

REU Program Evaluation: A Valuable Tool for Studying Undergraduate Socialization in Engineering

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“This [REU experience] is exactly what I envisioned when I was younger and I thought, you know, I want to be a professional scientist.”--REU Intern

This Work in Progress paper introduces research into whether and how a summer research experience affects undergraduate students’ sense of identity and belonging in engineering, their understanding of research as a process, and their development of research-related academic and professional skills. We draw from theories of situated learning [1] and socialization into professional communities [2] to ask what and how students learn during an NSF-funded Research Experience for Undergraduates (REU) summer program in materials science and engineering.

REU program evaluation data can offer valuable insights into student learning, but these data are rarely analyzed with regards to research questions. Typically, they are used for the evaluation and then discarded. This is a missed opportunity. The NSF requires REU programs to evaluate how well they achieve their goals [3]. As the evaluators for a three-year REU site at a medium-sized public research university in the United States, we pushed the boundaries of traditional program evaluation to generate data that can also be used to address research questions, in addition to conducting cumulative and summative evaluation of the program’s effectiveness. We propose here that evaluation data can be valuable for research, and likewise that designing evaluation instruments with research questions in mind can produce a richer evaluation. To access our research question, we designed new quantitative and qualitative instruments, included here as an appendix for other researchers to use. In this paper, we share our design process for these instruments, our research methodology (including how we achieved IRB approval to study evaluation data), and preliminary results from one summer cohort’s survey and interview responses.

REU sites typically evaluate their programs with quantitative surveys (e.g., [4], [5]), even though each site tends to serve only a few students. (For example, ours will serve about 30 students across three years.) Surveys that were designed for large-scale participant pools cannot capture nuances of students’ experiences, especially with REU programs’ comparatively low participant numbers. As a result, the effects of research experience on these students’ learning and identity are difficult for engineering education researchers to access. This is particularly problematic because many REU sites, including ours, are designed to serve marginalized populations in engineering and science. In our view, not studying these students’ experiences because their sample size is small is inequitable, and contributes to the existing knowledge gap about marginalized populations’ experiences and success in engineering. Designing evaluation methods to also allow research into student learning and identity formation is a powerful way to address this inequity.

Our aim was to understand students’ individual research experiences alongside their conceptions of what science is and their self-assessments of identity, sense of belonging, and

professional skills. These insights serve as indicators of more valuable outcomes of learning and professional development than the common over-focus in REU program evaluation on whether interns plan to attend graduate school.

METHODS

The research instruments included pre/post surveys and pre/post semi-structured interviews, and they were designed to be both practical and to capture rich insights into students' experiences and ways of thinking about research. To create them, Wylie drew from existing instruments commonly used for REU evaluation (i.e., [4]-[7],) as well as instruments that capture students' views of the nature of science (i.e., [8]-[10]). Our instruments needed to be brief to accommodate REU interns' busy days. Wayland conducted a pre interview and a post interview with each student, which took about 10 minutes and 15 minutes respectively [see Appendix]. Some questions were repeated pre and post, while others were specific to each interview. Wayland also asked students to complete online pre and post surveys that took 5-10 minutes each [see Appendix]. For both pre and post surveys, we asked a range of questions that addressed their sense of belonging to the field and their comfort level with specific research-related tasks. And for the post survey, we added questions about their experience at the REU, covering how much they participated in specific research-related activities and their satisfaction with different elements of the program. The survey instruments were not intended to be statistically reliable or valid, due to our interest in individual experiences and our small sample size. Instead, they allow us to compare each student's pre and post responses to look for changes, and to get an overview of any general patterns among students' responses.

