Engineering Student and Faculty Perspectives on Undergraduate Research Experiences

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Abstract

Surveys and interviews were conducted among faculty and students regarding undergraduate research experiences (URE) in an engineering program at an urban research university. In the student survey, students were asked to self-identify if they felt that their URE had provided them with 11 potential benefits. In the faculty survey, faculty were asked whether they thought that each benefit should be expected of a student participating in a URE. The interviews offered a greater understanding of student and faculty viewpoints with regards to UREs.

The results of the study illustrated that students and faculty have somewhat different perceptions of the benefits to be gained by participating in a URE. For example, students were often using the URE to develop skills that would help them acquire a job as an engineer in industry after graduation rather than as a direct pathway to graduate school. Additionally, large percentages of students identified as having received benefits from the URE that would help them in an engineering career. These were not always anticipated by faculty, and faculty may be able to improve UREs for many students by emphasizing in the URE the development of these skills for work in industry.

Introduction

Many interventions have been implemented to increase the number of students with STEM degrees graduating in the United States and to improve the skills of those graduates. One of these interventions is to engage undergraduate STEM students in research activities. Two of the reasons often given for encouraging participation in undergraduate research are to improve student retention in a discipline and to increase the number of students who pursue graduate studies. (Mogk, 1993; Morley, et al., 1998; Schowen, 1998; Seymour, et al., 2004; Zydney, et al., 2002a) One factor that can lead to an increased number of graduates is to increase retention rates; increasing retention would then lead to an increased number of graduates. If the undergraduate students enjoy their research experiences, they may be more likely to choose to pursue graduate studies. But not all students, particularly in a discipline such as engineering, are interested in immediately pursuing graduate studies after completing their undergraduate degree. For such students, a further benefit that might be attained with undergraduate research activities is to improve the skills of the students in preparation for careers in industry as engineers.

A study on student and faculty perceptions of the benefits of undergraduate research experiences (UREs) has been conducted in the engineering and computer science programs (hereafter grouped as "engineering") at an urban research university in the United States. Historically, the large majority of undergraduate students graduating from the engineering programs at this school do not directly enter graduate school; most pursue jobs in industry. Most of the students work at least part-time while undergraduates, and relatively few complete their studies in 4 years, with most requiring 5 or 6 years to graduate. Therefore, the focus of this study is on students who generally are not looking at participating in a URE as a way to bolster a graduate school application, but rather as a means to improve their resume for a job in industry or as a convenient part-time job. As a research institution, most engineering faculty have active research programs, and many mentor undergraduates in UREs. Typically, about 70 undergraduate students each year in engineering participate in research projects. Therefore, the surveyed faculty have often mentored multiple undergraduate students in their research projects.

In this paper, the research methodology used in this project is discussed, followed by a presentation of the study results. From this, student perceptions of the benefits of participating in undergraduate research are compared to the expectations of the faculty. This will show that there is some disconnect between faculty and student perceptions. Better understanding of the student views can provide faculty with a different approach when designing a URE and mentoring undergraduate researchers in engineering programs. It should be emphasized that this study is not attempting to determine what benefits were actually achieved by students, but rather focuses on studying the perceptions that students and faculty have about the benefits of UREs.

Background

There have been many studies that have looked at undergraduate research experiences for STEM students, although few have considered the benefits of UREs perceived by students and expected by faculty for a large number of students. Most of the studies that have included information on the perceptions of students or faculty have considered very small numbers of students and faculty, which can hinder the widespread applicability of their conclusions.

As mentioned, two of the more common reasons for increasing URE participation by students is to increase student retention and motivate more students to pursue graduate studies. (Burrows & Borowczak, 2019; Mogk, 1993; Morley, et al., 1998; Schowen, 1998; Seymour, et al., 2004; Zydney, et al., 2002a) Ideally, students engaged in meaningful research become more connected to their discipline and gain a deeper understanding of the material they are learning as students. In some cases, this has been shown to increase the retention of students if they begin research early in their undergraduate careers. But students are affected differently by UREs, as other studies have suggested that some undergraduate students change disciplines after performing undergraduate research due to their increased knowledge of their field and having experienced typical research set-backs. (Willis, et al., 2010) It has also been suggested that the connection between the faculty member's research interests and student's research interests can play an important role in determining a student's future interest in graduate studies. (Richard & Yoon, 2018)

