Materials Connection REU Site (MacREU R'Side) Evaluation, 2018*

Kevin M. Esterling
UC – Riverside
kevin.esterling@ucr.edu

Ludwig Bartels
UC – Riverside
ludwig.bartels@ucr.edu

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Abstract

This is the evaluation for the fifth year of the MacREU-UCR REU site. As it has in each of the past years, the program performed very well in exposing students to science and engineering, building their scientific skills and encouraging them to pursue a PhD. The evaluation of the program showed that the students gained considerable research skills and professional development that year in every respect we measured. This evaluation shows that the 2018 program equaled or nearly equaled the already very strong results of the previous years. In particular, the program maintained high levels of exposure to research and mentoring, applying the experience they gained to development of research skills, professional development and aspirations of a career in science and engineering.

1 Introduction

"Materials Connection REU" (MacREU R'Side) was a 10 week REU site, held in the summer of 2018, in which 11 undergraduate students, mostly from Southern California colleges, had the opportunity to conduct research in science and engineering labs on the UCR campus. The students largely came from demographic groups that are under-represented in STEM fields, including 50 percent Hispanic/URM students, and 46 percent female or not gender identified.

The PI carefully screened students with Skype interviews and carefully selected among applicants those who showed promise in science but were at risk of not pursuing a career in science. Among the 11 students, 2 hailed from two year colleges, 5 came from non-research intensive four year colleges and four from research intensive universities. In particular, the students had the following home institutions: Los Angeles Trade-Tech College, CSU Santa Barbara, UC Santa Cruz, Cal State Long Beach, Fullerton College, Northeastern, University of La Verne, and UCR.

All of the students' research projects were related to the growth and application of thin films or monolayer materials. Students were placed in a variety of labs within the Materials Science and Engineering program. Participants are exposed to a wide area of fields from catalytic chemistry to semiconductor processing and from solar cell manufacture to the improvement of medical devices. To learn more about the MacREU site at UCR, visit http://macreu.ucr.edu/. At this site, one can view short video presentations from each of the students that describes their research and experience in the program.

This evaluation draws on two data sources 1) a survey of participating students based on the REU survey template available on the "Student Assessment of Learning Goals" website http://salgsite.org, providing both qualitative and quantitative evaluation data, and 2) qualitative responses from the participating students provided via open-ended responses in the survey itself.

Overall, the fifth year of the program well met its academic goals of exposing students to research, building their academic research skills, and gaining their interest in pursuing science and engineering as a career at the PhD level. In every measure in this evaluation, the 2018 program equaled or nearly equalled the extremely strong results we observed from the previous four years of the program. In sum, the program was a strong success and met its goals of instilling an interest in science and engineering among students from under-represented backgrounds. In particular, the program maintained high levels of exposure to research and mentoring, and also showed significant improvements in the program's on-campus administration and students' experience.

2 Student Assessment of Learning Goals Survey Results

In this section, we present the results of a survey we administered to the 11 NSF-funded students, and all of these students filled out a survey. The survey comes from a template

for REU evaluations available at the Student Assessment of Learning Goals website.[1] We used this website to administer the survey and to generate the figures showing results.

Gains in THINKING AND WORKING LIKE A SCIENTIST: APPLICATION OF KNOWLEDGE TO RESEARCH WORK.

1. How much did you GAIN in the following areas as a result of your most recent research experience?	1:no gains	2:a little gain	3:moderate gain	4:good gain	5:great gain	9:not applicable	Mean	N
1.1 Analyzing data for patterns.	0%	9%	0%	0%	64%	27%	4.6	8
1.2 Figuring out the next step in a research project.	0%	0%	18%	36%	45%	0%	4.3	11
1.3 Problem-solving in general.	0%	0%	18%	27%	55%	0%	4.4	11
1.4 Formulating a research question that could be answered with data.	0%	18%	18%	27%	36%	0%	3.8	11
1.5 Identifying limitations of research methods and designs.	0%	0%	36%	27%	36%	0%	4.0	11
1.6 Understanding the theory and concepts guiding my research project.	0%	0%	18%	27%	55%	0%	4.4	11
1.7 Understanding the connections among scientific disciplines.	0%	9%	0%	36%	55%	0%	4.4	11
1.8 Understanding the relevance of research to my coursework.	0%	9%	18%	18%	55%	0%	4.2	11

Summary of scale results

The graphic below lists the mean and confidence interval (±3 times the standard error) for each item.

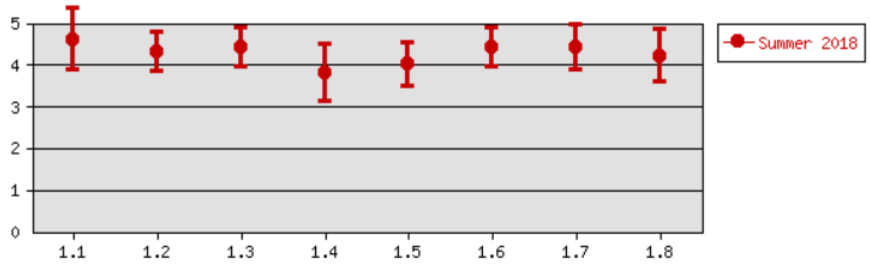

Figure 1: Gains in Thinking and Working Like a Scientist

Overall, the program well met its goals of introducing students to scientific research as a career and helping them to build capacity for conducting scientific research. This can be seen for example in Figure 1. In this section of the survey, students were asked to rate their own gains from the program in learning how to think scientifically and work like a scientist, and to apply scientific knowledge to research. On average, students report good to great gains in skills such as analyzing data for patterns, formulating a research question and understanding theory and concepts. While there is a little variability in responses, virtually all students report great gains in developing this capacity such that each of the confidence intervals exceeds the good category. The results for 2018 are similar to the results we observed in 2017. In each case the confidence intervals overlap between the two years.