Wylie and Wang used the program's first summer (2022) as a pilot study to assess how well the instruments captured the data we were interested in, and how feasible the data collection process was. We aggregated the numerical survey responses and used basic descriptive statistical measures to analyze trends in the data. While not statistically sophisticated, we observed measurable differences in responses between the pre-REU survey and the post-REU survey. We believe the differences observed in the pilot study responses capture crucial aspects of the students' experiences in the REU. We compared interview responses across students and between each student's pre and post interviews to look for relevant themes. From a practical standpoint, administering the surveys and interviews, which took around 10-15 minutes each, was manageable for us and not a great inconvenience to the students. During the process, students did not appear confused or bothered by the questions posed to them, and their responses addressed our research questions and seemed sincere and detailed. Accordingly, the only change we made for Year 2 was to remove a set of survey questions about students' emotional responses to doing research due to poor analyzability of the responses in the pilot and feedback from some students during the post-interview that they weren't sure how to answer those questions.

To use evaluation data for research requires IRB approval, in most cases. We worry that the IRB application process may pose a barrier to REU leaders, who are typically scientists and engineers who may not have experience with human subjects research. Here we offer guidance

based on our experience pursuing IRB approval for research on evaluation data, although IRB policies vary by institution. We did not apply for IRB approval for Year 1's data collection because we wanted to pilot-test our methods first. To prepare for Year 2, Wylie worked with an IRB staff member through multiple revisions of a protocol. Our IRB staff were primarily concerned about three issues that we imagine are common:

- Coercion: Participants must join a research study willingly. But REU interns are required to complete data collection for evaluation purposes. The IRB worried that this requirement might make students feel forced to let us use their evaluation data for research. On the other hand, we argued, the data would be collected regardless and students could always decide to leave the study after the program ends if they decide they don't want their interview or survey responses to be studied.
 - o There is also a general concern that students might feel pressured to participate in research conducted by their own professors or mentors, such as a fear that they could be punished through grades or poor treatment if they do not consent. We mitigated this problem by keeping the evaluation team separate from the REU program's leaders and faculty mentors, and by keeping students' decisions to participate in the research confidential.
- Confidentiality: In addition to typical protections, participants' identities must also be kept confidential from their research mentors. Accordingly, we carefully deidentified the survey and interview data (e.g., when students mentioned their demographics or research projects).
- Consent: Wylie proposed asking students to sign consent forms to participate in the study. The IRB judged that this was unnecessary because the data would be collected from the students anyway (for evaluation), so using those data for research fell below the threshold for consent. Instead, we were to notify students by email that the data we collect from them for evaluation purposes will also be used for research purposes, and that they have the right to opt out of the research study at any time by telling us.

A particular challenge was clarifying that we wanted to re-analyze evaluation data to investigate research questions. We had hoped that this approach constituted a "secondary" use of existing data, which is a less-protected category of data than collecting interview and survey data. However, our IRB deemed our study not to be conducting secondary analyses. Nonetheless, we wonder if other IRBs might consider repurposing evaluation data (especially deidentified data) for research as a form of secondary or archival data, which typically involves a simpler IRB review. Every institution's IRB is different, but we hope these lessons learned help other researchers to make the most of evaluation data by re-using them for research.

RESULTS

In this preliminary analysis, we focused on trends that we think our methods most valuably capture and that are often missing from typical evaluation methods: 1) the extent to which students had an experience of "real" research and 2) their identity as a researcher and engineer. The survey questions focused on comfort level with research-related tasks showed a

marked improvement in what we consider to be higher-level research tasks. (Ten of 12 students responded to the pre survey, while nine responded to the post survey. Seven responded to both.) Initially, students reported they were “somewhat” or “very” comfortable in their ability to do general tasks such as “working independently,” “problem solving in general,” and “managing my time.” This is contrasted with their lower initial comfort levels in doing more specific—perhaps higher-level—research skills, such as “defending an argument when asked questions,” “identifying limitations of research methods and designs,” “understanding journal articles,” and “writing scientific reports and papers.” Following the REU program, however, the results showed a change. On average, they reported at least “quite a bit of improvement” in such skills as: “understanding the relevance of research to my coursework,” “identifying limitations of research methods and designs,” “understanding journal articles,” “analyzing data for patterns,” “discussing scientific concepts with others,” “conducting observations in lab.” Putting these data together, the students self-reported marked improvement in their comfort with these higher-level research tasks.

