

Mentoring Relationships in Engineering Undergraduate Apprenticeship-Model Research: Students' Perceptions of Faculty Mentors

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Abstract

As the landscape of higher education evolves, the importance of undergraduate research experiences has become increasingly recognized for enhancing students' academic and professional development. Through close collaboration with research mentors, students are immersed in real-world research contexts, acquiring knowledge and skills directly applicable to their professional lives. Beyond the need for mentoring, the quality of mentoring is crucial, necessitating continuous examination of the undergraduate research process and conversations aimed at improving mentoring practices. This study explores the perception of undergraduate student researchers in a mechanical engineering department regarding their engagement with their faculty research mentors during a year-long research experience. This study uniquely solicits students' perspectives on areas for potential improvement in their mentor-student relationships. The study focused on answering two research questions: (1) How do students describe their working relationship with their research mentors during a year-long undergraduate research experience? (2) What do students wish that their research mentors had done differently? This qualitative study is part of a larger study that explores the experiences of undergraduate mechanical engineering students who participated in an academic year-long research lab experience. Data collected for this study includes interviews at the beginning and end of their research experience with this paper drawing specifically from the post-experience interviews. The findings highlight avenues for strengthening mentor-student relationships and advocates for the apprenticeship model as a tool for engaged learning.

Keywords

Undergraduate research, apprenticeship, faculty mentor, mentoring

Background

Undergraduate research has gained prominence across U.S. higher education institutions since the 1998 Boyer Commission recommended that institutions should “make research-based learning the standard” [1]. Literature has found undergraduate research to be beneficial to both students, faculty, and the institution [2], [3], [4], [5], [6].

Various forms of undergraduate research exist, including apprentice-style, capstone and senior theses, internships and co-ops, course based undergraduate research experiences, wrap around experiences, bridge programs, consortiums, and community-based research programs [7]. Of the various forms of undergraduate research identified in literature, the apprenticeship model of research is believed to be the first type of research model adopted by institutions engaged in

undergraduate research and is the most common across colleges in the United States and many other countries [8].

In the apprenticeship model of research, students start as a novice researcher, under the guidance of a more advanced expert, the mentor, who is often a faculty member, post-doc, or graduate student, until students become experts themselves. This model of research is instrumental to situational and observational learning [7]. Through close collaboration with their mentors, students are immersed in real-world research contexts, allowing them to acquire knowledge and skills directly applicable to their professional lives. This method aligns seamlessly with the principles of situational learning, which emphasizes the importance of the learning environment and the context in which skills are applied [9]. By participating in authentic research activities, students learn not only through direct instruction but also by observing and mimicking the behaviors, strategies, and techniques of their mentors [9], [10]. This observational learning process is crucial, as it enables students to adapt and apply what they have learned to new and varied situations [9], [11]. Mentors are thus a key component of this model of research and play a crucial role in the students' development.

Mentors provide “guidance, information, and support that help undergraduates become integrated into their disciplines” [12]. Common types of support that mentors provide undergraduate researchers spans intellectual, personal, emotional, and professional support [13]. Personal connections between faculty and students are fostered in mentoring relationships [14]. While it is important for undergraduate students to have a mentor in their research experience, the quality of mentoring they receive is critical. Ehrich et al. [15] argue that “poor mentoring can be worse than no mentoring at all.” Hence there is a need to continually examine the undergraduate research process and have conversations aimed at improving the mentoring practice.

The purpose of this study is to explore the perceptions of undergraduate student researchers in a mechanical engineering department related to their mentoring relationship with their faculty research advisors as they engage in a year-long research experience at a Midwest university in the United States. The study focused on how students perceived their engagement with their research mentors during their research experience as well as areas for potential improvement in their mentor-student relationships. This study will be useful in identifying avenues for strengthening mentor-student mentoring relationships, enhancing the quality of undergraduate research experiences, and advancing broader understanding and effectiveness of undergraduate research programs. This paper is framed by the following research questions:

1. How do students describe their working relationship with their research mentors during a year-long undergraduate research experience?
2. What do students wish that their research mentors had done differently?

Literature Review

Definitions of Undergraduate Research

There is no universally adopted definition of undergraduate research, but the definition proposed by the Council of Undergraduate Research is widely recognized [8]. The Council of

Undergraduate Research defined undergraduate research as “a mentored investigation or creative inquiry conducted by undergraduates that seeks to make a scholarly or artistic contribution to knowledge” [16].

