Fall 2024

PARADIM Research Experiences for Undergrads (REU)

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Contents

Introduction

Research Experiences for Undergraduates (REU)

PARADIM, the *Platform for the Accelerated Realization, Analysis, and Discovery of Interface Materials*, is a new national user facility at Cornell dedicated to the discovery and fabrication of materials with unprecedented properties that do not exist in nature. Each year PARADIM invites selected interns interested in growing new materials targeted by PARADIM users and/or improving the techniques used to grow, characterize, and provide theoretical guidance leading to their discovery and optimization.

The PARADIM REU Program is designed to give undergraduate students an introductory research experience in the growth, structural/electrical characterization, or use of first-principles theory relevant to thin films of transition metal oxides or chalcogenides currently being researched as next generation electronic materials within PARADIM. These projects include improving the techniques available within PARADIM to grow and characterize materials. Students selected will work on an independent research project using the advanced resources available in PARADIM facility labs and the facilities of the Cornell Center for Materials Research (CCMR).

Projects are scaled to be challenging yet achievable within the program's time frame, from early June through mid-August. This REU program culminates with a convocation held jointly with the REU students from Johns Hopkins University where each intern gives a final presentation. Interns also write a two-page report, due on at the end of the program, that will be posted on the PARADIM website.

Methodology

The Evaluation Team employed a Developmental Evaluation Methodology (Patton, 2011) in studying the program implementation and impact. Developmental Evaluation[1] focuses on collecting both qualitative and quantitative data applied to formative and summative study. Formative evaluation examined fidelity of the program's implementation (degree to which what was done met criteria of intent and professional standards of practice); areas for continuous improvement; and practices worthy of replication in REU programs locally and more broadly. Summative evaluation sought data providing evidence of program outcomes and impact, as well as for making a case for continuing REU program sustainability.

The data collected by the Team focused on four information sources:

1. Document Review – Examination of program and demographic data from PARADIM website and REU management and operations documents
2. Mid-course Mentor/Mentee Surveys

[1] Patton, M.Q. (2011). *Developmental Evaluation: Applying Complexity Concepts to Enhance Innovation and Use.* New York: The Guilford Press

3. Presentation Observations – Evaluator observations of intern presentations, employing a multi-criteria assessment instrument
4. Intern Survey – A post-program survey seeking intern information related to program quality (lectures, mentoring, research, presentation, virtual delivery)

After all data were compiled and analyzed, an REU Final Report is drafted to address the needs and interests of key stakeholders (funder, PARADIM leadership, REU planners) and to provide findings and recommendations to inform further program planning, i.e., what to maintain, what to revise, what to eliminate.

Findings

Student Perceptions

The PARADIM 2024 Cohort included (19) students, representing (18) universities:

Cornell PARADIM REU 2024	**Affiliation**
Baza, Xavier	University of California Los Angeles
Chen, Julianna	Penn State University
Congdon, Morgan	University of Florida
Glick, Viviana	Haverford College
Hasko, Sonia	Princeton University
Hellyer, Soren	Iowa State University
Jackson, Clara	Clark Atlanta University
Johnson, Kedar	Morehouse College
Qiu, Lawrence	Tufts University
Rouseau, Robin	Clark Atlanta University
Stanford, Valerie	University of Maryland Baltimore County
Van Orman, Isaac	Carleton College
Welp, Eric	Penn State
Jones, Tyi	Spelman College
JHU PARADIM REU 2024	**Affiliation**
Grabill, Sebastian	Calvin University
Gragg, Madalyn	Oregon State University
Katta, Shreenithi	Georgia Institute of Technology
Parikh, Naman J. Simmons, Quentin	Carnegie-Melon University University of Virginia

Directly after the conclusion of the 2024 REU program, the Evaluation Team administered a post-survey to all interns. The intent was to collect data from participants focused on what worked, what could have been better, and how the experience influenced future endeavors

Program Events/Activities

REU participants were asked to rate (12) events, from workshops on presentation skills and collaboration to "Hot Topic Talks" related to Materials Discovery. The scale ranged from "poor" to "excellent" with "fair" and "good" included on the scale. *Approval Rating* indicates the % of attending respondents who rated the speaker "good" or "excellent" none of the REU participants rated any of the activities as "poor" the remainder were those who marked the experience as "fair."

