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# How Undergraduates Research: Student-Mentor Experiences and Perspectives in STEM Research (Work in Progress)

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## Abstract

Undergraduate research experiences play a pivotal role in shaping students' scientific futures, either inspiring them to continue pursuing research or discouraging them from exploring further opportunities. This exploratory study aims to better understand the experiences of undergraduate researchers in science, technology, engineering, and math (STEM) fields through a population of undergraduate participants in a full-time multidisciplinary undergraduate research program. Student- and mentor-reported perceptions and scores were collected at the end of each summer term to evaluate the students' research performance and reflect on their experience and growth. Electronic (Google Form) surveys prompted students to self-evaluate their research performance over the summer term as a numerical score between 1 (worst) and 5 (best), and to provide a written justification for the selected score. Mentors scored their students with this rubric, and they were asked to provide positive feedback and suggest areas for improvement. A total of N=235 responses were included in the analysis from 162 unique students, with each response reflecting one unique summer term of research. The numerical scores revealed high agreement between student and mentor perception of student performance, with a mean absolute difference of just 0.23 (4.6%) between student and mentor scores. Written responses, comprising student reflections and mentor feedback, were then analyzed with the aid of large language models (LLM) for the identification and quantification of thematic patterns. This analysis focused on the cases in which discrepancies arose between student and mentor scores. Most notably, students consistently focused on tangible deliverables and outcomes while mentors typically focused on their students' growth as scientists. On average, students tended to score themselves slightly lower than their mentors score them, often referring to unexpected challenges. In those situations, the mentors' feedback revolved around the student's demonstrated "persistence" and "scientific maturity"- focusing on how the student handled obstacles. We expect results will improve our understanding of student-mentor relationships and perspectives within STEM research, with the future goal to aid in the development of effective mentorship programs and tools to improve undergraduate student research performance and outcomes.

## Introduction

As colleges increasingly emphasize the importance of hands-on learning experiences, undergraduate engagement with STEM research is becoming more common [1], [2]. Undergraduate researchers are often able to contribute to journal publications and conference presentations, benefitting both the undergraduate student, their research group, and their mentors. These experiences allow undergraduates to explore their interests to determine which research field is most interesting to them, and they provide an effective learning experience to apply practical skills for future careers [1]. Additionally, students who spend more time doing research during their undergraduate careers are more likely to be accepted into graduate programs and continue onto careers in science [3].

However, the pressures of rigorous scientific research can be intimidating to students without prior experience [4]. The challenges that arise are likely to be more complex than what is covered in traditional coursework. Thus, students can rely heavily on their mentors when being trained in lab techniques and also when developing their critical thinking abilities and communication skills. Navigating the unfamiliar challenges of research can be exacerbated by students' gaps in their knowledge and their ability to effectively communicate and collaborate; [5] which will lead to more responsibility on the mentors to guide students. It is in these formative stages that miscommunications may spiral into negative experiences and deter students from pursuing research further. This is especially important for students with underrepresented identities in STEM research, as negative experiences can further alienate minority students from certain fields and systematically hinder efforts towards inclusivity [6]. In a large nationwide study of undergraduate research experiences, it was found that the most common student request for improving research experiences related to improving the amount and quality of faculty/mentor guidance [7]. It is clear that mentors play an essential role in undergraduate students' development as scientists, and that there is a need for direct communication between students and mentors.

The SyBBURE Searle Undergraduate Research Program is a year-round research mentorship program that provides undergraduate students with technical training, skill-development workshops, and several scientific and academic mentors external to the student's lab group. The program aims to develop a mentorship and learning framework to better prepare students for careers in research, emphasizing critical thinking and independence in research and design endeavors [8], [9], [10], [11]. In this study, experiences from students and mentors who have participated in the program were analyzed to better understand the perspectives of undergraduate student researchers and of their mentors. We hypothesize that there are thematic differences between student and mentor evaluations of student research performance.

