YEAR 2 EXTERNAL EVALUATION

MERCED NANOMATERIALS CENTER FOR ENERGY AND SENSING (MACES)

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Executive Summary

The Merced NAnomaterials Center for Energy and Sensing (MACES) launched in summer 2015 with a five-year grant from the National Aeronautics and Space Administration (NASA) is completing the second year of its grant. In partnership with UC Santa Cruz (UCSC) and NASA Laboratories, MACES seeks to become a center of excellence in materials research and education. MACES faculty, staff, and students are working to develop functional nanomaterial platforms that will provide technological solutions for efficient and lightweight energy conversion devices, biosensors for space health monitoring and other terrestrial applications.

This report describes the evaluation of the second year of grant implementation in the project areas of education and outreach and dissemination. (Research will be addressed in a subsequent report.) Evaluation data were collected through student surveys, pre- and post-module evaluation forms, event evaluation forms, and review of program data.

The gender and racial diversity of MACES undergraduate and graduate students reflects the Center’s recruitment efforts and commitment to broadening participation. More than half of the students are either women or underrepresented minorities.

MACES undergraduate and graduate students report that MACES has had a positive impact on their intellectual development by increasing their STEM knowledge and their confidence in STEM abilities and by helping them develop critical thinking skills. The majority of students agree that MACES is creating an interdisciplinary learning environment that provides them with opportunities for interdisciplinary collaboration and teamwork, opportunities to communicate with researchers trained in different disciplines, and to apply approaches from multiple disciplines to research.

Participating in MACES has increased graduate and undergraduate student interest in STEM careers and increased undergraduate student interest in going to graduate school in a STEM field, suggesting that MACES is helping to increase the STEM workforce and also diversify the STEM workforce (since the majority of MACES students are from groups underrepresented in STEM).

The modules developed during the teacher professional development workshop in summer 2015 were implemented in high schools in grant Year 2. High school students reported statistically significant increases in their self-assessed knowledge in the key content areas for each of the modules. Almost all participating students also reported the modules increased their interest in STEM. Graduate students reported benefitting from development and implementation of the modules by gaining communication skills.
The following recommendations should be considered to build on the successes of the grant to date:

- Increase student opportunities for networking and interactions with industry, national labs, and MACES faculty.
- Enhance clarification about the NASA internship process, information about the project and equipment prior to the internship, and communication/coordination between MACES and interns.
- With the success of recruiting students from underrepresented groups, the Center is in a strong position to contribute to diversifying the STEM workforce. If the Center has not done so already, consider engaging with appropriate campus offices to provide information for faculty and students on ways to support an inclusive environment.

In conclusion, MACES has made meaningful progress in its educational and outreach goals in Year 2. MACES is providing opportunities for undergraduate and graduate students (many from underrepresented groups) to engage in interdisciplinary and innovative research, learn about NASA and participate in research with NASA scientists, and learn to communicate scientific ideas to high school students. High school students, undergraduate students, and graduate students report increased interest in STEM and STEM careers as a result of participating in MACES programs.
1) Introduction

1.1 MACES Goals and Evaluation Questions

The Merced NAnomaterials Center for Energy and Sensing (MACES), launched in summer 2015 with a grant from the National Aeronautics and Space Administration (NASA), is the first externally funded research center at UC Merced. In partnership with UC Santa Cruz (UCSC) and NASA Laboratories, MACES seeks to become a center of excellence in materials research and education. MACES faculty, staff, and students are working to develop functional nanomaterial platforms that will provide technological solutions for efficient and lightweight energy conversion devices, biosensors for space health monitoring and other terrestrial applications.

MACES is working to meet goals in the areas of research, education, and outreach and dissemination over the five-year project time period. The evaluation questions for each goal are listed below.

Research Goals
1. Establish a significant, multi-disciplinary, scientific research and education center at the host university with help from UCSC, that contributes to the programs of two or more of the NASA Mission Directorates.
2. Move increasingly towards gaining funding from sources outside of MIRO, by aggressively pursuing additional funding opportunities offered by the NASA mission directorates and other funding agencies.

Research Evaluation Questions
1.1 To what extent MACES has enabled a stimulating and collaborative nanomaterials research environment in terms of scientific impact and visibility?
1.2 To what extent has the affiliation with UCSC enhanced the center research?
2.1 To what extent is MACES creating a sustainable research infrastructure, gaining more support from sources outside of MIRO?
2.2 What partnership has MACES established and what are the outcomes of those partnerships in terms of sustainability?

