Investigating Undergraduate Researchers' Perceptions of Mentoring Relationships

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Background

According to the Council on Undergraduate Research, undergraduate research is defined as "an inquiry or investigation conducted by an undergraduate student that makes an original intellectual or creative contribution to the discipline" [1]. Undergraduate research is a high-impact educational practice that has myriad benefits for students. Faculty mentors report extensive learning gains by students who engage in undergraduate research in collecting data, collaborating with other researchers, synthesizing research literature, analyzing data, learning a topic in depth, demonstrating proficiency in lab techniques, and working independently [2-4]. However, in literature student researchers report that the most important elements of their research experience are personal relationships with other students and mentors, emphasizing the development of relationships with mentors over learning gains [5]. Education researchers have identified trends in those expectations, particularly regarding the importance of expertise versus socio-emotional support [6-8]. The literature shows significant benefits of mentoring for females, ethnic minorities, and first-generation college students, including increased retention and continuing education rates [6, 9-11].

The objectives of this study are (1) to assess the perceptions of undergraduate researchers at The Citadel about the role and characteristics of a good mentor, (2) to detail practices used by current undergraduate research mentors, and (3) to hypothesize generalized best practices for faculty engaging in undergraduate research.

Institutional Context-SURE Program

The Citadel's Summer Undergraduate Research Experience (SURE) Program had its inaugural year in the summer of 2017. The program allows students from all disciplines across campus to participate in a funded 10-week research experience based on the preference of the student and faculty pair.

The SURE Program strives to improve student skills integral to performing research. Students are expected to work for approximately eight or more hours per week in conjunction with their research mentors to facilitate one-on-one instruction and research skill development. The specific skills to be developed are dependent on the student/mentor's discipline. The program intends for the skills developed to evolve over the course of the summer. In general, students are initially taught how to perform several experiments. Once the students collect data, the mentors assist the students in performing quantitative and qualitative data evaluation [12]. By the end of the summer, mentors strengthen student capabilities in finding/assessing relevant literature related to their work. A weekly meeting serves as a structured event that facilitates one-on-one instruction. The student would present weekly findings to his/her mentor, read scientific papers together, and plan future experiments. In addition to conducting research with mentors, mentees are required to attend three lunch meetings throughout the summer experience. These lunch

meetings focus on professional development and mentoring; providing an opportunity for students to discuss research progress with peers [12].

The 2021-2022 SURE participants included 32 undergraduate students from various disciplines across campus. The participants were from the Civil and Construction Engineering Department, Mechanical Engineering Department, Electrical Engineering Department, Mathematics Department, Chemistry Department, Biology Department, Physics Department, Cyber and Computer Science Department, Criminal Justice Department, and Health and Human Performance Department.

Investigating Students' Perceptions of Mentoring Relationship

Survey Methodology: A survey was developed based on the measures used in a study by Ishiyama [6]. The SURE participants were asked to rank characteristics of a good mentor using a 6-point scale ranging from 1 to 6 (1 = least important and 6 = most important). The descriptors shown in Table 1 were used to characterize a good mentor. Eighteen undergraduate researchers (12 males and 6 females) ranging from sophomores to seniors participated in the survey. The survey was administered at the start of the SURE program.

Table 1. Characteristics of a good mentor adapted from [6].

Male or Female	
	Rank:1-6 (1 = least important; 6 = most important)
Communicative	
Accessible	
Helpful with project	
Expert in the field	
Friendly	
Personal concern	

Results and Discussion

The results of the SURE participants' perception of mentoring relationship are organized according to each research question. Investigating student perceptions of (1) good mentor characteristics and (2) the role of a mentor in research as differentiated by student sex.

Research Question 1: Does the perception of male mentees at The Citadel about the characteristics of a good mentor differ from the perception of female mentees?

