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Quality Mentorship Matters: An Innovative Approach to Supporting Student Success in Engineering Undergraduate Research

Dr. Eleazar Marquez, Rice University

Eleazar Marquez is an Assistant Teaching Professor in the Department of Mechanical Engineering at Rice University.

Dr. Samuel Garcia Jr., NASA EPDC

Dr. Samuel García Jr. is an Education Specialist at NASA's Kennedy Space Center and Assistant Professor of Practice for the LBJ Institute for Education and Research. Dr. García helps facilitate professional development to both formal and informal STEM educators utilizing NASA resources with a specific focus on Culturally Responsive Pedagogy. He also works with faculty serving in Minority Serving Institutions in developing STEM educational tools and resources for teachers to implement in their classrooms. Dr. García's research agenda is geared towards community and educational change by creating healthy, equitable, and culturally responsive learning environments for traditionally underserved populations. Dr. García. earned both his bachelor's and master's degrees from the University of Texas Río Grande Valley, formerly University of Texas Pan American and holds a doctorate degree in School Improvement from Texas State University.

Quality Mentorship Matters: An Innovative Approach to Supporting Student Success in Engineering Undergraduate Research

In this research study, the authors developed a new model of mentorship for faculty members to engage and support their group of students conducting undergraduate engineering research. Research efforts attest that mentoring undergraduate students is a critical role that can dramatically enhance student academic and personal outcomes. This finding is magnified in the context of STEM related disciplines, such as engineering, where efforts to pro-actively diversify the workforce are taking shape. Yet, not every form of faculty-student mentorship is proven to be effective, particularly when faculty conceal forms of knowledge and information regarding internship/employment resources, departmental and research opportunities, curriculum alternatives, exposure to graduate school, and professional experiences that may result favorable in future career aspirations. A fundamental component to facilitating successful student career paths is correlated to an authentic form of mentorship, which exposes students to a plethora of career opportunities and prepares them to navigate postgraduate experiences. The proposed model, which was implemented over a span of four years with a total of sixteen engineering students conducting undergraduate research, identifies four key elements in the transformative process: 1) develop student-faculty relationship; 2) faculty commitment; 3) genuine desire for the mentee to succeed, and 4) willingness from faculty members to disseminate appropriate technical and personal wisdom. This emerging model, termed RCDD (e.g., acronym for Relationship, Commitment, Desire, Disseminate), gives faculty members a template to advance undergraduate engineering student success through a genuine mentorship role. Results indicate that graduating students are better prepared when applying for employment or graduate school. It was also noted that the confidence level increased going into internship opportunities or full-time employment due to their undergraduate involvement in research and the guidance from the faculty advisor.

I. BACKGROUND AND MOTIVATION

According to the literature, 53% of all STEM majors are involved in some form of research activity throughout their undergraduate matriculation given its immediate and long-term benefits [9], [10], [11] [12], [13]. Studies reveal that participating in undergraduate research venues is notably beneficial towards nurturing academic development and clarifying career options post-graduation [13], [14]. Hurtado *et al*. [10] reported that research opportunities have further facilitated the decision of its participants to pursue STEM careers and Ph.D. studies post-graduation [13]. Such academic tool has further proven to increase the pursuit of STEM degrees and graduate education for every ethnic group [15], [16], [17].

Despite the numerous academic and personal benefits of conducting undergraduate research, studies identify two areas of major improvement: 1) effective faculty guidance and mentorship [11], and 2) number of underrepresented minorities engaged in research opportunities [10]. Russell *et al*. reported that an increase in faculty guidance can improve undergraduate STEM education [9], [11]. The study alludes that not every student participating in undergraduate research receives constructive faculty mentorship and guidance.

As such, genuine mentorship is a fundamental component that prepares students to experience success at every educational level. It provides academic and personal insight into unfamiliar domains the student is yet to experience. In higher education, for instance, mentorship roles are

critical given that approximately twenty to fifty percent of entering freshmen, according to Gordon, are undecided about their major, while seventy-five percent change their major at least once prior to matriculating [1]. Faculty mentorship is additionally indispensable as young adults will transition into professional roles post-graduation, and in numerous cases, particularly in STEM related disciplines, ethical principles are necessary to maintain the public's well-being. In this regard, Johnson outlines that faculty mentorship in engineering fields is utilized to transmit values, cultural mores, and ethical principles to the engineering profession [4].

