Syracuse University
School of Education

PARADIM
Research Experiences for Undergrads (REU)

Year 6 Final Report
August 2021

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.

This year's REU sought interns not only interested in growing new materials, but also those interested in optimizing and improving the equipment used to grow and characterize them. Molecular beam epitaxy (MBE) and MOCVD (metal-organic chemical vapor deposition) are state-of-the-art thin film growth techniques with atomic precision, and PARADIM offers unique systems with world class capability. Laser Pedestal and High Pressure Optical Floating Zone (FZ) are world leading bulk crystal growth capabilities. PARADIM also houses the world's highest resolution electron microscope which allows you to probe materials atom-by-atom. Electronic and structural properties are characterized at PARADIM using angle-resolved photoemission spectroscopy (ARPES) and x-ray diffraction (XRD). PARADIM is also spearheading new data-rich Artificial Intelligence/Machine Learning techniques to improve materials discovery.

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-point Survey: Assess mentor/mentee relationship as it relates to project productivity
3. Presentation Observations: Dual evaluator observations of a sampling of intern presentations, employing a multi-criteria assessment instrument
4. Intern Survey: 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.

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

Findings

Student Perceptions

Following the conclusion of the 2021 REU program, the Evaluation Team administered a post-survey to all interns. The cohort represented (11) universities:

Cornell REU 2021	Major/College	Mentor
Nathaniel Luis	Chemistry, Harvey Mudd	Brendan Faeth
Alex Kurland	Material Science Engineering, Cornell University	Darrell Schlom
Show, Veronica	Chemistry, Harvey Mudd College	Felix Hensling
Sarah Uttormark	Physics, Math & Norwegian, St. Olaf College	Tomas Arias
Nimit Mishra	Chemical Engineering, University of California Los Angeles	Betul Pamuk
Lanette Espinosa	Biochemistry, California State University	Elisabeth Bianco
Hanna Porter	Chemistry, Harvey Mudd College	Berit Goodge
Beatriz Avila-Rimer	Applied and Computational Math, Caltech	Noah Schnitzer
Sean Chang (SURF)	Mechanical Engineering, California Institute of Technology	Y. Eren Suyolcu
JHU REU 2021	Major/College	Mentor
Megan Michaud	Mechanical and Aeronautical Engineering, Clarkson University	Mojammel Khan
Avery Lenihan	Chemical Engineering, Western Kentucky University	David Elbert
Luc Capaldi	Mechanical Engineering, University of Vermont	Evan Crites
Muchiri Mbugua	Materials Engineering, University of Maryland	Ben Redemann

Mentorship Assessment

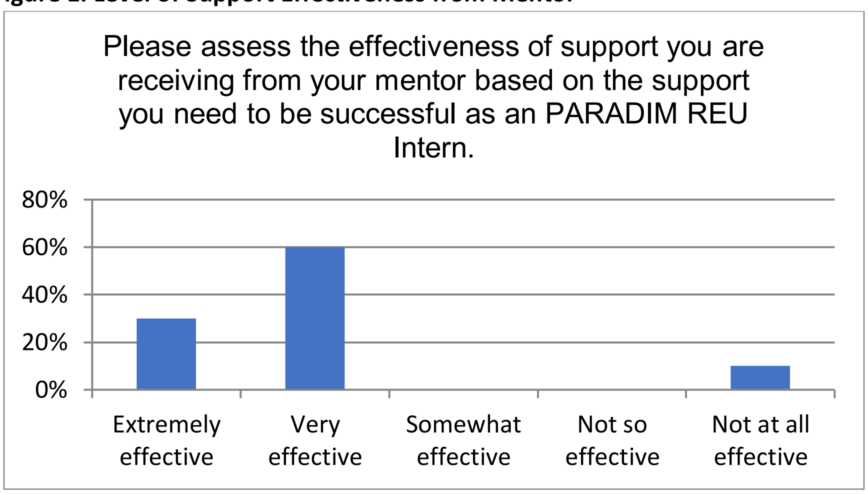
Students weighed in on their perceptions of their mentor experience in two areas:

1. The degree of support satisfaction: effectiveness, function, and communication
2. The degree of their understanding: role clarity, the underlying science, and the project's scope/goals.

