# Assessing Objective Attainment in a Research Experience for Undergraduates (REU) Program Focused on Community College Students

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# Assessing objective attainment in a Research Experience for Undergraduates (REU) program focused on community college students


## 1. Abstract

As part of the Engineering Research Center (ERC) Program of the National Science Foundation (NSF), the Nanotechnology-Enabled Water Treatment (NEWT) Center has run a Research Experience for Undergraduates (REU) program every summer since 2016. Starting in 2017, the NEWT REU program focuses on offering research experience to community college students from the metropolitan areas of the center's partner universities: Phoenix for Arizona State University (ASU), Houston for Rice University (Rice), and El Paso for the University of Texas at El Paso (UTEP). The objectives of the NEWT REU program are specified in NEWT's logic model, and they are to (1) provide community college students, especially from underrepresented minorities in science and engineering (URM), with professional research experience in NEWT laboratories, (2) improve the program participants' communication skills, specifically poster elaboration and presentation, (3) increase the number of URM students choosing to pursue careers or graduate studies in NEWT-related STEM fields, and (4) improve the mentorship skills of NEWT graduate students and postdocs participating as mentors. The NEWT REU program is run by NEWT staff from Rice and the participants are placed for ten weeks in NEWT laboratories at ASU, Rice, and UTEP, where they are generally mentored by graduate students. From the inception of the program, NEWT has collaborated with the University Office of Evaluation and Educational Effectiveness (UOEEE) at ASU to formulate the logic model and to provide external evaluation of the program. Evaluation is based on a social constructivism epistemological approach which assumes individual perceptions are relative and that reality is constructed socially. Therefore, participants' perspectives obtained through interviews are used to provide insight on their perception of the REU experience. Evaluation of the 2018 REU cohort (9 out of 11 students were interviewed) showed that the first two program objectives are being met—objectives 3 and 4 require long term longitudinal data for evaluation. In addition, the constructivist approach yielded qualitative information that allowed for more specific program appraisal. For example, the evaluation revealed that participants observed improvement in communication skills beyond those stated in the objectives (i.e., poster elaboration and presentation), such as being trained in how to read peer-reviewed articles. The evaluation also provided a more nuanced understanding of the quality of the participants' interaction with their mentors, allowing for better planning of mentor training in subsequent cohorts.


## 2. Introduction

As part of its education mission, the Nanotechnology-Enabled Water Treatment (NEWT) Center runs the NEWT Research Experiences for Community College Undergraduates (REU) program. This program is a ten-week summer internship where local community college students conduct research in laboratories at one of the NEWT partner institutions. The NEWT REU is based on the Nanotechnology REU with a Focus on Community College which has been running successfully at Rice University since 2010 [1].

The NEWT REU program allows community college students from the greater metropolitan areas of El Paso, Houston, and Phoenix to gain firsthand professional research experience in NEWT laboratories, and to improve their communication skills, such as the elaboration and presentation of research posters. The long-term objectives of the program are to increase the number of students from underrepresented minorities (URM) choosing to pursue careers or graduate studies in NEWT-related STEM fields, and to improve the mentorship skills of NEWT graduate students and postdocs participating as mentors.

From the inception of the program, NEWT's education team has collaborated with the University Office of Evaluation and Educational Effectiveness UOEEE at ASU to formulate a logic model and UOEEE also provides external evaluation of the program.

This report presents the results of the evaluation of the 2018 NEWT REU cohort, focusing on the program participants' perception of the program, and other findings that will serve as the basis for planning the 2019 cohort.

## 3. Background

One of the strategic goals of the Engineering Research Centers (ERC) Program sponsored by the National Science Foundation (NSF), such as NEWT, is "to increase the diversity of the scientific and engineering workforce by including all members of society …" [2] in order to address the "engineering diversity problem" referenced by Chubin, May, and Babco [3] in 2005. NSF data on engineering bachelor's degrees awarded between 2005 and 2014 indicates that engineering continues to have a diversity problem [4].