Other benefits that have been associated with engineering students in engaging in UREs include the students (1) gaining confidence in their abilities, (2) gaining an understanding of the research process, (3) improving communication skills, (4) improving team-work skills, (5) developing problem-solving skills, and (6) developing critical thinking skills. (Ghanat, et al., 2018; Kardash, 2000; Zydney, et al., 2002b) Many of these attributes are seen as necessary outcomes of an engineering program as included in the ABET accreditation criteria. (ABET, 2023; Lee, 2019) This indicates that some of the potential benefits UREs are helpful in the professional development of students interested not just in graduate school but in careers in industry with only a bachelor's degree.

There have been many studies focused on students who participate in summer NSF-funded Research Experiences for Undergraduates (REU) programs, such as by

Willis, et al. (2010), Hung, et al. (2010), Mahmud and Xu (2010), and Willits and Barnett (2010). A large number of students engaged in undergraduate research across a wide range of disciplines at the University of Michigan were studied by Hathaway, et al. (2002), and Nagda, et al. (1998). Seymour et al. (2004), and Hunter et al. (2007), studied students engaged in science research as undergraduates at a liberal arts school. Underrepresented minority undergraduate students in URE science programs were studied by Kang, et al. (2011). Marincel Payne, et al. (2019) studied a summer undergraduate research program at an undergraduate institution, surveying students and faculty on their experiences. They found that students improved communication and data presentation skills through their programs and developed more confidence in conducting research. In general, these studies found that students were impacted positively by their UREs; more details on some of the individual studies can be found elsewhere. (Reisel, et al., 2015)

A survey of thousands of undergraduates who had UREs in many STEM disciplines was done by Russell, et al. (2007) This study also gathered the opinions of faculty and graduate student mentors. Many of the students in this study were likely stronger academically than many of the students in this current study. Russell, et al.,(2007) concluded that participating in a URE increased students' confidence and raised students' awareness of graduate school. Additionally, the number of these students who expected to obtain a Ph.D. noticeably increased after the URE.

These and other studies provide valuable information, but also illustrate the limitations of previous work in studies on STEM UREs. Many of the studies focus on high-achieving students in highly competitive summer REU programs. As mentioned, such students may not be representative of mainstream engineering students who may not be able to participate in such programs due to financial or academic reasons. A focus on summer research activities may not closely replicate the experiences of students who do their UREs during the academic year when the URE must be balanced with coursework. While some studies considered large number of students, many of the studies considered a very small number of students; this limits the significance of the results. Many of the studies on STEM students have concentrated on students in the physical sciences, and these students may have more limited career options with a B.S. degree than do engineering and computer science students. Therefore, a larger percentage of students in the physical sciences may be focused on developing skills necessary for graduate school, whereas many engineering students may be more interested in developing skills that will help them secure a job in industry upon graduation. The work from the study described in this paper attempts to fill some of the resulting gaps in our understanding of the benefits and impacts of UREs on students in engineering and computer science.

Number	Potential Benefit
1	Developed my critical thinking skills
2	Developed my communication skills
3	Developed my problem-solving skills
4	Learned how to work independently
5	Learned how to work as part of a team
6	Learned how to conduct a research project
7	Improved my relationship with faculty and/or other students
8	Increased confidence in my research skills
9	Increased confidence in becoming a successful engineer/professional
10	Academic coursework became more relevant
11	Developed/increased interest in pursuing graduate studies

Table 1. Potential benefits of a URE presented to students in the on-line survey.

Research Methodology

Considering the benefits suggested in previous studies, one survey was developed for students who had participated in a URE, and a second survey was developed for faculty who had served as mentors to undergraduate students in their research projects. These surveys were designed to gauge the respondents' perceptions of UREs. Regarding the student survey, the survey was sent (on-line) to 110 students who had recently participated in undergraduate research in the college. Forty-one students completed the survey, representing a 37.3% response rate. The survey collected demographic information on the students, including age, gender, race and ethnicity, major, GPA, parents' educational background, and year in school. Students were also asked to identify their faculty mentor and the duration of their URE. Students who worked for more than one faculty mentor were asked to respond to the questions separately for each experience. Students were asked how much time they spent weekly on their project, who they primarily interacted with (faculty, graduate students, or undergraduate students), and the general nature of their work (experimental, theoretical, computational, clerical, or other). Finally, students were asked to identify the benefits that they believed they had gained from participating in undergraduate research. The options that were provided as potential benefits are listed in Table 1. These potential benefits can be grouped into broad categories. Benefits 1 – 6 focus on skills that can help the student in many future career paths. Benefits 7 – 9 speak more towards student confidence and feelings of belonging with peers. Benefits 10 and 11 are concerned primarily with a student's relationship with academia.