Presentations	Approval Rating
The Four Corners of PARADIM: Berit Goodge, Chad Mowers, Abby Neill, Drake Niedzielski	93%
Library Science, Jill Powell	56%
Workshop on Research Ethics and Responsible Conduct	100%
Science Communications and Presentation Skills Workshop: Prof. Julie Nucci, Jim Overhiser	100%
Hot Materials Talk - Bio-Inspired Composites, Lara Estroff	80%
Hot Materials Talk - Highest Resolution Image, Steve Zeltmann	100%
CNF Clean Room Tour	100%
Hot Materials Talk - How to Give a Great Science Presentation, Melissa Hines	75%
Hot Materials Talk - Bulk Crystals/Big Data, Tyrel McQueen	93%
CU Synchrotron Tour (Wilson Lab)	100%
Ethics Presentation - David Muller	100%
Presentation Review Sessions with Jim Overhiser	100%

Program Gains - Research Techniques

Through survey questions students were given the opportunity to reflect on the impact of the REU experience on their academic skills, interests and planning, preparation for the future, and their confidence level. As indicated below, the REU interns reported moderate to high gains in several areas including familiarity and mastery of a range of research skills and presentation skills.

REU participants were asked to reflect on their perceived academic gain in the following (8) areas.

Academic Skill/Area of Expertise	Achieved Moderate/Great Gain
Familiarity with a range of research techniques	93%
Mastery of project-specific research techniques	87%
Presentation skills	93%
Explaining my project to people outside my field	100%
Writing scientific reports or papers	80%
Understanding journal articles	87%
Conducting library database searches	40%
Making a research poster	67%

This year's REU included an emphasis on Presentation Skills, including multiple large group sessions and one-on-one tutoring. With a focus on the ability to communicate complex scientific research in layman's terms, the presenter offered several techniques including analogies and visuals to communicate research principals.

While *'Conducting library database searches'* and '*Making a research poster'* saw the least gains reported by students, the comments added some context for this. While some felt that they "*already have experience in those areas and did not improve much during this program.,"* others stated they were already proficient in a particular skill.

Many comments were positive, "*this program greatly improved my research abilities."* Still others reported gains in areas not mentioned on the survey. "*I have also gained more knowledge of lab safety and etiquette."*

Program Gains - Preparedness

Gains were also reported in areas related to preparedness. REU participants were asked the degree to which the REU experience prepared them for future work in a variety of fields as well as how the experience influenced areas of interest:

Academic Skill/Area of Expertise	Achieved Moderate/Great Gain
Preparation for advanced course/thesis work	87%
Preparation for graduate school	93%
Preparation for an academic or industrial career	93%
Interest in materials science research	93%
Confidence in my ability to contribute to science	100%

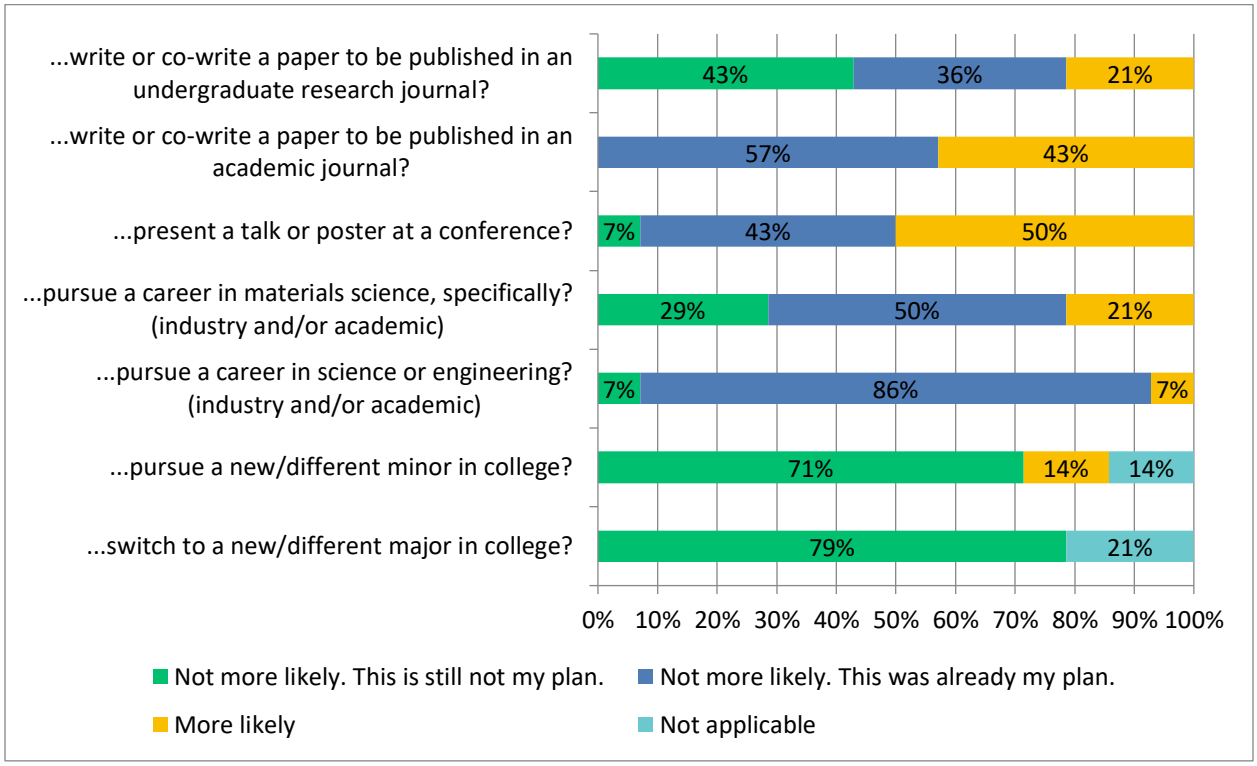
Again, in four out of five areas, 87% or more of the REU participants reported moderate to great gains reported in preparing the interns for their future academic/career as well as interest in materials science