Benefits of Undergraduate Research

Undergraduate research is a high impact educational practice that has numerous benefits for students [5]. It provides students with the opportunity to experience an education that is grounded in discovery, enhances students intrinsic motivation to learn, and increases early engagement in engineering program [4], [5]. Students acknowledge that engaging in undergraduate research is intellectually stimulating, and believe it equips them with the skills necessary to tackle future challenges, particularly in solving engineering problems [3]. Many students have indicated that their most effective learning experiences occur when they are actively involved in undergraduate research [2], [5].

Additionally, undergraduate research aids in the development of critical thinking skills and introduces students to open-ended problems with multiple solutions [3] a vital skill for early career engineers [17]. Undergraduate research has been discussed as a potential avenue to improve the retention of women and underrepresented minorities in engineering and address the shortage of diversity in STEM [18], [19], [20]. Other benefits of engaging in undergraduate research include boosting students confidence, enhancing cognitive and technical skills, improving computational skills and research writing skills, clarifying future career or educational paths, and providing insight into the process of knowledge creation [21], [22], [23], [24], [25].

Apprenticeship Model of Research

Apprenticeship as a concept of learning was developed by Lave and Wenger [9]. Apprenticeship learning experiences involves a learner collaborating with an expert mentor in authentic contexts [26]. Apprentices participate on the peripheral of a community of practice and gain the skills and knowledge needed to become experts in their chosen field [27].

The apprenticeship model emphasizes learning through direct observation and guided practice in real-world contexts. It incorporates modeling, coaching, and fading (referred to as observation, coaching, and practice by [9]), which has been shown to be highly effective in mastering complex skills and understanding nuanced processes [11]. In this sequence of activities, the apprentice observes the expert performing the process (modeling), which involves multiple subskills. Then, under the expert’s guidance and support (coaching and scaffolding), the apprentice attempts the process. As the apprentice gains competence, the expert gradually reduces their support (fading), allowing the apprentice to practice independently and achieve proficiency [11].

One of the critical challenges students encounter when transitioning from academia to industry is effectively applying the theoretical knowledge acquired in school to real-world practice [28]. The apprenticeship model of undergraduate research directly addresses this issue by allowing students to work closely with experienced mentors on real-world projects [26]. This model of research immerses learners in real-world contexts, provides direct mentorship and feedback, and fosters an environment where knowledge and skills are developed through active participation

and observation, leading to widespread benefits for students as they prepare for their careers [9], [10], [11]. This approach helps learners not only acquire technical skills but also develop the ability to adapt and respond to dynamic and complex situations in their respective fields [9], [11]. Studies have shown that that student-mentor interactions in an undergraduate apprentice model of research plays a role in helping students adjust to the professional research environment, which benefits not only students but also their research mentors [29], [30]. However, Hensel and Blessing [8] argued that despite the widespread benefits that the apprentice model provides, it is expensive to organize, and this cost implication places a restriction as to the number of students that can take advantage of it.

Undergraduate Research Mentoring

Mentoring has been conceptualized and interpreted in various ways by researchers. Mentoring is defined by Robnett et al. [31] as a relationship wherein someone more experienced (i.e., the mentor) guides and supports someone with less experience (i.e., the mentee) [31]. According to Robnett et al. [31], the mentoring that students receive in apprenticeships can take several forms, grouped under positive mentoring behaviors and negative mentoring. Positive mentoring behaviors can take the form of a psychosocial factor and an instrumental factor [15], [32], [33], [34]. The psychosocial dimension of mentoring centers on the personal connection between mentor and mentee, incorporating elements such as encouragement, guidance, and constructive feedback. The instrumental dimension focuses on professional socialization and skill acquisition, often tailored to a specific discipline or research methodology, and considered to be a task focused mentoring [31], [34]. Conversely, negative mentoring occurs when mentors engage in practices that undermine the mentoring bond [31], [32]. In Robnett et al.'s [31] study, both students and their mentors agreed that their mentoring relationships were marked by a high frequency of positive mentoring behaviors and relatively low instances of negative behaviors.

