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An ethnographic case study of undergraduate researchers in natural hazards engineering

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Engineering education utilizes various methods to broaden participation in engineering disciplines. Quantitative studies show the demographics and contributing factors of successful engineering researchers within educational pathways. However, there is a need to report on the rich experiences of students who participate in programs designed to prepare undergraduate students to remain and succeed in engineering fields. The paper explores the process and impact of the National Science Foundation (NSF) funded Natural Hazards Engineering Research Infrastructure (NHERI) Research Experience for Undergraduates (REU) using qualitative measures. A humanizing model of the undergraduate researchers as holders of knowledge framed their 10 week research program and associated research opportunities, faculty mentoring, and incorporation into the community of the natural hazards field. The focus of this case study highlighted autoethnographic reflections of REU participants who continued as researchers at various academic institutions or in industry. Led by the students as co-authors, light is shed on their 1) individual professional and personal developments during the process, 2) relationships with peers and mentors, and 3) the career impacts following the experience. This collection of guided reflective responses provide insight into the experiences, merits, and challenges of the undergraduate researchers' (now graduate students) summer experience.

KEYWORDS

REU, NHERI, undergraduate research, engineering education, Social Cognitive Career Theory

1 Introduction

In 2021, twenty-eight (28) students participated in a Research Experience for Undergraduates (REU) Program at various United States universities, all connected by a common thread: National Science Foundation (NSF) funded facilities and leading natural hazard engineering researchers. The Natural Hazards Research Infrastructure (NHERI) is a collaborative network that joins these universities, pushing the boundaries of

different, interdisciplinary fields concerning hazards: earthquakes, windstorms, tsunamis, and more (e.g., water hazards, wildfires, extreme heat). Initiatives like the NSF NHERI REU Program facilitate the active participation of undergraduates in meaningful and engaging research by building on the student's formal education and connecting them with supportive mentors and peers (Sutterer et al., 2005). The outcomes of REU programs are students who have garnered skills in their respective fields (Sutterer et al., 2005) through the completion of projects of which students feel a commitment towards and sense of ownership, whether the idea was student or mentor-generated (Halstead, 1997). REU programs hereby contribute to the increased number of students who are interested in, apply to, and succeed within science, technology, engineering and mathematics (STEM) programs and careers (Petrella and Jung, 2008; Economy et al., 2013). Many quantitative studies show the demographics and contributing factors of successful engineering researchers within the educational pipeline. However, there is a need to report on the rich experiences of students who participate in intentional programs designed to prepare undergraduates to remain and succeed in engineering. This paper aims to investigate the formation process and career and personal impacts of the NSF-funded NHERI REU program by exploring a collection of guided autoethnographic reflections of REU participants. These provide insights into the experiences, merits, and challenges from the student participants, capturing qualitative data on the NHERI REU impact. Each of the participants shares their individual backgrounds that led to their application and participation in the REU experience and subsequently provide perspectives on their 1) individual professional and personal developments during the process, 2) personal and professional relationships fostered with peers and mentors, and 3) the impacts on their careers following the experience. Altogether, this work seeks to highlight the longitudinal potentialities created by participating in a NHERI REU Program, the advancements of scientific knowledge, and creation of effective researchers and engineers.

1.1 REU program

The Council on Undergraduate Research, CUR, defines undergraduate research as "a mentored investigation or creative inquiry conducted by undergraduates that seeks to make a scholarly or artistic contribution to knowledge" (CUR, 2025). Research provides an opportunity for students to engage with the application of scientific methods and expand the limits of knowledge on our world and its function (Halstead, 1997). Undergraduate research initiatives are mutually beneficial for all involved parties: the institutions, faculty mentors, students, and, because of their research, society as a whole (Petrella and Jung, 2008; Adebisi, 2022).

The benefits of undergraduate research extend beyond the academic environment (Adebisi, 2022), from the development of resilience in facing challenges, reinforcing the value of creating and advancing original and evidence-based knowledge to the increase in confidence and self-efficacy in research that results from tackling each of these (Petrella and Jung, 2008; Adebisi, 2022; Bandura, 1977; Vielma et al., 2024; Nelson, Vielma and Browning, 2023). The "products" of REU programs are the students (Sutterer et al., 2005) who then work in careers in industry or conduct research that is often influenced to some degree by their experiences. Students can be discouraged by negative experiences just as much as they can be encouraged by positive experiences. For this reason, it is vital to design programs that focus on providing the best possible experiences for students. By enabling and supporting underrepresented groups, the NHERI REU can and has supported diverse cohorts of students in an opportunity that largely impacts the students' scientific identity and assists in realizing their goals (Economy et al., 2013). Using Social Cognitive Career Theory (Lent et al., 1994), this paper examines the ways in which the NSF NHERI REU experience, combined with other important factors, impacted three students' career pathways.