Likewise, in figure 2 students reported considerable personal gains in their own capacity to do research, in areas such as their own ability to contribute to science, their confidence to do well in future science courses, and understanding what everyday research is like.

[1] See `https://salgsite.net/`, accessed January 27, 2019.

PERSONAL GAINS RELATED TO RESEARCH WORK

2. How much did you GAIN in the following areas as a result of your most recent research experience?	1:no gains	2:a little gain	3:moderate gain	4:good gain	5:great gain	9:not applicable	Mean	N
2.1 Confidence in my ability to contribute to science.	0%	9%	9%	55%	27%	0%	4.0	11
2.2 Comfort in discussing scientific concepts with others.	0%	9%	9%	45%	36%	0%	4.1	11
2.3 Comfort in working collaboratively with others.	0%	9%	9%	9%	73%	0%	4.5	11
2.4 Confidence in my ability to do well in future science courses.	0%	9%	9%	36%	45%	0%	4.2	11
2.5 Ability to work independently.	0%	0%	9%	45%	45%	0%	4.4	11
2.6 Developing patience with the slow pace of research.	0%	9%	18%	45%	27%	0%	3.9	11
2.7 Understanding what everyday research work is like.	0%	9%	9%	18%	64%	0%	4.4	11
2.8 Taking greater care in conducting procedures in the lab or field.	0%	9%	9%	27%	55%	0%	4.3	11

Summary of scale results

The graphic below lists the mean and confidence interval (±3 times the standard error) for each item.

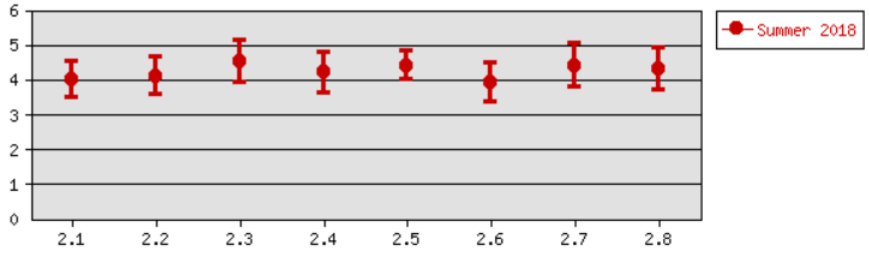

Figure 2: Personal Gains Related to Research Work

Like in Figure 1, the confidence intervals include a good level of gain response. The results from 2018 overlap those in 2017.

Figure 3 also presents firm evidence that students improved their professional skills such as how to prepare a scientific poster, keeping a detailed lab notebook and understanding journal articles. Students tend to report moderate to good gains in these skills across the board, with the exception of question 3.1, "Writing scientific reports or papers," which students gave only a moderate rating. While these are positive results in an absolute sense, overall the scores on these items are lower than scores on the same items in 2017. We need to investigate why that is and make corrections.

Figure 4 continues to support the view that students gained in their self-efficacy for conducting research, where students typically indicated their gained a fair amount or a great deal in their own feelings of efficacy in engaging in real-world science research, feelings of responsibility for their research project, feeling part of the scientific community, confidence in their own ability to try out new ideas or procedures on their own and interacting with scientists from outside of the school. The point estimates for these scores are a bit lower than 2017 but the confidence intervals for the two years largely overlap.

Overall, figure 5 shows that students rated the quality of their research experience as good, including their working relationships with their research mentor, the amount of time doing meaningful research and the overall experience, and the amount of time spent

Gains in SKILLS

3. How much did you GAIN in the following areas as a result of your most recent research experience?	1:no gains	2:a little gain	3:moderate gain	4:good gain	5:great gain	9:not applicable	Mean	N
3.1 Writing scientific reports or papers.	9%	27%	18%	18%	9%	18%	2.9	9
3.2 Making oral presentations.	9%	0%	9%	27%	55%	0%	4.2	11
3.3 Defending an argument when asked questions.	0%	9%	18%	64%	9%	0%	3.7	11
3.4 Explaining my project to people outside my field.	0%	9%	0%	36%	55%	0%	4.4	11
3.5 Preparing a scientific poster.	0%	18%	0%	18%	64%	0%	4.3	11
3.6 Keeping a detailed lab notebook.	9%	18%	18%	18%	27%	9%	3.4	10
3.7 Conducting observations in the lab or field.	9%	9%	27%	27%	27%	0%	3.5	11
3.8 Using statistics to analyze data.	0%	27%	27%	18%	18%	9%	3.3	10
3.9 Calibrating instruments needed for measurement.	0%	9%	27%	36%	27%	0%	3.8	11
3.10 Working with computers.	0%	18%	27%	36%	18%	0%	3.5	11
3.11 Understanding journal articles.	9%	9%	9%	36%	36%	0%	3.8	11
3.12 Conducting database or internet searches.	0%	18%	9%	27%	45%	0%	4.0	11
3.13 Managing my time.	0%	9%	18%	36%	36%	0%	4.0	11

Summary of scale results

The graphic below lists the mean and confidence interval (±3 times the standard error) for each item.