The scores for the characteristics of a good mentor were computed by weighing the proportions of students who listed the given characteristic by their rank (e.g., first place rank received a 6-point weight, and sixth place rank received a 1-point weight). Figure 1 illustrates the mean and the standard deviation (SD) of the perceptions of male, female, and all participants. It can be seen from Figure 1 that all participants perceived the communicative characteristics as the most important characteristic of a good mentor (All Mean = 5.37, SD = 0.8). The female mentee

group ranked communication as slightly more important than the male mentee group (Female Mean = 6, SD = 0 and Male Mean = 5.17, SD = 0.83). Among all mentees, the most frequently cited good mentor characteristic was "communicative" (Mean = 5.37, SD = 0.8), followed by being accessible (Mean = 4.69, SD = 0.8), helpful with project (Mean = 4, SD = 1.1) being expert in the field (Mean =3.75, SD =1.34), being friendly (Mean =1.62, SD = 0.62) and personal concern (Mean =1.56, SD = 0.81). Female mentees consistently emphasized that a good mentor was communicative, whereas male mentees frequently tended to emphasize expert in the field as an important quality.

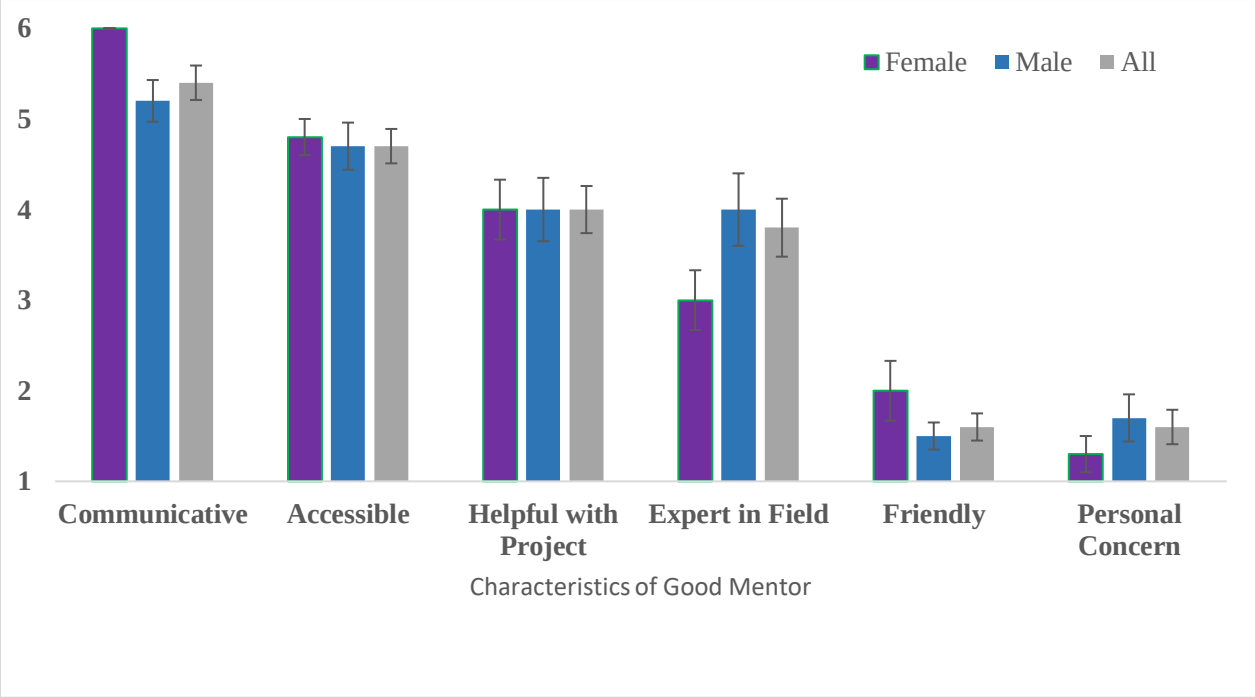

Figure 1. The mean and standard deviation of the undergraduate researchers' perceptions of characteristics of good mentor.

A two-sample t-test statistical analysis was conducted to see if there was a significant difference between the perceptions of male and female. Comparison of the mean perceptions was completed using the t-test assuming a two-sample with equal variances at five percent level of significance. The results showed that the difference between the mean perceptions of male and female mentees was not statistically significant at $\alpha = 0.05$ for any mentor characteristic (for communicative ($t = 1.95$, $p = 0.07$), for accessible ($t = 1.76$, $p = 0.86$) , for helpful with project ($t = 0$, $p = 1.0$) , for expert in field ($t = 1.32$, $p = 0.2$), for friendly ($t = 1.45$, $p = 0.17$) , for personal concern ($t = 0.88$, $p = 0.39$)).