Educational Goals
3. Enhance graduate students’ training so that they will be able to conduct original and innovative research, and broaden participation and enhance diversity in the STEM workforce.
4. Enhance the undergraduate STEM learning experience and increase the number of participating underrepresented minority (URM) undergraduate students.
Educational Evaluation Questions
3.1 How much progress has been made in creating the nanotechnology seminar course and a graduate nanoemphasis track with the four existing graduate programs?
3.2 To what extent has MACES enhanced graduate students’ learning and prepared them for tomorrow’s STEM workforce at NASA, other national laboratories, and industrial organizations?
3.3 To what extent is MACES broadening PhD participation and enhancing diversity?
4.1 What is the impact of the CSU Summer Research Program and the UC Undergraduate Research Program on participant intellectual development, STEM knowledge and STEM career prospective?
4.2 To what extent have NASA field trips enhanced undergraduate students’ STEM aspirations?
4.3 To what extent has MACES promoted URM undergraduate recruitment and retention?

Outreach and Dissemination Goals
5. Enhance the STEM learning experience by implanting technology-oriented scientific discovery modules through a high school teacher professional development workshop hosted by the center.
6. Increase STEM literacy via an open house, dinner with scientists, NASA field trip and website dissemination. In particular, increase the awareness of the importance of STEM on technology development and direct societal benefits of higher education in STEM.

Outreach and Dissemination Evaluation Questions
5.1 To what extent has the workshop hosted by the center enhanced teacher participants’ content knowledge, pedagogical content knowledge, attitudes, and integration of scientific practices in instruction?
5.2 To what extent have these modules enhanced student STEM learning?
6. To what extent have participants’ scientific literacy and STEM interest increased?

1.2 Evaluation Period

This report covers grant-related impacts and activities occurring between July 2016 (completion of Year 1 external evaluation report) and May 2017, which corresponds closely with the second year of grant funding.
1.3 Year 2 Data Collection Instruments

1.3.1 Annual Undergraduate and Graduate Student Surveys

The external evaluator, with input from MACES project staff, created online surveys (one for undergraduate students and one for graduate students) to collect data from the MACES core students about their perceptions of the Center and how it has impacted their education and research. Names and email addresses for students (8 undergraduates and 11 graduate students) were provided by the MACES team to the external evaluator.

Students were invited by email to take the survey in May, 2017, at the end of Spring Semester. Of the 19 students invited to the survey, 15 students (79%) responded. Response rates were 88% for undergraduate students (7 out of 8) and 73% for graduate students (8 out of 11).

1.3.2 Pre-Post High School Module Evaluation Form

Modules developed at the workshops for high school teachers during June 2016 were implemented during the 2016-17 school year. Participating high school students were given brief (2-5 question) pre- and post-module paper and pencil evaluation forms to assess change in knowledge and assess student interest in the module and interest in STEM. Data from the evaluation forms were entered into an Excel spreadsheet by the MACES team and provided to the external evaluator for analysis.

1.3.3 NASA Summer Internship Surveys

In partnership with NASA, MACES students were chosen through a merit-based selection process to participate in a 10-week summer internship at NASA during the summer of 2016. To collect data about the experiences of the interns and mentors, two online surveys were conducted by the external evaluator (one for interns and one for mentors) after the internship had been completed.

Of the 6 interns, three completed the online survey (50% response rate). Three out of four of the mentors completed the online survey (75% response rate).

1.3.4 Open House Evaluation Form

Paper and pencil evaluation forms were provided to participants at the MACES Open House on April 19, 2017. Fifty-nine attendees completed evaluation forms that addressed participant interest in MACES research and programs. The evaluation form also collected demographic information about attendees to help MACES assess
their outreach efforts. The MACES team entered data from the evaluation forms into Excel and provided the data to the external evaluator.

1.3.5 Review of Program Data

Information about student demographics and participation in activities was provided by MACES staff.

2) Research Goals

A thorough assessment of progress toward the grant-specific research goals will take place Summer 2017 and findings will be presented in the next report. Data collection efforts will include surveys or interviews with faculty and review of outputs such as collaborations, publications, grant proposals, and presentations.