Kulturel-Konak et al. [35] further grouped mentoring styles into five categories: reality checks, goal orientation, project management, emotional coaching and people connection. Reality checks provide students with honest and critical feedback [35]. Goal orientation helps students understand the broader context and develop a clear vision for their final outcomes [35]. Project management involves guiding students in effectively overseeing their research projects [35]. Emotional coaching offers emotional support, while people connection aids students in identifying and utilizing available resources within the research ecosystem [35]. Houser et al. [36], through an investigation into the roles of faculty mentors in an undergraduate research experience, grouped their mentoring styles as laissez-faire, democratic or autocratic, while Ralph and Walker [37] developed the adaptive mentoring model for undergraduates in engineering, nursing and education context.

Mentoring is an essential component of the undergraduate research experience [31], [36], [38]. Mentored undergraduate research has been identified as an high impact practice that enhances teaching and learning in higher education [5]. It influences student outcomes [5] and leads to their development of a professional identity [22], [27]. The extent of progress that undergraduate researchers attain in the research process is largely influenced by how they are mentored [12]. In the mentoring relationship, various forms of support that undergraduate researcher gain from their mentors span intellectual, personal, emotional, and professional [13]. These forms of support has been shown to increase undergraduate researchers' engagement in their discipline

[13]. Literature has also shown that undergraduate student researchers view building relationships with their mentors and colleagues as the most crucial aspect of their research experience [39] and generally consider mentors who communicated regularly as good mentors [14].

Theoretical Framework

The indicators of teacher’s roles for engaged learning [40], [41] was adopted as the framework for this study. One key component of undergraduate research is that it serves a means of student engagement [42]. The indicators of engaged learning identified in Table 1 show the different roles that faculty can play in an engaged learning environment. According to Jones et al. [40], a key indicator of engaged learning is the teacher's role. Teachers (referred to as research mentors in this study) act as facilitators by creating rich learning environments that encourage collaboration, problem-solving, and shared responsibility. They also serve as guides, helping students through mediation, modeling, and coaching. This service involves adjusting support levels, connecting new information to prior knowledge, and refining problem-solving strategies. Additionally, Jones et al. [40] note that teachers often learn alongside their students, especially in collaborative and technology-driven contexts, where roles can shift, allowing students to become the teachers and teachers to become the learners. Hence, we decided to adopt this framework to explore students’ perceptions of their faculty mentors' roles in an undergraduate research environment, to determine if it reflects an engaged learning experience. For this study, we thus focused on what the students said about their mentors and juxtaposed it against the indicators in the framework.

Table 1: Faculty Role for Engaged Learning (adopted from [40])

	Indicator of Engaged Learning	Indicator Definition
Faculty Roles	Facilitator	Engages in negotiation, stimulates and monitors discussion and project work but does not control
	Guide	Helps students to construct their own meaning by modeling, mediating, explaining when needed, redirecting focus, providing options
	Co-learner/co-instigator	Teacher considers self as learner; willing to take risks to explore areas outside his or her expertise; collaborates with other teachers and practicing professionals

Methods

This qualitative study explores students’ perception of their relationship with research mentors throughout an undergraduate research experience. Specifically, this study involves 10 undergraduate mechanical engineering students, 6 male and 4 female, who participated in an undergraduate research apprenticeship program for a full academic year in 2022/2023 session. The students were spread across different classes ranging from sophomore to senior and were engaged in 10 hours of paid research weekly with a faculty research mentor.

Structure of Undergraduate Research Program

Students received funding through a competitive application process where they submitted a brief research proposal with a faculty research mentor. The model of research follows an apprentice model in which students work closely with their faculty research mentors on the proposed project in the faculty’s research labs. Students self-select research mentors that they are interested in working with. Students interacted with their mentors about once per week to discuss progress on their individual projects, and also had the opportunity to interact with other undergraduate students and graduate students in their mentor’s lab, sometimes working on newly conceptualized ideas, or working to advance a similar project. The scope and nature of the research projects that students engage in varied depending on student and faculty mentors’ interests and needs. One key deliverable of the program is that at the end of the research process, the students must present a poster to disseminate their findings to the broader academic and research community. At the end of the research experience, some students contributed to developing a conference or journal publication with their mentor.

