

Board 301: Growing Entrepreneurially Minded Researchers with New Product Development in Applied Energy: NSF REU Comparison of Traditional Delivery vs. Virtual

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1. Introduction

Research experiences for undergraduates (REU) programs are traditionally delivered in-person, on-site, during the summer, and full-time (40 hrs. per week) for 10 weeks. However, this type of format may 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. The REU program context was entrepreneurial development and applied energy research where participants were introduced to a graduate school like experience by simultaneously gaining entrepreneurial training via customer discovery interviews, market analysis, and patent research, and at the same time conducting lab research within the energy field. As such, three learning gains categories were assessed: entrepreneurial competencies, career goals, and research skill development.

The guiding research question is as follows: *How do perceived learning gains (as it relates to entrepreneurial competencies, career goals, and research skill development) compare across a traditional REU (in-person, 10 weeks over summer, full-time) versus an REU delivered virtually, part-time, and over 10 months?*

2. Methods

2.1 Study Design and Participants

The study was based on an REU program at a Midwestern University. Program Participants were undergraduate students from various engineering majors across the United States (with a preference for students enrolled at minorities serving institutions). 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 institution); 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.

2.2 Data Collection and Analysis

Quantitative data was collected (using Qualtrics) through a retrospective post-then-pre survey design with respect to Career Goals (Figure 1), Entrepreneurial Competencies (Figure 2), and Research Skill Development (Figure 3). SPSS software was used to conduct paired-sample student t-tests for each survey item using an alpha value of 0.05 to test for a statistically significant difference between Year 1 (1st semester), Year 1(2nd semester), and Year 2 (end of summer).

| 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. | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | |
| I have a well-defined career plan. | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | |
| I see myself in the future as a research scientist. | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | |
| I see myself working in the future in an applied energy field. | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | |

Figure 1 Questions focused on career goals

| 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. | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | |
| I strive to develop creativity. | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | |
| I strive to realize my short-, medium- and long-term goals. | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | |
| I plan the necessary resources to realize my goals. | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | |
| I work in accordance with ethics. | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | |
| I work in accordance with sustainability. | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | |
| I strive to develop empathy. | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | |
| I take the initiative. | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | |
| I make decisions fast and flexibly. | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | |

Figure 2 Questions focused on entrepreneurial competencies

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. | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| I am confident in writing a literature review in an academic article. | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| I am confident in writing results in an academic article. | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| I am confident in writing conclusions in an academic article. | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| I am confident in my data collection skills. | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| I am confident in my data analysis skills. | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| I am confident in my skill to develop the methods section in an academic article. | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| I am confident about my ability to understand all the sections in a scientific article. | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| I am confident in making oral presentations at conferences. | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| I am confident in managing my time properly. | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| I am comfortable working in a research team. | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

Figure 3 Questions focused on the abilities to conduct research

3. Results

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.

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 24 items shown according to category.

With the paired t test, the null hypothesis is that the pairwise difference between the two samples is equal ($H_0: \mu_d = 0$). The goal is to assess if there is a statistically significant difference between

the pre (before participating) and post (after participating), implying a learning gain within that specific item.

In total (Table 1), 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.

Table 1. Total Quantity of Statistically Significant Perceived Learning Gains for Year 1 (Mid + Final) and Year 2

| 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 | 4 | 1 | 1 |
| Entrepreneurial Competencies | 6 | 3 | 2 |
| Research Skill Development | 7 | 9 | 8 |
| Total Statistically Significant Perceived Learning Gains (Pre vs. Post) | 17 | 13 | 11 |

4. Discussion and Conclusion

One-semester virtual REU and two-semester virtual REU had higher perceived learning gains than the 10-week summer in-person REU. These higher 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.

In conclusion, the one-semester virtual part-time REU showed the most significant perceived learning gains. As such, NSF should consider being more intentional on testing new approaches to REU delivery (including length and format) to see what best suits specific audiences. Offering different delivery mechanisms can be used in an effort to broaden participation in engineering and engineering research experiences.