## Methods

### *A. Participating Subject Information*

A total of N=235 survey responses were collected from 162 unique undergraduate students in their second, third, or fourth year of college. Data collection occurred at the end of each summer term between 2020 and 2024. Students who participated in the program multiple terms submitted one unique response for each summer term research experience. Research mentors were then asked to evaluate each student's performance and provide additional feedback on what the student did well and where there was room for improvement. Research mentors surveyed were either affiliated with the student's research lab or with the SyBBURE Searle Undergraduate Research Program. Program-affiliated mentors consisting of doctoral students, postdocs, professors, and university staff members with prior research experience who meet with students at least once a week. These weekly meetings are a chance for students to present updates on their research progress, practice formal poster or oral presentations, and discuss personal and professional goals, and therefore provide regular insight into student performance. Research mentors affiliated with the students' labs were also asked to submit feedback, and this data were included when available. Lab-affiliated mentors are typically the direct supervisor of the student in the lab. In this case, regular communication is expected but not enforced or standardized. Rather it is left up to the discretion of each student's supervisors and the principal investigator (PI) of their lab.

### *B. Data Collection and Survey Design*

Students in the SyBBURE Searle Undergraduate Research Program completed self-evaluation surveys and received mentor feedback at the halfway point and at the end of every term (Summer, Fall, and Spring). This study focuses solely on end-of-summer self-evaluations and feedback, as students worked full-time during the summer, and this time point allowed them to reflect on the entire experience. The survey defines the scoring criteria as shown in Table 1 and presents the same criteria to students and mentors to improve the validity of comparison between student and mentor responses. Students are asked to reflect on several aspects of their research performance (including project progress, accountability, independence, etc…) Table 2 lists the specific questions given to students to evaluate their research performance. On the other hand, mentors were asked to score only the overall research performance for the student rather than scoring each individual component. Additionally, mentors provided positive feedback regarding what the student has been doing well, as well as feedback regarding what aspects of research the student could stand to improve upon in the future.

**Table 1. Scoring criteria for student and mentor evaluation of student research performance.**

| Score | Description |
|---|---|
| 5 | Student steps up as a leader in some way (eg, spearheading a novel project, preparing a first-author manuscript) |
| 4 | Student does more than what is expected (eg, highly independent, contributing to a manuscript, training other lab members…) |
| 3 | Student meets expectations in this category (eg, punctual, follows instructions, communicative…) |
| 2 | Student does not always meet expectations in this category (eg, lack of preparation, infrequent research updates, unexplained delays…) |
| 1 | Student rarely meets expectations (eg, missing meetings, very little or no communication with mentors, not showing up…) |

**Table 2. Snippet from the student survey showing the research-related evaluation questions asked and the allowed format of the response.**

| Question | Response Format |
|---|---|
| **Research project(s) progress** | **Score 1-5** |
| **Why did you rank yourself this way for research progress?*** | **Written free response** |
| Research accountability (attending lab, completing tasks on time, etc) | Score 1-5 |
| Why did you rank yourself this way for research accountability? | Written free response |
| How independent do you feel in the lab? | Score 1-5 |
| What is one research related skill you learned this half of the semester? | Written free response |
| What difficulties are you facing in the lab this half of the semester? | Written free response |
| Any recent publications, patents, conference proceedings, or awards? | Written free response |

* Only responses to the first two questions (bolded) were analyzed in this preliminary study.

### *C. Data Analysis*

The differences between student and mentor scores were calculated to identify positive and negative score discrepancies. Positive score discrepancies are defined as cases in which mentor-provided scores were higher than student-provided scores, while negative score discrepancies are defined as cases in which mentors score students lower than the students scored themselves. All cases with score discrepancies were then analyzed more closely to better understand what underlying factors led to the difference between student and mentor perceptions of research progress. Score discrepancies were categorized, based on the corresponding written responses, as being due to a mismatch in perceived research project progress, or being due to a mismatch in the perceived growth and development of the student. In the latter case, manual coding of the responses revealed which specific skills were acquired by the student and identified by the mentor but not by the student response, leading to a positive score discrepancy, or the areas which mentors identified as having room for improvement, leading to a negative score discrepancy.

When considering the thematic content of all responses rather than focusing on those which presented with score discrepancies, coding and tallying of responses was complemented with the aid of the LLM ChatGPT (OpenAI, CA, USA). The use of LLMs in content analysis has been previously shown to have good agreement with human results [12], [13]. In this study, ChatGPT was prompted to identify commonly occurring themes in student and mentor survey responses, and to tally the number of occurrences. The LLM-outputted results were then manually validated.

