NSF REU Entrepreneurially Minded Applied Energy Program Evaluation: Traditional Delivery Versus Alternative Delivery (Implemented During COVID-19)

Abstract

Purpose: The National Science Foundation (NSF) Research Experience for Undergraduates (REU) programs are traditionally delivered in-person and full-time (40 hrs per week) for 10 weeks during the summer. However, this type of format has the potential to limit broader student participation. This study aims to compare learning assessment data between a traditional NSF REU (10 weeks of summer, full-time, in-person) to an alternative NSF REU delivered virtually, part-time, and over 10 months as a result of the COVID-19 pandemic.

Design: A retrospective pre-then-post survey was completed to assess perceived learning gains for each REU program. Three learning gains categories were assessed: entrepreneurial competencies, career goals, and research skill development. T-tests were used to evaluate a difference in means between pre-and-post.

Findings: Findings show the greatest quantity of learning gains within the Alternative program delivery. Moreover, a larger quantity of learning gains was perceived within the first semester of the alternative program delivery compared to the second semester.

Originality: This paper is original in that it's the first of its kind to assess an alternative REU program delivery (allowed only because of the COVID-19 pandemic) in comparison to traditional REU program delivery.

Practical Implications: The authors propose the National Science Foundation should be intentional about trying new approaches to REU programs delivery, including duration and format, as a way to broaden participation in engineering and technology.

Key Words: higher education, NSF, REU, undergraduate, engineering, engineering technology, energy, entrepreneurship, new product development, customer discovery, market analysis, STEM

Article Classification: Research Paper

1. Introduction

1.1 Problem Identification

Several authors have shown the importance of undergraduate research programs and their benefits to students, professors, and universities (Bauer and Bennett, 2003, Lopatto, 2007, Cox and Andriot, 2009, Seymour et al., 2004). Due to the benefits of undergraduate research, the National Science Foundation (NSF) has funded Research Experiences for Undergraduates (REU) in science, engineering, or mathematics programs, allowing students to participate in research programs at Universities across the United States during the summer (NSF, 2019a, NSF, 2019b). REU programs are traditionally delivered in-person, on-site during the summer, and full-time (40 hours per week) for 10 weeks. One of the main benefits of REU programs is the impact on a student's decision to pursue a graduate degree and a career in academia or scientific research (Kim et al., 2011). Additionally, REU programs have benefits related to retention, research skills, teamwork, and oral and written communication skills (Zhan, 2014). Moreover, REU programs are intended to broaden participation in STEM, as explained in a snippet from the NSF REU program solicitation NSF 22-601.

> *REU projects offer an opportunity to tap the nation's diverse student talent pool and broaden participation in science and engineering. NSF is particularly interested in increasing the numbers of women, underrepresented minorities, and persons with disabilities in research. REU projects are strongly encouraged to involve students who are members of these groups. (Underrepresented minorities are Blacks and African Americans, Hispanics and Latinos, American Indians, Alaska Natives, Native Hawaiians, and Other Pacific Islanders.) When designing recruitment plans, REU projects also are encouraged to consider students who are veterans of the U.S. Armed Services and first-generation college students.*

For all the focus that "should be" placed on underrepresented minorities (URMs), graduate school enrollment (which can serve as an indicator of REU participation) remains low for URMs. Per Table 1, non-URMs comprise about 16% of the US census population; however, non-URMs account for 57.5% of undergraduate engineering enrollees and 67.2% of graduate students enrolled in engineering. For all URMs in the table (e.g., women, Hispanic or Latino, Black or African American, American Indian or Alaska Native), the undergraduate engineering enrollment is substantially smaller than the US census population; for all URMs except the female students, the transition from undergraduate to graduate engineering programs only serves one-third to one-half of the group.