1.2 NSF NHERI REU

The NSF NHERI REU program is a hybrid 10 week program that is hosted by the various NSF NHERI sites and the NHERI Education and Community Outreach (ECO). Each program participant works 40 h weeks composed of "graduate school and professional development workshops, research group meetings, networking, mentor evaluations, timesheets, reflections, research, and research writing," (NSF NHERI DesignSafe, 2025).

Funding for undergraduate research comes primarily from the National Science Foundations and is supplemented by various institutions, agencies, or other sources. The Natural Hazards Engineering Research Infrastructure (NHERI) is a network of NSF-funded facilities and researchers that focuses on investigating earthquakes, windstorms, tsunamis, and other hazards (e.g., water hazards, wildfires, extreme heat). The 2024 NHERI REU program was composed of experimental facilities within NHERI plus the RAPID Reconnaissance Center, the Simulation Center, the CONVERGE Facility, and Cyberinfrastructure teams. These research sites and the collegiate leaders are shown in Table 1.

Altogether, these multi-hazard and interdisciplinary research sites enable students to form their summer experience to develop a fundamental understanding of and contribution towards the mitigation and impacts of hazards on communities. Each university receives funding for three undergraduate student researchers to participate in the NHERI REU summer Program. The sites work together to distribute selected students to their first or second choice sites.

1.3 NSF NHERI REU demographics

The NSF NHERI REU combines the valuable components of quality undergraduate research with another tenant of the program to encourage individuals in gendered, racial, and ethnic underrepresented groups to persist in engineering fields and to improve the diversity of such career fields (Sutterer et al., 2005). This is done through targeted recruitment efforts at minority serving institutions, MSIs, and holistic selection approaches. The research sites communicate throughout the selection process, selecting students with skills and interests to successfully complete the research projects expected during the summer months.

Demographic data, included in Table 2 above, were collected on the NHERI REU program impact between 2017–2023, with

TABLE 1 National science foundation NHERI research sites and university.

NHERI research site	University
Wall of Wind (WOW)	Florida International University
Real-time Multi-Directional Natural Hazards Simulation Facility (RTMD)	Lehigh University
O. H. Hinsdale Wave Research Laboratory	Oregon State University
NHERI Simulation Center (SimCenter)	University of California, Berkeley
Center for Geotechnical Modeling (CGM)	University of California, Davis
Large High Performance Outdoor Shake Table (LHPOST)	University of California, San Diego
CONVERGE Facility	University of Colorado Boulder
Boundary Layer Wind Tunnel Experimental Facility	University of Florida
Large-Scale Mobile Shakers	University of Texas at Austin
NHERI Cyberinfrastructure and Data Management team	University of Texas at Austin in collaboration with the Texas Advance Computing Center (TACC)
Rapid Response Research Facility (RAPID)	University of Washington

6 cohorts represented, comprising a total of 164 participants. Just under 40% of the participants self-identified as White (n = 65), about 19% as Hispanic (n = 31), and closely represented were Multiracial, Black, and Asian students (n = 23, 21, 21 respectively). The remaining students were American Indian or Alaskan Native, Native Hawaiian or Other Pacific Islander, and None of the above/Wishing not to answer (n = 1 each). Altogether, nearly half of the students (47%) identified as members of underrepresented racial and ethnic groups in STEM. The demographic impact includes 58% of participants who self-identified as non-male, 27% who are first generation 4-year college students, and 37% who are from non-Research Tier One (R1) institutions according to the Carnegie Classification of Institutions of Higher Education (American Council on Education, 2025).

This paper presents a research study centered on student data from a collection of autoethnographic reflections by three former NSF NHERI REU participants who are referenced throughout the paper. First, the backgrounds of the students were explored to identify themes and motivations behind their desire to participate in the NHERI REU program. Then, using the Social Cognitive Career Theory, individual professional and personal experiences during the NSF REU Program were analyzed, followed by 2) relationships with peers and mentors, and 3) the career impacts following the experience. Comparisons were made between the students whose pathways after the REU Program took them to industry and students whose pathways following the REU took them into academic pathways.