## Results and Discussion

Student-reported scores were found to have generally good agreement with mentor-reported scores (Figure 1). A score discrepancy was observed in 22.1% (52/235) of cases, and the mean absolute difference between student and mentor scores was 0.23, or 4.6% of the maximum score. However, a paired t-test did reveal significant difference between mentor and student scores ($p=0.0069$), with mentors typically assigning higher scores than students. Of the 52 cases with score discrepancies, 67.3% (35/52) showed a positive score difference in which the mentor gave the student a higher score than the student gave themselves. Notably, there were very few scores of 2 and no scores of 1 given by students or mentors, indicating the student cohorts in general met or exceeded expectations.

Only 4 student-mentor score pairs differed by more than 1 point; in each case the students gave themselves a score of 3 while their mentors scored them as a 5 (Figure 1). The discrepancy in all 4 of these cases was due to students feeling like they did not achieve enough of their goals, whereas their mentors noted that the goals they set were overly ambitious. The mentors' feedback focused more on how students approached their research and grew over the course of the semester, while the student reflection focused on whether or not they managed to output the tangible deliverables they had planned to at the beginning of the term. This difference in evaluation metrics was not unique to the cases with high score difference between mentors and mentees, but rather consistently appeared across all responses.

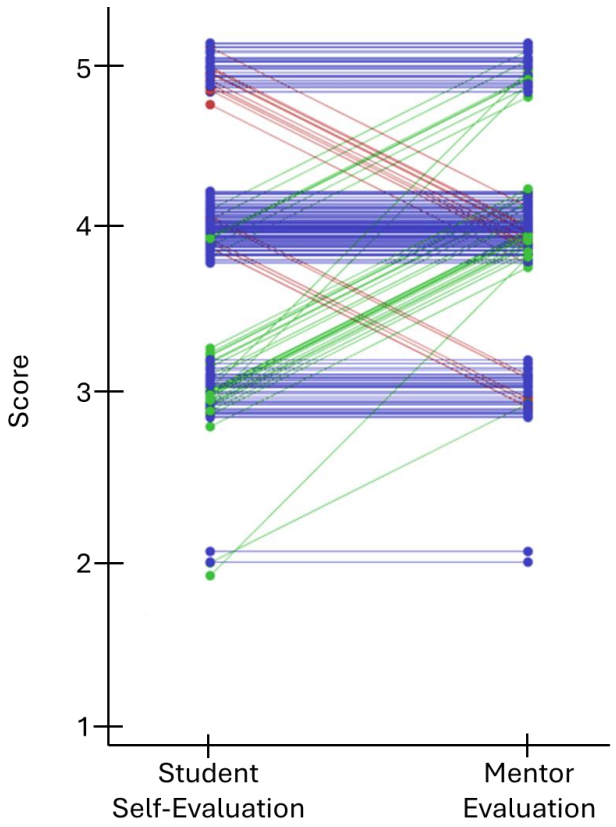


**Figure 1. Distribution of student self-evaluation scores and mentor evaluation scores; positive score discrepancies in which the mentor score was greater than the student score are shown in green, while negative score discrepancies in which the mentor score was lower than the student score are shown in red, and scores which were equal between student and mentor are shown in blue.**

Overall, mentors gave students higher scores than students gave themselves. A mismatch in student-mentor perceptions of research progress was observed in 48.1% (25/52) of cases with score discrepancies. On the other hand, a mismatch in student-mentor perceptions of student skill development and growth was observed in 71.2% (37/52) of cases; the specific skills or qualities mentioned in the mentor feedback in these cases are summarized in Figures 2 and 3 for cases of positive discrepancies and negative discrepancies respectively. In Figure 2, the skills shown represent student growth and the acquired skills that mentors observed in the student over the course of their research which led them to give the student a higher score than the student gave themselves. In Figure 3 on the other hand, the skills shown represent areas that mentors point to as having room for the student to improve upon as justification for giving the student a lower score than the student gave themself. In the vast majority of cases, the skills shown in Figures 2 and 3 were pointed out by the mentors but were not mentioned by the students. Additionally, the two largest categories that needed improvement, accounting for 66.6% of responses, were communication-related: communication with lab PI and presentation skills (Figure 3). This perhaps implies that communication is one of the more fundamental skills for students to hone, prior to which it is difficult for mentors to assist students or provide more nuanced feedback.