These marked improvements in comfort levels led us to focus on the quality of the research experience that the students had and how that experience affected their sense of belonging in the field. One clear strength of the program was that it gave students a rich experience of what daily life is like for a researcher. The “comfort level” responses described above clearly suggest that students had a profound research experience. We can also draw on other survey responses about their experience to support this view. In the post survey, all of the respondents said that they did “A great deal” (5 on a 5-point likert scale) of “Real-world research.” Similarly, all said that they “Feel like a researcher” either “A great deal” or “A fair amount” (5 and 4 on the scale, with an average of 4.44).

The evidence of a rich research experience also runs through the interviews. They all described in detail the wide range of things they did, often commenting on aspects of research they had not appreciated before the summer, such as the centrality of reading and responding to the field’s literature. One student in particular described how they learned another key skill being rigorous in keeping their lab notes:

I definitely learned a lot about keeping a lab notebook and working in the lab. That’s something that I’d never done before. So, learning how to be careful with samples and understand that, you know, if you make a mistake, you’ve got to write that down. You don’t just kind of keep moving on. Like, write it down, show that you’ve made a mistake and then repeat [the experiment]. ... Making sure that it’s clear which sample is which throughout my notes, especially for ... when I’m putting all this data together to present it. Making sure that I know exactly what’s what was a big issue, especially because I didn’t do that very well at the beginning.

This passage shows a hard-won lesson, one that could only come from an extended immersion in the daily practice of research.

For many of the students, this experience of research increased their sense of belonging to the field. For some, this experience of constantly learning, of being exposed to new ideas and testing out new approaches, fed their eagerness to go into graduate school. Others expected to dislike research as being too abstract and disconnected from daily life but found they loved the day-to-day work of designing experiments, working with lab equipment, preparing samples, and taking & analyzing data. For a few students, on the other hand, the in-depth experience of research made them realize that they had no interest in becoming a researcher. Some did feel too distanced from the hands-on work of making things (but wanted to work as engineers in industry), while one student realized that they just had no interest in the field.

These are valuable insights that students gain about research in practice, demonstrating the variety of desirable learning outcomes that are missed by typical evaluation surveys or by considering grad school interest as a primary indicator of student learning or program success. For example, doing research alongside faculty and grad students prepares students to decide whether engineering works for them as a major and/or profession. An REU experience is an important source of information about life as an engineering graduate student that informs interns' decisions about pursuing grad school themselves. Some students say that grad school was mysterious and not on their radar before the REU program, but working closely with grad students and learning about their experiences made them consider grad school for the first time. Yet even if they decide to leave engineering, that decision is based on personal experience of research and not just guessing. Further, if they decide to stay in engineering, but go into industry research, that should be seen as a positive outcome.

DISCUSSION

Undergraduate research experiences are a rich site for studying learning, identity, and belonging. They are many students' first exposure to the everyday realities of doing research. The students of this REU cohort - and many other REU programs - do not come from institutions with abundant research opportunities, so their experiences can powerfully illustrate the value of undergraduate research for students' skill development, understanding of research practices, and learning about graduate school and other engineering career opportunities.

We propose here a methodology for simultaneously conducting program evaluation and research about undergraduate learning and socialization. To gather more nuanced data about students' experiences and their understanding of research and engineering, we expand beyond the traditional pre/post evaluation survey to include pre/post interviews. As always, responses to survey questions—no matter how well-phrased—can be ambiguous. The qualitative data help us better understand what those responses mean. For instance, in the post interviews, two students both said that they wanted to continue to get a master's degree, but did not want to continue into academia. On the final survey, however, they differed in their responses to the question: "To what extent do you agree with the following statements? - I feel like a researcher." On 1-5 Likert scale, one gave a 2 ("Somewhat disagree") and another gave a 4 ("Somewhat Agree"). Reading

their more in-depth interview responses, it seems that one viewed research more as the province of academia, while the other saw industry as a possibility for a research career.