Level of Support

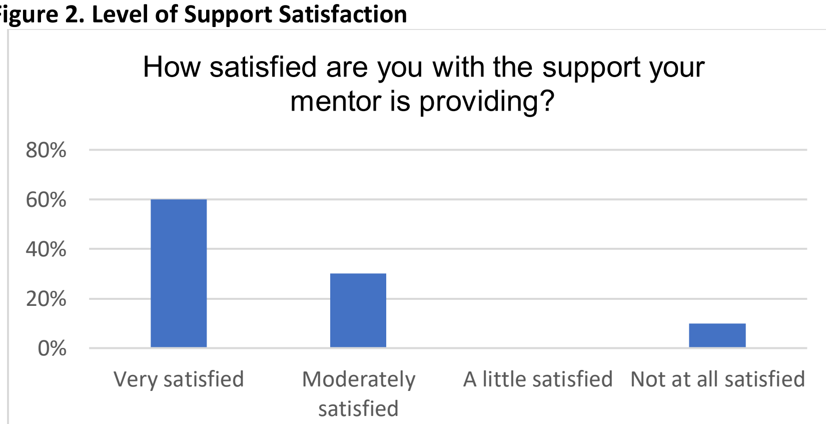
REU interns reported a high level of effectiveness of the support received, with 60% reporting the support as being "very effective" and the remaining 30% stating the support from their mentor was "extremely effective." One participant reported the support was "not at all effective." Offering, "my mentor has a tendency to be overly controlling of experiments, often jumping in to take over even when I have been trained and am under the direct observation of the tool expert."

Figure 1. Level of Support Effectiveness from Mentor



In a similar way, student interns reported on the level of satisfaction with the support they were receiving:

Figure 2. Level of Support Satisfaction



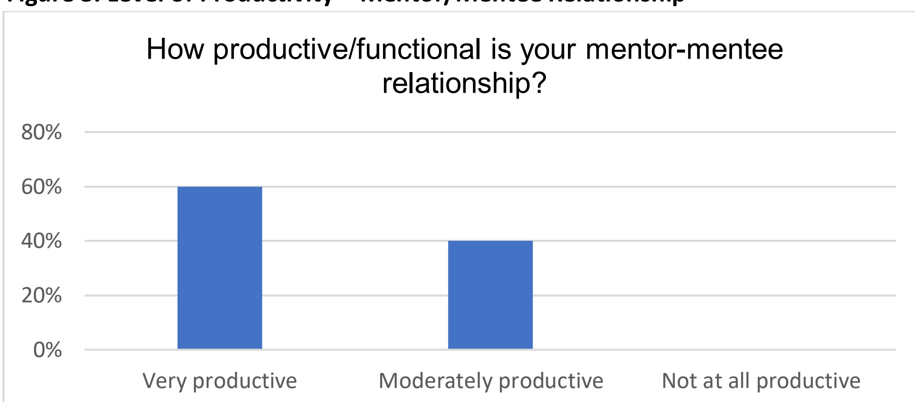
Students reflected on their satisfaction with mentors in the following ways:

- He is pretty hands off and sometimes I only check in with him once a week.
- He is supportive, but not in a way that is helpful to me.
- He's super nice and always responds.

Participants were also asked about the level of productivity of the mentor/mentee relationship.