2 Autoethnographic case study

The qualitative research was guided by the overarching research question, How do NHERI REU students experience the summer program activities during the formation of their careers? This case study explores how background and identity contributed to learning experiences, interests and career choices. Therefore, a research sub question was also explored: How did the research program experiences, coupled with background and contextual characteristics, contribute to the students' career pathways including interest development and career choices?

2.1 Theoretical frameworks

To engage these research questions, Figure 1 shows the Social Cognitive Career Theory in engineering (SCCT, Lent et al., 1994) that was employed to explore the experiences of students in the NHERI REU program. This theory emphasizes the various components that contribute to career formation. The theory also posits that personal inputs including social identities, along with the students' backgrounds, contribute to the ways in which they experience learning, which in turn impact self-efficacy–the belief that they can achieve their goals (Bandura, 1977), interests, expectations, and career choices. The theory also, importantly, highlights the ways in which contextual influences, in the form of support and barriers, impact students' career decisions. This study used SCCT to better understand the impacts of a program focused on supporting diverse students as they learned to conduct research in an academic setting and aiming to remove barriers for students underrepresented in engineering and research.

The program was also designed to use evidence-based educational supports such as guided practice in the research process, fostering a network of supportive mentors, and cultivating a community of learners and researchers within the natural hazards engineering and research fields. In these ways, the focused support elements also drew from various existing theoretical

10.3389/fbuil.2025.1535761

TABLE 2 Demographic data for participants to the NHERI REU summer program, 2017–2023.

	Demographic category	Number of participants	Percent (%)
Total Participants		164	100.0
	White	64	39.6
	Hispanic	31	18.9
	Multiracial	23	14.0
	Black	21	12.8
	Asian	21	12.8
	Other*	3	1.8
	Underrepresented in STEM**	77	47.0
	Non-male	95	58.0
	First-generation college students	44	27.0
	From non-R1 institutions	61	37.0

*Other includes American Indian or Alaskan Native, Native Hawaiian or Other Pacific Islander, and None of the above/Wish not to answer (n = 1 per category).
**Underrepresented in STEM, includes Hispanic, Black, Multiracial, and Other race categories.
Note: Percentages are rounded to one decimal place.

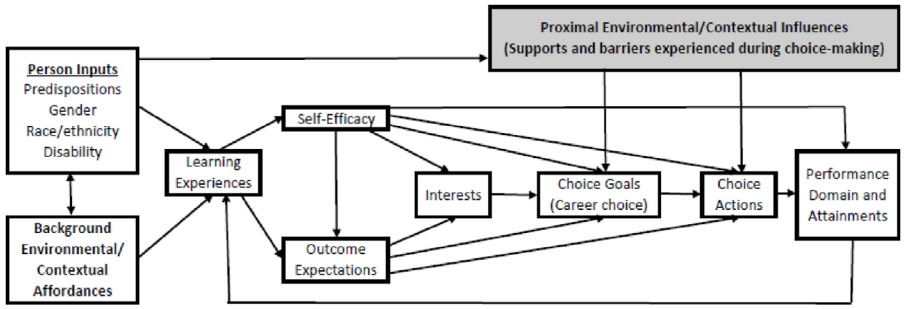

FIGURE 1
Social cognitive career theory (Lent et al., 1994).

frameworks in engineering education aimed at supporting and removing barriers for students in their formation as emerging researchers.

2.2 Methodology

The qualitative research is a case study (Yin, 2018) of volunteer research participants who were part of the 2021 NHERI REU summer Program. All the case study contributors participated during the same summer and were impacted by the systemic effects of the COVID-19 pandemic at the institutions where they conducted research. The case was therefore bounded by context and time as all undergraduate researchers participated during the 10 week research program during the same summer. Although each of the case study participants were part of different research projects at different institutions, they shared common experiences because of the pandemic as well as through organized virtual meetings with their peers and mentors. They also came together for an in-person research symposium with limited attendance at the end of the summer program to present their research and build stronger community bonds.

Because the data centers on the students' perspectives of their experiences in the REU program and their own interpretations and reflections on the impact of the program, this study is also autoethnographic in nature (Adams et al., 2021). The students' written autoethnographies were collected as data and shared from their point of view. These were the main sources of data used, and other artifacts produced during the REU program served as triangulation and validation tools.