As our initial results show, these methods capture valuable insights into students' experiences of "real" research and their sense of identity in engineering and research. In a future paper, we will compare our finished results with other researchers' findings. As we continue analyzing these data and collecting more data in summer 2024, we will follow additional emerging themes such as:

- How students perceive research and knowledge production
- How students conceptualize their own skills as relevant to engineering or research
- How students' sense of belonging and identity in engineering change after this research experience
- How interaction and communication with graduate student mentors contributes to student sense of belonging.

Further, this study raises questions that deserve future study, such as:

- How does mentoring undergrads impact grad students?
- How might training better prepare grad and faculty mentors to supervise REU students?
- Does doing research work contribute to students' perception of research as a human practice?

Given this ability to focus on the nuanced meanings that students draw from their experiences, we suggest that this method can better empower students from underrepresented groups, whose voices can be buried in large datasets of quantitative survey responses. We offered guidance on designing data collection practices to meet IRB ethical requirements for research. We hope these ideas can make it easier for engineering educators to study undergraduate research as a formative moment of socialization into engineering, whether as researchers or as professionals.

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APPENDIX: Pre/post survey and pre/post interview protocols

MSE REU 2023 pre-survey (exported from Qualtrics)

Q1 Welcome to the Materials Science & Engineering Research Experience for Undergraduates program at the [UNIVERSITY NAME]. We're glad you're here! This survey helps us evaluate how well the MSE REU program achieves its goals. We are NOT assessing you as an individual. Your responses are confidential, which means that only [EVALUATORS' NAMES] will know which responses are yours. We will share students' survey responses only in aggregate (i.e., as a group), not as responses from individual students and not with any names or other identifying information. Remember that we will also use your data in a separate research study about what students learn by doing research ([IRB NUMBER]). If you don't want your data to be included in the study, you can opt out by emailing us. This survey takes less than 10 minutes to complete, and you'll take a similar survey at the end of your REU program. Thank you for helping us improve this program for future students!

Q2 What's your name?

To what extent do you agree with the following statements?

Multiple Choice Question, for each question, participants are to select one of the given options:

- Strongly Disagree (1)
- Somewhat disagree (2)
- Neither agree nor disagree (3)
- Somewhat agree (4)
- Strongly agree (5)

(1) I feel like I belong in my college.

(2) I feel like I belong in my major.

(3) I feel like an engineer.

(4) I feel like a researcher.

How comfortable are you with doing the following tasks?

Multiple Choice Question, for each question, participants are to select one of the given options:

- Very uncomfortable (1)
- Somewhat uncomfortable (2)
- Neutral (3)
- Somewhat comfortable (4)
- Very comfortable (5)
- Don't Know or Not Applicable (6)

- (1) Problem-solving in general**
- (2) Analyzing data for patterns**
- (3) Identifying limitations of research methods and designs**
- (4) Understanding the relevance of research to my coursework**
- (5) Identifying social and ethical implications of my research**
- (6) discussing scientific concepts with others**
- (7) working collaboratively**
- (8) working independently**
- (9) Writing scientific reports or papers**
- (10) Defending an argument when asked questions**
- (11) Explaining my research project to people outside my field**
- (12) Conducting observations in a lab**
- (13) Using statistics to analyze data**
- (14) Understanding journal articles**
- (15) Managing my time**
- (16) Asking people for help**
- (17) Studying materials science & engineering**

Is there anything you'd like to explain about your answers? If so, please type here:

MSE REU 2023 post survey (exported from Qualtrics)