Table 1. 2018 URM Breakdown: Census, Undergraduate Engineering Enrollment, Graduate School Engineering Enrollment

	Non-URM	Women	Hispanic or Latino	Black or African American	American Indian or Alaska Native
2018 Census Population (United States Census Bureau, 2019)	16%	50.8%	18.5%	13.4%	1.3%
2018 Undergraduate Enrollment in Engineering (NCSES, 2019b)	57.5%	22.7%	14.4%	5.1%	0.3%
2018 Graduate Enrollment in Engineering (NCSES, 2019a)	67.2%	25.3%	4.9%	2.5%	0.1%

Thus, a problem exists given the limited participation of minoritized student populations in REU programs. It has been found that among the most important factors for students when accepting an REU offer are: stipend, housing, and meal package (Economy et al., 2013). Although participants generally receive a stipend of $6,000 for participating in the REU programs, those funds are not available in advance. In this way, students must cover upfront costs for housing, food (although a small stipend is usually provided), and travel costs to the site (with subsequent reimbursements). This situation limits, even more, the broader and more diverse participation of students.

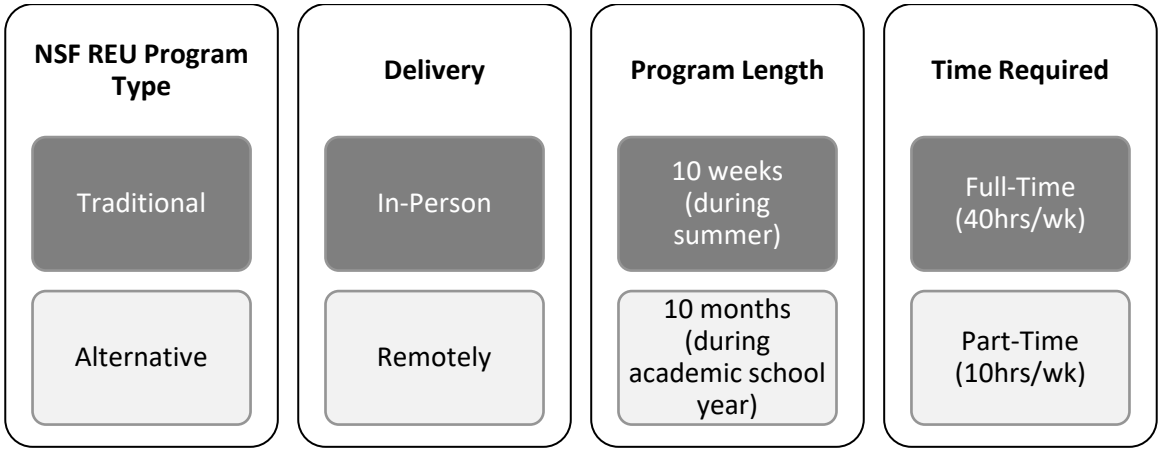

Figure 1. Visual Comparison of Traditional NSF REU vs. Alternatively Delivered NSF REU

1.2 Study Overview and Contribution to Literature

This study compares learning assessment data between a traditional REU (10 weeks of summer, full-time, in-person) to an REU delivered alternatively (10 months of the school year, part-time, virtually), as visually summarized in Figure 1. The REU programs studied aim to provide students with a research experience that combines the best aspects of academic applied research, the theoretical basis, and rigorous scholarship. As well as provide students with essential business practices such as real-world customer discovery and the generation of sound business plans.

Due to the COVID-19 pandemic, virtual education classes and programs have become widespread. This event allowed this study to compare the traditional delivery (in-person) and alternative (virtual) delivery mechanisms of the REU program. This comparison is the main contribution to the literature of this study since there is a limited number of articles (if any) that have made a contrast of this type. Additionally, there is a need to disseminate the findings to the community so that a different perspective can be considered for future versions of the REU programs.

The research question of the study is as follows: *How do perceived learning gains compare across a traditional REU program versus an alternatively delivered REU program?*

The next section will go into greater detail discussing overall challenges for obtaining an undergraduate research experience, provide an overview of the traditional NSF REU program requirements, and introduce readers to the alternatively delivered NSF REU program analyzed in this study.

2. Literature Review

2.1 Challenges for Gaining Undergraduate Research Experience

Currently, some approaches are being used to provide research experiences to engineering students. First, Virtual Student Federal Service (VSFS) is a remote internship program where undergraduate and graduate students from US Universities can work on specific projects for nine months. VSFS is managed by the Office of eDiplomacy in the U.S., and students can choose between hundreds of projects from different government agencies (VSFS, 2021). However, there is a gap with VSFS programs as the program has no learning outcomes, students are free labor for the US government, and there are limited opportunities for engineering internships.

