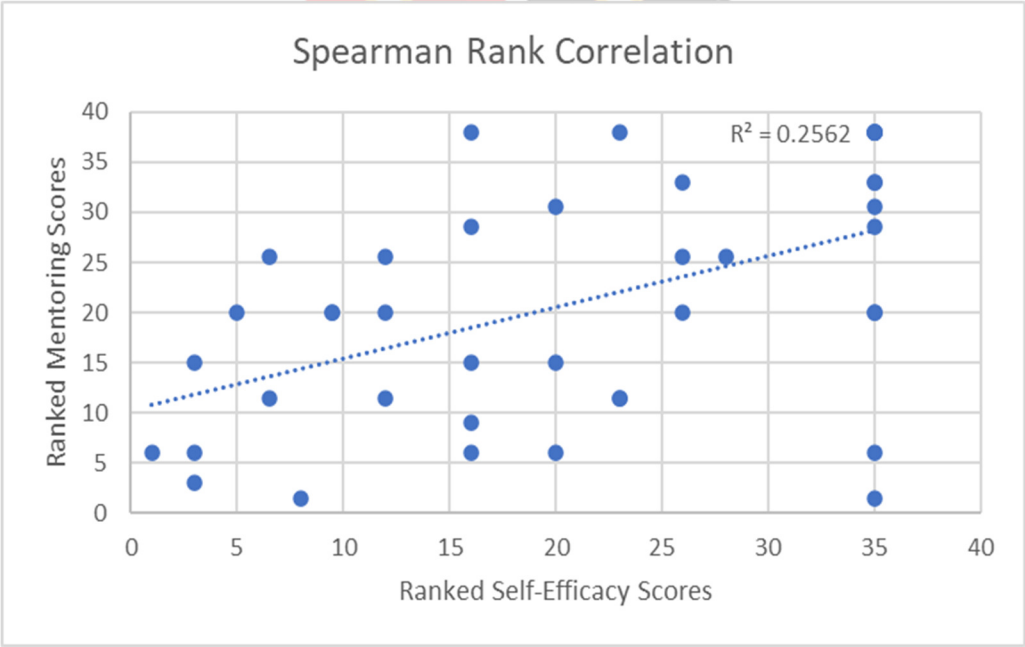
*Significant at $p<0.05$.

Fig. 2 Self-Efficacy Comparison Between Undergraduate Students with One Experience and Students with Multiple Experiences



Note: Participants rated each item in the survey using a five-point scale: (1) Strongly Disagree and (5) Strongly Agree.

Fig. 3 Correlation Between Self-Efficacy and Instrumental Mentoring Scores



Note: Spearman's rho= 0.51 and p <0.01.