Congratulations on reaching the final week of [UNIVERSITY'S] Materials Science & Engineering REU program! This survey helps us evaluate how well the program achieved its goals. We are NOT assessing you as an individual. Your responses are confidential, which means that only [EVALUATORS' NAMES] will know which responses are yours. We will share students' survey responses only in aggregate (i.e., as a group), not as responses from individual students and not with any names or other identifying information. Remember that we will also use your data in a separate research study about what students learn by doing research ([IRB NUMBER]). If you don't want your data to be included in the study, you can opt out by emailing us. This survey takes less than 10 minutes to complete, and we'll ask you to take a similar survey in a year as a follow-up. Thank you for helping us improve this program for future students!

What's your name?

To what extent do you agree with the following statements?

Multiple Choice Question, for each question, participants are to select one of the given options:

- Strongly Disagree (1)
- Somewhat disagree (2)
- Neither agree nor disagree (3)
- Somewhat agree (4)
- Strongly agree (5)

- (1) I feel like I belong in my college.
 - (2) I feel like I belong in my major.
 - (3) I feel like an engineer.
 - (4) I feel like a researcher.
-

How much did you improve in the following areas as a result of your experience in the MSE REU program? Please use the following scale of "No improvement" to "A great deal of improvement."

Multiple Choice Question, for each question, participants are to select one of the given options:

- No improvement (1)
- A little improvement (2)
- Moderate improvement (3)
- Quite a bit of improvement (4)
- A great deal of improvement (5)
- Don't Know or Not Applicable (6)

- (1) Problem-solving in general
- (2) Analyzing data for patterns
- (3) Identifying limitations of research methods and designs
- (4) Understanding the relevance of research to my coursework
- (5) Identifying social and ethical implications of my research
- (6) discussing scientific concepts with others
- (7) working collaboratively
- (8) working independently
- (9) Writing scientific reports or papers
- (10) Defending an argument when asked questions
- (11) Explaining my research project to people outside my field
- (12) Conducting observations in a lab
- (13) Using statistics to analyze data
- (14) Understanding journal articles
- (15) Managing my time
- (16) Asking people for help
- (17) Studying materials science & engineering

During the MSE REU program, *how much* did you do each of the following?

Multiple Choice Question, for each question, participants are to select one of the given options:

- None (1)
 - A little (2)
 - Some (3)
 - A fair amount (4)
 - A great deal (5)
-
- (1) Engage in real-world research
 - (2) Feel like a researcher
 - (3) Try out new ideas or procedures on your own
 - (4) Attend meetings of your research group
 - (5) Feel responsible for the project

- (6) Feel like you belong in the research group**
 - (7) Build a professional network of mentors and peers**
-

Please rate the following aspects about your experience in the MSE REU program:

Multiple Choice Question, for each question, participants are to select one of the given options:

- Poor (1)
- Fair (2)
- Good (3)
- Excellent (4)

- (1) My working relationship with my research advisor (i.e., a faculty member)**
 - (2) My working relationship with my research mentor(s) (i.e., the postdoc, grad student, technician, or other people you worked with closely)**
 - (3) The amount of time I spent doing meaningful research**
 - (4) The research experience overall**
-

How satisfied were you with the following aspects of the environment of the MSE REU program?

Multiple Choice Question, for each question, participants are to select one of the given options:

- Very dissatisfied (1)
- Somewhat dissatisfied (2)
- Somewhat satisfied (3)
- Very satisfied (4)

- (1) Support and guidance from my research advisor and mentor(s)**
 - (2) Support and guidance from other research group members**
 - (3) Support and guidance from program staff**
 - (4) Group social activities**
-

Is there anything you'd like to explain about your answers? If so, please type here:

Is there anything else you'd like us to know about your experience in the MSE REU program?