According to Levinson, a mentorship role can exert a greater influence on student success due to the relationship it builds between the protégé and faculty member [6]. He further describes the mentorship role as the most important relationship of young adulthood [6]. This type of influence can expose undergraduate students to comprehensive information regarding internship opportunities, employment resources, graduate school, curriculum alternatives, undergraduate research venues, and professional experiences that may result favorable in future career aspirations.

However, becoming a mentor in engineering related disciplines involves more than simply having a formal departmental position and hosting advising sessions regarding curriculum requirements or institutional opportunities. The authors in this study allude to a significant distinction between being an appointed advisor and being a mentor. According to Levinson *et al*, higher education is committed to fostering student development, but it provides mentorship that is limited in quantity and poor in quality [6]. Thus, the authors in this study characterize advising as a transactional process and mentorship as a transformative process. This distinction between the two prevailing roles posits that mentorship is a fluid and dynamic process that is rooted in a relational context. This resonates with what Levinson stated, '*mentoring is defined not in terms of formal roles but in terms of the character of the relationship and functions it serves*' [6].

Departmental advisors and advising sessions in engineering related fields are highly common, or even required by higher education institutions. The responsibility of departmental advisors is to ensure undergraduate students complete their intended curriculum, or respond to general questions regarding transfer credit hours, study abroad, and opportunities within the institution or department. However, such form of advising is considered more of an informative session rather than a mentorship experience.

A mentor, on the contrary, is an individual who is willing to develop a relationship with students on a personal level and assist in achieving their goals by recognizing strengths and weaknesses, and utilizing them as a tool to provide necessary guidance. A mentor imparts academic guidance, moral support, and leverages valuable information such as institutional, or personal knowledge, that afford students access to research and career opportunities. According to Kram quality mentorship provides students both *instrumental* and *psychosocial* support, which are key in shaping positive student outcomes [5]. Kram's view of mentorship goes beyond the traditional student-faculty interaction to one that is relationship driven and more individualized. This view reframes conventional perceptions of mentorship and offers an alternative approach that is organic, sustainable, and transcends the classroom boundaries.

Though serving as a mentor may have transformative effects on student development, not every faculty member is willing to adopt this role due to institutional factors that drive professional responsibilities. These types of responsibilities may be associated with tenure promotion aspects

such as grant writing, publication demands, travel, or establishing collaborative efforts across academia. Additional factors are based on personal experiences, attitudes, and perceptions that limit awareness of the value and need to engage in responsive forms of mentorship.

II. PROPOSED WORK

Therefore, having a greater impact on undergraduate student success demands for engineering faculty members to engage in [quality] mentorship roles rather than advising roles. In this study, the authors have developed a mentorship model which allows faculty members to establish a consistent rapport to become an instrumental and psychosocial support to shape student outcomes. The proposed model identifies four key elements of the transformative process: 1) develop student-faculty relationship; 2) faculty commitment; 3) genuine desire for the mentee to succeed, and 4) willingness from faculty members to disseminate appropriate wisdom (Figure 1). This emerging model, termed RCDD (e.g., acronym for Relationship, Commitment, Desire, Disseminate), gives faculty members a template to advance undergraduate engineering student success through a genuine mentorship role. These four elements have been diligently identified based on the combined mentorship experience of the authors in engineering related fields.

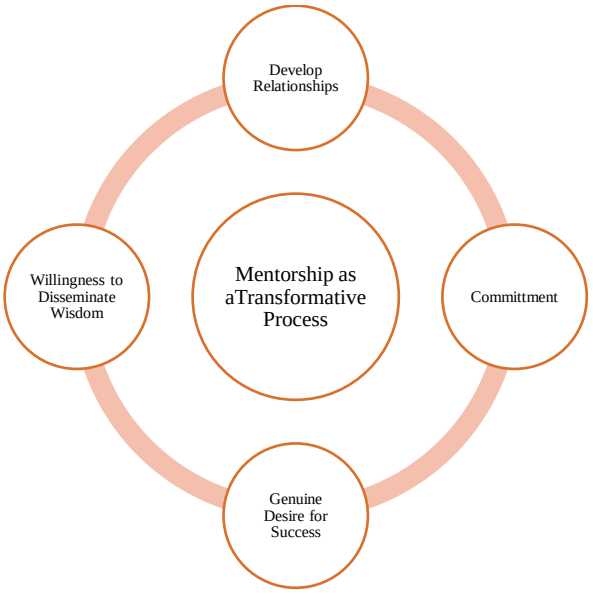

Figure 1. Proposed RCDD Model for Mentorship in Engineering

Element 1: Develop Student-Faculty Relationship

In this regard, the authors emphasize the need of developing instructor-student relationships as the primary element of the proposed mentorship model. Without a consistent, well-structured relationship, it is impossible to establish favorable communication channels in which engineering students feel comfortable inquiring or engaging about a wider range of academic and post-graduation opportunities. In a study conducted by Marquez and Garcia, it was concluded that

establishing a consistent rapport with engineering students can alleviate discomfort, eradicate intimidation barriers, and create a climate that impacts learning, engagement, and success [7], [8].

