

Using Narrative Inquiry to Assess Research Outcomes of Biomedical Engineering Entrepreneurial REU Undergraduate Students

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Abstract

Today's research in the biomedical engineering field focuses heavily on translational science, which works toward the ultimate goal of transforming research into tangible benefits to human health, including medicine, medical devices, and clinical practices. As translational research grows, programs are emerging that encourage undergraduate students to develop the skills and attributes required to assist with the transfer of basic research to bedside, including opportunity recognition, customer discovery, teamwork, and persistence through failure. These skills are also inherent in individuals that have an entrepreneurial mindset, which focuses upon generating solutions that create value for individuals, the community, and society.

In Summer 2023, the first iteration of a summer research experience for undergraduates (REU) program focused on entrepreneurial mindset development (eREU) was piloted at three institutions with 2-3 eREU students per program. Each eREU student was paired with a university-affiliated company working on translational medical devices and processes for 10 weeks, with the goal of furthering development of entrepreneurial and translational research skills such as opportunity recognition, making interdisciplinary connections, and persistence in the face of challenge. To understand the impact of entrepreneurial experiences, current research often utilizes quantitative measures, which does not capture students' lived experiences. It has been suggested that a reliable way to understand lived experience is through a qualitative methodology known as narrative inquiry, in which participants tell their personal stories from their perspective, a method that is underused in engineering education research.

Through narrative inquiry assessment and analysis of 17 participants' narratives, including 8 eREU and 9 traditional REU students, we found multiple themes that point to students developing promising translational research skills and attitudes. Students have developed the ability to recognize and take advantage of opportunities, overcome challenges, have grown to understand themselves and others in new ways, and sought connections between their engineering experiences and their real lives. Future work should capitalize on students' reflections on their experiences to increase the body of literature supporting translational research experiences for undergraduate engineering students, especially through qualitative measures like narrative inquiry.

Introduction

Biomedical engineering research has advanced to a focus on translational medicine, which works toward creation of usable technologies, medicines, and practices in the real world [1], [2]. For human healthcare to improve, researchers must be willing to take on projects with these translational goals [3]. Therefore, calls for translational medicine-focused research projects have encouraged researchers to develop specific skills and attitudes that bring the research into the real world, such as the ability to make interdisciplinary connections, an ability to innovate, and an ability to understand and communicate with diverse individuals [4], [5]. To move translational research forward, interventions for undergraduate engineers have begun to appear, which have been successful in helping students develop the skills needed to progress in the translational research area [6]. However, there still exists a gap in understanding how students perceive the skills they are developing, and most research programs are not yet specialized enough toward translational ventures.

Many of the skills desired for progression of translational medicine can also be associated with the entrepreneurial mindset (EM), which is categorized as a way of thinking that encourages a desire for knowledge (curiosity), an ability to draw connections between different knowledge areas (connections), and an ability to develop ideas that will benefit society (creating value) [7], [8]. In the few studies that have specifically implemented EM into research experiences, students have expressed feeling confident in their ability to generate creative ideas, recognize need, and utilize knowledge about product commercialization [9], [10]. Students also recognized the need to utilize current literature, recognize the customer base, and evaluate sustainability before capitalizing on product generation [11].

Though research has started to incorporate EM interventions, they have not yet done so in the translational medicine field, and the only way the outcomes of these programs have been assessed is through quantitative self-report surveys [9], [11], indicating a gap in qualitative exploration of the student experience in programs focused on translational science. Additionally, the student experience is nuanced and difficult to capture, bringing about recommendations to utilize a narrative approach to gain insight into students' true experiences [12], [13]. This work seeks to combine the need for impactful research interventions focused on translational science, and the need for more qualitative understanding of students' experiences within research programs.

This work is tied to a larger project, which implemented a brand new entrepreneurship research experience for undergraduates (eREU) program in Summer 2023. The goal of this program is to provide students with opportunities to partner with start-up companies during a summer research experience, giving them direct experience with entrepreneurial research, commercialization, and design [14]. To understand the entrepreneurial and translational outcomes of this program, we seek to answer the following research question: *How do undergraduate eREU students'*

narratives compare to traditional REU students' narratives, and what EM attributes do students include as part of their stories?