MSE REU pre-interview protocol
(9 questions, about 10 minutes)

I am [EVALUATOR'S NAME], a social scientist and a professor at [UNIVERSITY]. My job is to evaluate how well this REU program goes this summer. To do that, I'm going to interview you today for 20 minutes, and you'll take a 10-minute online survey. Your responses are confidential, which means that only I will know which responses are yours. I will share your interview and survey responses only in aggregate (i.e., as a group), not as responses from individual students. Remember that I will also use your data in a separate research study about what students learn by doing research ([IRB NUMBER]). If you don't want your data to be included in the study, you can opt out by emailing me.

I'd like to record our conversation so that I capture your words accurately. Then I'll transcribe the recording and then delete the recording. Is it ok with you if I record? Thanks, NAME, it's recording now.

1. Why did you choose to do research this summer? Why this program? Why MSE?
2. Have you done research before? By research, I mean outside of class, so for example as an independent study, in an internship, working in a lab or industry, etc.
 - YES: Tell me about it. (Why did you choose to do it? What did you do? What did you learn? How did it go?)
 - NO: Why not?
3. What do you hope to learn in this REU program?
4. What do you expect doing research in this REU program to be like?
 - What are you looking forward to?
 - What are you worried about?
5. After you graduate, what do you hope to do next in your career?

The next four questions are to find out how you think about research. There are no right or wrong answers.

6. What types of activities do researchers do to learn about the world?
7. How do researchers decide what and how to investigate?
8. What, in your view, is research?
9. About 65 million years ago, the dinosaurs became extinct. Of the hypotheses formulated by scientists to explain the extinction, two enjoy wide support. The first, formulated by one group of scientists, suggests that a huge meteorite hit the earth 65 mya and led to a series of events that caused the extinction. The second hypothesis, formulated by another group of scientists, suggests that massive and violent volcanic

eruptions were responsible for the extinction. How are these different conclusions possible if scientists in both groups have access to and use the same set of data to derive their conclusions?

MSE REU post-interview protocol
(8 questions, about 15 minutes)

I am [EVALUATOR'S NAME], a social scientist and a professor at [UNIVERSITY]. My job is to evaluate how well this REU program goes this summer. To do that, I'm going to interview you today for 20 minutes, and you'll take a 10-minute online survey. Your responses are confidential, which means that only I will know which responses are yours. I will share your interview and survey responses only in aggregate (i.e., as a group), not as responses from individual students. Remember that I will also use your data in a separate research study about what students learn by doing research ([IRB NUMBER]). If you don't want your data to be included in the study, you can opt out by emailing me.

I'd like to record our conversation so that I capture your words accurately. Then I'll transcribe the recording and then delete the recording. Is it ok with you if I record? Thanks, NAME, it's recording now.

1. Tell me about the research you did this summer.

Ask these follow-up questions if they don't answer them on their own:

- what is the purpose of your research?
- did doing research match your expectations?
- what surprised you about doing research this summer?
- what went well?
- what didn't go well?
- who did you work with? Mentors, peers?
- when you needed help, what did you do?

2. What do you think you've learned in this REU program?

-about research, MSE, yourself...

3. After you graduate, what do you hope to do next in your career?

The next four questions are to find out how you think about research. There are no right or wrong answers.

4. What types of activities do researchers do to learn about the world?

5. How do researchers decide what and how to investigate?

6. What, in your view, is research?

7. About 65 million years ago, the dinosaurs became extinct. Of the hypotheses formulated by scientists to explain the extinction, two enjoy wide support. The first, formulated by one group of scientists, suggests that a huge meteorite hit the earth 65 mya and led to a series of events that caused the extinction. The second hypothesis, formulated by another group of scientists, suggests that massive and violent volcanic

eruptions were responsible for the extinction. How are these different conclusions possible if scientists in both groups have access to and use the same set of data to derive their conclusions?

8. Feedback on the evaluation: pre survey and interview, midpoint focus group, post survey and interview. Did I ask the right questions? What else should I ask students? What do you think I should know about the program?