Although in this period there was a rise in the number of Hispanic recipients of engineering bachelor degrees from 7.5% to 10.4%, the percentage of Black or African Americans dropped from 5.2% to 4.2%. Similarly, the percentage of American Indian or Alaska Natives dropped from 0.6% to 0.4% during that time. Compared to their representation in the overall population, in 2014, Hispanics were 17%, Black or African Americans were 12%, and American Indian or Alaska Native were 0.8% of the U.S. population [5]. Similarly, the percentage of women in 2005 to 2014 who were awarded bachelor's degrees in engineering was 20% and 19.8% [6], while the population of women over 18 in the U.S. in 2014 was approximately 51% [7]. Therefore, all of these ethnic groups and women continue to be underrepresented among bachelor's degree recipients in engineering.

Because these populations are underrepresented at the bachelor's level, they are naturally underrepresented in the engineering workforce, as well as in populations who received master's [8], [9] and doctoral degrees [10,11] in engineering.

In contrast, even though the number of women receiving associate's degrees in engineering (13.2%) [12] are less than those receiving bachelor's degrees, a higher percentage of engineering associate's degrees are awarded to Hispanic, Black or African American, and American Indian or Alaska Native students in community colleges. For instance, in 2014, 17% of engineering associate's degree recipients were Hispanic, 7.3% were Black or African American, and 0.9% were American Indian or Alaska Native [12].

Therefore, one way to diversify the field of engineering is to tap into the diversity of community college engineering students and to provide them with activities that support and encourage students to pursue engineering degrees at four-year institutions and beyond. Early participation in research has long been recognized as one of the activities that improve the recruitment, retention, and career path of URM in science and engineering [13]. For this reason, the NSF requires ERCs to implement and support undergraduate research experiences.

At Rice University, the lead NEWT institution, the Office of STEM Engagement has run an REU program since 2010 [1]. This program served as the basis for NEWT's REU and its expansion to two additional institutions, Arizona State University (ASU) and the University of Texas at El Paso (UTEP), and both programs are run in parallel at Rice. Based on comments from participants in the 2017 cohort, special attention was given in the 2018 NEWT REU to provide training for the graduate students and postdoctoral researchers acting as mentors. The relationship between mentor and mentee is one of the most important factors in the outcomes of a successful undergraduate research experience [14,15], and in 2018, the NEWT REU program leads introduced improved mentor training based on the Entering Mentoring program [16].

## 4. Program implementation

The objectives of the NEWT REU program were established as part of NEWT's logic model, and they are to (1) provide community college students, especially from underrepresented minorities in science and engineering, with professional research experience in NEWT laboratories, (2) improve participants' communication skills, specifically poster elaboration and presentation, (3) increase the number of URM students choosing to pursue careers or graduate studies in NEWT-related STEM fields, and (4) improve the mentorship skills of NEWT graduate students and postdocs participating as mentors. The NEWT REU program is run by NEWT staff from Rice and the students are placed for ten weeks in NEWT laboratories at ASU, Rice, and UTEP, where they are mentored by graduate students or postdoctoral researchers. UOEEE provides external evaluation of the program.

### 4.1. Participant recruitment and selection

The NEWT REU participants are recruited from community colleges in the metropolitan areas of the center's partner universities: Phoenix area for ASU, Houston for Rice, and El Paso for UTEP. The recruiting strategy includes different activities, such as presentations by the program organizers in target community colleges, open house events, direct email invitations to the science and engineering faculty and relevant groups within the colleges, such as Scholarship and Veteran Affair offices. We also ask previous participants to distribute electronic flyers through their social networks. Program applications from the three metropolitan areas are received and compiled electronically at Rice University.

Participants are selected by the program leads from their application packages using a rubric developed by Rice's Nano REU [1]. The rubric considers the number of STEM courses taken by the candidates, their grades, two letters of recommendation (at least one from a faculty member), and a personal statement on the candidate's interest in the program. The candidates are then

sorted by their rubric score, and three students per available REU spot are invited to an interview with one of the program leads. After the interviews, the top candidates for each city are invited to register in the program. If they decline or fail to register, their place is offered to another student in the final list. Participants receive a stipend for the participation in the program.

Once admitted, participants are paired with one of the NEWT laboratories participating in the REU program. This pairing is done considering the student's major and stated interests. The projects are proposed by the faculty of the participating laboratories, who also designate a mentor for the participant, usually a graduate student or postdoctoral researcher.