Literature Review

Translational Biomedical Science and Entrepreneurial Mindset

Translational research in biomedical engineering hinges on the importance of turning ideas and experiments into real world practices and products for the benefit of human health and ability to thrive [4], [6]. Earning research funding in biomedical engineering often requires the goals of the project to be impact-oriented [15], which means recruiting researchers with the proper skills to translate research ideas into real products. This skillset is often associated with innovation, entrepreneurship, and the entrepreneurial mindset [15], [16].

The National Science Foundation's Innovation Corps (I-Corps) program focuses on training researchers in translational science through an entrepreneurial curriculum. They identify four "urgent" needs: "training an entrepreneurial workforce," "translating technologies," "enabling positive economic impact," and "nurturing an innovation ecosystem," [16] effectively bridging the gap between translational research and entrepreneurship. Additionally, literature on translational research often includes many desirable skills these researchers should have, which also coincides with what is expected of an entrepreneurially-minded individual [17], [18], such as leadership, building interdisciplinary connections, generating innovative ideas, and focusing on societal impact [1], [6]. It is crucial to prepare biomedical engineering students for a modern engineering industry that focuses on translational science [1], [4], which can also mean training students to develop an entrepreneurial mindset through various types of interventions, including research [15].

Entrepreneurial Mindset in Undergraduate Research

Undergraduate research has been identified as a necessary experience for engineering students to develop skills that are not often taught in the classroom [19], [20], [21]. In these experiences, students learn to design and manage experiments [22], present data both orally and through writing [10], work directly with collaborators and researchers [23], and see the impacts of their disseminated work. Many of the skills students claim to develop in undergraduate research experiences overlap with EM skills and attributes, such as value creation [8], making connections [24], and interdisciplinary communication [25], but research directly on EM outcomes through undergraduate research is limited [9], [10].

In many cases, undergraduates can be exposed to research through internship or co curricular programs such as REUs (research experiences for undergraduates) [26], [27]. Previous EM

research indicates the importance of exposure to extracurriculars for EM development [20], [28], and students themselves have reported developing EM skills through these experiences [29]. However, few papers have examined research programs or initiatives directly [9], [10]. In Treuren et al's [10] paper, they discuss the links between research and entrepreneurially minded learning (EML), including "test concepts via customer engagement," "exploring a contrarian view of accepted solutions," and "assessment of risk." Through this framing, they exposed students to research as early as possible in their curriculum, emphasizing these EML concepts. In Burkey et al.'s [9] paper, they piloted an REU program integrated with EM, including placing students in research projects that had commercialization goals and introducing EM topics through weekly seminars such as "Entrepreneurs and their Paths" and "Opportunity Assessment." Through this experience, two cohorts of students reported that they felt more knowledgeable about commercialization of products, and were able to develop and conduct experiments, generate creative ideas, and recognize business opportunities [9].

Direct integration of EM into undergraduate research experiences exists very minimally, and qualitative examination of EM development through these experiences does not yet exist. This work therefore fills multiple gaps in EM research and will provide further insight into the student experience within these research experiences.

Methods

The following sections will describe the methods used to formulate and thematically analyze the data collected in this study.

Study Design

This work is part of a larger project funded by the Kern Family Foundation. The purpose of this project is to encourage undergraduate engineering students to develop entrepreneurial skills through summer research experiences in biomedical engineering. This program builds off Research Experience for Undergraduates (REU) programs to incorporate an entrepreneurial aspect, called the entrepreneurial REU program, in which research students work at university-affiliated startup companies to gain experience with the business elements of biomedical engineering research. Though eREU students participated in an entrepreneurial environment through projects led by start-up company PhD mentors, the professional development experiences were the same for both the eREU and REU students, including group discussions on topics like career progression in research, and acquisition of professional skills associated with an EM.

The first iteration of the program took place in Summer 2023 with three associated institutions: Rowan University, Wake Forest University, and Worcester Polytechnic Institute. Each program

hired 2-3 students to participate as entrepreneurial REU students (eREU), and 10-20 participated as traditional biomedical engineering REU students.