However, developing such rapport and trust is highly dependent on the initiative of the faculty member to create a climate of approachability towards students [8]. A simple greeting that stimulates conversation, regardless of the context, can eliminate intimidation barriers and promote a stronger communication channel. As such, there are various settings in which engineering faculty members can cultivate strong rapports. It can take place in a classroom setting [7], a research group meeting, as a departmental advisor, a student chapter advisor, a student club advisor, through campus-wide involvement, etc.

Element 2: Faculty Commitment

Building a strong student rapport with team members can further be accomplished by devoting an acceptable amount of time to discuss various topics that may be of interest to student's undergraduate or post-graduation success. Oftentimes faculty members are completely immersed in professional responsibilities such as publishing, writing grants, service, and departmental obligations that student mentoring becomes secondary. As a result, students engaging in research venues may remain oblivious on specific areas which may be critical to their academic and personal preparation. Therefore, the subsequent element of the proposed model indicates that serving in a genuine mentorship capacity requires time, effort, and energy on behalf of the faculty member. Such time devotion will allow students to feel valued and comfortable inquiring about any desired topic. If commitment toward student mentorship is nonexistent, there is a risk their academic or professional potential may not be reached.

Element 3: Genuine Desire for Mentee to Succeed

Therefore, a genuine desire for the mentee to succeed, and the willingness to disseminate appropriate wisdom must be incorporated into the mentorship role. This brand of mentorship requires internal work deep of reframing traditional instructor-student relationships. As faculty advisors, there is a range of topics that may be addressed with the cohort of students conducting research in their group. Several of these may include getting started with graduate school applications, selecting advisor and/or institution for graduate school, applying for employment, receiving a letter of reference, grant and scholarship opportunities, writing proposals and papers, creating budgets, and interview preparation.

Element 4: Willingness from Faculty Members to Disseminate Appropriate Wisdom

Despite being aware of the numerous themes that can be shared with the research students to promote academic, personal, and professional development, a large number of faculty members retain certain information from students. However, if the number of undergraduate students conducting research are to assume the next leadership roles in society, or if an increase in underrepresented communities are to pursue STEM disciplines or graduate school, the faculty advisor must be willing to disseminate appropriate academic and personal wisdom.

In this context, minority groups such as Latino (4.1%), African American (3.8%), and Native American (0.4%) constitute the largest underrepresented communities pursuing advanced degrees in STEM disciplines compared to other ethnic groups [18]. Although studies have concluded that undergraduate research opportunities serve as a retention tool for underrepresented minorities in

STEM fields [23], [24], the percentages remain relatively low. According to the literature, 7% of the total STEM population is represented by the Hispanic community, while the Black community compromises 9% of all STEM workers [20]. These alarming statistics, in the context of undergraduate research opportunities, reveal that the number of underrepresented minorities conducting research might be even lower than those pursuing graduate school, meaning that the willingness from faculty members to disseminate appropriate wisdom is imperative.

Various government and academic programs have been instituted to promote diversity in higher education and increase the number of underrepresented groups in research efforts [19], yet the number of participants continues to remain relatively low. This persistent gap may further attribute to the faculty demographics constituted in higher education. It is well documented that underrepresented students are generally inclined towards seeking faculty advisors from their own ethnicity [22], which delineates the importance of instituting quality mentorship during the period of undergraduate research. According to the U.S. Department of Education, faculty from African American, Hispanic, and American Indian heritage hold the lowest percentages amongst the faculty ranks in higher education [21]. For instance, 6.3%, 5.6%, and 3.6% of African Americans hold Assistant Professor, Associate Professor, and Full Professor ranks, respectively, while Hispanics hold 4.3%, 3.9%, and 2.9% of the corresponding faculty ranks, and 0.4%, 0.4%, and 0.3% of American Indians occupy the equivalent positions [21].