Research Question 2: Does the perception of male mentees at The Citadel about the role of a mentor differ from the perception of female mentees?

The perceptions of mentees about the role of a mentor were also investigated. The mentees were asked to respond in one of two ways (very important or not important) to nine statements shown in Table 2.

Table 2. Roles of mentor adapted from [6]

Male or Female		
	Very Important	Not Important
1. Giving me advice about careers		
2. Helping me to find internship		
3. Working on my behalf		
4. Guiding research methods		
5. Helping me with research literature		
6. Guiding selection of research topic		
7. Listening to my personal concerns		
8. Is my friend		
9. Listening to my ideas		

To analyze the perceptions of SURE mentees about the role of mentor data, the mentee responses were coded as 0 or 1, with "1" representing very important and "0" representing not important. Next, the mentee responses were used to calculate three index scores (Career Support index, Research Support index, and Personal Consideration index). The responses to statements 1-3 were used to compute the Career Support index. The responses to statements 4-6 were used to compute the Research Support index. Finally, the responses to statements 7-9 were used to compute the personal consideration index. Figure 2 illustrates the mean index scores of females, males, and all mentees. It can be seen from Figure 2 that the female mentees perceived Career Support related items as the most important (Mean = 0.89) followed by the Research related items (Mean = 0.78), and the Personal Consideration related items (Mean = 0.56). The male mentees and all participants perceived the personal consideration items as very important with means of 0.7 and 0.78, respectively. The male mentees perceived Personal Consideration related items as the most important (Mean = 0.78) followed by the Research related items (Mean = 0.5), and the Career Support related items (Mean = 0.33).