research. Student comments further elaborated on how the REU experience was different from what they've done up until now. "*This was a good experience in materials chemistry work, pretty different from what I'd done before. I also appreciated the experience of working in an office and getting familiar with the kind of environment I would be in at graduate school*."
All respondents (100%) agreed that there was modest to great gains in their confidence in their ability to contribute to science.

REU Influence

To provide clarity, a follow-up question asked If the REU interns were likely to present, publish, or apply for an award/scholarship based on their summer research. Several interns stated that because of the REU experience they felt they were in a more favorable position to secure a scholarship. Others added they plan to present their work when they return to their school in the fall. Interns were also motivated by the opportunity to contribute to research likely to be published in the future and dedicated to continuing to refine the work.

Figure 1. As a result of this REU research experience, how likely you are to:

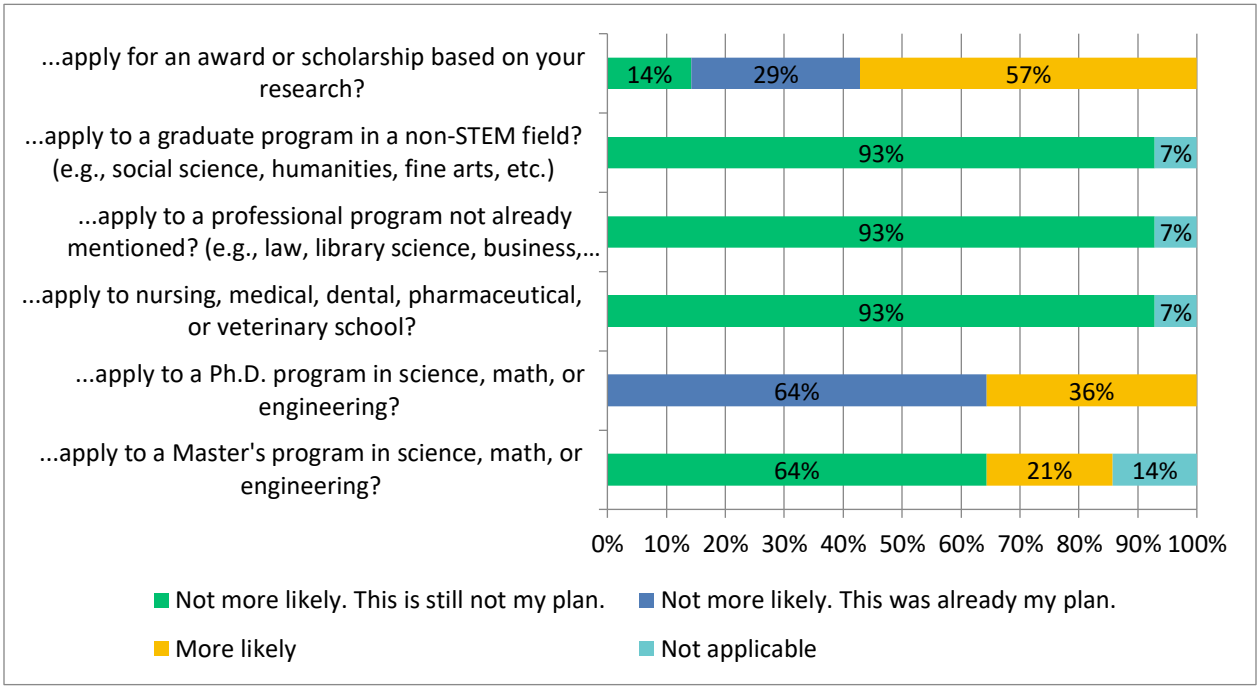


- *"I plan to apply for the Goldwater Scholarship using my research paper written for this summer."*

