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BOARD # 285: NSF REU Site: Developing the Entrepreneurial Mindset in Engineering Students through Energy-Focused New Product Development

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1. Introduction

Research experiences for undergraduates (REUs) are crucial in shaping academic and professional development. Engaging in research allows students to apply theoretical knowledge to real-world problems, fostering critical thinking, problem-solving, and analytical skills. Moreover, students benefit in many ways by living in the university dorms for 10 weeks, exploring a new university town, making new friends, and taking on new life experiences.

The purpose of this NSF Grantees Poster is to provide a holistic overview of undergraduate student researcher perceptions related to participating in an NSF REU Site program, titled "NSF REU Site: Growing Entrepreneurially-Minded Undergraduate Researchers with New Product Development in Applied Energy." This REU integrated the strengths of academic applied research, including a solid theoretical foundation and rigorous scholarship, with key business practices such as real-world customer discovery and the creation of viable business models. The intention of the REU was to equip students with an entrepreneurial mindset, expanding their research toolbox and skillset.

The guiding research question is as follows: What are perceptions associated with participating in an entrepreneurially minded undergraduate research program?

2. Methods

The study employed a qualitative research design to explore the perceptions associated with participating in an entrepreneurially minded NSF REU program. The study began with the selection of participants and their allocation to research teams; each of the 5 advisors mentored 2-3 participants. The participants then engaged in a 10-week, full-time, on-site research experience (the intervention) at a large Midwestern R1 University. At the end of the program, data was collected through a guided reflection questionnaire that focused on the student perceptions. The collected data was then analyzed using a thematic analysis approach to identify patterns and themes related to participating in an entrepreneurially minded NSF REU program

2.1 Intervention

The undergraduate research program was designed to enhance the participation and success of underrepresented groups in engineering through a combination of academic applied research, such as strong theory basis and rigorous scholarship, with essential business practices such as real-world customer discovery and generation of sound business plans. Delivered as a 10-week, full-time (40 hours per week) program at a large Midwestern R1 University, the intervention consisted of three key components: Onboarding (Virtual, Week 1), Project (In Person, Weeks 2-10), and Weekly Journaling.

2.1.1 Onboarding

The intervention began with a virtual intensive week at the beginning of the program to promote a sense of belonging, accountability, team development, and provide an overview of the research. This concise structure allowed students to quickly integrate into the program while minimizing information overload.

2.1.2 Project

For the following nine weeks, small mentoring groups were formed, with five faculty advisors each working with a team of 2-3 students. 2 graduate students served as project coordinators as well as near peer mentors. The students divided their work hours between a common laboratory shared with the rest of the cohort and their advisor's laboratory, where they collaborated with their advisor's research groups. Intentional Strategies to improve teamwork and collaboration were implemented, such as:

- *Collaboration:* Students worked in teams, balancing collective tasks with individual contributions. Additionally, students were required to present a research poster and presentation at the Undergraduate Research Symposium during week 10 of the research program as a team.
- *Mentorship:* Weekly one-on-one and group meetings with faculty mentors ensured continuous guidance.
- *Cohort Engagement:* Informal events, like coffee hours and shared meals, fostered camaraderie.

2.1.3 Weekly Journaling

The central intervention was a weekly journaling exercise, designed to enhance self-reflection, critical thinking, and motivation. Students documented their experiences, focusing on relationships, progress, and real-world connections. Journaling served as a learning tool to deepen engagement with program goals. Each week, students completed comprehensive written reflections addressing four key areas:

- *Cohort & Team Building:* Reflect on how team interactions influenced your motivation and learning this week. This section prompted students to consider how their diverse backgrounds and perspectives contributed to team success.
- *Advisor Dynamics*: Describe insights from advisor interactions and strategies for effective collaboration.
- *Progress Debrief:* Summarize accomplishments, challenges, and planned adjustments.
- *Real-World Relevance:* Highlight skills gained (technical and professional) and their potential applications in your future career.

Journaling was framed as a reflective practice akin to entrepreneurial journaling, where participants document their growth and insights over time. This approach reinforced motivation by connecting personal experiences to program objectives. The reflection process was designed to be developmental rather than evaluative, encouraging honest self-assessment and thoughtful consideration of team dynamics.

Through these three integrated components, the intervention created a comprehensive framework for supporting diverse teams while promoting both technical and professional skill development. The structure balanced formal research training with intentional community building and guided reflection, creating an environment conducive to both individual and team growth.

2.2 Participants

The participants comprised 14 engineering and engineering technology undergraduate students from various universities across the United States. Out of the 14 students, 10 identified as male and 4 identified as female. Most of the students were in the third or fourth year of their college education, pursuing majors such as mechanical engineering, electrical engineering, computer engineering, and industrial engineering. The ethnic composition of the participants was as follows: 29% White, 29% Hispanic or Latino, 21% Black or African American, 14% Asian, and 7% American Indian or Alaska Native. Overall, 72% of the students belonged to underrepresented minorities (URM), aligning with the focus of the undergraduate research program.

