Examining the Evolution of Research Self-efficacy in Undergraduate Students in the Natural Hazards Engineering

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The Natural Hazards Engineering Research Infrastructure (NHERI) - Research Experiences for Undergraduates (REU) Summer Program, funded by the National Science Foundation (NSF), provides research experiences for a diverse group of college students interested in mitigating the effects of natural hazards. The program engages in targeted recruitment for underrepresented students in engineering including women, first-generation college students, students who may not have research opportunities at their home universities, and members of racial and ethnic minority groups. The program structure and activities are designed to prepare undergraduates for research work with the ultimate goal of retaining students in science, technology, engineering, and math fields as well as preparing them for graduate school. This paper demonstrates an effective hybrid-model (virtual and in-person) research program for undergraduate students across a distributed network with eleven (11) participating research sites across the continental U.S. Through a longitudinal case study, data will be presented as evidence of 100% retention of the NHERI REU alumni in the engineering and STEM fields; enrollment in engineering PhD programs; and diversity measures for participation by gender, first-generation college student status, and race and ethnicity. The NHERI-REU Program also collects qualitative and quantitative data on the progress of students' preparation of scholarly work including their self-efficacy and confidence levels throughout the program. This paper will include the qualitative data to show students' increased confidence and levels of self-efficacy as they participated in a ten-week research experiences program. Thematically coded, student quotes will also show the various stages and degrees of experience and confidence in research that students bring to the program and how these converge to demonstrate high levels of success in scholarly products as well as increased confidence levels in research.

Introduction

The Natural Hazards Engineering Research Infrastructure (NHERI) – Network Coordination Office (NCO) is a National Science Foundation funded collaborative grant that aims to coordinate research and outreach activities for the multi-disciplinary natural hazards engineering research. As part of the NHERI-NCO, the Education and Community Outreach initiatives include opportunities for undergraduate students to conduct research to mitigate the effects of natural hazards. The Research Experiences for Undergraduates (REU) has been well-researched as a best practice for preparing college students for graduate studies (Willis, Krueger, & Kendrick, 2013), especially underrepresented students in engineering (Labrador & Perez, 2006). Curriculum was developed specifically for the NHERI REU program to introduce students to research work through rhetorical analysis of scholarly work. These first-time undergraduate researchers are recruited from various universities and bring with them diverse experiences based on their backgrounds. The REU program is designed to prepare students for graduate studies by immersing participants in a authentic research conducted within a tier one research facility alongside graduate students, postdoctoral fellows, research staff, and faculty. The program also provides career development workshops on applying to graduate school,

writing personal statements, developing a professional network, working in academia and industry as well as creating graduate level research products (i.e., posters, presentations, and papers).

The Natural Hazards Engineering Research Infrastructure (NHERI) – Research Experiences for Undergraduates (REU) Summer Program

The ten-week, residential NHERI-REU Summer Program is funded through the National Science Foundation (NSF) and takes place during the summer at eleven NHERI research sites across the United States. The sites conduct natural hazards interdisciplinary and multi-disciplinary research in coastal engineering, earthquake engineering, wind engineering, reconnaissance, computational simulation and modeling, and social science research. Each site hosts up to three (3) REU student researchers per summer, recruited primarily from minority serving institutions and non-Research Tier One institutions. The program aims to provide opportunities to undergraduates from marginalized groups in engineering and to undergraduates who may not have the resources during the academic year to participate in research at their institutions. Students are selected using holistic measures by each of the sites. The curriculum for the summer program aims to foster self-efficacy in research through (1) participation in authentic research work, (2) faculty and experienced graduate student researcher mentoring, and (3) community building across the natural hazards engineering and research communities.

Students meet weekly through virtual means to discuss their research progress, address any challenges, and discuss the rhetoric of scholarly publications and other activities. REU students also participate in career development workshops to prepare for a career in the natural hazards engineering and research community.

Students also attend their respective labs and research spaces in person and work with faculty and staff at their assigned site to conduct authentic research work. They are assigned an experienced faculty mentor and other mentors who can help them whenever they need additional guidance during their research projects. The structure of the mentoring is inclusive and provides mentorship as student needs help. Before beginning research, students and mentors collaboratively complete a mentoring form outlining the goals of the project, the milestones for the summer, resources available, communication preferences, and other elements aimed to provide inclusive mentoring of the diverse individuals.

Throughout the summer, students complete weekly guided reflections, and before and after the program, complete a pre- and post-assessment.

Methodology

This research study used mixed methods to collect data throughout the NHERI REU Summer Program for a five (5) year period, which included five different cohorts of student researchers. The data collection is designed to follow a case study that is bound by time as students participate in the program together, attend the same events virtually, and provide the same weekly deliverables. Although students have different experiences and perceptions based on

individual interactions at each of their sites, they are immersed as part of the community of undergraduate researchers for the NHERI network.