To assess the EM of the students who participated in this new initiative, both quantitative and qualitative metrics were considered. Students completed surveys at multiple points during the program, completed concept maps at the end of the program, and participated in narrative-style interviews. This work focuses on the results of the qualitative piece of EM assessment, where we examine the narratives of 17 students (8 eREU and 9 REU). Appropriate human subjects' approval was obtained prior to conduct of the study.

Narrative inquiry involves gathering personal stories from individuals to understand a specific life event or series of events [30], [31], often through one-on-one interviews [13], [32]. This method has been described as the most reliable way of capturing a lived experience, since an individual is telling their own story from their perspective [30], [33].

Participants

Seventeen students in total completed the narrative interviews. Eight of these students were eREU students, and nine were traditional REU students at these institutions, as represented in Table 1.

Table 1. Participant Demographics

Position	List of Student Pseudonyms
eREU	Barbie, Charlotte, Emily, Kevin, Mackenzie, Marker, Penelope, Wendy
REU	Football, George, Hades, Jenna, Lily, Miguel, Maria, Robin, S

Data Collection

Students from each of the three institutions were selected to participate in 45-70 minute in person narrative-style interviews in the last week of their program. As recommended in narrative inquiry research, interviews were as open-ended as possible, guided by a single prompt: "Pretend like you're talking to a potential future employer. Tell me a story that highlights the skills that make you qualified for an engineering position." The interview was guided like a conversation, with follow up questions asked as necessary, until the participants felt they had shared everything they wanted to share. The goal of this prompt structure was to encourage students to share traits they believe are beneficial in their futures without mentioning the EM elements of the research. Therefore, they are not influenced by their potential understanding of EM.

Data Analysis

After narrative data was collected, interviews were transcribed via Otter.ai and reviewed to ensure consistency. Narratives were then formulated by following narrative analysis procedures recommended in narrative inquiry research [13], [31]. Specifically, Kellam et al.'s [13] first method for narrative construction was used. This method recommends using the participants' own words as much as possible and writing the narrative in the first person. We felt this was the best approach to capture the students' experiences from their personal perspective. After a single researcher formulated the 17 narratives, a second researcher reviewed the narratives to ensure they followed a reasonable narrative pattern and that there were no mistakes or inconsistencies.

Then, the two researchers began the analysis of narratives process [31], where the goal is to extract themes within and across the narratives in the sample. First, one narrative was randomly selected and the researchers read and recorded general themes that appeared within the narrative. Using this same approach, two more narratives were randomly selected for the researchers to record general themes. The researchers then met and discussed the emergent themes. The remaining 14 narratives were then split in half and the researchers followed the same deductive coding process, pulling out general EM-related themes that were common across the narratives.

When an initial list of codes was developed, the two researchers practiced on two randomly selected narratives. The researchers met to discuss discrepancies and necessary changes were then made to the initial codebook. Another set of two training narratives was selected for the second round of codebook training, where it was determined that the codebook was representative of the data. The remaining narratives were inductively coded by each researcher separately and discrepancies were addressed in a series of code reconciliation meetings. After these themes were developed, they were condensed to include only the themes directly related to EM, as shown in Table 2.

Table 2. EM-Related Narrative Themes (adapted from [34])