3) Education Goals

3.1 Recruitment Activities

During Year 2, MACES actively recruited undergraduate and graduate students, particularly students from underrepresented groups through the following events:

- 8 trips to local colleges and universities (i.e., Merced Community College, California State University Stanislaus, UC Davis)
- MACES Open House

The gender and racial diversity of MACES undergraduate and graduate students (Table 1) reflects the Center’s recruitment efforts and commitment to broadening participation. More than half of the students are either women or underrepresented minorities.
Table 1. Characteristics of MACES Student Participants, Year 2

<table>
<thead>
<tr>
<th>Race/Ethnicity (all that apply)</th>
<th>Undergrad</th>
<th>Graduate</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>White</td>
<td>3</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>Hispanic</td>
<td>4</td>
<td>5</td>
<td>9</td>
</tr>
<tr>
<td>Asian</td>
<td>2</td>
<td>9</td>
<td>11</td>
</tr>
<tr>
<td>Black/African American</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>American Indian</td>
<td>1</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>Native Hawaiian /Pacific Islander</td>
<td>1</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>6</td>
<td>12</td>
<td>18</td>
</tr>
<tr>
<td>Female</td>
<td>3</td>
<td>6</td>
<td>9</td>
</tr>
<tr>
<td>Campus</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>UC Merced</td>
<td>9</td>
<td>16</td>
<td>25</td>
</tr>
<tr>
<td>UC Santa Cruz</td>
<td>-</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Student Type(^1)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Core</td>
<td>9</td>
<td>15</td>
<td>24</td>
</tr>
<tr>
<td>Participating</td>
<td>-</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>TOTAL:</td>
<td>9</td>
<td>18</td>
<td>27</td>
</tr>
</tbody>
</table>

3.1.1 MACES Open House

The second annual Open House took place on April 19, 2017. Of the 59 attendees who completed evaluation forms and answered the demographic questions, the majority were undergraduate (46%) or graduate students (22%) and most were from UC Merced (82%) (see Table 2).\(^2\) The Open House was attended by students from groups traditionally underrepresented in STEM, including women (57%) and underrepresented minority groups (for example about one-third\(^3\) identified as either Hispanic/Latino, Native Hawaiian/Pacific Islander, and/or Black/African-American).

\(^1\) Core students receive a stipend/fellowship from MACES to perform research on MACES projects and/or will be participating as NASA interns; Participating students perform research on MACES projects but do not receive a stipend/fellowship.

\(^2\) The MACES team collected completed evaluation forms, entered data, and made data available to the external evaluator.

\(^3\) Participants could select multiple race/ethnicity categories and therefore the percentages should be considered approximate.
Table 2. Participant Demographics from Open House

<table>
<thead>
<tr>
<th>Professional Status</th>
<th>Number</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Undergraduate</td>
<td>27</td>
<td>46%</td>
</tr>
<tr>
<td>Graduate Student</td>
<td>13</td>
<td>22%</td>
</tr>
<tr>
<td>Faculty</td>
<td>4</td>
<td>7%</td>
</tr>
<tr>
<td>High School Student</td>
<td>5</td>
<td>8%</td>
</tr>
<tr>
<td>High School Teacher</td>
<td>6</td>
<td>10%</td>
</tr>
<tr>
<td>Other</td>
<td>4</td>
<td>7%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Gender</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>10</td>
<td>43%</td>
</tr>
<tr>
<td>Female</td>
<td>18</td>
<td>57%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Race/Ethnicity(^4)</th>
<th>Number</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>White/Caucasian</td>
<td>21</td>
<td>36%</td>
</tr>
<tr>
<td>Black/African-American</td>
<td>1</td>
<td>2%</td>
</tr>
<tr>
<td>Hispanic/Latino</td>
<td>17</td>
<td>29%</td>
</tr>
<tr>
<td>Asian/Asian American</td>
<td>17</td>
<td>29%</td>
</tr>
<tr>
<td>Native Hawaiian/Pacific Islander</td>
<td>1</td>
<td>2%</td>
</tr>
<tr>
<td>American Indian/Alaska Native</td>
<td>-</td>
<td>0%</td>
</tr>
<tr>
<td>Other</td>
<td>2</td>
<td>3%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Institution</th>
<th>Number</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>CSU</td>
<td>-</td>
<td>0%</td>
</tr>
<tr>
<td>UCM</td>
<td>45</td>
<td>82%</td>
</tr>
<tr>
<td>Other</td>
<td>10</td>
<td>18%</td>
</tr>
</tbody>
</table>

The majority of participants (82%) "agreed" or "strongly agreed" that they learned more about the research activities of MACES at the Open House (Figure 1).