After they have been assigned a project and host laboratory, participants are tasked to introduce themselves via email to their respective mentors and faculty, and to request a description of the project and literature to help them understand the project's context (e.g., review articles and book chapters.) Finally, the participants are asked to prepare a brief presentation for the orientation session that summarizes their backgrounds, interests, and goals for the program, and a brief description of their host's research, and their summer project.

### 4.2. Program orientation

All the REU students travel to Rice to take part in a two-day orientation session. This session is crucial for cohort formation because it allows all of the participants from the different metropolitan areas to meet and interact in person for two days before returning to the different host universities. The orientation starts with the students introducing themselves using the presentation described above. A number of activities follow, from team-forming exercises (e.g., spaghetti marshmallow challenge [17]) and opportunities to socialize (lunch and dinner as a group), to activities designed to prepare the participants for the research experience. Most of the latter activities are based on the Entering Research curriculum designed by the University of Wisconsin, Madison [18]. Examples of these activities are Aligning Expectations, Effective Communication, and Research Ethics.

In the 2018 orientation, we emphasized reading and interpretation of peer-reviewed research articles, which was identified as a limitation by the previous cohort. The participants were provided with two articles, a standard research article, and a review paper, which were then analyzed in groups. We used this exercise to introduce strategies to read scientific papers, and highlighted the differences between the two types of articles. Based on feedback from this activity, we designed and conducted a session later in the program on how to interpret commonly-used graphs and figures in research articles.

### 4.3. Mentor training

The graduate students and postdoctoral researchers acting as mentors received training based on the Entering Mentoring curriculum [16]. The program leads met with the mentors prior to the orientation session to emphasize the importance of aligning their expectations with the mentee's, how to identify a concrete research project and prepare a clear project description for the students, and the nature of mentoring.

After the initial meeting, the program leads met with the mentors three times during the program (roughly once a month). The sessions were used to share the mentor's experiences with the REU students, and to continue the Entering Mentoring curriculum. Topics discussed included Assessing Understanding, Cultivating Ethical Behavior in Research, and Addressing Equity and Inclusion.

4.4. Weekly meetings and other activities

The REU students met weekly with the program leads to discuss progress in their research projects and to continue the Entering Research training, covering topics such as the relationship and communication with their mentors and coping strategies. The meetings took place via Zoom, and the program director, based at Rice, visited the participants at UTEP and ASU to meet with them in person and conduct the weekly meeting from their facilities.

In addition, participants received training from the Rice Center for Written, Oral and Visual Communication on how to create a poster describing their research results, and on Diversity and Inclusion by the NEWT Diversity Director.

The REU students also had the opportunity to join their respective research group and department meetings, as well as NEWT center-wide activities. The program also organized visits to local water or wastewater treatment facilities for the participants.

4.5. SCI Colloquium

At the end of the program, all the participants returned to Rice to present their posters at the Smalley-Curl Institute Summer Research Colloquium, attended by Rice faculty, staff, graduate and undergraduate students. Finally, the program was formally ended with a farewell dinner with all the participants and program organizers.

4.6. Evaluation

Evaluation by the UOEEE team from the initial program in 2016 has allowed NEWT to continuously improve the REU program. The 2017 program was NEWT's first REU specifically targeting community college students, and it introduced changes based on the deficiencies noted by the first NEWT REU participants in 2016, namely to offer a better introduction to the program and to form a more cohesive cohort. We succeeded in doing this by bringing all nine 2017 participants together both at the beginning and the end of the program, and by holding weekly meetings via Zoom. In addition, the REU program director (based at Rice) travelled to both ASU and UTEP to visit with the interns and mentors and hold Zoom meetings from all three REU sites.

## 5. Methodology for data gathering and analysis

The UOEEE designed the evaluation of the program to explore the community college students' experiences who participated in the REU program and to examine whether the program

objectives were met. Of the eleven participants who were in the 2018 NEWT REU program, nine participated in the evaluation process.