TABLE 3 Student author demographic information and undergraduate area of study.

Name	Gender	Race and/or ethnicity	Undergraduate degree/Major	Area of work/Study
Amina	Female	Middle Eastern/Asian	Civil Engineering	Academia – PhD
Daleen	Female	Latina	Mechanical to Civil Engineering	Academia – PhD
Tyler	Male	Latino	Civil Engineering	Industry – MEng

2.3 Participants

The three case study participants volunteered to take part in the research study. They organized the data collection and data analysis strategies and responded to guiding autoethnographic questions. The demographics of the students are listed in Table 3 to share transparency about their unique experiences, intersectionalities, and potential differences in part due to their backgrounds, identities, and degree pathways. We recognize that students may have different experiences based on the theory of Social Cognitive Career Theory that emphasizes that "person inputs" such as social identity, including race and gender, impacts the way individuals navigate education.

All students were undergraduates enrolled in engineering degrees at the time of their participation in the NHERI REU Program. They attended different universities and were part of the same REU cohort. After their REU experience, they navigated different educational pathways. The data were collected at specific times during their careers where their positionality could impact their responses. Data were collected before, after, and during the NHERI REU Program, and reflective, autoethnographic responses were collected when they were far removed from the NHERI REU program. The study participants were in both academia and industry.

2.4 Data and data collection

Each of the authors were prompted to write individually about their REU experiences following a similar structure that focused on the following key points of interest: 1) individual professional and personal developments during the formation process, 2) relationships with peers and mentors, and 3) the career impacts following the REU experience. More broadly the questions used to outline the individual reflections were separated into background (or experiences prior to participating in the REU program), during (capturing experiences during the program), and following the REU experience(s) (post-program career journey). Table 4 details the prompting questions for each of the selected timeframes.

Using Social Cognitive Career Theory, the analyses of these reflections centered around the three key time points of interest with additional consideration of components identified in the literature and the challenges faced in the duration of the research experience. Comparisons can also be noted between the students whose pathways following the REU program took to industry and students whose pathways following the REU continued in academic spaces.

3 Results

Social Cognitive Career Theory points to the various ways in which background and identity can influence learning experiences, which impact self-efficacy and interests (Lent et al., 1994). While analyzing the autoethnographic responses, themes emerged between the students' responses. Concepts such as the influence and value of background motivations for scientific research, or more specifically interests, expressed as passions, for the research focus offered in the NHERI REU Program, reinforced students' short- and long-term career development and goals. Further the performance within the NSF REU Program was largely impacted by academic and formalized structures as well as personal and social relationships. Finally, the outcomes of this experience greatly impacted the career actions pursued by individuals by exposure to concepts and development of skills and expansion of networks within natural hazards engineering research.

3.1 Personal inputs and background

For the three study participants, the motivation to pursue academic studies in STEM related fields in their undergraduate degrees was associated with a measure of exposure to concepts requiring scientific solutions or curiosities explored using scientific structures (i.e., scientific method exploration of everyday observations). Participants cited a curiosity around ways the world functioned that may be solved or optimized through processes and techniques they derived or contributed to. The course work, although challenging, inspired academic achievement and a fascination with engineering frameworks. This was especially true of concentrated topics applied to infrastructure systems that people encountered and interacted with daily. Daleen stated:

> I create my own internal world of whatever the topic is and play with it by mentally "poking" and "prodding" it again and again with questions and what I like to call "thought experiments" until my curiosity is fed. At the end, I gain a better understanding of the subject, not unlike the creation of a narrative, a story that is exciting to share with others.

The challenging nature of solving engineering problems and the potential for their application have been a driving force in the areas of focus pursued by the participants within a wider umbrella of STEM fields. The specific background motivations that may have led the students specifically to the field of hazards engineering research, derived from identifying a direct relationship because of exposure to

10.3389/fbuil.2025.1535761

TABLE 4 Prompting questions for individual author reflection.