For this analysis, data from the weekly reflections of students in the REU program were used to analyze how students qualitatively perceived their research self-efficacy. The students received weekly prompts to reflect on their successes and challenges, and these reflections were collected and combined. Additionally, these questions were tailored to draw on students' development of their engineering identities, growth mindsets, and self-efficacy. The data for this study were selected as the final weeks of the program to reflect on their final research self-efficacy perceptions, and analyzed by filtering using the research self-efficacy theoretical framework and categorized by themes.

Theoretical Framework

Self-Efficacy. To analyze the data, a self-efficacy theoretical framework was used. Self-efficacy, in this context, is an undergraduate student researcher's confidence and perception that their actions affect an outcome and that they are capable of reaching the goals they set (Bandura, 1977, 1982, 1986). In this case study, educational objectives were designed in an attempt to foster self-efficacy in research that could point students towards continuing to participate in research and continuing on to graduate studies where research could become the center of their studies. Particularly, we were also interested and finding out if students were also drawn to continue their careers in natural hazards engineering research fields.

The following are assumptions made from Bandura's social cognitive theory (Bandura 1989):

- People have the capacity to create internal beliefs and models, plans for action, and testing complex ideas;
- Behavior is goal-oriented and seeks to accomplish a task;
- People are self-reflective and able to analyze their experiences and thoughts;
- People can control their own behavior and actions;
- People learn by observing others; and
- The environmental events, personal factors, and behaviors interact together.

People's beliefs about their abilities are primarily informed by the following:

- **Performance experience** – a task can be accomplished because it was successfully achieved previously,
- **Vicarious experience** –the task can be accomplished because someone else modeled the task successfully,
- **Social persuasion** – verbal encouragement or discouragement,
- **Imaginal experience** – person's use of their imagination to envision their success, and
- **Physical and emotional states** – perceptions of physical and emotional experiences when facing a challenge (Bandura, 1977, 1986; Maddux, 1995).

Self-efficacy beliefs influence student behavior through (1) goal-setting; (2) affect; (3) cognition; and (4) selection of environments and activities (Bandura, 1986, 1989; Maddux, 1995).

Results

Students who participated in the REU program demonstrated strong self-efficacy in their reflections towards the end of the program. These beliefs in their abilities were informed by the self-efficacy theoretical framework. In the following results, 1-2 quotes were selected to represent how students discussed their self-efficacy in each of theme.

Performance Experience. Students' beliefs in their abilities were informed by successful completion of the tasks during the REU program. Students worked on an authentic research project with experienced researchers. They participated in the peer-review process and submitted their manuscripts for peer review of their research projects. Every student presented their research in a symposium with their peers, mentors, and other guests. The following quote from a weekly reflection represents the student's performance experiences and how they helped gain research self-efficacy.

> Going to the symposium and presenting what I worked on in front of my peers really helped grow this skill [confidence in my presentation abilities].

Performance experience was the most discussed theme throughout the students' reflections. Being able to present their research in various ways helped them gain confidence in their work. Additionally, the students discussed how they could continue this performance experience at their home universities or in subsequent summer research experiences.

Vicarious experience. Students also participated in research activities supported by mentors. Faculty mentors and postdoctoral/graduate student mentors helped facilitate students' entry into research activities, modeling the behavior, work-ethic, and task completion. One student had the following to say about their observations working with others who contributed to positive research self-efficacy.

> I was surrounded by so many great people throughout this experience, and pretty much all of them were more experienced/knowledgeable in coastal engineering than I was.

Being surrounded by experts in their field and observing how research was conducted helped students gain research self-efficacy. However, this theme was not as salient as the theme of performance experience, as expected.

Physical and emotional states. Students also discussed their perceptions about the physical and emotional states needed in engineering research to overcome challenges. The following quotations are examples of student responses that point to the physical and emotional states necessary to be successful in engineering research.

> Attention to detail and perseverance are essential skills to succeed as an engineer.

> It is ok to ask questions constantly. It's also ok to ask the same questions repeatedly until you understand. It's always better to keep asking than to settle for misunderstanding.

These physical and emotional states were important to note because many engineering programs do not focus on intentional reflection about these experiences that foster research self-efficacy.

Additionally, students increased self-efficacy beliefs that may impact their future behaviors, based on self-efficacy and social cognitive theory. The following are examples of these behaviors:

Goal-setting. Students set goals for branching out and trying other opportunities after the NHERI-REU program. For example, this student clearly articulated their next "challenge":

> My next challenge is to apply for an internship in the aerospace field.

Many students also discussed plans to apply to and attend graduate school. Most students knew what areas they wanted to apply to, and some students had goals of working with specific individuals in their field of interest.