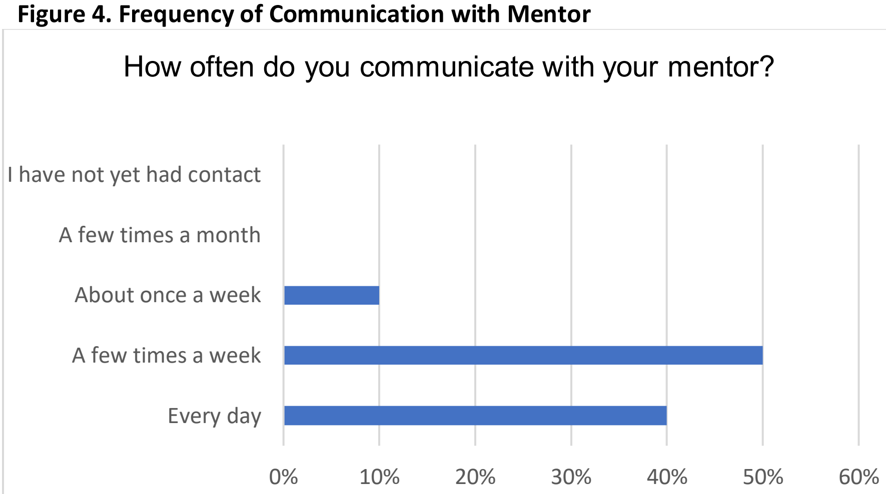
- I don't interact as much with my mentor as much as I do with one of the graduate students so sometimes, I feel like my mentor doesn't have a complete handle on what I am doing.
- Our professional relationship is fully functional. However, he has provided me with almost no practical or intellectual value as a mentor. All the high quality mentorship that I have received has been from other members of the lab.
- Felix is super knowledgeable and responsive. He is always able to answer my numerous questions for him and explains things in an easily digestible manner.

Figure 3. Level of Productivity – Mentor/Mentee Relationship



The majority (90%) of the REU interns communicate with their mentors several times a week.

Figure 4. Frequency of Communication with Mentor



Levels of Clarity and Understanding

- **Role Clarity**: Interns were asked to rate their clarity in understanding their role as an intern. All interns reported they had a clear understanding of their role as an intern (60% Very clear, 40% Extremely clear)
  - "I am here to learn about science and thin film growth, then assist in my mentor's research."
- **The Science:** Interns were asked to rate their understanding of the science underlying their project. One person had "little understanding," while the other 90% reported "moderate" (70%) or "great" (20%) understanding of their project.
  - "I would need to spend much longer than 10 weeks to have a great understanding of the theory behind my project."
  - "I've learned a lot about how phase diagrams inform the science and how to analyze the films we grow."
- **The Scope/Goals**: All interns reported some understanding of the scope and goals of their project, 50% had a "great understanding," while the remaining 50% reported a moderate understanding.
  - "I know what I am working towards and how I will get there."

Final Presentations

On August 16, 2021, the PARADIM Evaluation Team conducted assessment observations of a sampling of REU student presentations (8 of 13). The assessment metrics related to each presentation included:

- Organization,
- Visuals,
- Delivery,
- Content,
- Illustrations/Examples/Metaphors

A 1-5 Likert-type scale was employed: Poor/Inadequate; Below Average; Average; Above Average; Excellent/Professional Quality. In addition, each evaluator-observer took brief notes on the content and their perceptions of the presentations. Four students represented the Thin Film facility; four, Bulk Crystal Grown.

Observer reliability was assessed by comparing each observer's assessment of the five metrics over the eight presentations. The comparisons show very little, and no significant, difference in how each observer viewed a particular metric.

- Organization: Observer #1: 4.8; Observer #2: 4.9
- Visuals: Observer #1: 4.4; Observer#2: 4.5
- Delivery: Observer #1:4.6; Observer#2: 4.4
- Content: Observer #1: 4.6; Observer #2: 4.7
- Illustrations/Examples/Metaphors: Observer #1: 3.8; Observer #2: 3.9

Following is a summary of the combined findings from the two observers for each of the eight presentations.

1. **Alex Kurland (CU)**
   Rising junior in Materials Science
   Mentor: Darrell Schlom (attending)

Evaluator	**Organization**	**Visuals**	**Delivery**	**Content**	**Examples/ Metaphors/Illustration**
#1	5.0	5.0	5.0	4.0	4.0
#2	4.5	4.0	4.0	5.0	4.0
Average	**4.75**	**4.5**	**4.5**	**4.5**	**4.0**

Presentation Content: Thin Film, Molecular Beam Epitaxy

- Why its important: need to lower the cost
- Current methods present problems, exposure alters chemistry
- Solution: measurement made in vacuum

General concept: “grow” contacts directly onto material, no contact resistance, measurement made in vacuum.
*PARADIM can already measure in vacuum.