In the survey, students were provided with an opportunity to volunteer to be interviewed in detail about their experiences. Approximately half of the student respondents volunteered to be interviewed, and 12 students were selected for detailed interviews. The selected students displayed diversity in gender, GPA, and majors; an insufficient number of survey responses were from students in underrepresented minority groups to provide significant diversity based on race and ethnicity. The primary questions posed during the interviews are listed in Table 2, although the interviewer did adapt questions to follow-up on student responses during the interviews. The interview responses were grouped into several themes including student motivation for pursuing a URE, student's daily work experience, student's perception of support from supervisor, student's professional development, and student's perception of the value of URE. This information was then used to provide context to the survey results.

Faculty in the college were invited to respond to a survey regarding their expectations for students participating in UREs. The questions asked in the survey were very similar to those in the student survey. However, instead of gathering demographic information, the survey concentrated on determining the extent of the faculty member's experiences with working with the students in the URE. Seventy surveys were sent out, and responses were received from 16 faculty, representing a response rate of 23%.

In the survey, faculty members were asked to choose which of the benefits listed in Table 1 that they expected as outcomes for students participating in UREs. Faculty members were also provided the opportunity to be interviewed in depth regarding their experiences with UREs. The format and questions of the detailed interviews were similar to those with the students. Interviews with five faculty members were completed. These interviews provided some additional insights into the faculty members' perspectives on UREs.

Results and Discussion

Figure 1 presents the results of the student survey. The benefit numbers correspond to those listed in Table 1. The

Number	Question
Q1	Why did you choose engineering as a major?
Q2	How did you learn about undergraduate research experiences (URE)?
Q3	What did you hope to get out of your URE?
Q4	What was a typical day like?
Q5	Tell me about the projects you worked on and the tasks assigned to you.
Q6	What stands out about this experience when you think about it?
Q7	Who did you mostly interact with during the project? Who was guiding you? How was your relationship with him/her/them?
Q8	What were the best parts of the experience? The worst parts?
Q9	What do you feel you learned in your URE? (Research topic, major, research in general)
Q10	What have you learned about yourself?
Q11	What other benefits do you feel you got from the experience?
Q12	What skills do you think you developed in the experience?
Q13	Has the experience made you think differently about your decision to become an engineer?
Q14	How has the URE influenced your career goals?
Q15	Based on your experience, would you recommend a URE in engineering to all or some of your fellow students? Why?
Q16	What would have made your URE better? What can be done to improve UREs for other students?

Table 2. Primary in-person interview questions posed to the students during the detailed interviews.

results give the percentage of students who think that they received the benefit through their URE. It should be noted that these are self-reported benefits and are based on the students' own perceptions of their abilities and skills, and have not been independently measured objectively.

Each benefit was identified by at least 60% of the students as one that they believed that they had received from their URE; thus from the students' perspectives, all of these benefits should be considered as a benefit that the majority of students in UREs thought they received.