- *"I am hoping to present this work at MS&T24 in the student speaking competition."*
- *"Further work needs to be done on my research before it is ready to present / publish but I would very much like to do so once it is complete."*
- *"We got good results that just need to be refined. Hopefully they will result in a publication."*

Participants were asked the degree to which the REU experience influenced a their future academic planning, specifically whether or not to pursue a Master's and/or PhD program in science or other graduate program and the likelihood of their applying for an award or scholarship based on their research was also investigated. Survey results illustrate a majority of the participants (64%) had already planned on pursuing a PhD, while the remaining participants saw themselves as more likely to pursue a PhD in science, math, or engineering.

Figure 2. As a result of this REU research experience, how likely you are to:



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In their own words, interns were asked to elaborate on how the REU experience influence their thinking about future career and graduate school plans. A common theme of exploring, understanding, and solidifying the decision to pursue graduate school, specifically PhD programs, emerged as a result of an enriching research experience. Here are the key themes from the responses:

- Increased Understanding of Graduate School: Many comments highlight that the experience provided a deeper understanding of what graduate school entails, including research, lab work, and academic environments.

- *"I feel like I have a better understanding of how grad school works and am encouraged to pursue a grad degree."*

- Increased Confidence in Applying: Several participants mentioned feeling more confident about applying to PhD programs, especially after interacting with graduate students and gaining insights into the application process.

  - *"Being around the graduate students empowered me to prepare for and apply for PhD programs in colleges I would have dismissed as beyond my reach monetarily and academically. They taught me the tools and tricks of applying, information that I would not have as the first person in my family to apply for graduate school."*
  - "*The experience further confirmed for me that I really enjoy research, both lab work and planning/writing up/presenting my work. I am confident that I want to attend graduate school. My experience with the lab group also gave me some insight into what I'm looking for in groups I'm interested in for graduate studies. I have also been thinking more about going into industry after graduate school rather than academia, partially based on some conversations I had with people here."*

- Solidified Interest in Graduate School: Many comments reflect how the experience confirmed or reinforced the individuals' interest in pursuing graduate studies, often with a focus on specific fields such as condensed matter, materials science, or physics.

  - *"It just solidified my plans in going to graduate school."*
  - *I got valuable experience in a new field of materials science which cemented my commitment to a Ph.D program after undergrad."*
  - *"It only solidified my desire for graduate school (Ph.D) and to continue in academia."*

- Broadening Research Interests: Participants also noted that they were able to explore a variety of research topics, which helped them refine or expand their interests and potential graduate school areas of study.
  - *I am excited I was able to explore more research than just optics and it has given me confidence that wherever I go for graduate school will have research topics I will be passionate in."*

- Considering Future Career Paths: Some comments show that participants are considering their long-term career goals, including whether to pursue academia or transition into industry after graduate school.

These themes demonstrate the positive influence of the research experience in shaping participants' graduate school ambitions and research trajectories.

Mentorship

Each REU intern was paired with a mentor, typically a professor and a grad student. Overall, the vast majority of REU participants reported positively to their mentor/mentee experience. "*My mentor was amazing. I could ask her any question about my work or ask for advice on graduate school applications. I don't think I will ever find a better mentor than her."* However, in one instance the intern expressed being ill-suited for their mentor, but added that it was a valuable learning experience: *"It was overall okay. Unfortunately, I believe my mentor and I were not quite suited to each other. I think my mentor was expecting me to have a lot more experience than I did and did not adjust especially gracefully. But overall, it was a good learning experience, and I did learn a lot from my mentor."*

*In the survey, s*tudents weighed in on their perceptions of their mentor experience in three areas:

1. The degree of support received
2. The degree of a mentor's importance relative to the success of the REU experience
3. The degree to which a mentor influences an intern's future plans

Support Received

REU interns reported a high level of support, with 79% receiving "a great deal of support" and the remaining 21% receiving "some support" from their mentor. No participant reported receiving "no" or "little" support from their mentor. REU commentary offered a high degree of satisfaction with the mentor relationship. Most interns offered examples of their mentor/mentee relationship as being valuable and positive.