III. METHODS AND ANALYSIS

This research aims to explore the process of mentorship by examining the experiences and perceptions of students participating in the piloted study. The research draws from social constructivist theory that is based on the belief that all knowledge is socially constructed and mediated by historical and cultural factors [2]. Contemporary views and practical applications of social constructivism is a learning theory and pedagogical approach that is rooted in the work of psychologist Lev Vygotsky [3]. According to Vygotsky, “Education is realized through the students' own experience, which is wholly determined by the environment and the role of the teacher then reduces to directing and guiding the environment (p.50).” This theoretical position posits that the instructor has a significant influence in shaping the learning experiences of learners and serves as a critical role to foster the intellectual and cognitive development of students. The participant demographics for cohort 1 consisted of one female and ten male students (Table 1).

In this study, the proposed mentorship model was piloted with current and former undergraduate students of the corresponding author who are or have conducted research under his supervision. The authors utilized a self-developed, small survey instrument to inquire into engineering students’ experiences related to undergraduate research and about the effectivity of the proposed mentorship model. Specifically, the questions were designed to gather insights into their perceptions of mentorship in the research context. The survey was electronically administered via Qualtrics to eleven students enrolled in small private university in Texas. The students selected to participate in the study consisted of both present and past students that participated in research groups mentored by the faculty advisor. In this regard, survey questions were generated based on recurrent conversations the faculty advisor had with his undergraduate students during research meetings, office hours, or arbitrary settings. The authors note the following limitations of the piloted study: (a) small sample size; (b) self-developed survey instrument; (c) convenient sampling procedure.

The administered survey consisted of eight questions for Cohort 1 and Cohort 2:

Question 1. Prior to joining the group, did you engage in research efforts?

Question 2. If not, did you discuss this with the faculty advisor?

Question 3. Did you meet with the faculty advisor after you were accepted into the group?

Question 4. Did the faculty advisor respond in a pleasant manner?

Question 5. If so, did the faculty advisor give you a general overview of the current project?

Question 6. At any point did you talk (or email) the faculty advisor about graduate school or internship opportunities?

Question 7. If so, have you applied for any internship opportunities?

Question 8. Have you received a letter of recommendation from your faculty advisor at some point?

Table 1: Student Demographics – Cohort 1 and Cohort 2[1]

Variable	Total	Percentage
Gender		
Females	1 (1)	9.09% (40%)
Males	10 (4)	90.01% (80%)
Race/Ethnicity		
American Indian or Alaska Native	0	0%
Asian	1 (2)	8.33% (40%)
African American	1	8.33%
Hispanic/Latina/o	6 (3)	50% (60%)
Native Hawaiian/Pacific Islander	0	0%
White	3	25%
Other	1	1.89%
Duration of Involvement in Research Group		
1 Semester	5	45.45%
2 Semesters	1 (1)	9.09% (20%)
3 or More semesters	5 (4)	45.45% (80%)

[1] Cohort 2 information is in parentheses

The survey also included an open-ended question for both cohorts:

> Share your thoughts and reflections about your experiences collaborating with the faculty advisor (e.g., mentorship experience), and your overall experience conducting research

IV. RESULTS

Cohort 1 Results

The questions administered on the survey (Table 2) were intended to inquire about developing relationships, commitment to mentorship, genuine desire for mentee to succeed, and willingness of the faculty member to disseminate personal and academic wisdom.

Table 2. Student Response Percentages: Cohort 1

Question	N	Yes	No
Prior to joining the group, did you engage in research efforts?	11	81.82 % (9)	18.18 % (2)
If not, did you discuss this with the faculty advisor?	11	50.00 % (5)	50.00 % (5)
Did you meet with the faculty advisor after you were accepted into the group?	11	100.00 % (11)	0.00 % (0)
Did he respond in a pleasant manner?	10	100.00 % (10)	0.00 % (0)
If so, did the faculty advisor give you a general overview of the current project?	11	100.00 %	0.00 % (0)
At any point have you talked (or email) to your faculty advisor about graduate school?	10	70.00 % (7)	30.00 % (3)
If so, have you applied for any internship opportunities?	9	55.56 % (5)	44.44 % (4)
Have you received a letter of recommendation from your faculty advisor at some point?	10	60.00 % (6)	40.00 % (4)