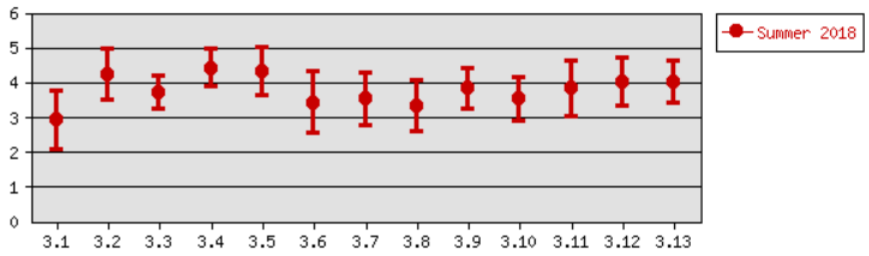

Figure 3: Gains in Academic Skills

with their mentors and getting advice from their mentors about graduate schools. These scores are similar to those from 2017.

The questionnaire also give students an opportunity to add more thoughts on the quality of their research experience and they wrote as follows.

- Mentors are usually busy and sometimes don't have time to chat or explore conversations. Mentor mostly talked to me when explaining what was needed from me.
- Mentoring was very high quality. Mentor was always willing to help and was always prepared.
- I did not have a good connection with my mentor because she had three different projects this summer. At the beginning of the program I had to go to lab and talk to my PI to be able to get a tour of the lab because my mentor never setup a tour for me before the program started. My mentor did not give me an introduction of my summer research until I insisted about it. She would not tell me when I had to

The following questions ask about your overall research experience and about any changes in your attitudes or behaviors as a researcher.

4. During your research experience HOW MUCH did you:	1:none	2:a little	3:some	4:a fair amount	5:a great deal	9:not applicable	Mean	N
4.1 Engage in real-world science research	0%	9%	18%	18%	55%	0%	4.2	11
4.2 Feel like a scientist.	0%	0%	9%	36%	55%	0%	4.5	11
4.3 Think creatively about the project.	9%	9%	9%	27%	45%	0%	3.9	11
4.4 Try out new ideas or procedures on your own.	9%	18%	18%	27%	27%	0%	3.5	11
4.5 Feel responsible for the project.	0%	9%	27%	9%	55%	0%	4.1	11
4.6 Work extra hours because you were excited about the research.	9%	18%	0%	18%	55%	0%	3.9	11
4.7 Interact with scientists from outside your school.	18%	9%	27%	18%	18%	9%	3.1	10
4.8 Feel a part of a scientific community.	0%	9%	9%	27%	55%	0%	4.3	11

Summary of scale results

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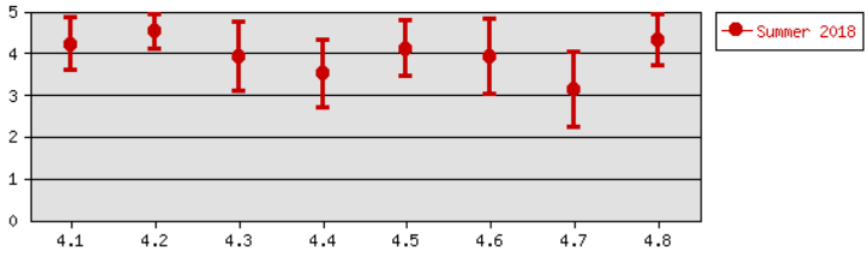

Figure 4: Attitude and Behavioral Changes

go to lab until I would ask and she would push back the time every time within a short notice.

- I didn't interact very much with my mentor as I was taught to be completely autonomous in lab.
- My interaction with people was valuable.
- Overall, it was a great experience. I was very glad to be paired with my mentor and lab. It definitely helped contribute to my self-confidence and motivation as a researcher.
- Would like if mentors could have a clear outline of there expectations, as well as background info to read up on. I had a great lab environment and PI, which helped me learn a lot. Also, my mentor was a big help and played a major in my success throughout the summer

Figure 6 summarizes the research communication activities students participated in. The program expected students to prepare a scientific poster as a part of the program, and most of them indicated that they either presented the poster or planned to present it. The program did provide students an opportunity to prepare a talk, but they did

These questions ask about your research experience.

5. Please rate the following:	1:Not applicable	2:Poor	3:Fair	4:Good	5:Excellent	Mean	N
5.1 My working relationship with my research mentor	0%	9%	18%	18%	55%	4.2	11
5.2 My working relationship with research group members.	0%	9%	9%	18%	64%	4.4	11
5.3 The amount of time I spent doing meaningful research.	9%	0%	27%	18%	45%	3.9	11
5.4 The amount of time I spent with my research mentor.	0%	9%	27%	18%	45%	4.0	11
5.5 The advice my research mentor provided about careers or graduate school.	0%	18%	9%	9%	64%	4.2	11
5.6 The research experience overall.	0%	0%	18%	18%	64%	4.5	11
5.7 Please comment on any of these aspects.	Enter codes for text answers					--	8

Summary of scale results

The graphic below lists the mean and confidence interval (±3 times the standard error) for each item.