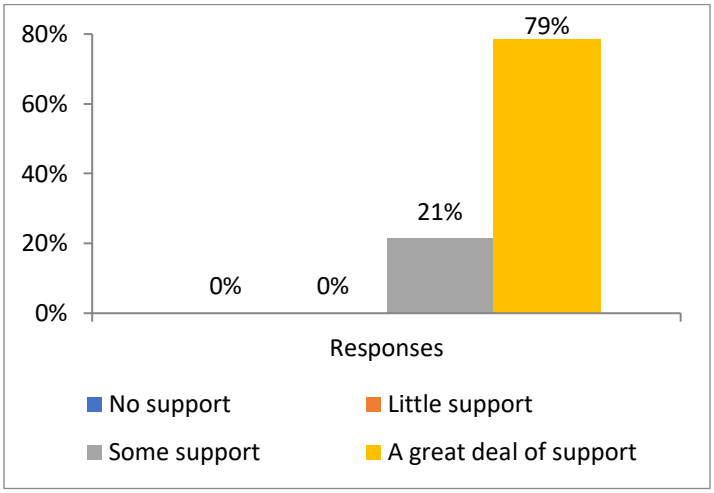


Figure 3. Level of Support Received from Mentor in Preparation of Final Presentation

- *My mentors were great and did an excellent job of offering guidance to excel in my work. They also gave me opportunities to work independently.*

- *My mentor was wonderful. I appreciated their support and readiness to always answer any questions I had, let me mess up, and guide me to figure out the answer to my questions and mistakes. They were very supportive, kind, and great throughout the program. I enjoyed working with them on a professional level, as well as getting to know them more personally and interacting with other grad students in the group.*

- *"My mentor was amazing. I could ask her any question about my work or ask for advice on graduate school applications. I don't think I will ever find a better mentor than her."*

- *"Allana was amazing and sacrificed a lot of her time for me. She is a great teacher."*

Importance of Mentor/Mentee Relationship

The vast majority (93%) of the REU interns felt that the mentor experience was integral to the success of the REU experience. (Figure 4) A review of survey data confirms the interns' view of a mentors importance relative to intern's experience as well as the overwhelming positive experience of the REU interns.

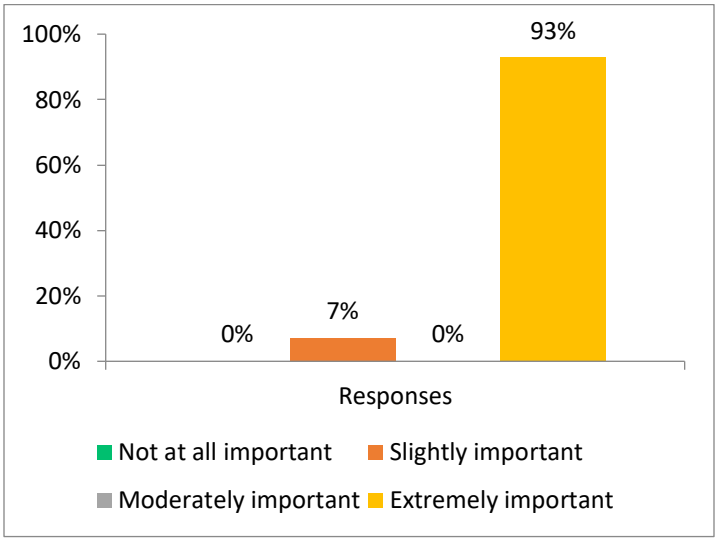


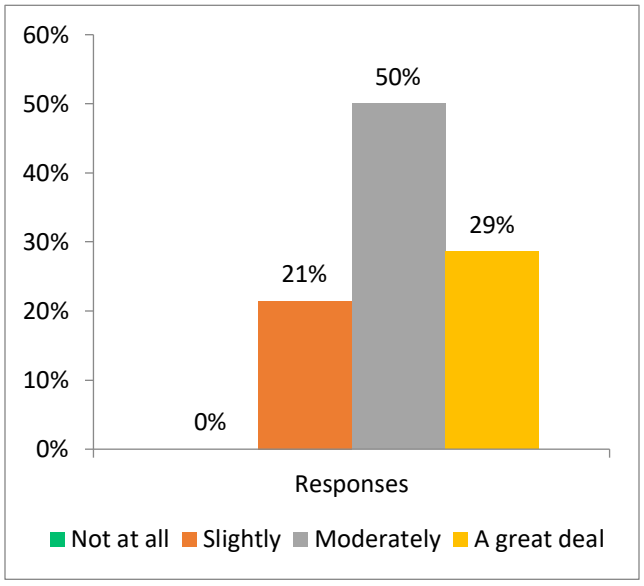
Figure 4. Importance of Mentor to REU Success