Code	Definition	Example
Curiosity	Asking questions and showing desire to know more about a specific topic	"I finished everything that I was working on, and my boss told me he's not gonna give me anything else, so I was like, I gotta do something. So I started researching seatbelts and pregnant women... I was like, it's the seat belt, it doesn't go over the chest properly...So I was looking at seatbelt design." - Emily
Systems thinking	Drawing connections between different knowledge areas and using theses connections to solve problems	"I didn't realize how big the field was until I actually came [to the research program]. At school, they've taught me more of the mathematics and physics side, and here it's more hands on. So they're more visual, which helps." - S
Desire to have an impact on people and society	Seeing chances to drive or create change and having the desire to do so	"I think this synthetic biology thing has a lot of really good real world applications. You can see the impact of how this is affecting different groups of people." - Robin
Developing new or existing skills	Building both technical and non-technical skills from a specific influential experience	"I definitely know that I have learned a lot of interpersonal skills by having to communicate a lot with the team for the project. My advisors are very busy, so I have to schedule meetings and reach out." - Mackenzie
Opportunity recognition	Recognizing the benefits of- and capitalizing on- a specific opportunity in one's life	"Medicine is a whole other world, unless you're exposed to it you have no idea. If I didn't do the study abroad program, and I didn't do the REU program, I would have no idea." - Marker
Self-reflection	How one feels about their abilities, personalities, and the way they do things, and the justifications they make for these abilities/personality traits	"I've also found that when I study, I like to do it alone, because I'm someone who gets distracted. Over freshman and sophomore year, I got better in terms of studying with noise around or doing work with distraction" - Barbie
Passion & Enjoyment	Expressing excitement or a willingness to start/continue an activity, task, or involvement	"I don't even view my research as work, I mean, obviously some days are better than others in research...But overall, I feel like even conducting research is just an enjoyable experience, and not really work but more of a fun time just working with others." - Football
Internal	Personal inspiration and determination to	"I was determined to have some sort of thing this summer that was not like the

motivation	set and complete goals or accomplishments	pizza shop I worked at before. Something that's career related...even if it's unpaid, I would just like to join a research group or do something I can put on my resume." - Penelope
Emotional support systems and structures	Feeling emotionally supported by specific people or structures	"One thing I definitely need, though, is a support structure...if you don't have a good foundation for yourself, you could be falling apart on your own and your work is not going to be to the standard that you want it to be...People that keep you sane, people that make you, you, and the people that give you meaning to what you do." - Miguel

Research Quality Considerations

To ensure research quality in both data making and handling, the research team utilized the qualitative research quality (Q3) framework [35]. Specific care was taken to ensure communicative and process reliability in the data collection and analysis processes. To ensure communicative reliability in data making, the narrative inquiry process utilizes the participants' own words to capture their ideas. The process of turning raw data into narratives preserves the participant's interpretation of their own experiences and helps to remove potential researcher bias. In data handling, the qualitative analysis of the participant data was completed by two researchers who iteratively met to train and practice using the codebook on the collected data, pausing to update definitions as deemed necessary based on the results of the training. To ensure process reliability in data making, the interviews were recorded by the interviewer and the transcripts were checked for correctness prior to the narratives being constructed. In data handling, all student narratives were double coded by two researchers, ensuring that the way that the codes were being applied to the narratives were consistent across the entirety of data analysis.

Results & Discussion

In response to the posed research question, *How do undergraduate eREU students' narratives compare to traditional REU students' narratives, and what EM attributes do students include as part of their stories*, we observed that participants' narratives portrayed entrepreneurial development through all of the themes presented in Table 2, but some differences were observed across the eREU and REU groups. In the following sections, we highlight the four major themes where differences were observed in detail.

Curiosity and Systems Thinking

The eREU students discussed curiosity 4.5% of the time and systems thinking 7.1% of the time, while REU students discussed these themes 2.7% and 2.3% of the time respectively. The eREU students also tended to provide more detail when discussing these themes. They emphasized how they ask questions, seek out information, and connect the information to prior knowledge to solve problems. Most often, they discuss these themes in relation to their summer programs. For example, Marker reflected on his research experience and the systems thinking he was able to learn:

I'm glad [the program] is what I chose to go into, because...it helped me understand how everything works together and how there's specialists within each system, and that the things I've been taught are useful and I can apply [them] in the industry I'm in during this internship.

Similarly, Charlotte described her curiosity about her research, connecting the understanding of background information to her future experiments and analysis:

I spent most of my lunch breaks reading extra material, just trying to educate myself more, make sure I understand as much as possible to be able to do the work that I was doing. Because if I'm just doing the experiments but I don't have the background information for it, I'm not going to be able to do the analysis that I need to do, I'm not gonna be able to understand what I'm getting as much as I need to.