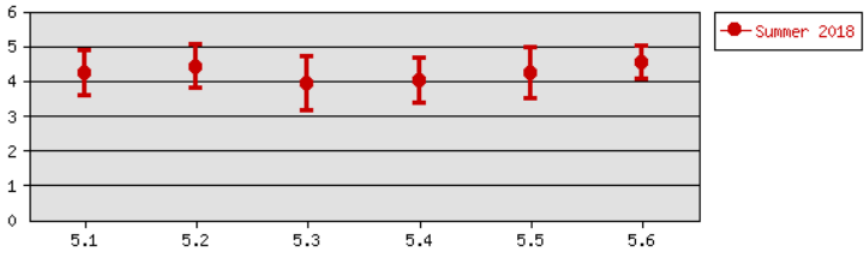

Figure 5: Quality of Research Experience

not have the opportunity to attend a conference or publish a paper during the summer session.

Figure 7 continues to lend support to our belief that the program enhanced students' interest in science and engineering as a career, typically indicating that the program confirmed and clarified their scientific career interests. Across all of the measures, students report agreeing that participating in the program enhanced their preparation for a career in science, especially items 7.2 "Doing research clarified for me which field of study I want to pursue," and 7.4 "My research experience has prepared me for graduate school." The scores on these items are similar to those from 2017.

Figure 8 also confirms that the program enhanced students' expectations and interests in pursuing research and science as a career, indicating gains in interest in enrolling in a STEM PhD or masters' program and working in a science lab. The program did not enhance students' interest in medical, dental or law school which is expected. This figure overall indicates both the effectiveness of the program in enhancing students' interest in science and also that the program did not typically select students already on the science track, since if students entered program on a science career track they also would have indicated no gains. Overall the point estimates of the scores on these items are a bit lower than what we observed in 2017, although the confidence intervals largely overlap.

The questionnaire also asked them to type in their intended degree and, "compared to your intentions BEFORE doing research, HOW LIKELY YOU ARE NOW to enroll

Research experience

6. As part of my most recent research experience...	1:yes	2:no	Mean	N
6.1 I presented a talk or poster to other students or faculty	100%	0%	--	11
6.2 I presented a talk or poster at a professional conference	9%	91%	--	11
6.3 I attended a conference	9%	91%	--	11
6.4 I wrote or co-wrote a paper that was published in an academic journal	0%	100%	--	11
6.5 I wrote or co-wrote a paper that was published in an undergraduate research journal	0%	100%	--	11
6.6 I will present a talk or poster to other students and faculty	82%	18%	--	11
6.7 I will present a talk or poster at a professional conference	100%	0%	--	11
6.8 I will write or co-write a paper to be published in an academic journal.	18%	82%	--	11
6.9 I will write or co-write a paper to be published in an undergraduate research journal.	0%	100%	--	11
6.10 I won an award or scholarship based on my research	0%	100%	--	11

Figure 6: Research Activities

in a graduate program leading to an advanced degree."

- My current major is in Chemical Engineering. After the program I still want to pursue research but now more inclined towards materials science.
- I knew I wanted to go to graduate school before I joined the program.
- Intended degree was bachelors of science. Now I am considering masters of even PHD.
- I originally planned only to complete a B.S. and was only beginning to consider graduate programs. Now I am certain I am enrolling in a Ph.D. program.
- I am a chemistry major. Prior to the program, I was debating on working on a higher degree in chemistry or enrolling in med-school. I'm now leaning towards medicine. I am equally as sure as I was before the program that I wanted to pursue a higher degree.
- Originally I thought that organic chemistry was my life and that that was what I wanted to continue doing, but after doing this research program I realized that organic chemistry is not for me. I was not good at it and soon realized that it was not as fun as I had made it out to be in my mind. I want to try out other labs though, to see if maybe there is something else that I am interested in doing research in.
- Computer Engineering, B.S. very likely.

Research experience

7. Rate how much you agree with the following statements.	1:Strongly disagree	2:Disagree	3:Agree	4:Strongly agree	Mean	N
7.1 Doing research confirmed my interest in my field of study.	0%	18%	55%	27%	3.1	11
7.2 Doing research clarified for me which field of study I want to pursue.	0%	0%	64%	36%	3.4	11
7.3 My research experience has prepared me for advanced coursework or thesis work	0%	27%	55%	18%	2.9	11
7.4 My research experience has prepared me for graduate school.	0%	9%	36%	55%	3.5	11
7.5 My research experience has prepared me for a job.	0%	36%	36%	27%	2.9	11

Summary of scale results

The graphic below lists the mean and confidence interval (±3 times the standard error) for each item.