- "*My mentor was great. We worked together through the entire summer given the nature of my project which I really appreciated."*
- *"Kathy was incredible in pushing me to work hard and to learn as much as possible."*

- *"My mentor was extremely knowledgeable, available when he could be, and was not always over my shoulder. He allowed me the freedom to learn and apply what I learned to my research project."*
- *"My mentor was wonderful. I appreciated their support and readiness to always answer any questions I had, let me mess up, and guide me to figure out the answer to my questions and mistakes. They were very supportive, kind, and great throughout the program. I enjoyed working with them on a professional level, as well as getting to know them more personally and interacting with other grad students in the group."*
- *"My mentor was amazing. I could ask her any question about my work or ask for advice on graduate school applications. I don't think I will ever find a better mentor than her."*
- *"My mentor was awesome, helped me with understanding our research and allowed me to reach my full potential."*

Mentor Influence

Interns were asked to rate their mentor's influence on their future plans. Close to 80% responded by acknowledging their mentor had a *moderate* to *great deal* (Figure 5.) of influence on their future planning. Approximately 20% reported being slightly influenced. Students describe their mentor's influence:



"My mentor was incredible. He taught me everything I needed to know and more to succeed in this position, including teaching me how to connect Physics and Chemistry. He also has offered a great deal of support in academic/career planning, which has been a huge help and has given me some clarity as to what I hope to do in the future."

"My mentor was very helpful in guiding me through my project while also giving me space to learn and solve problems on my own. I think it was very important to my success in the program that I had a knowledgeable mentor to help me and show me future opportunities that I wasn't aware of."

Figure 5. Mentor Influence on Intern's Future Plans

Overall Program Experience

The PARADIM REU Program at Cornell University offers students the opportunity to immerse themselves in cutting-edge research while benefiting from mentorship and collaboration with both faculty and graduate students. Participants shared valuable feedback about their experiences, highlighting various strengths and areas for improvement within the program. Comments reflect the participants' appreciation of the resources, learning environment, and mentorship, while also offering suggestions on how the program could enhance its structure and communication, particularly for students at Johns Hopkins University (JHU) and those balancing different aspects of their research work.

What were the best aspects of the REU program? What aspects are most need of improvement? Please take time to reflect and elaborate

- *I think the resources available are super encouraging to do good work. I think continuing to promote the PARADIM and Cornell resources are key for encouraging successful students. I think some improvement could be made in the onboarding. The summer is so short, but I felt like I spent a bit of time early finding who I needed to get training from and how to get access to rooms.*

- *The environment was great socially, both within the lab group and in terms of the REU activities. The PhD students were all very friendly and welcoming, and happy to act as mentors for their students and others, when things came up and one mentor was busy. They were all very helpful in preparing for the final presentations and giving feedback to us all. I think the biggest thing I struggled with was feeling a lack of direction in my project at times. There were multiple projects in the works, and it was confusing, especially at first, which I should focus on. Part of this is just the nature of the MBE lab setup, but the inconsistent workload of having intense growth days and then very relaxed schedules the rest of the time with nothing much to do was stressful to me at times.*

- *The best part of the REU program was the learning environment and the people I was around. I wish the training modules for the lab and equipment had been sent before the program started. However, the meals provided at the Hot Materials Talks made up for this slight annoyance in the beginning.*

- *I enjoyed the opportunities to dive deep into research while also having the opportunity to relax and connect with other REU students through trips and the other lab tours. I'm not aware of any aspect that especially needs improvement.*

- *The amount of freedom in our projects and the mentors.*

- *"My mentor was by far the best aspect of the REU. I think the Cornell trip for JHU Students at the end of the Summer needs some restructuring. Either JHU Students should be coming up to Cornell for a full week so they can tour the facilities, or they should not be coming up at all and should be presenting in person in a similar format at JHU while zooming in to Cornell. The Cornell trip was really not a fun experience for me when the 32 hours of the trip was roughly broken into 11 hours of driving, 4 hours of presentation practice, 8 hours of sleep, 7 hours of watching presentation, and only 2 hours of exploring the Campus. In my opinion, JHU students should go up to Cornell on Monday or not at all. Also, there was only 1 social event planned at JHU for the entire Summer. This was frustrating as I know many events were planned at Cornell. Luckily our REU cohort was proactive and went out on our own to explore Baltimore, but this should not fall on the interns at JHU when the interns at Cornell have many events planned out for them."*