Some eREU students also directed their curiosity toward their futures, using this research experience to make connections to their past knowledge. For example, Barbie expands on her curiosity about research to make connections about the differences between research and industry:

I only know what research looks like. So I think next summer I want to focus more on industry, I want to know what industry looks like...A goal of mine is...[to be] always asking questions and trying to get myself into different projects, even within the school year, kind of like just getting myself to know everything and have the lingo.

When the traditional REU students emphasized curiosity and systems thinking, they often reflected on a general curiosity about the engineering world, and did not often bring their curiosity back to emphasize elements of systems thinking. For example, Lily said:

My boyfriend is in the science field as well...and we always ask questions and get into this pattern of trying to understand things around us that don't make sense off the bat or things we've always overlooked. I guess at the end of the day it's just asking questions.

Similarly, Hades reflected on how he was curious about viewing a specific experiment, but did not connect it back to the research itself:

I wish I had the opportunity to go to the rat surgeries...but I didn't. So I'm gonna go to the next one for sure, and see how the whole process goes. I want to see if I'm gonna be grossed out or not.

Elements of curiosity and systems thinking are often stressed as key pieces of entrepreneurial mindset and intention, especially in the KEEN context, which include curiosity and connections as dimensions of their 3C's framework for EM [8], [36]. We observe the eREU students combining curiosity and systems thinking together as part of one process, in which their curiosity fuels elements of a system and their desire to understand the interconnectedness of different topics. Marker's curiosity about the program allowed him to consider applications of research to

industry, Charlotte's curiosity about her research topic allowed her to consider the effects of background understanding on conducting experiments and Barbie's curiosity about industry encouraged her to understand her knowledge gaps and how to fill them. It is possible that the eREU program's focus on working in an entrepreneurship setting with entrepreneurially-minded individuals encouraged this difference. Being able to comprehend the interdependencies of systems and how different elements work together often leads to higher levels of understanding of complex topics [37], [38]. This indicates that the eREU students may be developing this understanding of complex research problems, which may contribute to an ability to think ahead to how potential solutions to complex problems may affect users. This understanding is also crucial for identifying issues with their processes, drawing on a diversity of experiences, and considering the impact on society as a whole, which are key areas of consideration for translational science [1], [6].

Passion & Enjoyment

Not only did eREU students emphasize a complex understanding of their research, they also spent more time expressing their passion for and enjoyment of their research experience. Wendy reflected on how her perceptions of her research changed after she started to experience it, helping her build a passion for helping others:

I have not always been the biggest fan of biology or anything, so it was definitely a new thing and I thought I wasn't going to enjoy it at all but it was it was very interesting to see how you can consider all these things and how people don't just study the body to study the body, but they can also prevent people from getting hurt or frankly getting killed. I just thought that was really very interesting. I didn't realize how much it can do. I just kind of get a new perspective.

Some eREU students also emphasized how their passions for engineering were influenced by prior experiences, often courses. Marker discussed his passion for injury biomechanics after overcoming a sports-related injury:

My injury is what molded me into wanting to pursue injury biomechanics, which is why I'm here today. In high school, I enjoyed chemistry, but I know I didn't want to be a professor. So I didn't want to teach chemistry. And I'm a talkative, outgoing person, so I didn't want to sit in the lab [by] myself all day and be an actual chemist. So I was like, maybe I could mix that, I've always enjoyed biology anyway, so I decided I wanted to pursue BME. But I think it began from my experiences with injuries and stuff.

Though some of the traditional REU students emphasized similar themes of passion for their future career in engineering, they tended to emphasize the idea that their research program has made them appreciate other interests that are not related to the research they conducted during

the program. Robin explained how she did a previous research project in the biology area, which she appreciated more after participating in a chemistry-related research experience for this REU program:

I had actually been doing research with [grad student], who has been doing more biology and needed an extra hand in the lab. So I went in. And as I was doing that, I liked those concepts and how impactful that can be, not that chemistry isn't as impactful. But I just felt like this simbio has a lot more life breathed into it, when you're working on it. It's easier to get excited about what the projects are and what they're doing.