Second, some universities have an Office of Undergraduate Research, where professors can apply for funds to mentor students during the school year. In some cases, students even receive a small stipend. In this way, students can access research experiences. However, this program is not available at all Universities as it is limited to institutions with more resources as R1 universities. Additionally, the focus is on laboratory research, and it is an extra academic load with limited payment for students, limiting access. Furthermore, the experiences do not guarantee a cohort model where students can develop a sense of belonging.

Third, Course-based Undergraduate Research Experience (CURE) is an approach that provides research experience within the classroom. CURE allows the research to be more accessible for the students. Additionally, it will enable the students to confirm their interest in pursuing a career linked to academia or scientific research (Bangera and Brownell, 2014, Dolan, 2016). However, this type of experience is limited to universities with the necessary resources and courses to incorporate research, which is not always feasible in engineering, where courses are cumbersome in content, and instructors lack knowledge of how to teach how to do research. Also, the CURE program has outcomes controlled, and generally, the work is limited to the literature review and data analysis with a limited focus on real-world experiences.

In summary, the VSFS program is virtual (which allows for greater accessibility), however, there is limited focus on learning objectives and engineering internships are competitive. Many universities have an Office for Undergraduate Research that connects undergraduate students with professors to work on research, however, this is typically one-on-one and rarely includes a cohort model where students can develop a sense of belonging. Finally, CURE's can provide research experiences within the classroom, however, in an attempt to keep students on the semester track deliverables are contrived ahead of time, which limits the focus on real-world research. Research experiences for undergraduates (REU), regardless of whether the delivery is in-person or remote, overcomes all these gaps by including learning objectives, applying a cohort model, and customizing research experiences towards the student skillset.

But the question remains: *Which approach results in greater perceived learning gains – traditional REU or alternatively delivered REU?*

2.2 Traditional NSF REU Overview

For more than 30 years, the National Science Foundation (NSF) has funded Research Experiences for Undergraduates (REU) in science, engineering, or mathematics programs, allowing students to participate in research programs at Universities across the United States (NSF, 2019a, NSF, 2019b). Within the NSF REU solicitation, several requirements are listed for offering the traditional NSF REU program: (1) $6000 stipend, (2) additional funds *may* be provided for housing, meals, and transportation to/from the site, (3) includes 8-10 students per year, (4) is offered full-time (40 hours/week) over the summer and in-person.

Several studies have demonstrated the benefits of research experiences for undergraduate students (Lopatto, 2007, Cox and Andriot, 2009). One of the main benefits is the impact on a student's decision to pursue a graduate degree, a career in academia, or scientific research (Seymour et al., 2004). In-person programs expose students to a lab environment that creates structure and limits distractions (Sheng et al., 2014). Additionally, the students that have participated in the REU program have positively rated the relationships with the other research group members, which also provides them with a feel of a research environment and college life (Follmer et al., 2016). Studies have found that students enjoy the social environment of laboratory work (Sheng et al., 2014). REU's in-person programs allow students to improve their ability to use tools and equipment in laboratory facilities (Sheng et al., 2014, Cox and Andriot, 2009). Additionally, studies have revealed that students benefit from collaborative work with their peers and mentors while working in interdisciplinary settings such as laboratories (Follmer et al., 2015, Sheng et al., 2014)

REU programs have several associated challenges related to their execution. One of the challenges described by the professors is the management of the short duration of the program, which implies maximizing the time and experience of the students (Follmer et al., 2015). Additionally, there are challenges before the start of the program, such as the recruitment of students. Recruitment time is limited and usually between March and June. In addition, since students can back out last minute, logistic programs are generated, linked to housing, meals, transportation, etc. Due to the short period of time, another challenge mentioned by professors is

deciding what level of autonomy to give students and what type of tasks to assign them (Follmer et al., 2016). The students also identified challenges, which are mainly related to the program's structure concerning the definition of goals and timeline for each research project and the flow of information and directions throughout the project (Sheng et al., 2014). In some cases, communication between students and advisors in the summer is limited, so students receive more mentoring from graduate students. This is because some advisors do not work full-time during the summer. They have other projects, travels, and conferences, among others. Another challenge facing REU programs was the cancellation of many summer REU programs due to the Covid-19 pandemic. Therefore, some REU programs have migrated to virtual mode so that students can still have the research experience in the summer programs or during the academic year (CDCM, 2020, NCAR, 2020, PARADIM, 2020).