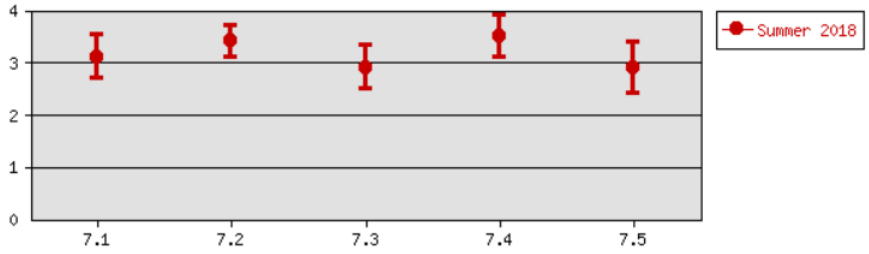

Figure 7: Effects of Research Experience on Personal Advancement

- Intended degree M. D.-have many options and would still like to explore those options
- I want to be more independent in the my career. Getting a Masters or PhD will allow me a certain freedom in industry or academia.
- Im currently working toward a degree in Civil Engineering with a minor in materials science. I intended to apply to grad school prior to the program, but was slightly on the fence about masters or PhD, after the program, I am more certain in getting a PhD

The questionnaire included an open-ended question asking students to reflect on how their research experience influence their own thinking about future career and graduate school plans. The students wrote,

- I enjoyed the experience of a lab, therefore I am more open now to form part of a research lab.
- I was able to explore the areas of science I had the most interest in and how new discoveries in those areas influence our society. This allows me to better narrow down graduate school and programs.
- I already had a set career plan before the program.

Research experience

8. Compared to your intentions BEFORE doing research, HOW LIKELY ARE YOU NOW to:	1:not more likely	2:a little more likely	3:somewhat more likely	4:much more likely	5:extremely more likely	9:not applicable	Mean	N
8.1 enroll in a Ph.D. program in science, mathematics or engineering?	9%	18%	18%	18%	36%	0%	3.5	11
8.2 enroll in a masters program in science, mathematics or engineering?	18%	18%	18%	27%	9%	9%	2.9	10
8.3 enroll in a combined M.D/Ph.D program	18%	27%	18%	0%	36%	0%	3.1	11
8.4 enroll in medical or dental school?	64%	9%	9%	0%	9%	9%	1.7	10
8.5 enroll in a program to earn a different professional degree (i.e. law, veterinary medicine, etc.)	91%	0%	0%	0%	9%	0%	1.4	11
8.6 pursue certification as a teacher?	64%	0%	18%	9%	9%	0%	2.0	11
8.7 work in a science lab?	18%	18%	18%	36%	9%	0%	3.0	11
8.8 Other. Please state your intended degree and, compared to your intentions BEFORE doing research, HOW LIKELY YOU ARE NOW to enroll in a graduate program leading to an advanced degree.	Enter codes for text answers						--	10

Summary of scale results

The graphic below lists the mean and confidence interval (±3 times the standard error) for each item.

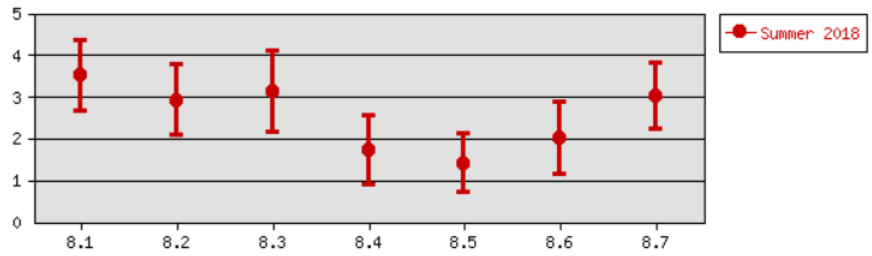

Figure 8: Effect of Experience on Entering the Pipeline

- Helped me see what grad school is like and how it will benefit me in the future.
- My experience helped me realize that I want to attend graduate school and enroll in a Ph.D. program. It showed me that research is a career path I am much more interested in pursuing than I previously thought.
- After doing actual research, I am more certain that I should pursue a career in medicine. I enjoyed my experience in MacREU, but there are certain politics that go into research that I never anticipated. I will say that the aspect of research is a joy, but your experience is also highly dependent on whom your working with.
- It influenced it quite a lot because I did not realize what it actually meant to do research. I thought grad school would be you just continuing a regular course load and only be doing research on the side, and that is not what it is at all. Realizing that you are in lab almost full time for all 5 years is not what I thought it would be. This made me think, is this something I can do? I am currently not sure about grad school, but I think if I find a lab that I love I would definitely apply.
- I used to not consider graduate school at all. Now, I know I definitely wish to

pursue a Ph.D. I am just unsure of whether I want to pursue it immediately after graduation or after spending time in industry. However, it is still up in the air as to what field I wish to hone my graduate degree in.

- Leaves me with a lot of options that I would like to explore
- I am now aiming higher than I was prior. I don't want to settle for a B.S.
- It feels much more probable, and I have a more concrete idea of what I need to do and what type of research I want to do

The questionnaire also asked students to reflect on other ways the program enhanced their interest in science as a career and led to personal gains, and they wrote,

- I met interesting people form other disciplines. I gained insight on how a single discipline can branch into different subjects. How different disciplines can come together to solve a single problem from different perspectives. I also made good connections with peer and professors.
- Being able to network with all of the staff and faculty at the school was very beneficial.
- Doing research has really challenged the way I managed my time and tested my ability to work well with others. In both regards, I have to be better.
- I gained a lot of hands on experience and learned a lot of lab techniques, and I really enjoyed that!
- Cleanroom experience.
- Great learning experience working with different tools and machines
- Networking was a great gain.
- I met a lot of great people from many different experiences, and I learned to connect with and understand many different types of people

Figure 9 indicates that students overall were satisfied with the organization and structure of the program itself. The program included training and involvement with lab personnel; we had a dedicated staff person (Rebecca Ryan) and graduate research assistant (Adam Berges) who were able to provide constant attention to the group training and activities, and more planned social activities. Overall we see high levels of satisfaction, especially on items 11.2 "Support and guidance from program staff," and 11.4 "Support and guidance from other research group members."