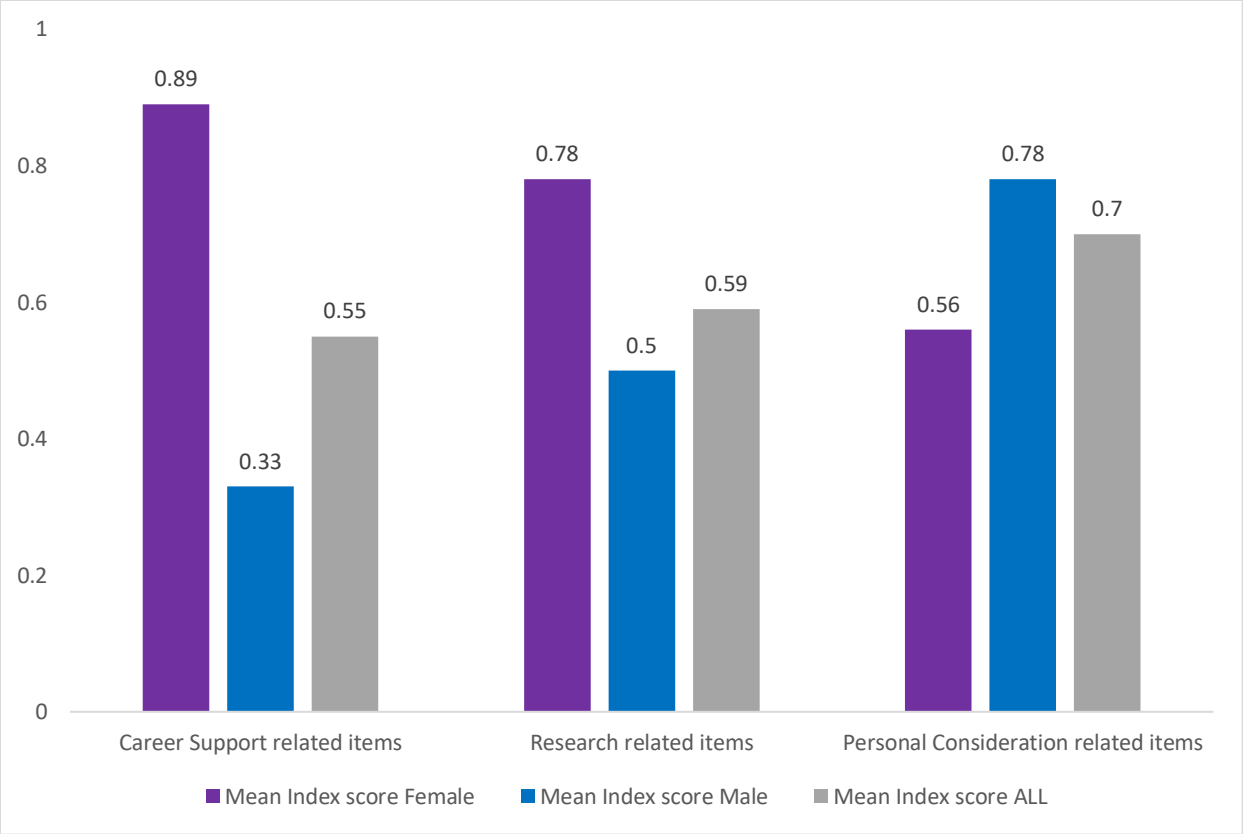

Figure 2. Undergraduate researchers' perceptions of role of mentor

The results regarding the mentor role in contrast with good mentor characteristics are insightful. While students reported the lowest levels of importance for the characteristics of "friendly" or "showing personal concern", more than half of the students surveyed placed the "Personal Consideration related" role items as "very important". However, the underlying theme of strong communication characteristics may also have been considered by the student when rating the role statement "listening to my ideas," thereby clarifying the results. Regarding both mentor characteristics and roles, the mentor's research expertise is given a moderate score (neither highest nor lowest). This may indicate there are gendered differences in the top criteria students want in a mentor, but that reliably students will regard the research content itself as the next highest.

Mentoring Methodology Used by Faculty

***Narrative Collection Methodology*:** Six faculty mentors from across the disciplines volunteered to submit narratives to describe their mentoring methodology to provide a qualitative complement to the quantitative data obtained from mentees. This narrative format was utilized in order to provide context to mentoring choices that may have been obscured in a survey due to the small sample size. Faculty were asked to address the following points in their narratives:

- How do you get your mentee engaged and excited about research?
- How do you teach your mentee about various elements of research?

- How do you help your mentee understand and see research from start to finish?
- What are ways that you use to nurture mentees' self-sufficiency?
- How are you building interpersonal respect and trust?
- Are you involving your mentee in all parts of the scientific process?
- What are the ways that you are using to introduce your mentee to new opportunities?
- Any challenges you have faced?

The complete narratives are included below. Common themes include:

- Use of initial tasks or conversations to increase student interest in the research field and/or specific project
- Gradual scaffolding of research tasks throughout the research experience to correspond with increasing student researcher self-sufficiency and skills
- Mentors emphasize customization of meeting formats and project deadlines to the student – thus needing to first gain an understanding of the student's personal accountability, communication style, and background knowledge

The six faculty narratives have been anonymized. Faculty A, D, E, and F are male while Faculty B and C are female. Further, all but Faculty B teach in STEM departments. Faculty B teaches in the School of Social Sciences.

Faculty A's mentoring methodology - novice undergraduate researchers progress towards a level of independence gingerly as they experience the varying aspects of the scientific process. Self-sufficiency cannot be abruptly taught, nor developed. However, the confidence and capabilities of the mentee increase as the mentee engages in experimental design, conducting experiments, interpreting results, and communicating their work to others. As the mentee encounters each aspect of research, they develop some capability to think critically about the research project develop, which leads to a level of self-sufficiency.

It is imperative to gradually involve the mentee in the various aspects of the scientific process, rather than potentially overwhelm the mentee by presenting each aspect all at once. Initially, it is critical the student understands the large picture of the research. This can be accomplished by having the mentee read articles written on topics related to the research project to grasp the context of the project. After the mentee apprehends the large goal of the research, the mentor can clarify the specific hypothesis the mentee will study. It is instructive to have the mentee sketch the different possible experimental outcomes before the experiment is performed. This ensures the mentee is aware of various experimental parameters and comprehends how the data they collect is related to a hypothesis. When it comes time to performing the initial experiments, it is beneficial to have the mentee and mentor each perform the experiment and compare results. Novice researchers inflate their experimental skills and require guidance in performing elementary tasks. When the mentor/mentee performs the same experiment together, the mentor can offer advice/insight during different experimental steps. Direct supervision further provides additional safety measures. The mentee can next learn how to analyze/interpret the data, and the mentee can perform statistics with the two data sets from the mentor, and improving mentee confidence, while enabling the mentor to gain confidence in the mentee. The mentees can utilize

their experimentally obtained data to create the figure previously sketched during the formation of their hypothesis. Lastly, the mentee can discuss their results and their meaning at a research meeting.