2.3 Alternatively Delivered REU Overview (Offered in Response to COVID-19 Pandemic)

Remote REU programs have emerged as a suitable alternative for students to benefit from the opportunity to conduct research during the COVID-19 pandemic (Lichtenwalner et al., 2021). While some institutions decided to carry out the REU virtually over the 10-week summer session, others opted to skip a summer and request a one-year no-cost extension (Nyarko et al., 2022, Zhang, 2022). In this way, numerous REU programs decided to migrate to virtual due to the covid-19 pandemic (Lawanto et al., 2022, CDCM, 2020, NCAR, 2020).

Virtual REU brings multiple benefits, such as having wide participation of students (Chin, 2020). As well as, students can be easily replaced in case someone backs out. Due to Covid-19, many student internships were canceled, for this reason, providing a distance REU program provides alternatives and new opportunities for students (DelVescovo et al., 2022). A virtual program allows students to connect with others and build a more extensive network (Nyarko et al., 2022). Another benefit of moving to a virtual format, studies have discovered, is the availability of live-streamed webinars, technical presentations, and conferences in which students could participate (DelVescovo et al., 2022).

The remote REU presented a unique set of challenges in addition to the usual logistical challenges associated with hosting an REU. For example, creating a meaningful experience for the students (Ross et al., 2021). REU virtual presents some challenges related to computer fatigue, commitment, and participation, which increases the probability that students will drop out of the program (Ross et al., 2021). Additionally, many students are focused on graduating, applying to grad school, or looking for a job, which makes participation even more limited. Another challenge that arises is working with other students or mentors who are in different time zones (DelVescovo et al., 2022). This issue makes it more difficult to manage schedules (Nyarko et al., 2022). One of the most significant issues reported by one of the virtual programs was access to commercial software, software licensing, or access to laboratories (DelVescovo et al., 2022). At the same time, tasks such as teaching coding are much easier in person, since the teacher can walk around the room to help students who are stuck, or support groups can be created in the classroom (Lichtenwalner et al., 2021). Additionally, remote programs can lead to frustration for students in solving problems that may have been quickly resolved face-to-face (Nyarko et al., 2022). This also means more work for advisors. Finally, virtual programs create

more distractions for students and require more extraordinary project management skills, especially for 10-month virtual programs.

3. Methods

3.1 Study Design

The study was based on an REU program at a Midwestern University. Program Participants are undergraduate students from various engineering majors across the United States focusing on minorities serving institutions. The experience provided in the program combines the best aspects of applied academic research, such as a robust theoretical foundation and rigorous scholarship, with essential business practices, such as real-world customer discovery and the generation of solid business plans.

Year 1 REU (virtual + part-time + 10 months): The intervention begins with an intensive week at the beginning of the onboarding (first semester) and mid-way (second semester) of the program (to promote a sense of belonging, promote accountability, promote team development, and get an overview of research. Then, small mentoring groups are formed with five advisors, in which each advisor works with three students. Students participated in the program for two semesters, completing weekly critical thinking exercises to learn about the advisor's lab, research practices, and entrepreneurial competencies. In addition, students received weekly emails informing students of professional development activities. These activities were complemented by the continuous development of the individual development plan. Part of the students' main activities was to do applied research in energy on specific projects assigned by the advisors.