Notes:
Used problem vs. solution introduction, offered sound approach to guiding audience along the logic of his work. Darrell Schlom (mentor) attending, affirms mentee by positive nodding, engaging the student. Mentee looks toward and speaks to mentor as his audience.
Questions from audience were responded to with clarity.

2. **Nathaniel Luis (CU)**
Rising Junior, Harvey Mudd College
Mentor: Brendan Faeth

Evaluator	**Organization**	**Visuals**	**Delivery**	**Content**	**Examples/ Metaphors/Illustration**
#1	5.0	5.0	5.0	5.0	5.0
#2	5.0	4.5	5.0	5.0	4.0
Average	**5.0**	**4.75**	**5.0**	**5.0**	**4.5**

Presentation Content: Superconductors: what are they and what do they require to work properly.
- Superconductors conduct electricity without resistance
- Challenge: need to be incredibly cold to work.
- What is ARPES and what can it tell us?
  - angle-resolved photoemission spectroscopy
  - Critical temperature and band structure.

This summer’s question: How does electron doping effect band structure? Presentation focused on one element Cs Doping – isolating on that to determine its effects.

Notes: Introduction to topic and each sub-topic (e.g. “So, why did I….”) offered solid teacher-presenter approach
Show bands in doped vs. non-doped samples. Quantify the “doping amount” via ARPES.

Learned: successfully produce electron doped multilayer
Next steps: better control the doping to achieve uniformity?
Question: Lena, Brendan

3. **Sean Chang (SURF) 10:11 – 10:24**
Rising Sophomore: California Institute of Technology
Mentor: Y. Eren Suyoicu

Evaluator	**Organization**	**Visuals**	**Delivery**	**Content**	**Examples/ Metaphors/Illustration**
#1	4	3.5	5	4	3.5
#2	5.0	4.5	4.5	5.0	4.0
Average	**4.5**	**4.0**	**4.75**	**4.5**	**3.75**

Presentation Content: What is a superconductor?

- Thin film – substrate (foundation) thin film grown by MBE
- Gives research history
- Three things I did this summer
  1. Xray reflectivity (calculating thickness)
     a. We use this for calibration – thickness and growth time. We compare to flux and then adjust source temperature
  2. Xray Diffraction (XRD) same as #1 but different angles
  3. Resistance vs temperature

Results:

- Found optimum temperature for DBCO films
- Critical temps are correlated with growth temps
- High quality DBCO films at -750 C

Notes:

Good visuals of utility of work in real life, e.g., train. “Background as to why we do this at all.” Scans the whole room, Darrell affirms nodding.

4. Veronica Show (CU) 10:24

Rising Senior: Harvey Mudd College
Mentor: Felix Hensling

Evaluator	**Organization**	**Visuals**	**Delivery**	**Content**	**Examples/ Metaphors/Illustration**
#1	4.5	4	4	4	4.5
#2	5.0	4.0	4.0	4.5	3.5
Average	**4.75**	**4.0**	**4.0**	**4.25**	**4.0**

Presentation Content: Transparent Semiconductors: medical or flexible devices

- In_2O_3 – Gives pros and cons
  Cons: Grain boundaries – unstable
- How to grow single material Idiom Oxide
- Why Suboxide MBE?

- **My job – gauge the quality of these films – looked for three main features (How to tell if a film is “good’?)
    - Hybrid peaks
    - Thickness fringes
    - Full width Half max

Good setting up of purpose for purpose for work through pros and cons of In_2O_3. Revisited pros and cons through presentation. Nice sub-topic explanations.