Time frame (with respect to REU experience)	Questions
Background	Where were you studying? What were you studying? What were you considering for your post-graduate pathways? How does your personal background impact your career interests? (Why natural hazards? Why NHERI)?
During the Program	Where did you do your REU? Who were your mentors? Who did you work with? What was your research about? How did that work and structure feel? Specifically, what were the challenges? How did you develop personally and/or professionally? What were your relationships like with your peers and mentors?
After the Program	Where are you now? How has your participation in the NHERI REU program impacted your research trajectory/career trajectory/network?

natural hazards in their formative years. These periods of exposure to natural hazards, e.g., Hurricane Katrina (2005), Hurricane Maria (2017), M6.4 Earthquake in Puerto Rico (2020), Hurricane Laura (2021), and proximity to the physical, social, and environmental aftermath of the respective areas to such disasters largely reinforced the urgency and passions behind their scholastic and career pursuits. The authors cited feeling unsettled, helpless, or despair at both the immediate responses to and in the long-term recovery of systems that contributed to community resilience, whether their own or in proximity. These experiences were reflected in the choice goals and actions selected by authors and study participants: the pursuit of ways to prepare and mitigate before disasters and to address these gaps in knowledge that contribute to the damages and recovery afterwards. Importantly, these pursuits were not limited to a purely infrastructure focus but rather, required a holistic approach to community resilience. Amina stated,

> In a world of progress and wonder, I was able to see pockets left behind whether through manufactured or naturally driven events. This motivated me to explore a career centered around service to lessen the burdens of affected communities while improving the scientific foundations of discovery from the bottom up.

As the authors navigated their undergraduate careers motivated by these background experiences and predispositions, they often found themselves at a crossroads: the pursuit of either an industry and consulting or a research-centric internship. For these authors, the application of engineering skills was a key point of interest and could have been applied in either setting. Both provided invaluable experiences and opportunities for skill development. Through access of supportive influences proximal to the students (e.g., an author took a course taught by a visiting scholar who was a postdoctoral student at a NHERI site) and choice goals and actions (e.g., other authors looked for hazard specific research opportunities), the students selected to engage in the NSF-sponsored NHERI 10 week research experience, familiarizing themselves with the advancement of fundamental engineering theories and their applications in hazards research beyond the abstract and academic spheres.

Choice actions included submitting applications and required materials for consideration to participate in the NHERI REU Program. Each research contributor, prior to participating in the NHERI REU program, completed an application process that included faculty recommendations pertaining to their personal and professional characters as well as a suite of prompted questions and essays that reflected their interests in the program. These were coupled with selected site preferences which then were used to assign each student with a NHERI Site and an associated research team developed at their respective sites. Table 5 features the home universities, assigned NHERI sites, research teams, and project titles/outputs to provide a scope of the environments in which the students participated during their REU summer(s).

It is important to note that the student participants had the motivation and support to apply to the NHERI REU Program. By successfully submitting their application to participate, they were considered and then selected by their site to participate in the research project coinciding with their time at the NHERI site. Interests coupled with support systems contributed to their goals and actions, resulting in favorable outcomes for the participants.

3.2 Performance and experience

The output of the REU, such as the titled research projects in Table 5, do not necessarily reflect the entire scope of the intended project and project outcomes that were originally derived by the students or tasked by the Primary Investigators (PIs). The NHERI REU Program was designed to foster community through weekly research meetings and career development workshops. The program also aimed to increase research self-efficacy by providing meaningful research experiences and a scaffolded curriculum during the weekly research meetings. A final aim was to provide mentorship which intended to increase their social network and social capital within the natural hazards engineering research community. The following section focuses on these

TABLE 5 Student author NHERI REU Project(s) site and Project(s) information.

Name	Home university	NHERI site	Research project title	Research team	Research outcome
Amina	Louisiana State University	University of Colorado Boulder, CONVERGE	Design-Level Events and Residential Construction Performance: Hurricane Laura Case Study	Tracy Kijewski-Correa Lori Peek Heather Champeau Jessica Austin	DesignSafe Data Depot publication #3234
Daleen	University of Puerto Rico - Mayaguez	Lehigh University, RTMD	Mitigation of Seismic Risk to Critical Building Contents via Rolling Pendulum Isolation Systems: Multi-Directional Hybrid Shake Table Tests	Phillip Harvey Liang Cao Esteban Vega Villalobos James Ricles	DesignSafe Data Depot publication #3227
		University of Florida, NHERI Boundary Layer Wind Tunnel	Higher-Order Turbulence and its Effects on Structural Loads and Response: A Study on Experimental Equivalence	Mariel Ojeda-Tuz Kurtis Gurley	DesignSafe Data Depot publication #3624
Tyler	University of California, Berkeley	Lehigh University, RTMD	Investigation of Semi-Active Controlled Friction Dampers for Seismic Hazard Mitigation	Liang Cao James Ricles	DesignSafe Data Depot publication #3246

targeted experiences of the students during their REU research projects and the individual professional and personal developments resulting from the research and other non-research activities (e.g., workshops).