Results indicate that the faculty advisor met with (100%) of the students once admitted into a research position, engaged in a pleasant conversation (100%), and gave a general overview of the project (100%). Such results exemplify the commitment on behalf of the faculty advisor to build a relationship with the students and disseminate important aspects of the research project. Oftentimes, this procedure is conducted by graduate students or post-doctoral fellows. However, in this case, the faculty member implementing the proposed mentorship model was willing to commit time, effort, and energy to engage students on a personal level. Seventy percent of the students conducting undergraduate research further mentioned that at one point they engaged in conversations regarding graduate school with their faculty advisor. This statistic reveals that students have confidence in approaching the faculty member to inquire about graduate school life or opportunities. Thus, the student ensures the research advisor is willing to disseminate personal and academic knowledge regarding. It is further noted that 60% of the undergraduate students conducting research received a letter of recommendation from the faculty advisor, while 56% had applied to internship opportunities. These results indicate that the mentor imparts academic guidance, moral support, and leverages valuable information towards career opportunities.

Open-ended Responses

The survey distributed in the study included a short answer section for students to share thoughts and reflections about their experiences collaborating with the faculty advisor. Based on the results gathered from the data, the authors highlight a total of four student responses - from both current

and former students - that offers a unique insight at the impact of the mentorship model enacted by the faculty advisor.

The following statements are from current students who are participating in research efforts:

> *"I have received some guidance during my time researching. Although I will not be pursuing graduate school, Dr. Z provided helpful information on the prospects and benefits of graduate programs. Furthermore, he offered his support in any future careers my group or myself choose."*

> *"I received a form of mentorship throughout my engineering internship in the summer of 2018 with Anadarko Petroleum Corporation. This mentorship served not only help me on my summer project, but also to learn the "ins and outs" of the work-life at Anadarko. Through this mentorship, I could meet with an individual who was assigned to me and ask him any question regarding the oil & gas industry, processes within the job, or the company in general. We would see each other through daily meetings and team bonding events, but would specifically meet to discuss my progress in the company and on my project once a week. I very much appreciated this experience, as it allowed me to have a contact who I felt comfortable asking absolutely anything work-related."*

In addition, the following statements stem from two recent graduates who participated in a research group during their time as undergraduate students:

> *"I consider Dr. Z a mentor, role model, and friend. Prior to meeting Dr. Z, I was at a low point emotionally, financially, and academically. Joining his lab as a volunteer was a turning point in my life. His energetic style and genuine passion for research and teaching brought out the best in me. Dr. Z not only provided guidance in areas of the academic nature, but also in life. He was a complete mentor. The college experience is multi-faceted. Things are oftentimes about more than just research, and I believe Dr. Z recognized this. The skills he taught me made me not just a better job candidate, but a better person. At a university where my social economic status made me feel like an underdog, Dr. Z never allowed to feel sorry for myself. He was the model of what I wanted to become: an educated Latino. Working with him on a day to day basis was a constant reminder that my dream was not impossible. He took the time to explain things to me one on one and when out of his way provide guidance. As a senior, I became the team lead in his lab. Entering a newfound leadership role, he taught me to be a good leader, and empowered me to give my time, patience, and knowledge to others the same way that he had done for me."*

> *"Professor Z served as a bridge to the oil and gas industry, where I currently work. Joining a research group at Rice could prove difficult and competitive. I heard about an opening in Professor Z's research and although I hesitated at first because I had never been exposed to the research's field of study before, Professor Z opened his doors and took the challenge to mentor me."*

Cohort 2 Results

Similar to cohort one, the faculty advisor met with (100%) of the students once admitted into a research position, engaged in a pleasant conversation (100%), and gave a general overview

of the project (100%). Additionally, all students (100%) indicated that they had a conversation with the faculty advisor regarding graduate school. These results reflect the consistent and intentional approach of the faculty advisor to cultivate rapport with all students under his guidance. Sixty percent of the cohort surveyed reported having received a letter of recommendation from the research faculty advisor, while 80% had applied to internship opportunities. These statistics further serve to highlight the importance of high quality mentorship on student experiences, outcomes, and career opportunities.