5. Megan Michaud 10:40 – 10:55
First Year Student: Clarkson University
Mentor: Mojammel Kahn

Evaluator	**Organization**	**Visuals**	**Delivery**	**Content**	**Examples/ Metaphors/Illustration**
#1	5.0	4.0	4.0	5.0	4.0
#2	5.0	5.0	4.5	5.0	4.0
Average	**5.0**	**4.5**	**4.25**	**5.0**	**4.0**

Presentation Motivation: Spintronics
Important because free layer where electrons can change direction. Our job – find material
Goals: Synthesize (3) Ternary Germanium Chalcogenides
Synthesis Techniques:

- Flux Growth, (XRD) not the best results
- Scanning Electron Microscopy (SEM)
- Single Crystal Diffraction.,
- LAUD

Future: Physical Property Measurement System Analysis
Darrell Schlom: impressed with mapping

Nice visual illustrating real lab objects side by side with its function. Sound explanation as to why the resulting data was not “good data.” Handled questions well.

6. Avery Lenihan (JHU) 10:56 – 11:10
Rising sophomore: Western Kentucky University
Mentor David Ebert

Evaluator	**Organization**	**Visuals**	**Delivery**	**Content**	**Examples/ Metaphors/Illustration**
#1	5.0	4.0	4.0	5.0	4.0
#2	4.5	4.5	4.0	4.0	3.5
Average	**4.75**	**4.25**	**4.0**	**4.5**	**3.75**

Presentation Content: Making a dashboard to visualize and control PARADIM's data infrastructure, creating the foundation of the understanding required to optimize the use and growth of materials data infrastructure.

Notes the disconnect in materials Science:

- Competition, scientist aren't data scientist,
- Current Science: Apache Kafka
  Katka: Topics, Producers, consumers

Problem: NO FLEXIBILITY

- "I was thinking like a data analyst not a lab person."
- Solution: Cube.js
- SQL : (translates) made easy = Cube.js

The Future: Fix auto-generated schema and add more complicated measures and calculations

Notes: Good opening visual defining the purpose of the work. Use of "When it goes wrong" vs. "When it goes right" very effective.

7. **Luc Capaidi (JHU) 11:10 – 11:25**
   Rising Senior: University of Vermont
   Mentor: Evan Crites

Evaluator	**Organization**	**Visuals**	**Delivery**	**Content**	**Examples/ Metaphors/Illustration**
#1	5.0	5.0	5.0	5.0	4.0
#2	5.0	4.5	4.5	4.5	4.0
Average	**5.0**	**4.75**	**4.75**	**4.75**	**4.0**

Presentation Content: Synthesis of Motivation

- Renewable energy is not keeping up with global demand

Objectives:

- Explore progression of transition of metal nitrides
- Use PARADIM capabilities to synthesize tantalum nitride
- Explore the hi-pressure phase space of tantalum – nitrogen system

Techniques:

- Hi pressure optical floating zone furnace
- Arc melter
- Mettallic Flux

Set up purpose well, e.g., need for renewable energy. Nice logical description of steps to followed and what was learned. Strong demonstration of equipment and how it was used.

8. **Muchiri Mbugua (JHU) 11:25-11:40** 2 Projects
Rising Sophomore: University of Maryland
Mentor: Ben Redemann

Evaluator	**Organization**	**Visuals**	**Delivery**	**Content**	**Examples/ Metaphors/Illustration**
#1	5.0	5.0	5.0	5.0	5.0
#2	5.0	5.0	4.5	5.0	4.0
Average	**5.0**	**5.0**	**4.75**	**5.0**	**4.5**

Presentation Content: What is a Floating Zone (a crystal growth method)
No container and no contamination
High Pressure Optical Floating Zone (JHU)

- Hi pressure chamber
- Upper pulling drive
- Empty space
- Fiber laser channels
- Lower pulling drive

Muchiri developed a component HPLDFZ (favorite- because a mechanical engineer)
Notes: Set up purpose well, i.e. why the floating zone approach. Good illustrations of equipment in use and what was designed.