The structural support provided by academic and social mentors or by peers provided an immediate sense of belonging in research work according to the students' autoethnographic data. There are some systemic supports provided by the NSF REU Program through weekly meetings with a designated NHERI ECO education specialist who facilitated the REU experience by providing individual guidance and larger group meetings. Herein, REU participants were provided the space and time to process the ongoing research experience and challenges and gauge the experiences of their peers not placed at the same NHERI experimental facility or site. The group meetings provided positive contributions to the individual performance of the participants with respect to the summer experience (e.g., learning technical writing and communication skills), career skills (e.g., diversity and ethics in engineering), and other means of professional advancement (e.g., industry panels and LinkedIn profile creation). Checkpoints for the research component of the REU provided additional opportunities for feedback and milestones for students to feel a sense of progress even when specific research advancements may have stalled or faced setbacks. These supports were important to highlight and normalize within research work.

The individual REU sites and research teams were some of the most integral components which the authors interfaced with. The frequency and nature of these interactions were central to the research outcomes of undergraduate students whose summer internships culminated in a paper and presentation showcased at a symposium of all REU participants at the end of their programs. These interactions were regulated to fit the needs of the participants with mentorship interchangeably in the form of graduate and/or faculty assistance. The authors noted consistent check-ins with both PIs and graduate student mentors as key cornerstones in their successes. The mentorship process was necessary for the introduction to concepts and research motivations which were often proposed by the PI as an original 10 week project or a contribution to an ongoing larger research project. Daleen stated, "Throughout the whole process, my mentors provided valuable guidance and helped me grow professionally, especially in academic writing." Mentors often aimed at preparing the participants for graduate studies and introduced them to components that they would face. Their co-sponsorship of the students' work and endorsements to the students' characters and abilities had unquantifiable benefits for students extrinsically (e.g., career trajectories, letters of recommendation) and intrinsically (e.g., research confidence). One author noted an instance of benign recognition by her research team and mentor as an engineer during their participation in the annual Natural Hazards Workshop as formative in their development. They herein felt more empowered to address critiques of their work, engage with field experts, participate in forums, and reinforce the value of collaborative work.

3.3 Challenges faced

Within Research Experiences for Undergraduate Programs, the expectation is to place students in existing research projects where they can make a significant contribution to the work. Because

students come into a project at different stages of the engineering research process, students have a variety of experiences, and their challenges differ from site to site. This was not any different for the NSF NHERI REU students. They faced challenges consistent with other REU programs, and because of this, support structures such as a network of mentors and individual check-in meetings were provided.

The authors noted challenges associated with participation in the program, many of which are associated with rigor of the project, tasks, and software, or feelings of inadequacy such as "imposter syndrome". The feelings of being underprepared or overworked can be expected when encountering a new experience with a short time for completion. Participants were encouraged and expected to interface with new techniques and programs which they may not have been privy to or interacted with during previous internships, research experiences, or classroom settings. The structure of the REU Program, while beneficial in providing a framework within which to operate, challenged the authors to create or redefine their time management skills.

The introduction to new topics in research and associate technical writing skills associated with preparing literature reviews and project reports posed additional challenges which one author cited as the motivation for pursuing a course-based master's program as opposed to a doctoral program. It is worth noting, however, that the technical skills and overall topics were of interest to the author and were credited in their pursuit of a graduate program. He stated:

> While I did find my research project to be interesting, … I did not particularly like writing a research paper. I did understand its importance … documenting and sharing the knowledge … , but it was not something I wanted to do….What I really enjoyed was the technical aspects of engineering, and I still loved to learn about more advanced ways of doing those things. And that was something I could do at the graduate level by taking graduate classes. That's when I decided that I would apply for graduate school, specifically for a course-based masters degree in structural engineering.

Through the various activities in the NHERI REU program, the students weighed their skills and interests and considered different pathways which required or prioritized specific products such as research publications. The student saw the importance of the academic and scholarly writing process and chose a graduate degree pathway that did not place as much importance on publications as products for educational success.