Maria had a similar experience, where she enjoyed her research, but also realized how passionate she is about the area of tissue engineering:

I kind of idealized cell culture before this. I always thought, "oh, wow, it sounds so cool". And I still think it's cool. But I also realized that it's like, sometimes the cells die. And that sucks. It really sets you back. And just kind of looking at it in a little bit more of a realistic way helps a lot. So I realized I really liked materials, and I really like cell culture. So that's kind of why tissue engineering is kind of the perfect in between for those. So I think that's kind of what I want to do.

Previous research on students at institutions with the eREU program revealed that these students tend to express greater interest in conducting research in the future after exposure to the program when compared to an institution without an eREU program [14]. Other research suggests that if students are exposed to topics in engineering that they are interested in, they are more likely to continue pursuing engineering in the future [39], [40]. It is possible that the exposure to an entrepreneurial setting, which the eREU students had never been exposed to before, ignited their interests in a different way than what we observed with the REU students. Though the eREU students did not necessarily experience different general programming or activities than the REU students, they often had broader requirements for their research project including accounting for FDA considerations and having interaction with customers. However, it is promising that even though REU students tend to express greater passions for topics outside of the research they conducted as opposed to eREU students, they still discuss their overall passion for engineering, which may be due to previous experiences that ignited their passions.

Opportunity Recognition

Though all 17 students mentioned this theme in their narratives, traditional REU students tended to stress the ability to recognize and capitalize on a variety of different types of opportunities, whereas the eREU students tended to focus specifically on their internship experiences as a part of the eREU experience.

Wendy discussed how her advisor for her computer science club sends out internship opportunities, which is how she discovered the eREU program:

And this one, [the eREU], was one of the programs I was reading into, and was one of the first ones that I applied to. I applied to about four more as well, one of them was in an analytics position and two of them were for back end programming positions. I mean, I still ended up doing back end programming for most of this one, but I applied to a few different things.

Similarly, Charlotte discussed how it was important to her to find a summer internship, so she reached out directly to a PI at the REU institution she attended:

I looked on [REU Institution]'s website and found that Dr. [PI] existed, and I sent her an email about looking for an opportunity. And she wrote back and said "I have an opportunity I think you may be interested in." She didn't know who I was, I just put myself out there and tried, and there's no way this would have happened if I hadn't just sent her that email. I reached out and looked for opportunities where there didn't seem like there were any. I think a lot of people feel inhibited by fear that people are gonna think they're silly or dumb or anything like that. And so they don't ask questions. They don't put themselves out there for fear of rejection.

Like Charlotte, many of the eREU students reflected on how they were able to recognize the importance of finding and capitalizing on opportunities, but they specifically focused on highlighting experiences related to internships or research, while the traditional REU students expanded to discuss outside experiences like clubs or sports. For example, Football discussed how he decided to pursue track and field even though his main sport is soccer:

Track was something I actually picked up in college. I'd always attend all the meets and watch[ed] and eventually the coach saw me and said "You were really good. You should throw for javelin". So I was like, well, why not? Let's try some new things. Like I might not ever get this opportunity again.

Football reflected on how even though he was brand new to the sport, he was able to grow and connect with others:

This past year is my first year actually competing, with javelin I was actually able to place at our meet which was really cool. It's really a lot of fun, I love practicing...[I love] the comradery, everyone is really cool.

George discussed how an experience abroad in Spain made him rethink the way he approaches work-life balance:

We covered a decent amount of material and did some interesting stuff, but there was never really any homework or things we had to do outside the classroom. It was like, once we leave the school, we're on our own for the day type of thing. I loved where we were, it was a very small city, Alcoi. It was really peaceful and cute, we could walk the streets at night and not worry about getting robbed or anything. Something I took away from that experience was the importance of work life balance, definitely. It was just such an intangible feeling of relaxation there sometimes.

Recognizing and capitalizing on opportunities is a key element of a strong EM as recognized throughout the literature [41], [42], and a crucial element of translational research [6], [15]. All students were able to reflect on this, but it is possible that the eREU students were more focused on experiences they deemed directly beneficial to their future career goals. Research indicates that students with higher entrepreneurial self-efficacy tend to feel more inclined to entrepreneurial-focused careers [43], [44]. Since students in the eREU program were exposed directly to entrepreneurship interventions during the summer, including customer interaction and interaction with mentors who were practicing entrepreneurs, it is possible they were influenced toward a higher entrepreneurial self-efficacy [45], thus focusing their opportunity recognition reflections on opportunities that point toward their career goals.