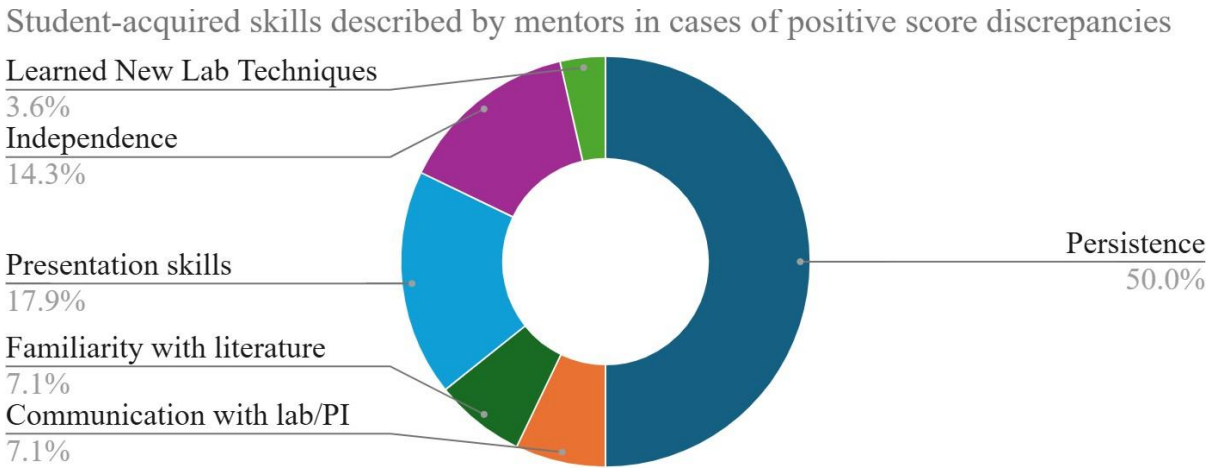


**Figure 2. Skills and qualities identified in the mentor feedback for cases of positive score discrepancies (mentors gave student a higher score than student gave themself). Each slice represents the percentage of mentor responses that were manually coded into the corresponding bin.**

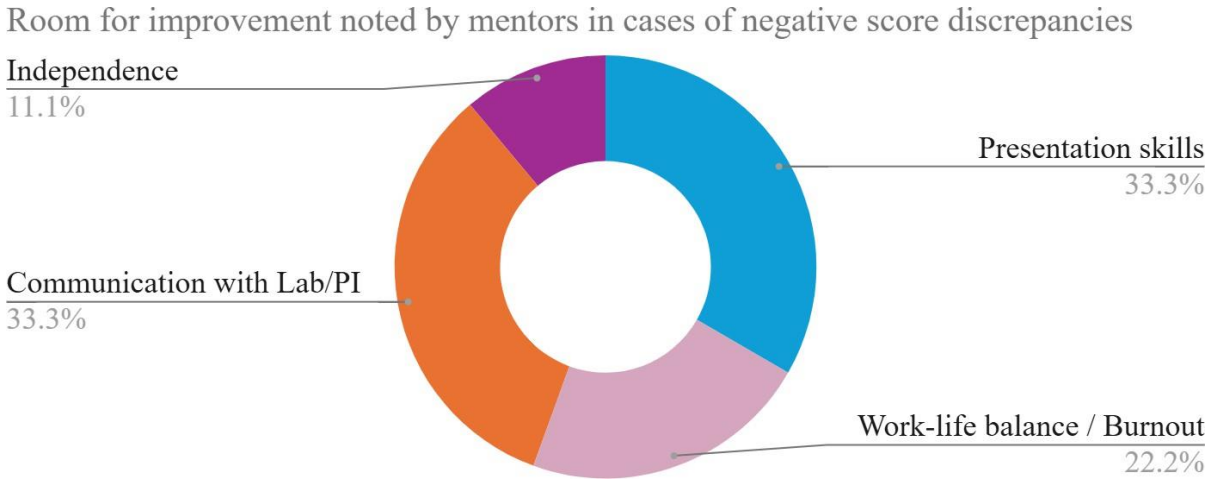


**Figure 3. Skills and qualities identified in the mentor feedback for cases of positive score discrepancies (mentors gave student a higher score than student gave themself). Each slice represents the percentage of mentor responses that were manually coded into the corresponding bin.**