Year 2 REU (in-person + full-time + 10 weeks): The intervention begins with a virtual intensive week at the beginning of the onboarding of the program to promote a sense of belonging, promote accountability, promote team development, and get an overview of research. For the following nine weeks, small tutoring groups were formed with five advisors, in which each advisor worked with two students. The students had to divide their work hours between a common laboratory with the rest of the cohort and work in their advisor's laboratory (where they shared with their advisor's research groups). Students were required to complete weekly critical thinking exercises on the advisor's lab, research practices, and entrepreneurial competencies. In addition, students received weekly emails informing them of professional development activities. Part of the main activities of the students was to carry out applied energy research in specific projects assigned by the advisors and customer discovery interviews related to the projects carried out.

3.2 Participants

Program participants are undergraduate engineering students from across the United States. The demographic characteristics of each group of students are presented below:

- Year 1 REU (virtual + part-time + 10 months): A total of 15 students participated in the study, 9 females and 6 males; 11 students from minority-serving institutions (including historically black college or university, tribal college or university, and Hispanic-serving institution); 5 juniors and 10 senior level students; all 4 time zones represented; 11 first-

generation students; all 15 students come from a minoritized population (e.g., Black, Hispanic, American Indian); the 15 students were working with 5 different advisors, 3 students per advisor.

- Year 2 REU (in-person + full-time + 10 weeks): A total of 10 students participated in the study, 6 females and 4 males; 8 students from minority-serving institutions (including historically black college or university and Hispanic-serving institutions); 4 juniors and 6 senior level students; 7 students come from a minoritized population (e.g., Black, Hispanic, American Indian); 10 students were working with 5 different advisors, 2 students per advisor.

3.3 Data Collection

The study considers data collection with a quantitative instrument; a post-then-pre-survey with a Likert scale was used. The retrospective post-then-pre-design was applied, a popular tool for evaluating students' self-reported changes in knowledge, awareness, skills, confidence, attitudes, or behaviors. In traditional pre-post design, students answer questions before and after participating in an educational program. However the retrospective post-then-pre design, information is collected only at the end of the program to attenuate response shift bias(Colosi and Dunifon, 2006).

The survey used a Likert scale, a psychometric scale commonly involved in research. The scale was from 1 to 5, where 1 strongly disagrees, 2 somewhat disagree, 3 neither agree nor disagree, 4 somewhat agree, and 5 strongly agree (Albaum, 1997). Also, a not-applicable (N/A) option was included. The survey section focuses on three main areas: career goals, abilities to conduct research, and entrepreneurial competencies. The survey questions focus on academic research, and career goals were based on two previous studies of REU programs (Gonzalez-Espada and LaDue, 2006, West et al., 2011). The survey section focuses on entrepreneurial competencies and was based on a previously validated survey from another investigation in the area (Štemberger, 2021). Appendix A. shows the details of the survey that was answered by participants.

In Year 1 (Virtual + Part-Time + 10 Months), data was collected midway in December 2021 (end of Fall 2021 semester) and at the end in May 2022 (end of Spring 2022 semester). The purpose of collecting data midway was primarily to implement corrective action if major issues were found. In Year 2 (In-Person + Full-Time + 10 Weeks), due to the shorter duration of the program, data was only collected at the end of the 10-week summer program.

3.4 Data Analysis

Quantitative data was collected from the participants through a retrospective post-then-pre design using the Qualtrics survey software. SPSS statistical software was used to analyze the numerical scale questions and compare and examine the answers before and after participating in the REU program. Numerical variables were created for the Likert scale in the survey used to calculate the average of all the participants in each of the questions.

A paired-sample student t-test analysis was performed for each survey item using an alpha value of 0.05 to test for a statistically significant difference between middle year 1 (first semester), final year 1 (second semester), and final year 2 (summer). The analysis was performed for each item, comparing before and after each survey item (24 items per year).

4. Results (Survey)

4.1 Perceived Learning Gains – Career Goals

The purpose of this section is to showcase findings comparing perceived learning gains specific to the four Career Goal items. Paired sample student's T-test was conducted for each item using a 0.05 alpha value to test for a statistically significant difference between Year 1 Mid, Year 1 Final, and Year 2 Final to assess perceived learning gains (e.g., pre vs post) across each of the Career Goal items. As shown in Table 2, Year 1 Mid, Year 1 Final, and Year 2 Final assessments respectively demonstrated statistically significant perceived learning gains across 4, 1, and 1 items.