Figure 10 indicates mixed views of the training offered, although in each case students typically report gaining a good amount or a great deal of learning from each program element. This might be an area for future improvement, although there is only so much training students can do over the course of a 10 week program.

The following questions ask about aspects of the research program.

11. How satisfied were you with the following aspects of the research program?	1:Not applicable.	2:Very dissatisfied	3:Somewhat dissatisfied	4:Somewhat satisfied	5:Very satisfied	Mean	N
11.1 The application process.	0%	0%	18%	55%	27%	--	11
11.2 Support and guidance from program staff.	0%	0%	0%	27%	73%	--	11
11.3 Support and guidance from my research mentor.	0%	9%	18%	9%	64%	--	11
11.4 Support and guidance from other research group members.	0%	0%	18%	9%	73%	--	11
11.5 Research group meetings.	9%	9%	18%	18%	45%	--	11
11.6 Financial support.	0%	0%	0%	55%	45%	--	11
11.7 Group social activities.	0%	0%	9%	55%	36%	--	11

Figure 9: Satisfaction with the Program

Training Sessions

12. How MUCH did the following activities support your learning?	1:Did not do this activity	2:Not at all	3:A little	4:A good amount	5:A great deal	Mean	N
12.1 Workshop(s)on science writing and presentation.	9%	0%	9%	64%	18%	--	11
12.2 Training in library/internet/database search methods.	64%	0%	18%	9%	9%	--	11
12.3 Safety training	0%	0%	18%	36%	45%	--	11
12.4 Ethics seminar(s)	55%	9%	18%	9%	9%	--	11
12.5 Training in human or animal subjects regulations.	64%	0%	27%	9%	0%	--	11

Figure 10: Gains from Professional Training

Figure 11 indicates that students learn about research opportunities such as MacREU from a variety of sources, including item 14.2 "In class," 14.3 "An academic advisor," and 14.5 "A presentation given by professors or students about their research." These results clearly show a strong improvement in the advertising, publicizing and communication of the program to prospective students.

Students also indicated other sources for this information in an open ended question, including two that learned of the program from the previous year's participants:

- From previous students that have had this same experience.
- A friend told me about this program.
- Current lab's Principal Investigator
- Researching undergraduate research experiences online
- Prior participant, and their personal and public talks.

Figure 12 shows that students report a wide range of motivations for participating in research, with high responses on items 15.2 "Gain hands-on experience in research," 15.6 "Have a good intellectual challenge" (by 20 percent), 15.7 "Work more closely with

How did you find out about research opportunities on campus?

14. I found out about research opportunities from:	1:yes	2:no	Mean	N
14.1 I knew this institution offered research opportunities to undergraduates before coming here	73%	27%	--	11
14.2 in class	27%	73%	--	11
14.3 an academic advisor	36%	64%	--	11
14.4 an announcement (flyer, poster, email, website, etc.)	36%	64%	--	11
14.5 a presentation given by professors or students about their research	45%	55%	--	11
14.6 Other (please specify):	Enter codes for text answers		--	6

Figure 11: Ways to Learn about Research Opportunities on Campus

What motivated you to do research?

15. I WANTED TO DO RESEARCH TO: (select all that apply)	1:yes	2:no	Mean	N
15.1 explore my interest in science	100%	0%	--	11
15.2 gain hands-on experience in research	100%	0%	--	11
15.3 clarify which field I wanted to study	91%	9%	--	11
15.4 clarify whether graduate school would be a good choice for me	82%	18%	--	11
15.5 clarify whether I wanted to pursue a science research career	82%	18%	--	11
15.6 have a good intellectual challenge	100%	0%	--	11
15.7 work more closely with a particular faculty member	45%	55%	--	11
15.8 participate in a program with strong reputation	82%	18%	--	11
15.9 get good letters of recommendation	73%	27%	--	11
15.10 enhance my resume	100%	0%	--	11
15.11 Other (please specify)	Enter codes for text answers		--	3

Figure 12: Motivations to do research

a particular faculty member" (by 18 percent), 15.8 "Participate in a program with strong reputation," and 15.10 "Enhance my resume."

The questionnaire also provided students an open-ended question to report motivations they have to do research. Only one student responded to this, who wrote "Enhance my resume and explore what entails to do research."

Students were also given the opportunity to reflect on how the program impacted their career plans, and they wrote as follows. Typically the responses were quite positive although we do note some suggestions.

- Speakers helped to clarify my career plans by exploring career possibilites for professors.
- The GRE prep class needs to improve by a lot. The vocabulary that is practice in the time session should not be practice by pictionary or kahoot. The vocabulary

should be practiced by doing writing activities and learning context clues of each word. The session can also focus on roots of the words. There should be more math practice ion these session because even though studies show that we score higher in math it is possible that we do not remember geometry and some of us are not required to take statistics which is a huge part in the quantitative portion.

- The GRE prep as well as being able to walk in the shoes of a grad student for 10 weeks.
- We only casually discussed graduate school as a group and I discussed it extensively with my mentor. However, a group information session would be very helpful.
- The sessions were really helpful especially the guest speakers who talked about their experience in graduate school.
- GRE Prep and Guest Speakers helped greatly.
- It helps me understand my options more in depth.
- I went to a brief program about applying and listened to other peoples experiences which helped a lot

Students also were given an opportunity to write suggestions on how to make the program experience better.