A goal for mentoring undergraduate researchers is to develop a level of independence in the mentee. Performing research requires a holistic knowledge of every aspect of the research project. Novice researchers are unfamiliar with the interconnectedness of each aspect of research. They require a stepwise introduction into each aspect of research and must be reminded of how the differing aspects are interconnected upon introduction to a new aspect.

Faculty B's approach to mentoring undergraduate students in research includes getting them involved in various elements of the research process, from start to finish. She gets mentees engaged and excited about research by connecting it to real-life experiences and illustrating how research can be used to improve people's lives. For example, this past summer the mentee and mentor researched service providers' perspectives regarding the use of home security technology for survivors of domestic and sexual violence. To illustrate the importance of this research, she presented her mentee with examples of how technology is used in abusive relationships and, conversely, how it can be used to increase victims' safety.

For this faculty, some of the main goals of mentoring undergraduate students in research are to promote critical thinking and foster independence. An important part of this is understanding and working through challenges that occur during the research process. Research is an iterative process and is often non-linear; challenges faced in engaging in research can be just as instructive as successes and provide important learning opportunities for novice and expert researchers alike.

Creating rapport between mentors and mentees is also important, particularly when dealing with sensitive research topics. To cultivate interpersonal respect and trust within this professional relationship, she meets with students in a relaxed environment – such as a coffee shop – and continually emphasizes that they are a team. Regarding the latter, she does not make her mentees do anything that she does not do, even the most menial tasks. Sharing tasks solidifies the collaborative work being performed. However, over time, her involvement in certain aspects of the research decreases, which both facilitates and is a result of their increased confidence to work independently.

Successful mentors should go beyond teaching research and critical thinking skills and should provide students with additional opportunities for both professional and personal growth. To do so, she co-authors conference presentations with mentees and facilitates their attendance and participation in professional meetings in their field.

Faculty C's mentoring methodology (by virtue of the duration of most undergraduate research experiences) results in her presenting students with a research task rather than a general research question. She provides students with instructions of what they will be measuring and how it will be done. In this way, students are quickly able to feel they are contributing to the larger field with the data they collect. Generally, this more concrete "task" is closely related to their lived experience or their expressed future career interests. Additionally, she conveys to the student that

he or she is not directly following the traditional scientific research method because she has done the initial literature review step for them to get them started on active research sooner. They discuss how research projects in graduate school would follow a more traditional process while a corporate research project may be more similar since most staff scientists would be hired to execute a specific research task, which may then be expanded to include additional directions.

As the project progresses, she provides the student with a partial collection of existing literature for review. This forms the basis of their literature review and allows the student to identify their own expansion of the research project based on any research gaps. They discuss the validity of their ideas and how such ideas could be combined into their existing project or may form the basis of future work. At the end of the process, the student is tutored on how to present their project (data from the initial task, literature review, and new/proposed research) into a coherent final product for dissemination, either a research poster or paper.

Throughout the undergraduate research experience, she tailors the interactions with the student to their personality and prior work/research experience. For example, if she has a military veteran as the student researcher, they have relatively short deliverable-focused meetings. With such students, depending on their intrinsic personal accountability, they may even forgo weekly in-person meetings and instead opt for email check-ins, particularly during the literature review phase of research. This conveys a high amount of trust in the students and allows them to feel more responsible for the project. For students without any prior research or work experience, or those which personalities requiring more rapid affirmation of their ideas before they pursue/complete a task, she schedules more regular in-person meetings, which may even include hands-on working sessions with both present.