Student Perceptions

REU participants were asked to rate (11) events, from workshops on research ethics and presentation skills to talks from oxides to electrons and guided materials. The Likert-type scale ranged from Poor and Fair to Good and Excellent. Approval rating in the table below indicates the % of attendees rating the events in a combined Good/Excellent category. Only one program was rated Poor, and that by one attendee. All other responses were rated Fair (9-37%), Good (9-73%) or Excellent (9-64%).

Presentations	Approval Rating
Research Ethics and Responsible Conduct	36% (20% no attend)
Jill Powell, Library Science	37% (45% not attend)
Jim Overhiser, Good Science Communication	63% (10% not attend)
Julie Nucci, Power Point	63%
Darrell Schlom, Oxides/Transistors	100%
Paul McEuen, Ethics	91%
Jje Shan, Two dimensional materials	82%
Tyrel McQueen, Guided Materials Discovery	82% (18% not attend)
Lena Kourkoutis, Seeing with Electrons	91% (9% not attend)
Betul Pamuk, Computer Experiments/Density Theory	91% (9% not attend)
Melissa Hines, Scientific Presentation Skills	9% (91% not attend)

Program Gains – Research Techniques

Through survey questions, students reflected 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, REU interns reported moderate to high gains in several areas.

Academic Skill/Area of Expertise	Perceived Moderate/Great Gain
Familiarity with a range of research techniques	91%
Mastery of project-specific research techniques	91%
Presentation Skills	73%
Explaining my project to people outside my field	91%
Writing scientific reports or papers	73%
Understanding journal articles	54% (9% N/A)
Conducting library database searches	9% (9% N/A)
Making a research poster	No data

From approximately 73% to over 90% of respondents reported solid gains in all research areas except two (Understanding journal articles; Conducting library database searches). Comments from students this year on these areas of least gain closely paralleled prior REU respondents. Some felt they had done quite a great deal of the library search activity in the past; others stated it was less applicable to their project or that they were comfortable using home university tools. Some, too, felt they got what they needed from the mentor or faculty or that they perceived themselves as proficient prior to the REU.

Gains were also reported in areas related to preparedness for future work, as well interest in scientific research/career.

Academic Skill/Area of Expertise	Perceived Moderate/Great Gain
Preparation for advanced course/thesis work	64%
Preparation for graduate school	82%
Preparation for academic/industrial career	82%
Interest in materials science research	73%
Interest in some other scientific research/career	72%
Confidence in ability to contribute to science	91%

There were clear gains in perceived preparation and interest, in some cases over 80%. It should also be noted that in some cases individual students may come to the experience with high levels of preparation, leaving little room for "gain."

Comments from six of the students on why they experienced little gain in some areas provided a variety of responses worthy of some reflection on the part of future program planners, primarily regarding the importance of consistent support by mentors and coordinators.

- I really didn't get any support on writing the paper or making the poster….assumed I knew how to do it…mentor expressed disappointment (leading to some guilt) in certain courses I hadn't taken…expressed my lack of knowledge.
- Feedback from coordinator not that helpful; mentor much more helpful.
- Didn't do many searches, so little growth

- “Little or no gain” based on external factors
- Summer experience showed me that materials science research might not be best for me

Q6. As a result of this REU research experience, how likely are you to:

- switch to a new/different major
- pursue a new/different minor…
- pursue a career in science or engineering…
- pursue a career in materials science…
- present a talk or poster at a conference…
- write or co-write a paper to be published in an academic journal…
- write or co-write a paper to be published in undergraduate research journal?

Only 9% of respondents stated they would be more likely to switch majors; 18% regarding minors, with the majority saying this was never a consideration. The same was true with interest in pursuing a science or engineering career, with over 80% seeing it already in their plans and the rest saying the REU experience made it even more likely. There was an fairly even split regarding the question of interest in a materials science career, with one-third seeing it as already a plan, one-third more likely, and one-third still having no interest. In regard to the likelihood of writing and/or presenting, a strong majority saw the REU experience has making it much more likely they would do so.