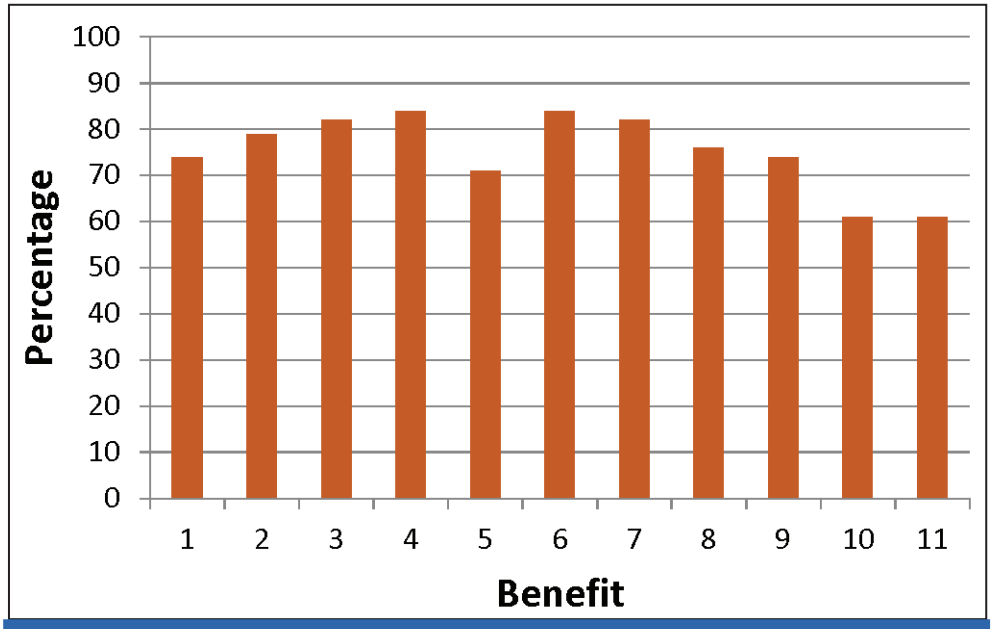

Figure 1. The percentage of students (n=41) who responded in the student survey that they believed they received the particular benefit from their URE. The benefits numbers correspond to the benefits listed in Table 1.

Several of the benefits were identified by more than 80% of the students as ones that they believed that they had gained. These benefits are (3) Developed my problem solving skills, (4) Learned how to work independently, (6) Learned how to conduct a research project, and, (7) Improved my relationship with faculty and/or other students. The benefits that were identified as gained by the fewest number of students are (10) Academic coursework became more relevant; and (11) Developed/increased interest in pursuing graduate studies; both of these were cited by 61% of the respondents. The 61% was 10 percentage points lower than any other benefit. While still a significant percentage, a considerably smaller percentage of students were self-identifying receiving these benefits than the other nine benefits. It can be interpreted that these two benefits were less commonly thought to be received by the students.

While the survey doesn't independently evaluate the attainment of these benefits by the students, the student survey results are consistent with the idea that, in general, UREs potentially provide the listed benefits to the majority of students. Considering the distribution of the benefits into the broad categorizations discussed above, more students in this study found that UREs were beneficial to skill development rather than being impactful on relating to academics or altering a career path. With many students, the strategy of using UREs to help improve retention of students through making coursework more relevant or to increase the number of future graduate students will work; however, it appears that even more students will find the UREs beneficial for skill development and confidence building as they prepare for their careers. It can be noted that improvements in skills and confidence may also help improve retention of students.

The survey results can also be used to compare how the students perceived how the URE was structured: working independently vs. working as part of a team (Benefits 4 and 5). In the survey, 84% indicated that the URE helped them learn how to work independently, while 71% indicated that the URE helped them learn how to work in a team. This is a substantial percentage of students identifying these benefits, and so using UREs to develop these skills appears, in general to be successful. But these results show that if a primary goal of using UREs is to develop teamwork skills, some faculty may need to examine the way they have designed the URE so as to further increase the percentage of students who feel that they improve their teamwork skills through the URE.

The in-person interviews provided additional insights into the students' perceptions of the UREs. Some of the more common themes identified from the student interviews are listed below.

1) Most of the interviewed students interviewed did not plan to be involved in a URE when they started college.

2) Most of the students pursued a URE to gain engineer-

ing experience and develop skills. Half of the interviewed students specifically cited a URE as an alternative to an internship or co-op in industry.

3) Eight of the 12 interviewed students viewed the URE as a path to graduate school, and four students identified financial reasons as the reason behind doing undergraduate research. This latter result suggests that providing reasonable financial incentives may be necessary to encourage a notable percentage of students to engage in a URE.

4) The interviewees identified performing a variety of tasks, including data collection, data analysis, computer-related tasks, and conducting literature reviews; these are tasks expected from a research experience. However, five of the 12 students indicated that they performed administrative work, which is generally not a productive use of a URE.

5) There was great variability reported on the interaction with and guidance from their mentors. Generally, students preferred more (but not excessive) guidance and instruction.

6) Students primarily worked with graduate students, and most of those that worked with graduate students found this a positive experience.