The evaluation is based on a social constructivism [19,20] epistemological approach which assumes individual perceptions are relative and that reality is constructed socially [21]. Since constructivists study how and why participants construct meanings and actions in specific ways [22,23], then the experiences of the REU students, their interpretation of their experiences, how they used these interpretations to give meaning to and influence their interactions with others in and outside the laboratory is sought. This type of data could only be adequately captured by a qualitative research approach [24–26]. Thus, participants were interviewed by phone and the interviews were designed to elicit such insight. The interviews lasted approximately 30 minutes. The unit of analysis throughout the study was the REU participant, a student from a community college. The interview data was transcribed, read numerous times, and coded. Themes that emerged were examined, analyzed, and discussed. Institutional review board approval was sought prior to data collection. Pseudonyms are used in report writing to protect the identities of students.

### 5.1. Participants

One of the main objectives of the NEWT Research Experience for Undergraduates (REU) program is to provide community college students, especially underrepresented minorities, with professional research experience in NEWT laboratories. The participants for this program were, therefore, selected from community colleges that were considered feeder schools to the three universities involved (ASU, Rice, UTEP).

Of the eleven community college students who participated in the REU program, nine took part in the evaluation of the program. Three of the nine were from ASU, one from UTEP, and five from Rice. Of the nine, four identified as male and five as female. One participant identified as African American, five as White, one as Other, and two preferred not to identify. Five of the nine participants identified as Hispanic.

Table 1 lists the demographics of the NEWT REU students. All participants stated that they were U.S. citizens or permanent residents (as required by NSF, the funding agency) and did not have any conditions covered under the Americans with Disabilities Act.

Of the nine participants, eight had heard about the REU program from a faculty member in their community college. Two students noted that they had also seen flyers about the program in their school. Only one REU student mentioned that he had heard about the program from a friend.

*Table 1. 2018 NEWT REU participants' demographic information.*

| REU Student | Gender | | Ethnicity: Are you Hispanic or Latino? | | | What is your race? Please select all that apply. | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Male | Female | Yes | No | Prefer not to say | Black or African American | White | Other | Prefer not to say |
| 1 | | 1 | | | 1 | | | | 1 |
| 2 | | 1 | 1 | | | | 1 | | |
| 3 | 1 | | 1 | | | | | | 1 |
| 4 | 1 | | 1 | | | | | 1 | |
| 5 | | 1 | 1 | | | | 1 | | |
| 6 | | 1 | | 1 | | | 1 | | |
| 7 | 1 | | | 1 | | | 1 | | |
| 8 | | 1 | 1 | | | | 1 | | |
| 9 | 1 | | | 1 | | 1 | | | |
| **Total** | **4** | **5** | **5** | **3** | **1** | **1** | **5** | **1** | **2** |

## 6. Findings

The interview findings describe participants' impressions of the orientation they received, what attracted them to the REU program, how they saw their roles in the lab, their interactions with REU organizers, and their thoughts on the quality of mentorship they received. They also discuss the communication and research skills they acquired. The findings also describe their overall REU program experience, diversity and inclusion, and recommendations for improvements.

### 6.1. Orientation

Participants received a two-day orientation at Rice University at the beginning of the REU program. They were asked the extent to which the orientation to the NEWT Center was useful and helpful. All REU students indicated that the orientation they received was useful, for a variety of reasons:

- It set expectations: Six of the nine participants said that the orientation provided them a good idea of what to expect during the 10-week program. For instance, REU3 mentioned, "I'm glad we actually went over there [Houston] to meet them, so we get like an overall of what to expect." Another participant, REU6 stated, "There, they had two days of meetings where they went over things, and kind of basically it was just an orientation for what we should expect and what would be coming."

- Made connections: For four of the nine participants, the orientation was a forum in which REU students were able to connect to each other and to others in the program, and it helped connect the dots between what they were doing and the bigger picture. REU5 said that the activity of presenting what their goals were with their projects and what lab they were going to be working was very useful:

  > "So that sort of helped me realize that actually other people share similar passions, like I actually found people who want to be chemical engineers. It was great because we got to

meet each other, know each other's passion and also we got to be familiarized with the center and the mentors because we meet with mentors during that orientation."