\(^4\) Participants could select multiple race/ethnicity categories and therefore the percentages should be considered approximate.
Participants’ level of interest in Research Experiences for Undergraduates (REUs), the MACES Graduate Program, and NASA Internships was fairly high, with about three-quarters or more of the participants stating they were at least somewhat interested in these programs (Figure 2). Interest overall was highest in the NASA Internship, with about two-thirds of participants reporting they were “very interested” in this opportunity.

Most participants indicated being “very interested” in careers in the field of Science/STEM (63%), and a third in the field of nanomaterials (Figure 3). Three-quarters or more of the participants were at least “somewhat interested” in a career in STEM or in the field of nanomaterials.
In terms of Open House activities, almost all respondents attended the keynote address, which was also reported to be the most interesting activity (Table 3).

Table 3. Interest in Open House Activities

<table>
<thead>
<tr>
<th>Activity</th>
<th>N Attended</th>
<th>% found most interesting among those who attended</th>
</tr>
</thead>
<tbody>
<tr>
<td>Keynote Address</td>
<td>52</td>
<td>83%</td>
</tr>
<tr>
<td>Poster Session</td>
<td>34</td>
<td>26%</td>
</tr>
<tr>
<td>Lab Tours</td>
<td>8</td>
<td>38%</td>
</tr>
</tbody>
</table>

3.2 Education

3.2.1 Enhancing Learning - Intellectual development and STEM knowledge

Consistent with the grant’s goal to train students to conduct original and innovative research, undergraduate and graduate students are reporting on the annual survey that MACES has had a positive impact on their intellectual development by increasing STEM knowledge, helping them develop critical thinking skills, and increasing their confidence in their STEM abilities (Figure 4). All students agreed their department and advisors were supportive of their participation in MACES.
In comparison to the grant’s first year, students in Year 2 were more likely to agree that MACES had made contributions to each of these areas of student development (Table 4). The increase in number of students agreeing that MACES increased their STEM knowledge is especially strong; in Year 1 64% of MACES students agreed their STEM knowledge has increased because of MACES whereas in Year 2, that number increased to 94% (statistically significant increase, \( p \leq 0.05 \)).

**Table 4. MACES’s Impact on All Students’ Intellectual Development and STEM Knowledge. – Year 1 & 2**

<table>
<thead>
<tr>
<th>% Agree / Strongly agree</th>
<th>Year 1</th>
<th>Year 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>MACES has increased your STEM knowledge.</td>
<td>64%</td>
<td>94% ( \uparrow )</td>
</tr>
<tr>
<td>MACES has helped you develop critical thinking skills.</td>
<td>57%</td>
<td>78%</td>
</tr>
<tr>
<td>MACES has increased your confidence in your STEM abilities.</td>
<td>75%</td>
<td>89%</td>
</tr>
<tr>
<td>Your department/advisor supports your participation in MACES.</td>
<td>79%</td>
<td>100% ( \uparrow )</td>
</tr>
</tbody>
</table>

* \( N=12 \) in the “increased your confidence” statement

\( \uparrow \downarrow \) Significant difference to \( p \leq 0.05 \)

**3.2.2 Workforce Preparation – STEM career perspectives**

On the survey students were asked to reflect on career interests and how well MACES was preparing them for various career trajectories. The majority of undergraduate and graduate students felt that MACES increased their interest in a STEM career, 86% and 73% agreeing with the statement respectively (Figure 5).
79% agreed with the statement overall (both graduate and undergraduate), compared to 64% in Year 1 (non-significant increase, findings not shown but are reported in the Year 1 external evaluation report).

Undergraduate students overwhelmingly agreed that MACES had increased their interest in STEM graduate studies (86%), similarly to Year 1 (79%) (non-significant increase, findings not shown but are reported in the Year 1 external evaluation report).

Among graduate students, almost all agreed that MACES participation increased their knowledge of NASA mission and career opportunities. In terms of career preparation, most graduate students reported the program was preparing them for being a researcher at a government lab or research institution (60%), followed by being a researcher in industry (36%) and faculty (20%).

### 3.2.3 Interdisciplinary Learning Environment

Almost all students agreed that MACES provided them with opportunities to work on an interdisciplinary team, communicate with researchers trained in different disciplines, collaborate across their discipline, and apply approaches from multiple
disciplines to research (Figure 6). The level of agreement with comparable statements is higher in Year 2 than in Year 1, but differences are not statistically significant (Table 5).