2.3 Data Collection Instrument

At the end of the 10-week REU program, participants completed a final reflection responding to the following questions:

1. *Entrepreneurial Mindset:* The entrepreneurial mindset is defined as "the inclination to discover, evaluate, and exploit opportunities." What are the 3 most important things you learned about an entrepreneurial mindset (or entrepreneurship) by participating in the REU program?
2. *Research Skills:* Identify the top three research skills gained while participating in the REU program.
3. *Advisor Research Lab:* What did you like about working with your advisor? What opportunities for improvement can you recommend?
4. *Connect to Real World:* What skills did you learn that are important for engineers conducting research in the real world? Please consider both professional skills (e.g., communication, collaboration, etc…) and context specific skills (e.g., topic area).

2.4 Data Analysis Procedure

Thematic analysis was conducted on the reflections using NVivo. Several preliminary sub-themes were identified as shown in Table 2. Students identified several areas for improvement with the NSF REU program, as shown in Table 1.

3. Preliminary Results

Table 1. Participant Suggestions for Improvement

Some opportunities for improvement can be found in the lab, just more tools for a wide range of applications as it was lacking some things. However, I know this is because of the shared

lab environment during the construction of the new building so that was not his fault and was out of his control.
The potential for improvement that I would offer would be to create more opportunities for connecting with advisors outside of the workplace.
Although, I believe the expectations of the team and the project could've been more clear and established at the beginning of the program and this would've helped the team understand our assignment better and in turn helped the progression of our project in a timely manner.
In terms of opportunities for improvement, I find it challenging to suggest any, as I believe our communication was already very effective. Perhaps, to enhance the experience further, we could explore additional workshops or seminars that focus on specific research techniques or advancements in the applied energy field.
However, for the most part, I was left to my own devices, and whenever I was given tasks that were really specific, I always felt resentful to do it in that way. In particular, I think that there were certain ways to do it better. However, because of it, I felt really uncomfortable doing things in an environment where I had to be my own boss. And that is another part; my own agency was challenged here, and I had to figure out how to push my way through and do what it is I needed to do. I say that being provided with clear goals would help me succeed in an environment, and I am sad to say that I did not necessarily get that. This, I know, would be different if I were a graduate student, instead of a glorified lab assistant.
I believe that one area of improvement could be that of a timely approach to a project, in the beginning of the REU me and my lab-mates were a bit confused as to what to start working on, and while I know that we cannot start working fully on something without getting the concept first, it would be less confusing if a plan of expected events was laid out from the beginning, something like a timeline of things we have to accomplish before the projects end
Additionally, I found that my advisor's communication style regarding research goals could be more direct. At times, the expectations and specific objectives for our projects were not clearly outlined, leading to some uncertainty and confusion. Enhanced clarity in setting research goals would have contributed to a more structured and productive experience.

Table 2. Preliminary Themes and Sub-Themes for NSF REU Student Reflections

1. Entrepreneurial Mindset	2. Research Skills	3. Advisor Research Lab	4. Connect to the Real World
•Collaborative leadership •Enterpreneurial Knowledge Development •Interviewing Skills •Market Analysis Skills •Market Research Exposure •Market Skill Development •Networking Skills •Personal Skill Development •Problem Solving •Product Development Skills •Risk taking and Resilience	•Collaborative Leadership •Future Aid •Literature Review •Personal Skill Development •Problem Solving and Analysis •Research Components •Source Validation •Technical Learnings •Writing Skills	•Advisor Engagement Time Suggestion •Advisor Testimonials •Collaboration •Communication •Feedback Reception •Guidance •Query Resolution •Suggestions •Work Environment	•Collaboration •Data Analysis •Engineering Skills •Personal Skills Development •Problem Solving •Research Components •Soft Skills •Team Communication •Technical Learnings •Time Management •Writing Skills

4. Conclusion

The guiding research question is as follows: What are perceptions associated with participating in an entrepreneurially minded undergraduate research program?

Overall, the NSF REU experience was valuable, providing students with hands-on research exposure and opportunities for independent growth. However, several areas for improvement were identified. Enhancing lab resources to accommodate a wider range of applications would be beneficial, though it is understood that temporary constraints impacted this aspect. Clearer expectations and structured timelines at the outset of the program could improve efficiency and reduce initial confusion. Additionally, creating more opportunities for engagement with advisors outside the workplace and ensuring more direct communication about research goals would help students navigate their projects with greater confidence. While autonomy was a valuable learning experience, providing clearer guidance and goals from the beginning would support students in achieving their full potential. Incorporating additional workshops or seminars on specific research techniques could further enrich the experience. Overall, these refinements would enhance the structure and effectiveness of the program while maintaining its strong foundation in research and professional development.

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