REU6 said the following about her experience at the orientation:

> "[I]t helped just put names to faces, and actually meet the people who are running it. I feel like if I had just started here at ASU, I wouldn't have felt quite as connected to the other interns and the directors and everything. I thought it was really good that it kind of had that ... the feeling where we're going to start off in Houston, and then we have our time in the lab here, wherever, here at ASU or UTEP or Rice University for the different interns, and then at the end we go back to Houston and present. To me, it feels like a good way to start and end it with that."

REU7 said this about his orientation experience:

> "They went over what NEWT stands for. The director had our mentors. Each of us kind of got the scope of what our project was going to be, so we all got to find out what we we're doing. They also had a PowerPoint that shared it for the whole group, so everybody got to know that we're all working on something similar, but not identical, but a good opportunity for everybody to just learn how we're all playing a part in this program."

- Provided guidance on how to read articles, interpret graphs, and identify trustworthy sources: For four of the nine PPs learning how to read articles was as important aspect of the orientation. REU4 put it this way:

> "It was really, really useful, because like, I've never done research before. They showed us how to read articles, scientific articles, and how to look for different sources, how to find the different sources. To know when you're reading something ... how to know what you're reading will be trustworthy... So they teach us how to understand how an article... is actually trustworthy. Just pretty much how to learn how to go over an article and actually understand better."

Lastly, one ASU participant offered a suggestion for improvement. The student felt that an orientation at her home school to let her know where the labs were and to meet her mentor during orientation would have been helpful. She said,

> "We did have an orientation, but that was in Houston. At Rice University... It was very helpful. Except we didn't really have an orientation at ASU. So we mostly were at Rice, so I feel like that was not too helpful. Because you know we're at ASU, not Rice University. So maybe an orientation like 'Oh, this is labs.'...Yeah because we didn't know, I didn't know where I was even located until the first day."

In summary, the orientation helped prepare the participants by providing them an understanding of what to expect, an opportunity to connect the pieces of the program and connect with other REU students, and basic skills needed for research.

6.2. Attraction to the REU program

To understand what had attracted these students to participate in the REU program, participants were asked what made them interested in participating. Six of the nine said that they were interested in experiencing a research environment. Four of the nine connected the program with their future academic goals, such as becoming a chemical engineer. Three other common attractions to the program included the opportunity to work with nanoparticles, the opportunity to work in an area of research related to water treatment, and the prestige of the university.

These comments indicated that participants' interests were in line with the short-term outcomes of the program, which is for community college students to gain "increased awareness of research career opportunities in STEM fields" and "increased interest in pursuing academic and career goals in STEM."

6.3. Interactions with REU organizers and mentors

When asked to describe their interactions with REU organizers, participants' responses were very positive. The REU students said that organizers were always available and reachable, and consistently responded to questions in a timely manner, kept participants motivated and on track, checked on students to see whether they needed anything, and provided useful information related to what participants were doing during Monday meetings, via group chat, text messages, or email.

All nine REU students were assigned to the lab of a current NEWT Center faculty member. Six of the participants had a least one NEWT graduate student as their main mentor. One was mentored by a NEWT postdoc, one by a research scientist, and one by an undergraduate student. All REU participants indicated that they received their desired level of mentorship and described the quality of the mentorship as positive. They described their mentors as helpful, available to answer questions, easy to communicate with, attentive, knowledgeable, able to make the mentee feel comfortable, and able to involve the mentee in different experiences.

Participants also provided some suggestions for improvement. For instance, REU3 mentioned that he had two mentors with different disciplinary backgrounds. Although he saw this as a positive, he felt that they had conflicting opinions, which created complications. He explained it this way, "when you ask for some opinions, one of them says one thing and the other says a completely different thing. So in that way, it's kind of complicated." He also indicated that the differences between the two mentors, in terms of personality, behavior, and disciplinary focus, caused a level of discomfort for the mentee. Another participant, REU7, was unhappy with his mentor for not realizing that he needed his own project in a timely way.

Areas of improvement could be addressed in activities related to mentor training to address dealing with differences in personality and disciplinary focus in the lab. In addition, clearly identifying expectations could easily eliminate the struggle that REU7 faced.