Data Collection

The appropriate institutional review board approval was obtained prior to data collection. Data collection involved semi-structured interviews that were conducted either in person or via Zoom based on the preference of the participants. The interviews were conducted in two phases: a pre-interview at week 4 in the program and a post-interview at the end of the research experience. The questions asked about students’ experiences in the research program, ranging from their motivation to the challenges they encountered, how they navigated the challenges and other questions that explored various facets of their undergraduate experience. Preliminary results from the pre interviews were published in an earlier paper [23]. The data for this study was from the post interview protocol and relevant interview questions analyzed in this study are in Table 2.

Table 2: Relevant Interview Questions

1.	How often did you get to interact with your advisor?
2.	Did you find it beneficial working with your advisor? Explain?
3.	Is there anything that you wish your advisor would have done differently?
4.	Would you consider working with your advisor in the near future? Explain?

Data Analysis

Data was transcribed using a transcription software and reviewed for accuracy. The data analysis employed reflexive thematic analysis [43]. Braun and Clarke [43] outlined six phases of reflexive thematic analysis, which were followed in this study. First, the authors re-read the data to familiarize themselves with it, making initial notes on how best to address the research questions. Second, codes were inductively generated from the responses to the interview questions in Table 2. Third, similar patterns across codes were coalesced to generate themes. Fourth, these themes were reviewed in relation to their connection to the research questions. Fifth, the themes were iteratively refined, and descriptive names were assigned to each. Finally, the themes were organized into a coherent narrative.

Findings

RQ1: Student Descriptions of Mentoring Relationship

To answer the first research question, we analyzed how students described their engagement with their faculty research mentors. Students’ responses were grouped under the following themes: (1) mentors demonstrate experience and expertise, (2) mentor engagement and support of students, (3) Communication between mentors and student researchers. Note that we use “mentors” to refer to students’ faculty research advisor.

Table 3: Themes, Alignment with Framework, and Saliency for RQ1

Indicator of Engaged Learning	Theme	Definition	Saliency (# participants of 10)
Guide, Co-learner/co-instigator	Mentors demonstrate experience and expertise	Mentors’ deep understanding and knowledge of the research projects	4
Facilitator, Guide	Mentors engagement and support of students	Active and attentive involvement with students' research experiences, commitment and support for their welfare.	6
Facilitator, Guide	Communication between mentors and student researchers	Frequency and structure of student’s interaction with their mentors	10

Mentors Demonstrate Experience and Expertise

This theme captures how undergraduate researchers in this study described their mentor’s deep understanding and knowledge of the research projects or topics they were engaged in. It highlights how mentors guided student researchers through their research endeavors and facilitated access to additional expertise when necessary. Critical intellectual and technical support functions that mentors provided ensured that undergraduate student researchers succeeded in their projects.

Students acknowledged the value of their mentors being knowledgeable about their research. For example, Participant 10 said, "It is useful to have somebody who has a lot of experience in the field so you that can kind of guide you through your project." Additionally, Participant 11 described their mentor as: “He knows what he's talking about. He was able to help us problem-solve and think of things that we otherwise wouldn't have thought of because he knew much better than us on how robots work and that sort of thing." Furthermore, students identified that their mentor’s expertise was helpful in helping them tackle technical issues. For example, Participant 8 said: "I'm blessed, Dr. [name removed], is very helpful, his expertise helps us to battle those technical issues."

Participants expressed that their mentors experience was helpful in providing useful perspective that was able to help them in project setup, scope management, and in understanding how

individual projects fit within the larger context of the lab's research. For example, Participant 9 said:

I noticed that a lot especially at the beginning when I had not really much idea of how to like set up a project, he helped keep me from using too wide of a scope and like focusing on one thing. It's also really helpful because I mean, talking to anybody is helpful, but especially your mentor who has a perspective on all the projects in the lab. Working with your mentor can help you see how your project fits like in the grand scheme of all the research. And then I would say, thirdly, it's helpful to work with an mentor because they can give you feedback on your ideas and your research and just give you another outside perspective from somebody who's really experienced in the field.

In instances where their mentor lacked specific expertise in a part of the student's research, they were instrumental in facilitating access to external experts to help address technical challenges in that project. Participant 9 went on to say:

Yeah, I guess it's just like, he [research mentor] isn't a fluid dynamics simulation guy.... So, I think just yeah, like finding the specific field knowledge, which we kind of did. We did find like a couple of the other professors that we could like, shoot emails with, but I think just like the timing of when those were, it was like the times when we were asking the questions they were out of the country, that kind of thing and then it just never really materialized from there. But yeah, I think that would be more just like referring me to the experts on specific problems I was having.