- *My project was great and so were the mentors. There is improvement needed when it comes to information. Being at Johns Hopkins, I felt like we were getting the short end of the stick in regard to information about the final presentations, talks, or tours happening. We got last-minute information about housing and the general itinerary for the Cornell presentations. If we got the information beforehand, I could have been better prepared.*

- *It was fun to be in Baltimore for a while. The JHU section felt like an awkward cousin of the Cornell program.*

- *The social aspect in the office was fun and engaging. The fun events are great. I would have some more realistic parameters for how much students would work each week. I was pushing 75 hours a week at the max and I knew some people who've worked 19-hour days.*

- *"The best aspect was the professional development. In the future, I would recommend giving a little more support to the participants."*

- *Research in general was great, the facilities are very nice, talks were generally informative and augmented the experience. It seems kind of strange to drive the Hopkins folks over to present just for one day, maybe unnecessarily stressful, but otherwise I think everything was great.*

- *The mentors and the opportunity to work on well thought out projects that significantly contribute to the field were the best aspects. I don't think there are many areas that need*

improvement. The problem I have with REUs in general is that 10 weeks is not long enough for most research, so there was some stress and worry about not finishing my project all the way.

- *The cohort, the mentors, the PI's, Jim, Brenda, and the beautiful campus.*

- *The best aspect was the level at which we got to incorporate ourselves in the existing research and not just work on "side" projects. The aspect most in need of improvement is consistency in guidance in presentations between speakers, as Jim and the presenter for the larger REU group gave contrasting advice on formatting, etc.*

Finally, participants were asked how likely they were to recommend this REU program to their peers.

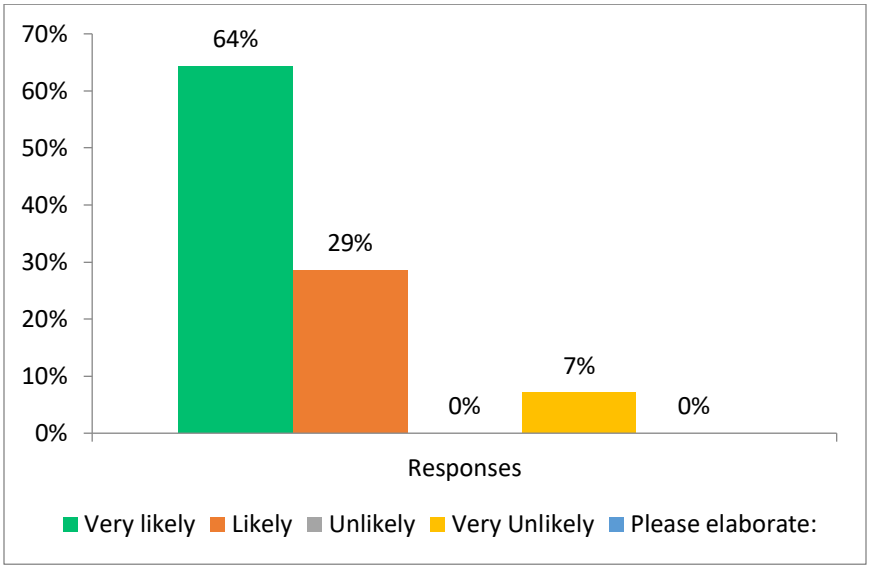


Figure 6. Likelihood of Recommending Program to Peers

Students' responded favorably with 93% stating they were likely or very likely to recommend the program to peers. Overall, the PARADIM REU Program provides a positive, enriching experience, offering valuable research opportunities, professional development, and social engagement. Participants appreciated the support from mentors, the access to resources, and the dynamic learning environment.

Student Presentations

The PARADIM Evaluation Team conducted virtual observational assessments of the REU student presentations, utilizing a comprehensive set of evaluation metrics. These metrics focused on key areas such as organization, visuals, delivery, content, and the use of illustrations, examples, and metaphors. Presentations were rated on a 1-5 Likert scale, ranging from Poor/Inadequate to Excellent/Professional Quality.

As both the numerical scoring and the observations demonstrate, there was a high degree of quality in the presentations by the 18 presenters. In nearly all the five variables studied by the evaluation team, students across the board scored at and above 3.5 (above average), with many receiving top grades of 5.0 (excellent/professional quality).

These averages reflect strong overall performance in *organization, visuals, delivery, and content*, while there is room for improvement in the use of *examples, metaphors, and illustrations*. In addition to numerical ratings, the evaluators also recorded brief notes on the content and their overall impressions of each presentation. A summary of each category is provided below:

1. Organization (Avg. score: 4.76)

Most presentations were well-organized, with a clear structure and logical progression through the content. Presenters generally provided a clear path through their research, and in many cases, additional steps beyond their current research were discussed. A few presenters struggled slightly with flow, particularly due to nervousness or delivery issues, but overall, the organization was strong.