Q7 In commenting on presenting, publishing, or applying for an award based on the summer research, students’ comments fell into three categories:

- Their confidence and interest are increased and will drive them
- They have definite plans for doing so at the home college
- They hope to co-publish with their mentor
- One expressed not applying or publishing anything from the summer research

Q8 In responding to questions as to the likelihood of applying to particular educational and career options, the results were very clear:

- Over 80% were already planning to apply to PhD programs; 27% to masters programs (increased by another 27% resulting from the summer program).
- One person said he/she was more likely to apply to a professional program, e.g., law, but beyond that no students stated they would apply to anything but a PhD or masters program.
- The summer program did, however, spur interest in applying for awards or scholarships, with over 60% stating it was more likely, while nearly 20% already had it in their plans.

Q9 All of the students responded to the question asking for comments on how the REU experience influenced their future career and grad school plans. Five focused on how they have learned about the potential of tangible experimental research and its place in grad school. Three others expressed renewed interest in materials science as a career option. One has been influenced to explore fields beyond chemistry and one other is now considering going into industry and pursue the Masters if it becomes necessary.

Q10-13 These questions all focused on the role and value of the PI/Grad mentor in the interns' summer REU experience. All but one student stated that the mentor was extremely important to the success of the REU experience; one responded "slightly important."

When asked what degree of support they perceived actually receiving from their mentor, nearly 50% said "a great deal," followed by 36% (4 students) stating "some support," and 2 students stating "little." No one perceived receiving no support at all. Beyond support for their project the students were also asked the degree to which the mentor influenced their future plans. There was a fairly even split between Moderately (36%)/Great deal (18%) and Slightly (9%)/Not at All (36%). These results were not unexpected considering the great number of students who stated earlier that they had already made quite solid plans for the immediate future.

When asked to elaborate on their mentor experience, five students described what the evaluators labelled an Excellent Experience, four perceived it as Good with Reservations, and three, Ineffective.

Those perceiving excellent mentoring pointed to such factors as: Great working and personal relationship; helpful in answering all questions on subject matter and futures; thorough; affirmed interest in research; never too busy for my questions. The issues raised by those perceiving their experience as Good with Reservations included: Wish mentor had been more involved early in project; had none for a while, but other mentors jumped in; mentor rarely in lab, assumed I was supposed to know all about lab work, but I did learn how to learn from different styles, e.g. mentor and grad student supporters, and how to be more assertive and collaborative.

Q14-16

The final questions inquired as to how likely they were to recommend this REU program to peers (55% very likely; 36% Likely; 9% Unlikely), and expanded this to ask for comments on best aspects of the program and those most in need of improvement. All students responded to all questions.

Best Aspects (Excerpted)

- *I felt my research was actually meaningful and that when progress was made that it actually could lead to something really cool.*
- *Everyone in PARADIM, McQueen labs, and IQM were super friendly and supportive. I could ask anyone for help and they would or would refer me to someone else they thought could better help me. Nice having everyone not just a mentor wiling to help you ….*
- *The best part was definitely being in person.*
- *I enjoyed my cohort! Also hearing talks from PIs and some of the mentors was great!*
- *The people were the best part. I made some incredible friendships that I hope will last a long time.*
- *I appreciated the emphasis on the presentation and science communication.*

- *The number of resources available in the lab and the number of individuals willing to help with mentorship.*
- *Other students were the best part.*
- *Being able to make posters, slides, and reports that would be critical skills in the future.*
- *I enjoyed the research I was doing and the people I was doing it with.*

Recommended for Improvement (Excerpted)