In Participant 9's account, we see that issues such as timing and availability can impact the effectiveness of seeking external expertise where their research mentor did not have complete expertise on student research needs.

Mentor Engagement and Support of Students

This theme captures the key qualities described by students regarding their mentors' engagement, including attentiveness, commitment to student growth, active involvement, and support for their welfare. It highlights how such engagement impacts students' research experiences and outcomes. Students sometimes described their mentors as deeply caring and attentive to their progress. Participant 2 noted, "I think we have a really good relationship. I think he cares deeply about what I'm doing and how well I'm doing it." This sentiment was echoed by other students who appreciated the mentors' attentiveness and engagement. Participant 8 highlighted:

What mainly helps us is that he is very attentive. He makes sure to stop by the lab and advise students on the go. While we're working on making the substrates and actually working in the lab, he stops by to ensure every student is moving smoothly and on the right track. He's the best research mentor anyone can wish for. And I say genuinely, I believe so. And I've been telling Dr. [name removed] this ever since I joined the lab, because he believes in freshers, newbies. This is again, what's unique about not only the lab about Dr. [name removed]. Very few professors would believe in students with zero research experience and would let them join the lab just because they believe that you're going to handle all the challenges, you're going to learn fast, and you're going to succeed eventually. He's um, unique in the sense that if you, most of the students, undergraduate students in the lab, they had no experience prior to joining life. However, all of us are currently excelling.

Similarly, students expressed that their mentor was there to provide support when they needed it. Participant 1 said “he gave me advice more on the, like the theory of research side when it's like I found someone else who did something really similar and I was a little disheartened, he helped me a lot on that.” Some of the support that mentors provided their students extended beyond research agendas. Participant 5 hinted that engagement with their mentor also involved career insights:

We definitely talk about, you know, a lot of things beyond just my research project, specifically like I said, with like [field] in general, like what it was like to get the PhD in [field], what it's like to be tenure-track, what it's like to do all these things. So, I think it's been very enlightening, just having a new, or just having another perspective on a career that I want to get into.

Two students who expressed that they possess the ability to lead or self-direct their research expressed satisfaction that their mentors allowed them a great deal of independence and high level of autonomy. These students explicitly described that this nature of engagement with their mentors contributed to reduced stress, a sense of control over their projects, and personal growth in leadership and self-direction. Participant 1 said:

I'm a pretty heavy self-starter, so it was helpful that he allowed me the flexibility to work on my own and the access to the lab, just to have a space to work on campus instead of just doing it from home. It was also nice not to have a lot of stress on top of school, as this research is for me to learn.

Participant 5 corroborated this view, stating: “I feel like [my research mentor] gives me a lot of autonomy and I'm very much like a, I'm a natural leader in like taking charge and, I definitely thrive with like, having the autonomy to do so.” Overall, students valued mentors who were deeply invested in their research and outcomes. They appreciated mentors who and supported them via show of care, being flexible to allow them lead, and provided support when needed.

Communication Between Mentors and Student Researchers

This theme highlights the frequency and structure of students' interaction with their mentors. Students in this study reported communicating with their mentors frequently, at least once a week. These interactions included both individual meetings and group meetings with other lab members. Students indicated that group meetings provided valuable opportunities to interact with peers and learn about their research projects. Participant 6 said:

So, my mentor Dr. [name removed], our working relationship was pure being professional. We met every week serve as like all the other undergrad and grad students. It's like a live meeting, where we just talk about all our projects and there we would talk about the problems we're having and then the arc, my mentor, and all the other researchers would sort of pipe in and give suggestions. If at all, we would take turns describing our project, and all around those meetings were very helpful.

An example of interactions that were held on individual basis is the account of Participant 10: “I met with [my research mentor] every week individually and then I would say like maybe once a week or so he just like would stop in the lab and we'd have a brief conversation about things.” Another student stated that the frequency of their meeting was dependent on the stage at which they were in their projects.

Scheduled meetings were not the only times when mentors got to interact with their students. Participant 7 said, “I really like the fact that, he's super accessible. So, it's not like, during the week, if I have a question, I'm like, waiting days on end for him to like, get back to me.” However, some students did point out that scheduling physical meeting was a problem, and they had to communicate via e-mail instead. Participant 4 said:

I would say I try to communicate once a week. mostly it's via email, but occasionally, in person. I'd say in person, it's, it is a little more difficult to schedule meetings. I have to say a lot of the communication, as far as steps, it's been with the other students in the lab.