> There is so much value to going to graduate school, so I want to get my master's degree at some point, and doing this program helped me decide that.
>
> I have a clearer decision about my future career goals…My short-term goal for this year is to apply for graduate school and being admitted in a structural engineering program.
>
> Going to graduate school is absolutely an obtainable goal for me.
>
> The NHERI REU experience has cemented my interest in applying to a master's program in coastal engineering. I am so excited to begin this process, and to find a program that fits my interests.

Some students also pointed to the impact they wanted to make with engineering research. These goals aimed at higher levels of impact and a life-long career.

> [R]esearch and developing real world solutions for major problems is the path I would like to take for my career.

Although goals like these were less frequently stated in the reflections, students did discuss during interviews their goals to have a greater impact in society's most pressing problems. Being able to see the impact they can have in natural hazards engineering is a positive behavior for their self-efficacy.

Affect. Affect was shown through the connections that students made with people in the NHERI network. In particular, students made connections with their peers and mentors, and although we cannot specifically mention names, these individuals fostered a genuine impact in their affect toward continuing work in the natural hazards' disciplines. For example, the following student reflection shows how the stronger ties developed to expand the student's engineering support network.

> I was able to successfully expand my engineering network. I got closer with the faculty and student mentors at my school…I was able to form solid relationships with my peers at the symposium.

During a large focus group at the end of the program, students also mentioned the positive impact their mentors had on their experiences during the summer. They discuss how, at the

beginning of the program, they felt intimidated to ask mentors questions, and by the end of the program, the students felt a part of the research network and connected to the people who worked closely with them.

Cognition. As designed, the NHERI-REU summer program aimed to increase students' knowledge about engineering research. Many students pointed to specific topics they learned as well as skills necessary for engineering research work. The following quotes from student reflections showcase some of these.

> I learned a lot about this topic [seismic design] over the course of the summer.
>
> I feel well-prepared…I learned important investigative skills this summer through the REU program.
>
> In engineering research, not only is it important to find out what does work, it can also be just as important to find out what doesn't work, so even if your research is not going the way that you anticipated it would, it is still valuable.
>
> The research process is not as organized and structured as it's made out to be…It's never going to go exactly as [it's] planned to.

Additionally, students also gained knowledge about disciplines outside of their college majors and how they can be applied to multiple settings.

> I thoroughly gained some knowledge about some other disciplines, especially how you use equipment to collect data when natural disasters occur.

Because the program is structured as a distributed network across sites, students were also introduced to the work at other sites. This gave them an opportunity to see how their work connected to other natural hazards engineering research and how expansive the effort could be.

Selection of environments and activities. As can be seen in the quotes, NHERI-REU students reflected on specific activities, disciplines, areas of study, research projects, and even universities they would like to apply. One student felt confidence in the support that they could receive through the connections made during the summer program.

> [T]here are a handful of people that would be willing to have me study under their guidance [for graduate studies].

These research self-efficacy beliefs may lead to behaviors that steer NHERI-REU alumni towards attending graduate school, continuing research, and pursuing work in natural hazards engineering disciplines.

Discussion

This case study shows the many levels of self-efficacy fostered within a summer research program aimed to intentionally increase these skills. It is important to note that written reflections about the students' experiences are not part of all summer research programs. However, reflections facilitate students' abilities to foster their research self-efficacy. In fact, this

is part of social cognitive theory—people are able to be self-reflective and analyze their experiences and thoughts.

Also, many undergraduate engineering research programs focus only on increasing the content knowledge and awareness along with networking skills. This case study shows the highlights that undergraduates acknowledged with affective beliefs and physical and emotional states that lead towards research self-efficacy. Within engineering fields, there are certain emotional states needed to successfully overcome challenges but such emotions are under studied (i.e., Lönngren *et al*., 2020). The NHERI-REU student researchers pointed to some of those states and experiencing them led students to be able to see themselves as successfully navigating natural hazards engineering research in their future careers.

Conclusion

As expected, the design of the NHERI-REU program increased the student self-efficacy (Nelson, Vielma, & Browning, 2023). However, upon taking a deeper look into the reflections of students, we hear from the students about their perceptions of their increased self-efficacy. Students find elements of their experience important to highlight in their reflections including the connections made that increased their affect to engineering research as well as the emotional states needed to be successful in the NHERI-REU program. This leads to a need to prepare faculty and graduate student mentors to promote emotional development within first-time researchers as well as understand the stages and components necessary to successfully foster students' growth in these areas. There is a difference between the instructional mentoring and social emotional mentoring necessary to develop success in engineering research (Ann Mabrouk & Gapud Remijan, 2023). Among engineering programs, there is a need to incorporate these components into curricula. The hope for these results is that they contribute to the need to expand engineering educators' tools for supporting the positive development of holistic researchers.

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