- *I think a basic introduction to what research and lab work is might be helpful. Knowing what literature review is, what a lab notebook is, how to use it, how to properly label and track your samples might be helpful for people who do not know what research is or if they have done only computational work where working in a lab presents new challenges.*
- *If I could change the time of the weekly meetings I would. I did often enjoy the Thursday talks…from a professional, but often they were around 12-1p.m. …right in the middle of experiments …would have to stop in the middle of the projects for an hour and come back. Sometimes this was not feasible, such as during long growths that must be monitored….I would have preferred bright and early, around 9 a.m., the same time we would have our weekly lab meetings.*
- *It would have been nice if some of the activities the Cornell students did were done with JHU students as well.*
- *I would suggest more group activities.*
- *I think the organization of the program in terms of administrative work (getting paychecks on time, getting our IDs and bus passes working, getting refunds, etc) could use a lot of work. I still have not received some of my paycheck….*
- *I would have loved to have had a bit more structure, but definitely a personal preference.*
- *My gripes with the program were really administrative things. This wasn't really anyone's faulot, just made it hard to get around sometimes (like when our cards were deactivated one day).All the problems were eventually resolved, but they were frustrating at the time.*
- *I hope no student in the future has the same experience I did. I sat in my dorm room by myself every day and went on google meet and zoom meetings with grad students and my mentor who could have very easily come to campus but decided not to. They could have given me an in-person experience, but they decided not to…*
- *Worst part was not having access to choose what project I wanted to pursue or what mentor I wanted to work with; and not spending enough time with other students.*
- *I think a better experience would be if we could have access to some of the Cornell facilities like the gym.*
- *I really wish there were fewer required presentations/deliverables. At times, these things would get in the way of me doing the research I was there to do.*
- *Make sure that someone is qualified and prepared to be a mentor.*
- *Maybe…cut down on the amount of things to turn in at the end of the program.*

Additional Considerations for Future REU's

- **DE Planning:** Evaluator summaries and student comments throughout the report provide clues as to what worked well, what might be improved in program content and support, and what might be considered removing. Employing four metrics in future planning might be a useful approach to using the results of the developmental evaluation (What to Maintain, What to Revise, What to Eliminate, What to Invent/Add).
- **Differentiation**: The students come from a variety of IHEs and represent the range of classes from freshman to senior. What they bring to the summer experience vis a vis formal and informal academic and research experiences thus differ. Considerations might be given to some differentiation related to readiness for the program. For example, learning beforehand the prior experience of the interns in such areas of skill as research, lab work, literature searches might recommend brief technical skills sessions by the university or science community specialist. These could be delivered on campus early in the program or on zoom or in a collection of REU webinars.
- **Mentors**: Unquestionably, the role of mentors (and graduate students) is critical in supporting the success of the projects and the satisfaction of the students. Many students perceive their mentor relationship and value as exceptional. Others felt it was moderately attended to by the mentor, and in a few cases, it was sorely lacking in effectiveness. Continued attention to the recruitment, requirements, and support of mentors, as well as demonstrating appreciation to the stars among them, should reap ongoing maintenance and growth of quality. The evaluators realize this is often a sticky issue with veteran faculty, and one that needs a special approach. And at times where remediation may not be possible mid-program, a backup plan to provide the intern needed support might be part of future planning. In some cases, graduate students served as excellent backups and perhaps this can be even more formally embedded.
- **Balance:** Although there was overall praise and satisfaction expressed by the students for all aspects of the program, there were some findings that suggest questions program planners might wish to consider: Is there the best balance among the major components of the program – lab work, knowledge and skill presentations, interactive group engagements, self-selected socializing and campus use? Are time and timing maximized? Is the best mix of programming offered as required and optional, e.g., library skills?
- **Administration/Management:** For the most part, in both sites, the program ran smoothly from time of application through final presentation and evaluation survey. REU program administrators drew from their professional experience as well as from prior summer sessions. The parts functioned well to contribute to a whole perceived by most students as greatly beneficial. This was also true with the administrative and professional support provided students in preparing presentations, slides, and the like. The proof in this case was in the high quality consistent throughout the cohort. As in any multi-part program, however, there are glitches. Some can't be avoided, and good

management is figuring it out well and asap. Others, however, may suggest a change or two in the administrative role and the management plan. Clues to consider can be found in student comments regarding the REU program as a whole. The intention of the program leadership in employing a Developmental Evaluation consultant team has from the start been continuous improvement. The results of this intention have been clearly seen in the ongoing growth of each summer experience.