7) Some of the students were able to attend conferences and work on preparing publications, and these students found these activities very beneficial in terms of improving communication skills and becoming more familiar with their profession and research activities in general.

8) Most of the students interviewed found that the URE helped with their professional development, with approximately half the students expressing that the URE helped clarify their career goals. Most students found that they did develop applied engineering skills through their URE.

9) All of the students interviewed thought that the URE was a worthwhile experience, and most would recommend that others participate in an URE.

From the survey and interview results, there are several findings to emphasize. (1) It appears that most of the students thought that the URE helped them develop their applied engineering skills. (2) If designed to result in the preparation of conference presentations or journal articles, UREs provide an opportunity to develop the communication skills of participants. (3) For students considering graduate school, a URE should give the students a chance to experience research before committing to graduate school, potentially helping to clarify their plans. (4) For the students in this study not considering graduate school before the URE, the experience did not act as a motivation for most students to change their plans.

The results from the faculty survey are shown in Figure 2, which contains the percentages of the 16 respondents who selected a benefit as one that they expected students to receive in a URE. It should be noted that statistically it is difficult to directly compare the percentages between the faculty survey and the student survey. However, it can be useful to compare how often students and faculty noted a particular benefit in comparison to other benefits.

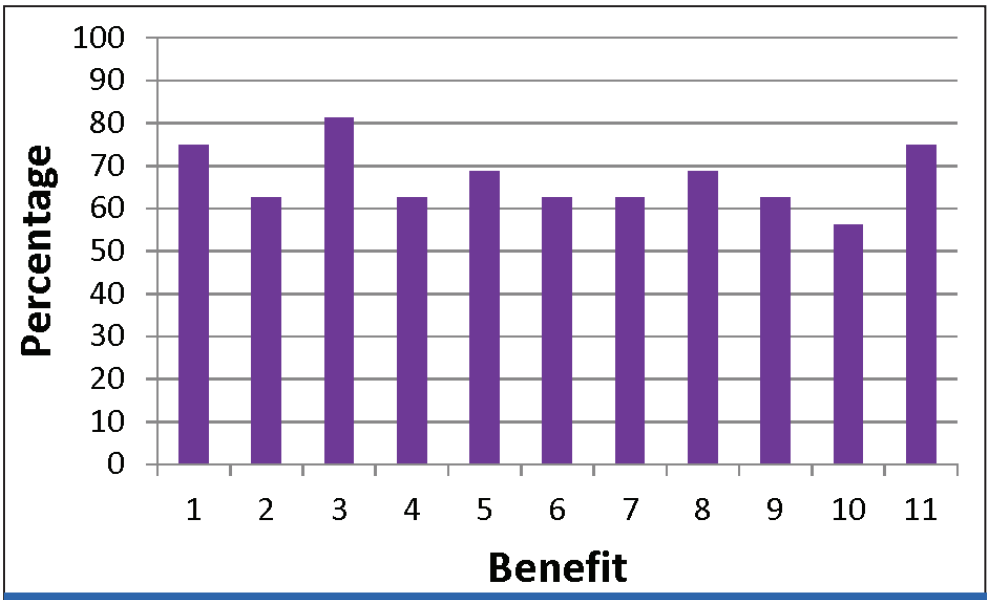

Figure 2. The percentage of faculty (n=16) who responded in the faculty survey that they expected that a particular benefit should be received by students participating in a URE. The benefit numbers correspond to the benefits listed in Table 1.

Looking at the faculty expectations of benefits, each of the perceived benefits was expected by at least half of the respondents. The benefit that was expected by the largest percentage of faculty was #3 (Develops a student's problem-solving skills). The next most-expected benefits were #1 (Develops critical thinking skills) and #11 (Develops or increases interest in pursuing graduate studies. This does differ somewhat from that reported by being gained by the students; while #3 was nearly the most frequently cited benefit received in the survey from the students, #1 was in the bottom half of the benefits identified as received by students. Additionally, a relatively low percentage of students saw the URE as increasing or developing their interest in graduate studies. So, for some benefits, faculty may be expecting UREs to produce one outcome but fewer students are finding that those outcomes occur.