- It would be best if mentors receive some training about how to deal with us mentees and training expressing whats expected from them. It seemed that mentors were not very familiar with their responsibilities as mentors. It gave the impression that Mentors were not aware they would be having a mentee for the summer
- Hands on training with different research equipment.
- Better connection with my mentor. More outgoings with the participants. Better GRE sessions.
- Having a clearer path of how to reach my goal of research during the program.
- The program was great. I don't have any criticisms.
- Overall this research program was really great. I learned so many things and got first hand experience in lab tools that I would, otherwise, not use.
- Starting the project sooner.
- Better structure of prior knowledge req.Coming from physics to chemistry was a big switch in skills.
- It was slightly disorganized in the beginning, it would have been better to make meetings with mentors more mandatory early on

And students were asked an open-ended question on how to make the experience better overall.

- More organization when it comes to have keys/PPE/access and all permits required for the undergrad to do research prior to our arrival or during the first week of our arrival. Have a schedule when it comes to the integrations of the undergrad to the lab. It would be nice if the PI is a bit involved too; I only saw my PI once.
- A presentation that describes the gradute school application process and what to expect during graduate school.
- Better organization.
- More tours of the facilities available.
- More group activities like the ropes course would really enhance the sense of community among the other attendees.
- I think one thing that would be great to have done would be more time using the clean room and maybe being trained in to use other facilities as well. I did enjoy the tour but I would have liked to be trained.
- Emphasis on mentorship, to establish a connection as well as encourage further exploration of the project.
- More social events with cohort. It was great having a small and intimate program.
- Touring labs prior to selection.

3 Aggregate Evaluation 2014-2018

In this section of the evaluation report we examine summary measures of the responses across sets of items in the survey. We compare whether the responses vary across important subgroups (not male and Hispanic), and we test whether the average of the response change across the years that we have administered the program. In each year of the program we submitted a detailed evaluation of the SALG data; please see those reports for detailed findings across all of the items of the survey for each of the individual years.

Over the five years we had 87 students compete the survey (including students in the same program in 2015 and 2016 but funded through the Semiconductor Research Corporation). In the survey 46 percent identify as not male (one student did not gender identify) and 51 percent identify Hispanic and we will use these self-reports to examine whether there are any differences in perspectives regarding the program for these two groups (the program also had a number of students from other URM groups who identify as African American, Native American, and Pacific Islander, but there are not enough observations from the students to reliably make statements, and it would not be sensible to collapse them into a single group, and so as a result we only examine the Hispanic category).

The SALG survey contains blocks of questions that are intended to create a scale relevant to important objectives of an REU site. The annual reports show the outcomes for each year for each of these questions. For this report, we condense the items into summary scales. To construct each scale, we first used factor analysis to confirm the items formed a coherent scale. One block of items (the third block regarding skill acquisition) yielded two factors, one related to communication skills and the other related to research skills so we separate these into two indexes. The remaining blocks each yielded a single factor. All skipped responses or not applicable responses are set to missing.

The first factor measures students gains in thinking and working like a scientist: application of knowledge to research work. The responses ranges from 1 (no gains) to 5 (great gain). The question prompt was, How much did you GAIN in the following areas as a result of your most recent research experience? and the questions were:

- Analyzing data for patterns.
- Figuring out the next step in a research project.
- Problem-solving in general.
- Formulating a research question that could be answered with data.
- Identifying limitations of research methods and designs.
- Understanding the theory and concepts guiding my research project.
- Understanding the connections among scientific disciplines.
- Understanding the relevance of research to my coursework.

The second factor measures students personal gains related to research work. The responses ranges from 1 (no gains) to 5 (great gain). The question prompt was, How much did you GAIN in the following areas as a result of your most recent research experience? and the questions were:

- Confidence in my ability to contribute to science.
- Comfort in discussing scientific concepts with others.
- Comfort in working collaboratively with others.
- Confidence in my ability to do well in future science courses.
- Ability to work independently.
- Developing patience with the slow pace of research.
- Understanding what everyday research work is like.
- Taking greater care in conducting procedures in the lab or field.

The third factor (part a) measures students gains in communication skills. The responses ranges from 1 (no gains) to 5 (great gain). The question prompt was, How much did you GAIN in the following areas as a result of your most recent research experience? and the questions were:

- Writing scientific reports or papers.
- Making oral presentations.
- Explaining my project to people outside my field.
- Preparing a scientific poster.
- Conducting observations in the lab or field.
- Managing my time.
- Defending an argument when asked questions.

The third factor (part b) measures students gains in research skills. The responses ranges from 1 (no gains) to 5 (great gain). The question prompt was, How much did you GAIN in the following areas as a result of your most recent research experience? and the questions were:

- Keeping a detailed lab notebook.
- Working with computers.
- Using statistics to analyze data.
- Calibrating instruments needed for measurement.
- Understanding journal articles.
- Conducting database or internet searches.

The fourth factor measures students overall research experience and about any changes in attitudes or behaviors as a researcher. The responses ranged from 1 (none) to 5 (a great deal). The question prompt was, During your research experience HOW MUCH did you:

- Engage in real-world science research
- Feel like a scientist.
- Think creatively about the project.
- Try out new ideas or procedures on your own.
- Feel responsible for the project.
- Work extra hours because you were excited about the research.