Through communicating with mentors, students were able to find value in the perspectives and feedback that their mentors offered. Participants highlighted that their research mentors' insights were particularly helpful in stimulating their thought pattern and helping them adjust their approach to certain projects. For example, Participant 9 expressed:

I think it is very helpful, even just having a second person to talk to about it. There are a few times where I'd be talking through an approach, and I can see on his face that he's not super sold. As we talk through it, I can see if I'm totally off base or if it just needs tweaking. I think it helped a lot.

In the account of Participant 5, their mentor shared a more aligned perspective with them on their research project. They stated, "I think we have very similar perspectives on a lot of things, and that makes it easy. I feel like we're on the same page about a lot of things. I look up to her and can see myself wanting to do what she does." Irrespective of whether the perspectives of mentors aligned or differed from their students, students expressed appreciation of having their mentors’ perspectives of their research projects.

Overall, students reported frequent communication with their mentors as benefitting their research experience and they highlighted how this communication helped them refine their research ideas and grow as researchers.

RQ 2: What Could Research Mentors Have Done Differently?

To answer the second research question, we analyzed what students felt that their research mentors could have done differently to improve the research process. Students’ responses were grouped under the following themes: (1) Students express satisfaction with research mentors (2) Students desire for enhanced guidance

Table 4: Themes, Alignment with Framework, and Saliency for RQ2

Indicator of Engaged Learning	Theme	Definition	Saliency (# participants of 10)
Facilitator, Guide, Co-learner/co-instigator,	Students expressed satisfaction with research mentors	Students who felt that their mentoring relations was satisfactory and made no further suggestions	4

Facilitator, Guide	Students desired enhanced guidance from their mentors	Students expressed that they were not satisfied with mentoring relationship and desired improvement	6
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Students Express Satisfaction with Research Mentors

In students’ responses, four of the 10 students seemed to be satisfied with how well their relationship was and did not offer any more suggestions as to what could be improved. Their satisfaction stemmed from the work structure of their research engagement, mentors being accessible and mentors displaying humane qualities in their interaction with students. For example, Participant 6 said, “As for like, what could be better? I guess. I'm not sure. Honestly, I was, I'm really happy with my setup.” Moreover, Participant 7 said that their mentor was very accessible and was content with the mentoring relationship, saying: “I don't think [there is anything my mentor could have done differently]. I really like the fact that, he's super accessible. So, it's not like, during the week, if I have a question, I'm waiting days on end for him to get back to me.”

Students Desire Enhanced Guidance from Their Mentors

This theme captured the thoughts of students who desired that their mentors had done something to improve on their mentoring relationship. One of the issues that students identified that affected their mentoring relationship was that their mentor was very busy. A student expressed that they wished that their mentors had more time and was more available. For example, Participant 3 said:

I know that he is very busy, he's got all of the behind-the-scenes stuff that I talked about that he needs to do. And he's got a lot of undergrads and a lot of grad students under him. So, I realized that he can't meet with me every day, he can't be there to explain everything. And, and that's something that surprised me at the beginning.

Students who worked with mentors who were not always available expressed that it was difficult for them to get help when they needed and expressed that they wished that their mentors were more available, as this would have helped them to stay more on schedule. Participant 11 said:

I do wish he would have been available a bit more to like, help out with us, because he is he's really busy. He's involved with like everything. So, he has a lot of meetings, it's kind of hard to get a hold of him if we had questions or something. So, I mean, there's not a lot we can do with that, but I do wish he would have come in a bit more often, because then we might have stayed on schedule better.

In addition to being surprised about mentor availability, one participant also discussed communication challenges with their mentor. Participant 4 stated that they had communication as a major challenge in their mentoring relationship with their mentor, expressed a desire that their mentor had clearly defined what their expectation was at the beginning of the research process. Participant 4 said:

If I get maybe hope for, wish for something that could have been done better on my mentor's part is maybe kind of at the introduction, part of the research I felt like I wasn't clearly told, or how to start. And for someone who kind of their only understanding as a couple of articles that they read,

in the beginning. I think those beginning steps are extremely helpful because then, from there, you can build on but if you can't take those first steps, then you can't, you can't start making those decisions and understandings for yourself. So, I kind of I kind of wish I had a little more clear, kind of 'do this' at the beginning. It doesn't have to be throughout the entire experience, but especially at the beginning, I was hoping for more explanations on what I what I needed to do. I mean clearly defined expectations.