Emotional Support Systems and Structures

Despite 16 out of the 17 narratives including discussions of emotional support, traditional REU students spent more time discussing this as a crucial need.

When eREU students discussed emotional support, they often referred to mentors, advisors, professors, or other individuals directly connected to their academic, research, or career goals. For example, Penelope discussed a supportive professor in one of her classes:

I think my favorite class so far was material and energy balances...the professor was so sweet and so supportive. And I think it just made me really excited to be in ChemE. I think sometimes when professors aren't super friendly and supportive, it kind of makes you uncomfortable to actually engage with them. So I guess she was really supportive in asking for our input on how things were going.

Similarly, Barbie discussed working with a graduate mentor who helped ease her stresses during her summer research experience:

I got to work closely with the grad mentor, so I was asking him a lot of questions. And I think it was really helpful to tell him "Okay, this is really new to me. And I'm not really a robotics engineer. And I feel like this is really related to Robotics Engineering". So he gave me a lot of different papers on how robots work, and then how to test robots, how that would work as well.

For the traditional REU students, they focused more on support outside of career or research-related activities, such as family and friends. For example, Maria reflected on how her job during the COVID-19 pandemic helped her socialize with individuals at college:

I went back to working at the same restaurant I was working at, and I had my group of friends there. So I wasn't lonely by any means. But in school, it was just mostly online group chats and stuff like that. So I feel like having that group of friends from my job really helped give me that confidence to make friends in classes.

Lily reflected on how her mother has always encouraged her as a first generation college student:

My mom has always been a supporter of mine, she's always in my corner. I have a really small family, it's just me, my mom, and my sister. So we talk about how it's just the three of us against the world. My mom's like "I don't understand anything you're doing, but I know you're doing great. Just shoot for the stars." She always says that.

Emotional support is not as commonly discussed as an element of EM, but recent research suggests that an emotional component of a well rounded EM exists that captures how entrepreneurially-minded individuals handle stress and taking risks [46]. It is possible that the eREU students' focus on career-related emotional support may be based on a higher entrepreneurial intent as a result of their eREU program interventions. eREU students were tasked with interacting with customers, working with different teams of designers, and taking into consideration government regulations. Although they were mentored directly by entrepreneurs, they may have recognized the need for additional support to lead to successful execution of these entrepreneurial related tasks. As discussed in the previous section, entrepreneurial interventions may lead to higher entrepreneurial self-efficacy, which may then lead to higher entrepreneurial intent [43], [45]. Research states that those with greater entrepreneurial intent tend to experience more positive emotions like optimism [47], [48], so it is possible that eREU students did not feel as much of a need for emotional support outside of their direct career-related endeavors.

Conclusion

This paper highlights the narratives of REU and entrepreneurial REU students participating in translational biomedical research internships during the summer of 2023. Through analysis of these 17 narratives, we extracted nine themes connected to Entrepreneurial Mindset, which is beneficial for those performing translational research. Of these nine themes, the eREU students tended to highlight the technical elements of curiosity and systems thinking in a different way than the traditional REU students, where they emphasized the progression from curiosity about a specific topic to the systems thinking surrounding that same topic. eREU students also emphasized their passion for their research topic and enjoyment of their research experience, focused extensively on career-related opportunity recognition, and emphasized emotional support in the career context. These findings potentially point to stronger entrepreneurial intention, entrepreneurial self-efficacy, and clear career goals in the eREU students. This indicates that the eREU program may help to facilitate these developments, leading toward engineering students with capabilities to conduct impactful translational biomedical research. Although this work focused on biomedical research experiences for these students, we speculate that the entrepreneurial mindset themes expressed by these students may also translate to students of other engineering disciplines and undergraduate research programs. Therefore, we encourage future work to continue exploring students' reflections of their personal experiences with different types of undergraduate research to contribute to literature emphasizing the importance of these experiences.

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