Faculty D's mentoring methodology is to excite the mentee about research and to teach the mentee about various elements of research by having him or her read journal articles. The mentee presents one or two journal articles at each of their meetings. After the mentee presents an article, he asks if there may be other ways to collect similar data and if there may be other interpretations of the data. Reading articles not only introduces the various elements of research but exposes the mentee to the final product. In addition to reading articles, the mentee also starts by collecting data individually. This forces self-sufficiency, as the mentee will make numerous logistical decisions. Afterward, he visits the field sites and collects data together with the mentee. He can thereby answer questions as they arise, train the mentee in data collection methods, while discussing all aspects of the study. In addition, conducting grunt work in tandem with the mentee builds interpersonal respect and trust.

While the mentee usually focuses most on data collection, the mentee is involved in all parts of the scientific process, including the articulation of a research question, literature review, data collection, data interpretation, writing, and presenting. However, mentees typically need extra support with conducting statistical analyses, plotting supplemental figures, and identifying the main findings on which to focus the manuscript or presentation. Another challenge with undergraduate researchers is student turnover: a mentee will not remain in his team for long. To manage this, he either has the mentee submit a conference proceedings paper during the fall

semester after the summer research experience or train younger mentees to continue their experiments into the following year.

To introduce the mentee to new opportunities, he invites the mentee to meetings with former colleagues who have conducted similar research and asks the mentee to bring a list of questions. This provides the mentee with exposure to outside expertise.

Faculty E's mentoring methodology approach is to slowly transition from something resembling an academic lecture course to independent research. In the first two weeks of the project, he meets with the students every day and gives them an individualized lecture on background information necessary for the research project. He ensures the student understands the question they are trying to answer and works with them to develop a schedule for the project. They read a scientific paper together and discuss the relevance to their project and the areas for further study. Since the supervised projects are usually in applied mathematics, the mentor must make sure the student is familiar with mathematical software such as Python packages or MATLAB, which typically involves providing the student a crash course in computer programming. Students seem to be well engaged and invested in the project at this phase, likely because it resembles an academic course.

After the first 2-3 weeks of the project, the mentor then transitions to meeting with the student less often and gives them more independence on researching the project. This transition can be problematic. Most students continue working on the research, but not every student continues the research with the same enthusiasm as they did when they were under his close tutelage. Over the years, he has adjusted the mentoring style to make the transition from lecture to independent research more gradual. He gradually meets with the student less often per week, but still keeps tabs on their progress and makes sure they are making constant progress. He has found it is helpful for students during the independent phase of their project to have a well-defined deliverable with a set deadline. This deliverable could be a report, presentation slides, poster, or software. It could also be an oral summary of a research paper or an informal presentation to a small research team.

Faculty mentor E has been mentoring undergraduate research projects since 2007, and he has found that students are getting distracted in their projects more frequently. This may be due to fatigue from the 2020 pandemic, increasing demands on student's time, or simply because he (the mentor) is getting older and falling into the teachers' platitude of "the students get worse every year." In Summer 2020, in the second week of the project one of his research mentees revealed they had also committed to two other research projects during the same summer. In Summer 2021, a student abruptly stopped working on the project after 4 weeks due to mental health problems and struggled in their courses the following academic year. In Summer 2022, he tailored a research project for the student's major and received approval from his major advisor for this project to be their senior thesis, but in Fall 2022 the thesis course instructor decided all students should work on new projects. These three examples point out possible pitfalls in summer research projects. Although he did supervise other successful research projects during this time and the three example students did produce good partial results, he believes that he could have mitigated these problems with better communication with the student and academic

departments. Research mentors must remember that research does not occur in a vacuum, and it is important to be somewhat aware of the student's commitments, living conditions, academic and career plans, and general happiness.

Faculty F's mentoring methodology involves a top-down approach to research as a means of motivating undergraduates to conduct research. To do this, he first provides the student with a big picture or "big why" of the research problem that their research effort will address. Then, he asks them to break down the problem into small and manageable pieces. This has helped his students to better understand and appreciate the value of the work they do on the research. After the research project is broken down into smaller workable packages, doable by an undergraduate student, he then introduces a few alternative research methods or data collection options to the student and asks the student to gather more information and evaluate the different options. In a follow-up meeting, they discuss advantages and disadvantages of each option and decide about using the best methods. Then, he assigns the student the task to learn that method. At this point, he typically provides the student with several resources to learn more about the selected tool or method, but he leaves the responsibility of learning the tool/method largely to the student.