6.4. Communication skills

One of the short-term outcomes for NEWT REU participants is that undergraduate students gain increased communication skills (poster elaboration and presentation)[a]. Therefore, REU students were asked to describe activities they engaged in that helped them improve their communication skills. REU1 mentioned the Awkward Mentor Case Study activity: "As part of our Monday weekly meeting, we had awkward mentor case study. It is a situation that they give us about how an intern is interacting with the mentor. Whenever the intern has a question, the mentor feels like it's a drag to answer them and all... how to deal with situations like that." She felt that this was useful because it provided her idea on how to deal with such a situation in a timely and respectful manner.

Another student, REU4, noted that being in the lab and working on a project required constant communication with her mentor. He saw this type of communication as necessary to keep everyone "on the same page" at all times. He also noted that it prevented him from making mistakes, helped him know what he needed to do next, and what his mentor was doing.

REU5 discussed the presentations that participants delivered to their colleagues during orientation. The presentation involved introducing themselves and their mentors, and briefly talking about their research plans for the summer. She saw that presentation as a helpful activity because it provided her practice in communicating with other interns that she did not know in a friendly, yet professional manner. She also saw the activity of having to contact her mentor and faculty member by email prior to coming to the program helped her get practice for "a proper way" to communicate by email.

Yet another participant, REU6, mentioned that although there were many different activities that required communication, one area in which she experienced the greatest growth was how to ask questions. She realized that thinking through what she was struggling in with in the lab, and expressing herself in a way that articulated that struggle clearly to others would allow them to know what she needed. She explained it like this:

> "I feel like if it's one [thing] that I've specifically learned more throughout this process, is that if I have a question in the lab, to be able to clearly and coherently explain the question that I have. One of the experiments that I actually ran yesterday, the paper that I was kind of basing it off of was not as clear, and then we ended up making some changes. But it did take a bit of back and forth, as I kind of had a question and then they were trying to answer it, and I realized that the question I was asking wasn't really exactly where I was struggling. Then I went back and looked at the paper some more, and then came back and was able to say, 'Okay, here's my exact question.' At that point, they were able to help me more in figuring out what I could change and what shouldn't be changed from the method that the paper described to get the experiment to work well in our lab."

[a] Logic model for NEWT program

REU7 had a mentor from another culture and experienced instances of intercultural communication. This student said that this experience helped him develop a new perspective on what it takes to communicate with people who are different from him, which he appeared to appreciate. He said:

> "Probably the main one would be when we're working in the lab. Usually at the beginning, [my mentor] had to walk me through the different experiments and the tests that she was doing. She had to give me the ideas, the concepts, what we're actually doing in the procedures... She's [from another country] and she'd only been in the US for three years, so she speaks English, but she has a heavy accent and it was at first difficult to understand her because I wasn't used to her way of talking. At the beginning when she was explaining all of it, and she'd use a word that I'm not quite sure what she said, I constantly had to tell her to stop for a second and explain what she just said so I made sure I didn't misunderstand her. … Eventually we got to a point where now, if we were to talk, I understand her really, really well, but we have communicated that much. It just took some time for us to get used to each other, and used to each other's way of talking, and understanding the way we get stuff done... It gave me a new perspective on communicating with someone who [is] culturally different, socially you're different, everything is just kind of off, but at the same time we still have to make it happen. It was kind of a nice perspective to have."

Lastly, the Monday meetings and weekly presentations were mentioned by four PPs as having helped them in different ways. REU2 and REU3 noted that these occasions provided an opportunity for everyone to come together and communicate, get feedback, and learn how to communicate in a different way. These meetings had a different impact on REU8, who felt that it increased her confidence level. She also felt that practicing for the presentations helped her learn the material and understand it better.

In summary, the experiences that NEWT REU participants had in and out of the laboratory helped them gain invaluable communication skills. Students learned important skills beyond poster elaboration and presentation. For instance, intercultural communication, email communication, effective project level communication, and articulating clear and concise questions are invaluable communication skills that students have learned as a result of their experiences during the summer. Students also reported increased confidence in communicating ideas and data to an audience.