2. Visuals: (Avg. score 4.47)

Visual aids were generally effective in supporting the presentations, with many students using clear and relevant graphics. However, some visuals lacked creativity or were not as engaging as they could have been, missing opportunities to fully capture the audience's attention. A few presenters made excellent use of moving visuals and arrows to enhance understanding, while others could have benefited from more dynamic visuals.

3. Delivery: (Avg. Score: 4.47)

Most presenters demonstrated confidence, with clear speech and good pacing. Eye contact and engagement with the audience were common strengths. However, a few students read from slides or their notes too often, which detracted from the natural flow of their presentations. Nervousness occasionally impacted delivery, but overall, presenters conveyed their material effectively.

4. Content: (Avg. score 4.29

Content was generally strong, with clear definitions and explanations provided. Many students successfully conveyed complex information in a digestible way, though some presentations lacked deeper explanations, particularly in answering the "why" behind the research. A few presenters excelled at providing context and addressing audience questions clearly and confidently.

5. Examples/Metaphors/Illustration: (Avg. score 2.71)

This was the weakest category overall. Most presenters did not incorporate real-world examples, metaphors, or illustrations to make the material more relatable. Those who did include examples were able to better connect their research to everyday applications, making

their presentations more engaging for the audience. This is an area for potential improvement across the board.

Recommendations

1. Improve Onboarding and Information Sharing:
    - Recommendation: Streamline the onboarding process to ensure interns are well-prepared and equipped with essential information before the program starts. Provide early access to training modules for lab equipment and program logistics to minimize confusion and save valuable time during the short summer program.
    - Rationale: Interns expressed concerns about spending time early in the program figuring out training and access logistics. Enhancing onboarding will allow interns to focus more on research from the beginning.
2. Enhance Project Direction and Clarity:
    - Recommendation: Ensure that mentors provide clear project outlines and consistent guidance throughout the research process, especially in labs with multiple ongoing projects. Consider scheduling regular check-ins with mentors to discuss project focus and goals.
    - Rationale: Interns noted feeling lost or unsure at times related to project direction, particularly in environments with varying workloads. Providing clearer structure will reduce stress and increase research productivity.
3. Improve the JHU-Cornell Coordination:
    - Recommendation: Restructure the Cornell trip for JHU interns to allow for a longer stay and more exploration of Cornell's facilities. Alternatively, provide virtual or localized presentation opportunities at JHU to minimize logistical challenges. Additionally, ensure more consistent social and academic event planning across both campuses.
    - Rationale: JHU students felt that their experience was less cohesive compared to Cornell interns, particularly in terms of social and event planning. A more integrated approach will ensure all interns feel equally engaged and supported.
4. Increase Use of Illustrations and Metaphors in Presentations:
    - Recommendation: Incorporate specific training in the use of illustrations, metaphors, and real-world examples to help students connect complex scientific concepts to relatable ideas. Encourage mentors to review this aspect with interns during presentation preparation.
    - Rationale: The presentation evaluations revealed that the use of examples and metaphors was the weakest area. Improving this skill will help students communicate their research more effectively to both scientific and general audiences.
5. Provide Clearer Guidance on Presentation Expectations:
    - Recommendation: Standardize the guidance provided on presentations, ensuring all interns receive consistent advice from different speakers and mentors. Develop a comprehensive presentation rubric that mentors can use to support their interns.
    - Rationale: Interns reported receiving contrasting advice on presentation formats from different speakers. Consistency in feedback will help them prepare more confidently.
6. Extend Program Duration or Modify Research Expectations:

- Recommendation: Either extend the program length or adjust project expectations to better align with the 10-week timeframe. Provide additional opportunities for students to continue working on their projects remotely after the program, if necessary.
- Rationale: Some interns expressed concerns that 10 weeks was not long enough to complete their research. Adjusting expectations or providing follow-up opportunities will help reduce stress and allow for more thorough project completion.

7. Continue Focusing on Professional Development:
    - Recommendation: Maintain the emphasis on professional development, including presentation skills, communication training, and career planning. Consider expanding one-on-one tutoring sessions for presentations and continuing to offer workshops on graduate school applications and career paths.
    - Rationale: Interns highlighted the value of professional development as one of the most beneficial aspects of the program. Expanding these opportunities will further enhance their preparedness for future academic and career pursuits.

By implementing these recommendations, the PARADIM REU Program can continue to enhance its already successful model, offering an even more rewarding and impactful experience for future participants.