Table 2. Student's T-test Comparing Pre- and Post- Career Goals (Statistically Significant p-Values are Highlighted with a Gray Cell)

Data Collection Period	Year 1 Mid (Virtual + Part-Time + 10 Months)	Year 1 Final (Virtual + Part-Time + 10 Months)	Year 2 Final (In-Person + Full-Time + 10 Weeks)
Career Goals: I plan to attend graduate school.	0.013	0.351	0.780
Career Goals: I have a well-defined career plan.	0.002	0.305	0.193
Career Goals: I see myself in the future as a research scientist.	0.031	0.050	0.037
Career Goals: I see myself working in the future in an applied energy field.	0.015	0.142	0.054
Quantity of Statistically Significant Learning Gains	4	1	1

4.2 Perceived Learning Gains – Research Skills

The purpose of this section is to showcase findings comparing perceived learning gains specific to the eleven Research Skill items. Paired sample student's T-test was conducted for each item using a 0.05 alpha value to test for a statistically significant difference between Year 1 Mid, Year 1 Final, and Year 2 Final to assess perceived learning gains (e.g., pre vs post) across each of the Research Skill items. As shown in Table 3, Year 1 Mid, Year 1 Final, and Year 2 Final assessments respectively demonstrated statistically significant perceived learning gains across 7, 9, and 8 items.

Table 3. Student's T-test Comparing Pre- and Post- Abilities to Conduct Research (Statistically Significant p-Values are Highlighted with a Gray Cell)

Data Collection Period	Year 1 Mid (Virtual + Part-Time + 10 Months)	Year 1 Final (Virtual + Part-Time + 10 Months)	Year 2 Final (In-Person + Full-Time + 10 Weeks)
I am confident about my ability to work independently.	0.010	0.049	0.051
I am confident in writing a literature review in an academic article.	0.002	0.005	0.015
I am confident in writing results in an academic article.	0.132	0.033	0.029
I am confident in writing conclusions in an academic article.	0.082	0.005	0.019
I am confident in my data collection skills.	0.008	0.049	0.052
I am confident in my data analysis skills.	0.055	0.104	0.032
I am confident in my skill to develop the methods section in an academic article.	0.005	0.019	0.017
I am confident about my ability to understand all the sections in a scientific article.	0.002	0.019	0.029
I am confident in making oral presentations at conferences.	0.011	0.020	0.008
I am confident in managing my time properly.	0.012	0.285	0.132
I am comfortable working in a research team.	0.271	0.012	0.032
Quantity of Statistically Significant Learning Gains	7	9	8

4.3 Perceived Learning Gains – Entrepreneurial Competencies

The purpose of this section is to showcase findings comparing perceived learning gains specific to the nine Entrepreneurial Competency items. Paired sample student's T-test was conducted for each item using a 0.05 alpha value to test for a statistically significant difference between Year 1 Mid, Year 1 Final, and Year 2 Final to assess perceived learning gains (e.g., pre vs post) across each of the Entrepreneurial Competency items. As shown in Table 4, Year 1 Mid, Year 1 Final, and Year 2 Final assessments respectively demonstrated statistically significant perceived learning gains across 6, 3, and 2 items.

Table 4. Student's T-test Comparing Pre- and Post- Entrepreneurial Competencies (Statistically Significant p-Values are Highlighted with a Gray Cell)

Data Collection Period	Year 1 Mid (Virtual + Part-Time + 10 Months)	Year 1 Final (Virtual + Part-Time + 10 Months)	Year 2 Final (In-Person + Full-Time + 10 Weeks)
I strive to develop ideas.	0.004	0.048	0.022
I strive to develop creativity.	0.038	0.104	0.052
I strive to realize my short-, medium- and long-term goals.	0.005	0.026	0.111
I plan the necessary resources to realize my goals.	0.026	0.104	0.138
I work in accordance with ethics.	0.167	0.197	0.168
I work in accordance with sustainability.	0.011	0.104	0.168
I strive to develop empathy.	0.038	0.104	0.343
I take the initiative.	0.096	0.049	0.096
I make decisions fast and flexibly.	0.111	0.104	0.037
Quantity of Statistically Significant Learning Gains	6	3	2