### 6.5. Research skills

Participants were asked to describe activities that required research skills and how these activities helped them improve their research skills. Several students reported improved communication skills in the context of the research they participated in, particularly through reading, writing, and vetting of ideas through discussion.

Seven of the nine participants mentioned reading peer reviewed journals. Since the journal was a scientific journal and they read it within the context of a research project, they saw this activity as a research activity. They read journals to learn about the topic that they were working on, to

learn what others had done, and to apply what they had learned in their own experiments. Reading, however, is also a communication skill. Reading peer-reviewed journals is necessary for effective communication and learning in a research environment. For example, REU4 said the following when asked about research skills:

> "I would have to like read all the time so I could actually learn how to do different processes for particles and just implement them in an experiment as well… [these readings] will actually point us in the right direction. So, if we were like stuck in one place and we didn't know how to fix the problem, if we read a little bit more about the different processes other people tried or other research groups tried, they will help us out to actually fix the problem."

REU7 explained that he had learned how to be more selective and more focused in his reading.

> "Even after comparing a paper that I read in the beginning, and then now if I read the same paper, I can kind of pick out different things. Near the start, I would read a large portion of the publication or journal, but sometimes they can be very long, and if you're reading quite a few, that's not optimal. I feel like now I'm able to better narrow down and see, okay, these are the points that are important for me, see if those match, and then only then if they do, then go deeper into the article."

Another student, REU5, also discussed taking notes to document what was done in the lab so that it could be communicated with others. She said, "I would say it's taking notes...those notes I am actually using for building that poster today. So that's one of the research skills...like how to take notes in a good way to help me towards my final project."

Another area of growth was an understanding of the research process. Four participants described learning how to use various instruments and conducting experiments with them, and learning various lab procedures as the research skills that they had acquired. A couple of students described experimentation and designing experiments as research skills that they acquired.

One REU student learned that research required learning why something doesn't work and debugging the experimental process. REU8 described, "sometimes I didn't get the results I wanted, and I was always like 'ugh'. But now I'm like, 'Okay, let's track what we did wrong. Let's redo this.' Or something wasn't working. We ask questions, we're like, 'Okay, why isn't this working?' So I feel like that definitely helps me. Because in [high] school you're like, 'Oh, this doesn't work. Let me just write source of error, and that's it.' Yeah, this is where my error is, this could've happened. And you get almost your full grade."

### 6.6. Overall REU Program Experience

To bring together the experiences of participants in the program, they were asked to describe what they thought were the most successful aspects of the REU program experience and what they learned or gained through their experience in the REU program. It is not surprising that

each student's perspective was unique. The themes that emerged from their responses are summarized in Table 2 for each REU.

*Table 2. 2018 NEWT REU participants' feedback on the most successful aspects of the experience and the main learning outcomes.*

| REU | The most successful aspects of the REU program | What the student learned or gained through his/her experience |
|---|---|---|
| 1 | Weekly meeting which provided companionship and a sense that the student was not alone in the kinds of things that she was expected to do. | 1. Learned about how research environment works<br>2. How weekly meetings are used to talk about the progress of research projects |
| 2 | Learning to conduct research in a short period of time, which taught student how to plan and use her time efficiently; it also taught her to be patient. | Learned what graduate school looks like. |
| 3 | Learning through reading and through retaining information to understand the presentations. | Technical communication |
| 4 | Helpful mentor. | 1. Research is a professional work because student got paid for it.<br>2. Being more proactive in looking for answers and trying different things<br>3. Making mistakes, learning from them, and keep going. |
| 5 | 1. Monday meetings where students shared ideas about how they were doing.<br>2. Orientation because student learned about the campus and to meet and greet the mentors. | Research requires patience. |
| 6 | All the things that REU did and the research. This included presenting their PowerPoint presentation on their work, participating in meetings with faculty and others in their areas, being involved in research and seeing what research means and what it looks like. | Realizing that research may be a career option. |
| 7 | 1. Other interns with whom he developed friendships and getting a good understanding of how research is carried out.<br>2. The program has given a student the "concept of" graduate school as a possibility in the future. | Research requires a good deal of communication skills |
| 8 | Learning what research involves and its multidisciplinary nature. | Lab work. |
| 9 | The directors who made sure that students had everything they needed. | A hands-on understanding of nanotechnology. |

In summary, the REU program experience was positive and accomplished the key programmatic objectives: (1) taught students about communication, (2) research kills, and (3) for a couple students, it provided ideas about a possible future in research.