![Figure 6. MACES’s Impact on Students’ Interdisciplinary Learning](image)

| MACES provides you with an opportunity to work in a team with individuals trained in different disciplines. | Undergraduate (N=7) | Graduate (N=11*) |
| MACES provides you with an opportunity to communicate research to researchers trained in different disciplines. | 79% | 86% | 89% | 94% |
| MACES provides a way for you to collaborate with people outside of your own discipline. (Grad only) | 82% | 100% |
| MACES provides you an opportunity to apply approaches/tools from multiple disciplines to research. (Grad only) | 80% |

* N=10 for “...provides an opportunity to apply approaches/tools from multiple disciplines”

| Table 5. MACES's Impact on All Students' Interdisciplinary Learning – Year 1 & 2 |
|---|---|---|---|
| % Agree / Strongly agree | Year 1 | Year 2 |
| MACES provides you with an opportunity to work in a team with individuals trained in different disciplines. | 79% | 89% |
| MACES provides you with an opportunity to communicate research to researchers trained in different disciplines. | 86% | 94% |

↑↓ Significant difference to p≤0.05

Graduate students were also asked what they felt were the most important skills necessary to work effectively in an interdisciplinary team. Of the seven respondents (out of eleven) who gave an answer, communication was without doubt the most mentioned skill. Six student underscored communication skills, for example:

“Number one would be communication because that is how projects get started. Other skills such as leadership, attentiveness, perceptive/discrimining,
are among the many skills needed to work effectively on a team from different disciplines. There definitely needs to be expertise in experimental techniques for experimentalists and in theory for theorists. “

“Willingness to communicate areas where you may be stuck.”

“One of the most important skills is having good communication and understanding of one another. In such research groups like MACES, there are a lot of different ideas and perspectives. It is difficult to come to an agreement on many matters. Though, with effective communications everyone can voice their concerns, possible solutions and have an active discussion in order to have a successful research partnership.”

3.2.4 Student Satisfaction, Gains and Challenges

When asked to write what they most gained from participating in MACES, undergraduate students commented mostly on general research skills:

“A fundamental understanding of research and an internship at NASA”

“Learning how to conduct research”

“Research experience and resume assistance, meeting astronaut.”

“I learned a lot more about nanoscience and was able to get experience in a lab setting.”

“I gained experience in a "wet" lab for the first time, and was able to network with students, post docs, faculty and researchers from UC Merced and from other places like Harvard, LBNL, and NASA. I also gained a new perspective on the potential that smart materials have, with regards to future technology.”

Graduate students also described the increase in confidence in their research projects and abilities, access to a motivated interdisciplinary research community, and enhanced networks, for example:

“Confidence in research”

“Background and ideas on my research and suggestions on how to overcome any issues.”

“Making sure the research that is being conducted is "sound."”
"Colleagues from different disciplines, faculty that I could resort to for their expertise, outreach activities that takes me out of the research setting, and meeting different experts in their field as guest speakers.

“I gained an access to a plethora of networking resources that has helped a great deal in conducting my research.

“I gained access to group of professors and researcher that are passionate about their research. Being engaged with them has not only helped me develop better research skills, but has also inspired me to also be passionate and motivated for my research.”

Graduate students who participated in the development and implementation of the modules for high school students also identified benefits, such as enhanced communication skills:

“Coming up with a lesson that would enlighten high school students and aligning the lesson with the high school teacher’s lessons was enjoyable. What I got out of it was the opportunity to work with high school teachers and communicate various ideas within the realm of nanoscience that is digestible for high school students and piqued most of the students interest or were fascinated by it. Communicating in simple but profound ways to high school students by making connections with common things they are familiar with was among the biggest benefits I got out of this experience.”

“It has allowed me to think of ways to explain more complicated scientific principles and applications in simpler terms so that high school students can understand it.”

Students were also asked to identify the academic challenges they experienced as an undergraduate or graduate student and the extent to which MACES helped them meet these challenges. For most students, the primary academic challenge was balancing the rigors of classwork, research, and other requirements. Many reported that MACES funding reduced this struggle (for example, providing funding so did not have to be a TA). Representative student comments include:

“BALANCING school and research that was a pain. Maybe finding ways to manage time better?”

“At the beginning of the fall semester, I was juggling so many activities: taking 16 units, on-campus job, three different executive board positions, and research (old and current projects). By the end of the year, I was able to stop working (thanks to the MACES stipend), and my advisor encouraged me to focus on things that were more important, so I also dropped a board position in one of my organizations.”
“My greatest challenge is finding time to do all the things required of me. MACES has provided funding which makes getting materials easier.”