Benefits #4 (Working independently), #6 (Learned how to conduct a research project) and #7 (Improved relationship with faculty and/or other students) were among the lowest in terms of percentage of faculty expecting students to receive the benefit, but more than 80% of the students identified that the UREs provided did provide these benefits. This suggests that some faculty may not recognize very attainable potential benefits that can be gained from UREs by students. Conversely, a relatively large percentage of faculty thought increased teamwork skills (#5) was an expected benefit, but this was one of the lesser cited benefits by students. This further supports that some existing UREs might not involve as much teamwork as faculty expect.

The faculty interviews also provided some additional insights from the perspective of faculty. Some of the more common themes are discussed below.

1) Several faculty members stressed that UREs provide an opportunity to teach students about safety protocols in the labs, and the importance of following these protocols.

2) There was a general expectation that students would become more self-sufficient during their URE.

3) The interviewed faculty thought that UREs were primarily a way for students to gain experience as opposed to being a way to earn money.

4) Four of the five faculty interviewed saw the URE as a way for students to make themselves more attractive to future employers upon graduation, rather than as an entry point for pursuing graduate studies. These four faculty wanted to tailor the URE to best help the students in getting a job in industry. This result also shows that the faculty who were interviewed may have tended to be in the minority of the survey respondents with regards to Benefit #11.

5) The faculty interviewed cited seeing students develop both soft skills (confidence, responsibility, leadership) and applied engineering skills in their UREs.

Table 3 orders each benefit from the two surveys, based on the percentage of respondents who cited that particular benefit: the benefit ordered first corresponds to the benefit cited by the largest percentage of students or faculty. We can interpret the ordering as the strength of the benefit; a higher ordering corresponds to either a stronger expectation for that benefit by the faculty or as a stronger perception of achievement by the students. While Figures 1 and 2 show that all the benefits were either received by a majority of students or expected by a majority of faculty, Table 3 allows for a quick comparison

Benefit (Table 1)	Student Ranking	Faculty Ranking
1	7	2
2	5	6
3	3	1
4	1	6
5	9	4
6	1	6
7	3	6
8	6	4
9	7	6
10	10	11
11	10	2

Table 3. Rankings of each benefit as derived from the percentages of students responding that they had received that benefit in a URE, and faculty identifying that they expected that benefit to be received by students through a URE. A higher ranking corresponds to a larger percentage of respondents citing that benefit. The benefit number corresponds to those listed in Table 1.

of how each benefit ranked in comparison to the other benefits for each group. It can be seen that there are some considerable disparities between the two groups. With better faculty understanding of how students view UREs, faculty may alter the design of the UREs that they oversee to further enhance the largest benefits of UREs for the students. For example, if the student is interested in preparing for an entry-level engineering job in industry, faculty should design the URE to emphasize skill development for that purpose, rather than trying to entice the students to attend and better prepare them for research in graduate school. Results of this nature have been noted elsewhere. (Reisel, 2008)

Considering all of the results presented, it appears that there is some disconnect between the two groups when it comes to identifying the benefits of UREs that can be experienced by students. This is also likely an effect of what each group views as the purpose of the URE. Many of the students may have been looking at using the URE for their professional development to prepare for jobs in industry upon graduation while many of the faculty may have been looking at the students as preparing for graduate studies. These are significantly different views of the purpose of the URE. Considering that undergraduate research does appear to offer benefits that are desired by industry (improved communication skills, confidence, improved problem solving skills) (Reisel, et al., 2016), more faculty may want to consider tailoring the UREs towards meeting the goals of the students participating in the project by focusing on the development of skills sought by industry in new graduates.

Conclusions

In this work, we have found that students and faculty perceive the attainment of various benefits through participating in an undergraduate research experience somewhat differently. At least half of the students viewed each proposed benefit as having been gained, and at least half of the faculty identified each proposed benefit as being expected outcome of a URE. But there were differences between the strength of expectation of benefits of the faculty and the strength of gaining the benefits by the students.

From this, it may be possible to reconsider the purpose of many UREs. If students beginning a URE are not particularly interested in immediately attending graduate school upon graduation, faculty could design UREs to focus on the development of the professional skills needed by students as they prepare for careers in industry. For students expressing interest in graduate school, the faculty can design the UREs to develop the research skills needed by successful graduate students. Overall, using undergraduate research experiences for its potential benefits beyond preparing students for research-based careers may make expansion of UREs more valuable to more students.

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