The fifth factor measures students perceptions of their research experience and interactions with mentors and colleagues. The responses ranged from 1 (not applicable) and 2 (poor) to 5 (excellent). The question prompt was Please rate the following: and the questions were:

- My working relationship with my research mentor
- My working relationship with research group members.
- The amount of time I spent doing meaningful research.
- The amount of time I spent with my research mentor.
- The advice my research mentor provided about careers or graduate school.
- The research experience overall.

The sixth block of items asked about students ability to give presentations or to collaborate on journal articles and we report on those outcomes elsewhere in the final report.

The seventh factor measures students perceptions of their research experience as preparation for a future career in science. The responses ranged from 1 (strongly disagree) to 4 (strongly agree). The prompt was Rate how much you agree with the following statements. And the questions were:

- Doing research confirmed my interest in my field of study.
- Doing research clarified for me which field of study I want to pursue.
- My research experience has prepared me for advanced coursework or thesis work
- My research experience has prepared me for graduate school.
- My research experience has prepared me for a job.

The eighth and final factor measures students plan to pursue an advanced degree and career in science or engineering. The response categories ranged from 1 (not more likely) to 5 (extremely more likely). The question prompt was Compared to your intentions BEFORE doing research, HOW LIKELY ARE YOU NOW to: and the questions were:

- Enroll in a Ph.D. program in science, mathematics or engineering?
- Enroll in a masters program in science, mathematics or engineering?
- Pursue certification as a teacher?
- Work in a science lab?

Table 1: ANOVA results

	F1	F2	F3a	F3b	F4	F5	F7	F8	Combined
Not Male	-0.13	-0.10	-0.19	-0.29	-0.20	-0.04	-0.16	-0.27	-0.19
Hispanic	0.00	-0.05	0.00	0.17	-0.22	-0.07	0.16	0.24	0.07
Year 2014	-0.28	-0.23	-0.55*	-0.24	-0.20	-0.42	-0.34*	-0.75*	-0.42
Year 2015	0.20	0.26	0.09	0.10	0.25	-0.04	0.18	-0.08	0.15
Year 2017	0.01	-0.04	0.13	0.23	0.09	-0.06	0.08	-0.26	0.11
Year 2018	-0.16	-0.28	-0.50*	-0.34	-0.42*	-0.21	-0.18	-0.78*	-0.48
Constant (baseline 2016)	4.56*	4.58*	4.35*	4.06*	4.66*	4.45*	3.37*	3.72*	5.27*
N	79	85	77	73	86	87	87	73	55
Maximum	5	5	5	5	5	5	4	5	6.1

*$p < 0.10$ two tail test

Table 1 presents the ANOVA (OLS regression) results that examine differences between female or Hispanic students from the other students, and also the average outcomes across the three years. Cell entries that reach statistical significance are indicated with an asterisk.

The constant row gives the average index score for each factor for the year 2016. For factors 1 to 5, the average response indicated a great gains response, and an agree response on factor 7. The average for the eighth factor, changes in career plans, centered on much more likely. Overall, the results from 2016 were exceptionally good since they average at the top response category on nearly each dimension. The rows for years 2014, 2015, 2017 and 2018 indicate the change in this average compared to 2016. Note that a cell entry of 1 in these rows would indicate an expected change of one full response category on the survey. Examining the cells for these two rows we observed no difference between the baseline year (2016) and the results in years 2015 and 2018.

The 2014 results for F3a (communication skills development), F7 (preparation for a career and science) and F8 (intent to pursue a career in science) are statistically lower than the base year, but only by a small amount, and are big enough only to change the predicted result for F3a to "good gains" and for F8 to "somewhat more likely." These lower scores can be attributed to 2014 being the first year of the program when we were still establishing procedures and best practices.

The results for 2018 are somewhat lower for F3a, F4 (overall research experience) and F8, bringing the predicted category down to "good gains" for F3a and F4, and "somewhat more likely" for F8. In examining the results, we find that all of these differences (with the exception for that of F8) are driven entirely by the responses of a single student. This student indicated in an open ended response that he or she did not get support from the designated mentor. S/he writes, "I did not have a good connection with my mentor because she had three different projects this summer. At the beginning of the program I had to go to lab and talk to my PI to be able to get a tour of the lab because my

mentor never setup a tour for me before the program started. My mentor did not give me an introduction of my summer research until I insisted about it. She would not tell me when I had to go to lab until I would ask and she would push back the time every time within a short notice." This student's response underscores the importance of training and monitoring the graduate student mentors, who are key to the REU participant's experience in the program.

Next note that the point estimates for the "not male" (one student does not gender identify) and Hispanic categories are all small and not statistically significant, which indicates that the students in these two categories do not tend to experience the program any differently from all students on average.

4 Conclusion

Overall, the program was very successful in its goals of interesting students in a career in science and engineering, in equipping them for such a career, and providing with strong research experience and skills. Furthermore, the evaluation scores for this year were equal to or greater across the board compared to the fourth year of the program (2107). In addition, while the program maintained high levels of exposure to research and mentoring, it also showed significant improvements in the program's on-campus administration and students' experience.

We look forward to building on this evaluation and even improving MacREU even more in 2019.