4.4 Summary

In total (Table 5), across all three categories, Year 1 Mid, Year 1 Final, and Year 2 Final assessments respectively demonstrated statistically significant learning gains across 17, 13, and 11 items. As such, the highest quantity of perceived learning gains occurred for the Year 1 Mid group (e.g., one semester, virtual, 10 hrs per week); the least quantity of perceived learning gains occurred for the Year 2 Final (e.g., traditional approach to REU – summer, full-time, in-person).

Table 5. Total Quantity of Statistically Significant Perceived Learning Gains by Group

Data Collection Period	Year 1 Mid (Virtual + Part-Time + 10 Months)	Year 1 Final (Virtual + Part-Time + 10 Months)	Year 2 Final (In-Person + Full-Time + 10 Weeks)
Total Statistically Significant Perceived Learning Gains	17	13	11

5. Discussion

This study sought to compare perceived learning gains in a traditional REU program versus an alternatively delivered REU program. The REU evaluated in this study focused on entrepreneurship and applied energy, where participants experienced a graduate school-like

experience while simultaneously obtaining entrepreneurship training through customer discovery interviews, market analysis, and market research. At the same time, the students conducted laboratory research in the field of applied energy. Three categories of learning achievement were assessed: entrepreneurial competencies, career goals, and research skills development. T-tests were used to evaluate the difference in means between before and after. As a result of the study, the findings show that the one-semester virtual REU and the two-semester virtual REU had higher learning gains than the 10-week face-to-face summer REU.

These higher performance gains can potentially be attributed to five main factors. First, the participants worked directly with the advisors during the virtual program. Compared to the in-person program, participants mostly worked independently or with graduate students. Second, the virtual program had limited laboratory time on the part of the participants. As a result, students completed more research-oriented tasks (beyond data collection within the lab environment). In contrast, in the face-to-face summer program, students focused more on data collection in the laboratory than on conducting research through literature reviews and article writing. Third, the virtual program allowed for more touchpoints with the advisors. In the virtual program, the participants met with the advisor weekly, about 16 times per semester, that is, 32 times during the entire program. In this way, the students spent more quality time with the advisor. Unlike the virtual program, in the in-person program, participants typically met with the counselor once a week, about 10 times total throughout the program. Fourth, the one-semester (4-month) and two-semester (10-month) virtual REU allowed students more time to synthesize information compared to the 10-week in-person program. Fifth, the part-time aspect of one semester (4 months) and two semesters (10 months) allowed participants to consume small chunks of information each week instead of large chunks during the full-time summer session.

REU's remote programs emerged as a suitable alternative for students to benefit from the opportunity to conduct research during the COVID-19 pandemic (NCAR, 2020). Similar to this study, other research has discovered that online or hybrid REU programs may be a good alternative for non-traditional or minority students who might not have the opportunity to engage in research (Lichtenwalner et al., 2021). Likewise, the study by Collins et al. (Collins et al., 2022) concludes that widely accessible online REU experiences are a great alternative for the future of REU programs. Additionally, this study has similarities with other studies in the literature. Lawanto and colleagues (Lawanto et al., 2022) stated that virtual REU programs in Engineering Education Research have a significant impact on increasing participants' research and communication skills. According to the findings of this study, the virtual REU has higher learning gains than the in-person REU. In contrast, DelVescovo et al. (DelVescovo et al., 2022) propose that virtual REU programs are not an optimal solution, at least not for programs that focus on hands-on experiences.

6. Conclusion

As the main takeaway from the study, the one-semester virtual REU showed the most significant learning gains. In this way, NSF should be intent on testing new approaches to REU delivery (including length and format) to see what best suits specific audiences.