Tables 3 and 4 list common themes mentioned in student and mentor responses. From Table 3, the most frequently occurring themes in student responses were related to publications, unexpected challenges which delayed timelines, and amount of data generated. In contrast, Table 4 shows that mentors more commonly highlight the time and effort that students invested into research, their familiarity with literature, perseverance through unexpected challenges, and collaboration with others in the lab. Mentors focused more on the process and the student growth, while students focused more on tangible outcomes. This may reflect that experienced mentors are less surprised by delays to research timelines, whereas students are less able to adapt to unexpected developments. This could also indicate that students concentrate on short-term output and project completion, while mentors are more invested in longer-term outputs which are dependent on student growth and development rather than short-term findings. This may be due to academic mentors motivating students by emphasizing traditional milestones like research publications, and suggests that setting short term goals with students could better align expectations.

**Table 3. Commonly occurring themes in student self-evaluation.**

| **Theme** | **Examples from responses** | **Count** |
|---|---|---|
| Research Output | Significant, data, optimize, progress, accomplish, new skills, finalized figures, new techniques | 48 |
| Deliverables | Conference, draft manuscript, submitted, abstract, publish, oral talk, writing paper, deliverable, publication-ready | 38 |
| Setbacks | Major setbacks, stalled, slow start, troubleshooting, failure, frustrating, data was limited, altering participation, pressured | 16 |
| Dedication | Spent a lot of time, overtime, adequate, giving myself grace, normal progress, experiments, try my best, normal standards | 15 |
| Independence | Independent, independence, understanding, promising, my own project | 11 |
| Consistency | Consistently, update(s), regularly | 7 |

**Table 4. Commonly occurring themes in mentor feedback.**

| Theme | Examples from responses | Count |
|---|---|---|
| Consistency | Steady, consistent, progress, progressing | 12 |
| Deliverables | Figures, draft, paper, thesis, manuscript, conference, talk | 12 |
| Independence | Took initiative, juggling, strides | 9 |
| Dedication | Time and effort, desired outcome, tons of work | 9 |
| Perseverance | Persevering, switching projects, unforeseen obstacles, resolving, nitty gritty | 7 |
| Growth | Contribute, apply, learned methods, literature review, adjust methods, helping labmates, scientific maturity | 7 |

These preliminary results indicate some fundamental differences in priorities and perceptions of research performance between students and their mentors. However, there are several limitations to be noted. Firstly, the provided mentor feedback and scores are shared with the students; because of this, mentors may be biased to give more positive than negative feedback in order to maintain a positive relationship with their students. Another limitation is the selection bias which arises since all the students surveyed are participants in a selective research program offering a wealth of resources, support, and mentorship which are not necessarily as accessible to undergraduate researchers outside of the program. In the future, it would be valuable to compare these results to responses from students doing research for credit or employed by a lab without the resources of a mentorship program. Finally, the students included in this study ranged from first-years performing research for the first time, to upperclassmen who have had prior experience (through the SyBBURE Searle Undergraduate Research Program or independently). Stratifying students by the number of terms they have spent in their lab or in the program may reveal insights into longitudinal changes in student perspectives and performance. Similarly, while demographic information, such as race and ethnicity or gender, was not considered in this study, the inclusion of these factors in the future may strengthen the analysis and yield more nuanced findings.

## Conclusion

In this study, discrepancies between student and mentor feedback were analyzed to identify areas of miscommunication or misunderstanding between students and mentors. We observed that student and mentor performance scoring was generally aligned, although students tended to slightly underestimate their performance. Content analysis of survey responses showed that students had a tendency to focus on tangible output and adherence to their research timeline when discussing their performance, while mentors primarily remarked on students' commitment

and scientific growth despite unexpected challenges or delays. In addition, it was found that communication and presentation skills were the most commonly mentor-reported areas upon which students could improve. In the future, these findings may be used to inform approaches to undergraduate research experiences and mentorship for improved student outcomes.

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