Overcoming and addressing these challenges was a testament to both the participants' personal abilities and, once again, the value of structural support. Where structural supports did not previously exist, the students created them. Regular interactions with peers, research mentors, and social mentors all contributed to successful outcomes of the summer research experiences. Despite facing steep learning curves and navigating unfamiliar environments (e.g., cultural and neurodevelopmental differences), the outcomes and attainments of the program remain overwhelmingly positive. Tyler noted the challenges and how these were faced during the REU Program:

> It was all overwhelming to be doing that for 40 h a week, day in and out for 2 months, especially towards the very end, when I had deadlines to get results and my code was outputting incorrect results. It was incredibly frustrating and I was on the verge of tears yet I knew that this is what I want to do […] I continually would meet with my graduate mentor, referred to the background knowledge of my dynamics and vibrations class, spent countless hours perfecting my code, all while being very patient with it, and learning to improve.

All participants faced obstacles like those mentioned by Tyler. The supports available through the program as well as their own interests and preparation helped them overcome the challenges. Those supports included having an education expert meet individually with each student weekly; the meetings were personalized to help each student address concerns, practice advocating for themselves at the sites, and strategizing writing sessions and timelines for deliverables. A network of peers was available to them at the site they were assigned to and across the NHERI REU network. Important to overcome the research challenges were Tyler's mentor, a graduate student, and background knowledge in the knowledge needed to address the research work.

Individual interests, background skills and knowledge, personal attributes, and support within the environment were essential to address obstacles. As Tyler mentioned, patience was also important, and an interest in research work and growth mindset (learning to improve) played a key role in the skills needed to overcome research challenges. The NHERI REU Program was designed to help students reflect on their challenges using a growth mindset. Although not mentioned directly in Tyler's reflective autoethnography, weekly reflective questions aided in reflexive thinking of strategies that can be used to overcome challenges. These reflections, coupled with individual meetings with the education specialist, may help to provide ideas and planned approaches to the challenges faced at the research site.

3.4 Outcomes and attainments

Built into the structure of the NHERI REU Program were weekly deliverables that scaffolded the final program outcomes and provided feedback and opportunities to foster research self-efficacy. The completion of the NSF REU Program was filled with both tangible and intangible outcomes with benefits that proliferated long after the summer experience. The authors noted personal developments within such an experience resulting from lessons learned on their own or imparted upon them by mentors and peers. The authors associated feelings of confidence, accomplishment, and contentment with the completion of their research projects and with having overcome the challenges they faced throughout their summer research projects. About this, Daleen stated, "Overall, I felt a sense of ownership to my contribution in the research and enjoyed having the space for my creativity." The publication of their work on an open-source platform such as DesignSafe gave additional value to their work that employed a sense of pride that was shared by their peers and others within the larger NHERI network.

Professional outcomes for the students were manifested differently based on each unique experience with the facilities, research teams, personal goals, and other factors. Generally, participants received exposure to and understanding that the scope of hazards research extends beyond any [one] discipline and is strengthened by those alternate perspectives. In fact, the authors were encouraged to implement these diverse perspectives and community-centered approaches in their careers. The applied nature of research completed in the NHERI REU program aided in visualizing the impacts of the research conducted by students and may inspire similarly motivated future research projects. "After months of being plunged into online learning, the work I conducted reinvigorated my interest in applied research and reinforced my hope to continue in a career fusing theory with real life implementation." This quote from Amina's authoethnographic responses illustrates how interests combined with authentic and meaningful experiences were able to fuel continuation of the research work and propel her towards applying for a doctoral program in natural hazards engineering research.

While REU experiences generally aim to develop research skills within students and encourage participation as researching graduate students, adjacent skills and opportunities were opened for the NHERI REU students who participated in this study. The NHERI network by nature is a broad collaborative network that spans multiple disciplines and geographies across the United States The authors noted that participation in this REU Program expanded their own networks and equipped them with skills and experiences that are useful in numerous contexts. "I was shocked at how much I was talking about this internship, and how useful it actually was at showcasing my skills as an engineer. Not only did NHERI assist me on my graduate school journey, but it also assisted me in the industry space." Tyler, through this comment, explained how the NHERI REU experience was brought into spaces with industry interviews and how connected the network was. Being part of the NHERI network helped Tyler in these ways.