However, this study has limitations. First, the study considers only one university and only one REU program. Second, the study only considers one topic area. More personalized assistance or in-person laboratory work may be essential in other topic areas. Third, only one online and in-person delivery was assessed. Considering a bigger sample size with more replications would impact the statistically significant of the results. Fourth, the study only evaluates two small groups of participants; however, the statistically significant findings are optimistic especially due to the small sizes. Fifth, there may be room for improvement in the survey elements, for example, language and area of focus. Finally, the REU program targeted minority populations, i.e., African Americans, Hispanics/Latinos, and American Indians. Perhaps other demographic data would result in different findings. Sixth, the survey assessed perceived learning gains; although this is important as it reflects motivation and intent, perceived learning doesn't always equate to actual learning.

In conclusion, it is recommended that NSF try to test new approaches for REU delivery, including different durations and formats. Future research should test these different approaches at different universities through different REU programs within different topic areas. In addition, different elements in the survey should be considered according to the topic areas of each REU program.

Appendix A. Qualtrics Survey

Career Goals
To what extent do you agree with the following statement?

	Before participating in the program						Current participating in the program					
	Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	**Strongly disagree**	N/A	**Strongly agree**	Somewhat agree	Neither agree nor disagree	Somewhat disagree	**Strongly disagree**	N/A
I plan to attend graduate school.	○	○	○	○	○	○	○	○	○	○	○	○
I have a well-defined career plan.	○	○	○	○	○	○	○	○	○	○	○	○
I see myself in the future as a research scientist.	○	○	○	○	○	○	○	○	○	○	○	○
I see myself working in the future in an applied energy field.	○	○	○	○	○	○	○	○	○	○	○	○

Figure 2 Survey Questions – Career Goals

Abilities to Conduct Research

To what extent do you agree with the following statement?

	Before participating in the program						Current participating in the program					
	Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	**Strongly disagree**	N/A	**Strongly agree**	Somewhat agree	Neither agree nor disagree	Somewhat disagree	**Strongly disagree**	N/A
I am confident about my ability to work independently.	○	○	○	○	○	○	○	○	○	○	○	○
I am confident in writing a literature review in an academic article.	○	○	○	○	○	○	○	○	○	○	○	○
I am confident in writing results in an academic article.	○	○	○	○	○	○	○	○	○	○	○	○
I am confident in writing conclusions in an academic article.	○	○	○	○	○	○	○	○	○	○	○	○
I am confident in my data collection skills.	○	○	○	○	○	○	○	○	○	○	○	○
I am confident in my data analysis skills.	○	○	○	○	○	○	○	○	○	○	○	○
I am confident in my skill to develop the methods section in an academic article.	○	○	○	○	○	○	○	○	○	○	○	○
I am confident about my ability to understand all the sections in a scientific article.	○	○	○	○	○	○	○	○	○	○	○	○
I am confident in making oral presentations at conferences.	○	○	○	○	○	○	○	○	○	○	○	○
I am confident in managing my time properly.	○	○	○	○	○	○	○	○	○	○	○	○
I am comfortable working in a research team.	○	○	○	○	○	○	○	○	○	○	○	○

Figure 3 Survey Questions – Research Skills

Entrepreneurial Competencies
To what extent do you agree with the following statement?

	Before participating in the program						Current participating in the program					
	Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	**Strongly disagree**	N/A	**Strongly agree**	Somewhat agree	Neither agree nor disagree	Somewhat disagree	**Strongly disagree**	N/A
I strive to develop ideas.	○	○	○	○	○	○	○	○	○	○	○	○
I strive to develop creativity.	○	○	○	○	○	○	○	○	○	○	○	○
I strive to realize my short-, medium- and long-term goals.	○	○	○	○	○	○	○	○	○	○	○	○
I plan the necessary resources to realize my goals.	○	○	○	○	○	○	○	○	○	○	○	○
I work in accordance with ethics.	○	○	○	○	○	○	○	○	○	○	○	○
I work in accordance with sustainability.	○	○	○	○	○	○	○	○	○	○	○	○
I strive to develop empathy.	○	○	○	○	○	○	○	○	○	○	○	○
I take the initiative.	○	○	○	○	○	○	○	○	○	○	○	○
I make decisions fast and flexibly.	○	○	○	○	○	○	○	○	○	○	○	○

Figure 4 Survey Questions – Entrepreneurial Competencies

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