He asks the student to create a research framework figure to show the overarching processes of the research as well as the inputs and outputs of each step of the project. Then they discuss the different processes and make sure the mentee understands the overall picture of the research. Instead of giving his mentees a "task" to do, he typically asks them to find alternatives to solve a "problem." Then, they discuss the advantages and disadvantages of each alternative, and the mentor guides the student to choose effective approaches to solve the problem. From the very first day, he lets his mentee know that while doing a research project they will have a "research collaborator" and "research team" relationship rather than teacher and student. He gives mentees his personal cell phone number and asks for their preference (rather than availability) for scheduling meetings. If the scope of the project is doable by mentees, he involves them in all parts of the project. Otherwise, he will let them understand the big picture of the research but will let them know that certain parts of the project (such as coding or advanced data analysis) will be done by others. However, in all cases, he makes sure that they understand the overall processes of the research and the inputs and outputs of all research steps - even those steps that they are not directly involved in. When they learn a new tool/method, he explains the various ways that the tool/method is/can be used in industry. He also emphasizes the importance of undergraduate research as a gateway to start successful graduate studies. The most important challenge is the short time that undergraduate students spend on their research project.

Recommendations for Effective Mentoring of Undergraduate Researchers

From the accumulated mentor narratives and student survey results, several recommendations emerge.

(1) Mentors should communicate often and effectively with and be accessible to mentees throughout the research process. These characteristics were rated as most important in the student survey. Communication methods may vary greatly based on the personalities of the individual student-mentor pair. Different example methods can be seen in the faculty narratives.

(2) Mentors should listen to the ideas and concerns of their mentees. This was uniformly important throughout the faculty narratives. All faculty mentioned methods to increase student interest in the project/field and support their self-efficacy as researchers. Further, the student survey, regardless of student gender, emphasized the importance of mentor "personal consideration."
(3) Mentors should provide career support, particularly for female mentees. While all undergraduate students should receive some level of career support, the female students surveyed indicated this as the most important role of the faculty research mentor. Particularly for female students in STEM, intentional career building support, may build their confidence to enter the workforce and engage in research.
(4) Students should be made aware of the academic journals and societies in the field so that they feel part of a larger research community. All faculty in their narratives provided some way they engaged the student researcher in literature review activities. Some began with the review while others used a literature review as a complement to the student's data analysis work. This may further assist students under the category of "career support" by understanding the existing field of knowledge and the institutions working at the forefront. Students could use such knowledge to identify potential schools for graduate study.
(5) Students should be encouraged to attend conferences in their field. This is another way to make the student feel part of a community and show the student best practices in research and presentation.

Conclusions

While this study includes all disciplines in the cohort, mentoring in the context of research is critical for all disciplines, especially for engineering students. These mentoring practices enhance oral and written skills and knowledge of career opportunities while connecting faculty with students on a personal level; all skills that prepare students in ways that a traditional classroom setting cannot do. Additionally, the interactions between students of various disciplines allows engineering students to obtain different perspectives that enhance and broaden their perspectives on issues. It is important to note that the results of this study should not be generalized to draw broader conclusions due to a relatively small sample size and the intermingling of STEM and non-STEM majors in the dataset. Further data collection and analysis are warranted over the next few years before conclusions can be made. Future analysis can probe the influence of gender on undergraduate mentoring by including the gender of the faculty mentor in the analysis. The small current sample size precludes differentiation of female mentee perceptions between those who have a male versus female mentor. Additionally, the student survey can be deployed at both the start and end of the summer research program. This would allow identification of changes to student preferences after they experience undergraduate research mentoring and/or specific mentor practices. Lastly, the survey could be modified and distributed among faculty mentors to assess similarities and differences in the prioritization of mentorship characteristics and roles between the mentee and mentor.

The results of this preliminary study indicate that:

- Both male and female mentees characterized a good mentor as communicative.
- Overall, all mentees ranked Personal Consideration related aspects higher than Career and Research Support.
- Male mentees are more likely than female mentees to emphasize the Personal Consideration role of mentors.
- Female mentees are more likely than male mentees to emphasize the Career Support role of mentors.

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