Additionally, two studies have been conducted to show the overall research self-efficacy of participants in the NHERI REU program (Nelson et al., 2023; Vielma et al., 2024). Positive outcomes in these studies showed increases in research self-efficacy which can translate into career choices and actions to pursue graduate studies. Of the six NHERI REU cohorts to date of which the authors were a part of, 35% of students pursued STEM graduate degrees and 8% of all cohort participants pursued doctoral degrees. Two of the participants in this study, at the time of publication, were enrolled in doctoral programs, and all three research participants went on to graduate programs focused on natural hazards engineering research.

4 Discussion

The formation of engineers in the natural hazards engineering research fields remains an important educational task for mitigating the effects of natural hazards around the world as climates increase the intensity and frequency of disasters. This study qualitatively illustrates the experiences and outcomes of three engineering students who participated in the NHERI REU Program, sponsored by the National Science Foundation. Sustained efforts to broaden participation across engineering and scientific disciplines are fundamental to cultivating a multifaceted workforce capable of generating transformative approaches to contemporary and anticipated societal issues.

Social Cognitive Career Theory points to ways in which educators can support students as they design their career paths. Having supportive environments and helping students through barriers toward success remain an important part of their development, especially in engineering and research. Programs such as the NHERI REU Program are also designed with specific goals to address the educational challenges of broadening participation in engineering. This program specifically recruited participants from diverse backgrounds to engage in research. The program also provided support structures to aid in the challenges that research work affords through a network of experienced and caring mentors. Mentors addressed technical challenges as well as difficulties associated with social aspects of uncertainties in research experiences. Mentors and an educational specialist worked together to support students through individualized attention towards their specific needs. Career workshop activities targeted social and technical preparation for graduate school. The program also implemented a formatively evaluated curriculum that scaffolds the deliverables produced by the REU students. This curriculum introduces students to the rhetoric of academic writing. Having a system of support that intentionally assists all students in the program remains a critical component for positive outcomes.

As Tyler, Daleen, and Amina also shared, their background experiences contributed greatly to their interest and preparation in natural hazards engineering research. Helping students navigate their interests remains an essential component of their formation as young scholars. Having champions to dialogue with and reinforce students' interests and reflect on their future contributions with their careers also remains important piece of their narratives. Students in this study had the space to dream about how they could contribute to the world in ways important to them based on their personal experiences and were given the opportunities to prepare academically for this work prior to the NHERI REU experience. Increasing interest can contribute to resilience in challenging times throughout the students' academic and research journeys. Reminding students of their much-needed contribution to the field, through mentors and educators, can increase their retention in the field.

Like all research studies, this qualitative study has limitations. First, the students' experiences are unique. All the student authors in this work continued to complete some degree of graduate schooling (course-based masters or otherwise) and were making reflections of their summer experiences, which occurred in the Summers of 2021 or 2022. These summers and experiences were also historically affected by the height of the COVID-19 pandemic wherein some of the students were offered hybrid or fully virtual research experiences which may differ from traditional REU experiences that included a housing and relocation aspect.

While the professional outcomes of the REU can often be tracked and documented, the intangible, personal developments made

by students are greatly underrepresented. The autoethnographic case study highlights the experiences of the participants 3 years after they participated in the REU Program and documents the program impact on their career trajectories through the use of Social Cognitive Career Theory (SCCT). This case study centers around student authors who are the authentic holders of knowledge. They were asked to reflect on their REU summer(s) beginning with the background and motivations, then the duration of their experience and any challenges they may have faced, and finally the impact this program had on their career trajectory to date. The inspiration for their pursuit of a STEM career and specifically their REU summer participation were largely informed by personal outlooks and experiences with the natural, built, and social environments around them. The REU summer experience itself was largely found to be impacted by the structural support that was provided for or developed by the students and integral to overcoming personal and professional setbacks. Altogether, the NHERI REU experience and the network developed within the NHERI structure have longstanding positive impacts for participants in whatever career path they pursued.

Data availability statement

The datasets presented in this article are not readily available because Data is the autoethnography of each research participant and the data belongs to each participant. Requests to access the datasets should be directed to AM, meselhea@oregonstate.edu.

Ethics statement

Ethical approval was not required for the studies involving humans, because the authors are the research participants. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study. Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

Author contributions

AM: Conceptualization, Formal Analysis, Investigation, Methodology, Writing–original draft, Writing–review and editing. KV: Conceptualization, Formal Analysis, Methodology, Supervision, Writing–original draft, Writing–review and editing. DB: Conceptualization, Formal Analysis, Investigation, Writing–review and editing. TR: Formal Analysis, Investigation, Writing–review and editing.

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