Discussion

Apprenticeship Model as Engaged Learning

The findings from the study generated different themes on the nature of relationship between research mentors and their students. In examining the mentoring relationship between faculty and student in the apprenticeship model of research, we were guided by the metrics established by Jones et al. [40], [41] in their study, where they highlighted that research mentors played different roles encompassing facilitating, guiding and co-learning summarized in Table 5.

From the findings, the theme of 'mentors demonstrate experience and expertise' reveals how mentors used their wealth of knowledge and experience to guide students, particularly in addressing technical challenges. Mentors also functioned as facilitators in enabling access to additional expertise when they lacked specific subject area knowledge, emphasizing that mentors did not see themselves as all-knowing but as co-learners and co-investigators in the research process. Participants appreciated their mentors for stimulating discussions about their research projects, reflecting a facilitative role as described by Jones et al. [40], [41]. Mentors also helped in scoping projects, preventing students from going too wide, thus acting as guides according to Jones' framework. Additionally, participants reported that mentors did not control their projects but rather guided and facilitated their engagement in research, underscoring the guiding function of the mentor. Participants noted that professors were deeply invested in their research engagement, reflecting a guiding role. They also highlighted the frequency and structure of their interactions with mentors, which included briefing and debriefing sessions, incorporating elements of both guiding and facilitation roles.

Table 5: Alignment of Themes with Framework

	Theme	Facilitator	Guide	Co-learner/co-investigator
RQ 1	Mentors demonstrates experience and expertise		x	x
	Mentor Engagement and support to students		x	
	Communication between mentors and student researchers	x	x	
RQ2	Students' express satisfaction with research mentors	x	x	x
	Students desire enhanced guidance from their mentors	x	x	

The themes generated to answer the first research question showed that faculty functioned in the roles of facilitators, guide, and co-learners/co investigators, which are indicators of engaged learning [40], [41]. This finding shows that the undergraduate research under the apprenticeship model is a platform for engaged learning. This assertion is similar to that made by [29]. Engaged

learning is a crucial component of the undergraduate education experience and more participation should be encouraged.

Frequency of Communication Matters

In examining student recommendations for improving mentor-student relationships, students suggested that research mentors should have clearly defined expectations and well-structured schedules at the beginning of the research process. These recommendations align with the best practices for undergraduate research mentors outlined by Shanahan et al. [44]. Our study extends Shanahan et al.'s [44] recommendations by emphasizing the importance of research mentors balancing their schedules to remain accessible to their students. From our study, we argue that the success of any mentoring relationship relies heavily on accessibility for the relationship to thrive. This finding is also in line with Ghanat et al. [14] who stressed that mentors should be accessible to students and should communicate effectively. Additionally, from our findings, most of our participants indicated that they met with their mentors at least once a week. We suggest that this practice is good practice that should be encouraged for the success of mentoring relationships. This finding is also in line with [12], [29] who identified sufficiently frequent interaction as a key factor in improving undergraduate research outcomes and student's overall satisfaction with the research experience. Aikens et al. [12] suggested that faculty mentors should meet with their students at least once a week. However, it is important to note that beyond frequent meetings, mentors must also be genuinely invested in the growth of their mentees, as indicated in the theme 'mentor engagement and support to students.'

Conclusion

This study highlights the significance of the apprentice model of research as a tool for engaged learning. Our analysis revealed that mentors in the undergraduate research experience served as facilitators, guides, and co-learners throughout the research process. This underscores the critical role that research mentors play within the apprentice model. Our findings also indicated that this model can effectively enhance student engagement, making a strong case for increased participation and funding of undergraduate research programs. Additionally, we identified several ways in which research mentors can improve their mentoring relationships with mentees in an undergraduate research setting. These insights aim to contribute to the enhancement of the undergraduate research process, advocating for practices that foster better support and guidance for students. It is our hope that this research will inform and improve the approaches used in the apprenticeship model of research, ultimately benefiting both students and mentors.

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