Of the nine participants, three (33%) (REU1, REU2, and REU7) said that they will likely pursue a graduate degree. REU4 said that he intends to look for other research opportunities. REU5 and REU6 felt that they would like to enter a career in research, while REU8 said that the area of water treatment might be an option. For REU9, the experience had provided general knowledge of what graduate school would be like. REU3 was not sure about what his plans would be. These reflections indicated an increased awareness and interest in pursuing opportunities in research and careers in STEM related fields.

6.7. Diversity and Inclusion

To be successful in any environment, a culture of inclusiveness is required to make students feel that they belong and are not excluded for any reason. To set expectations for such an inclusive culture with diverse individuals, the NEWT diversity and inclusion leadership provided students training at the orientation they received at Rice University. Eight of the nine participants indicated that they had attended such a training, while one responded as unsure.

Respondents were provided with an opportunity to give an example of specific aspects of the NEWT environment that allowed them to feel included and provided them the opportunity to participate fully as an individual. Participants provided the following responses:

> "Just by the fact that you can present- I mean they don't change anything, you are a presenter as the PhD student ... even though you are not a PhD student."

> "Regardless of diversity, within the lab we have many people from many regions or within the group we have many people from many countries like myself and we're all treated equally and fairly. We're all given the same opportunity, were given the same resources. We're all included."

> "In my lab group, there was people of all ethnicities and race and gender, so we had a fairly diverse group ... If there was anything that felt like it was a limitation, it was my being the only undergraduate student in the group. Everyone was graduate student and above. I lacked the experience that they had, but at the same time, they didn't treat me like a kid. They didn't treat me like I was below them or any way. Everybody was still accepting, and more or less they treated me like a person. It was enjoyable."

6.8. Lessons Learned

The analysis of the participants' interviews suggests that the short-term outcomes of the program are being met, with the students showing increased awareness of research career opportunities in STEM, and increased interest in pursuing academic and career goals in these fields. The participants also reported learning communication skills; however, the evaluation revealed that students observed improvement in communication skills beyond those stated in the objectives

(i.e., poster elaboration and presentation), such as being trained in how to read peer-reviewed articles.

In addition, the evaluation revealed barriers and challenges encountered by the participants over the course of their participation in the REU program that need to be addressed for the 2019 cohort. One of the common challenges described by four of the nine students was that their topic or content knowledge was inadequate. For instance, one was a biology major, but much of the lab work was based on chemistry and physics, which she found challenging. Her suggestion was to match the student's major to the topic of research.

The lack of alignment between the project topics and the participant's interests is partially due to the limited number of projects available to the participants, but we believe that this is also due to the highly specialized nature of the research that may not match the participants' expectations of the topic, resulting in a steep learning curve for them. For example, a biology major interested in general environmental topics might be placed in an environmental microbiology project and the student may need to learn quickly about the complexities of microbial ecology and not really consider this a topic of their interest. One possible solution to this challenge is to work with mentors to design projects that may appeal to a wider variety of students and ask the candidates to select their project preferences as part of the application to the program. In addition, the program leads can spend additional time during orientation discussing the participants' expectations for their research topics as part of the Aligning Expectations activity [16], and encourage their mentors to address this topic at the beginning of the program.

Other suggestions included providing students an adequate workspace with access to a printer, providing students who were not from Rice a brief orientation within their own campus, and better mentor training. These suggestions will be incorporated in the 2019 cohort, by organizing campus-specific orientation events and addressing the specific concerns with the mentors during training.

## 7. Conclusion

Evaluation of the 2018 NEWT REU cohort provided valuable insight into the outcomes of the program. The evaluation suggested that the short-term outcomes of the program were met, with the participants reporting increased awareness of STEM-related research opportunities and interest in pursuing academic degrees and/or careers in these fields, and improvement in their communication skills. In addition, the evaluation revealed several barriers and challenges encountered by the REU students that will be addressed in future cohorts.

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