Table 3. Student Response Percentages: Cohort 2

Question	N	Yes	No
Prior to joining the group, did you engage in research efforts?	5	00.00 % (0)	100 % (5)
If not, did you discuss this with the faculty advisor?	5	80 % (4)	20 % (1)
Did you meet with the faculty advisor after you were accepted into the group?	5	100 % (5)	0.00 % (0)
Did he respond in a pleasant manner?	5	100 % (5)	0.00 % (0)
If so, did the faculty advisor give you a general overview of the current project?	5	100 % (5)	0.00 % (0)
At any point have you talked (or email) to your faculty advisor about graduate school?	5	100 % (5)	0.00 % (0)
If so, have you applied for any internship opportunities?	5	80 % (4)	20 % (1)
Have you received a letter of recommendation from your faculty advisor at some point?	5	60.00 % (3)	40.00 % (2)

Open-ended Responses

As part of the survey distributed in the study, an open-ended section was included to afford students the opportunity to reflect on their overall research experiences and collaboration with the faculty advisor. Based on the results gathered from the data, students reported having an overall positive undergraduate research experience. The notable themes drawn from participant data were a high level of student autonomy; consistent faculty support; an increase of engineering skills applicable to industry; applied engineering and problem-solving opportunities; and exposure to non-industry related career opportunities. One student response did indicate the need for more intentional interaction and communication with the faculty mentor to ensure project goals are met.

The following statements and reflections shared by student participants highlight nature and approach taken by faculty advisor to afford and provide students with the necessary opportunities, resources, and support to fashion a student-driven, academically rich undergraduate research environment:

> "*Research was incredibly beneficial to the generation of skills that are applicable to both industry and graduate school. Although I hit roadblocks at certain points of my project and education, my advisor was always there to provide a meaningful way forward. Furthermore, my input always felt valid which gave me the sense that I was valuable to the team.*"

> "*By and large, my faculty advisor, Dr. X, has delegated virtually all research tasks to his students with the exception of budgeting, the overall goal, and the topic. He has allowed us to decide how we want to study the motion of drill bits and their vibrations (which is*

the topic), which is something that I have greatly appreciated because it allows for the students to develop higher level executive decision-making skills that will be useful in industry."

"*Dr. X's lab is the only undergraduate-only lab in the MECH department, which I would say has made my experience conducting research very positive because unlike some of my friends and family members who have conducted research in larger labs at other institutions, my experience has been very enjoyable and I have been involved with all aspects of research, not just data entry (as one cousin's experience was) or a very small aspect with no knowledge of the end goal.*"

"*It was great! Dr. X would provide us with the needed materials, and would meet with us when we needed guidance*."

In addition, the following statement reflected the potential for undergraduate research experiences to reveal and expose students to graduate school opportunities:

"*My experiences with my faculty advisor helped teach me about the academic side of engineering. Contrary to the work experiences I gained from my internships in industry, engaging in undergraduate research gave me a much better understanding of pursuing further education in an engineering field. Overall, research was a very rewarding experience.*"

Moreover, one student did provide critical feedback that could inform future research experiences for other students:

"*Would've liked more frequent check-ins on team progress with the faculty advisor to keep us on track. It was sometimes hard to progress without clear deadlines or deliverables.*"

V. CONCLUSION

In this preliminary study, the authors explored and examined the process of mentorship and its impact on student development by employing a social constructivist framework. In particular, the study characterized advising as a transactional process and mentorship as a transformative process. This distinction between the two prevailing roles posits that mentorship is a fluid and dynamic process that is rooted in a relational context and requires a deep commitment of time, effort, and energy. Most importantly it requires the capacity to develop a sense of reciprocity, a genuine desire for the mentee to succeed, and the willingness to disseminate appropriate wisdom. Thus, the proposed model was piloted with a faculty member conducting research. Results indicated that the transformative process of mentorship in engineering related fields plays a critical role on student academic success, efficacy, and outcomes.

Future Work

The authors note the following limitations of the piloted study: (a) small sample size; (b) self-developed survey instrument; (c) convenient sampling procedure. Thus, Phase 2 of this long-term project includes surveying current undergraduate students conducting research in every

engineering discipline and identifying the mentoring areas of need. The authors are in the process of developing an agenda to create survey data and organize focus group interviews with such students. In this regard, focus group interviews will be utilized to facilitate collective reflection and dialogue by providing students opportunities to openly discuss their learning experiences with fellow peers. The facilitation of the focus group interviews employs a semi-structured approach in which the researchers generate a series of open-ended questions designed to guide group conversation. This approach will assist in generating an organic, conversation-oriented environment that encourages participant autonomy such that individual and collective experiences are respected.

Once the survey and focus group interviews have concluded, the authors will initiate, in Phase 3 of the project, a series of meaningful conversations aimed at engaging engineering faculty members who have undergraduate research students in exploring collaborative efforts to implement the proposed model. This effort will draw on data collected from the study to inform the material required to develop and facilitate in-depth, dynamic training sessions in which the model is explained in detail.

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