“One the greatest academic challenges has been balancing my first year as a grad student. I was a Teacher Assistant (TA), Student and Researcher. Though, once MACES funded me as a GSR, and I didn’t have to TA anymore it helped me focus more on research.”

Access to advisors and experts was another MACES advantage that students reported helped them meet their academic challenges:

“I was given support of a faculty advisor and a graduate mentor. I was able to conduct research on my own and come up with problem solving skills that would allow me to fix the experiments.”

“My greatest challenge was selecting an advisor. Rotating with a MACES advisor showed the great opportunities the program offers.”

“RDE and MACES helped with these challenges. The professor who knew about RDE was very instrumental in making sure our procedures were correct.”

Access to resources (equipment, connections, faculty) were also often identified by graduate students as ways that MACES helped them meet the challenges of conducting MACES-sponsored research. Students also mentioned challenges associated with meetings, reports, and presentations. The responses of the 5 graduate students who answered this survey question were:

“Some of the necessary equipment was not available on the UC Merced campus, however, through collaboration with MACES faculty from UCSC, we were able to observe their setups to build similar ones. Furthermore, MACES faculty enabled access to equipment in Lawrence Berkeley National Laboratory.”

“The greatest challenge was constructing a multi-discipline project. MACES gave me the connections needed to gain the knowledge to organize the project.”

“The many reports and presentations have eaten into time spent in the lab.”

“Meeting research goals. As MACES fellows we are expected to produce meaningful results that met our goals as a MACES group. MACES fellows, like myself, present our research progress monthly, which is sometimes beneficial. Though, I think these meetings could be improved by having professors more engaged in the students research then just going to another meeting without interest. A way to mitigate this problem is by reducing the number of meetings instead of monthly presenting data maybe every two months to show something meaning.”
“Needing reagents and MACES has helped fund these efforts.”

Graduate students were also asked to report on the progress they have made writing or submitting a manuscript, helping with grant writing, and drafting and submitting fellowship proposals. Five students reported their progress, most of whom mentioned writing fellowship proposals and progress toward manuscripts:

“Collected a lot of data and made figures that would influence the writing of manuscripts and fellowship proposals.”

“I have had the opportunity supported by my advisor to write one summer fellowship proposal that earned me a fellowship this summer.”

“I have submitted a few fellowship proposals, have a few upcoming grants due in the fall. I plan to have enough data for a manuscript by the end of the summer.”

“Recently this year I have been second author in two papers, and hope to soon finish off my manuscript for my first author paper. I also applied to a fellowship for the upcoming academic year.”

“Through mentorship by my MACES faculty advisor, I was able to prepare and submit a manuscript, as well as 3 different fellowship proposals.”

The majority of MACES student participants reported being “satisfied” or “very satisfied” with MACES overall, including the quality of research, the research experience, the mentoring from MACES advisor and their interactions with faculty and students (Figure 7).

### Figure 7. Student Satisfaction with MACES

<table>
<thead>
<tr>
<th>Category</th>
<th>Undergraduate (N=7)</th>
<th>Graduate (N=11)</th>
<th>% Satisfied / Very satisfied</th>
</tr>
</thead>
<tbody>
<tr>
<td>The quality of research conducted at MACES</td>
<td></td>
<td>100%</td>
<td>82%</td>
</tr>
<tr>
<td>The MACES research experience</td>
<td></td>
<td>100%</td>
<td>86%</td>
</tr>
<tr>
<td>The mentoring you received from your MACES</td>
<td></td>
<td>100%</td>
<td>82%</td>
</tr>
<tr>
<td>advisor</td>
<td></td>
<td>100%</td>
<td>86%</td>
</tr>
<tr>
<td>Interactions with MACES graduate students</td>
<td></td>
<td>86%</td>
<td>73%</td>
</tr>
<tr>
<td>Interactions with MACES undergraduate students</td>
<td></td>
<td>100%</td>
<td>71%</td>
</tr>
<tr>
<td>Interactions with MACES faculty</td>
<td></td>
<td></td>
<td>100%</td>
</tr>
<tr>
<td>Interactions with MACES overall</td>
<td></td>
<td>100%</td>
<td>86%</td>
</tr>
<tr>
<td>MACES overall</td>
<td></td>
<td>100%</td>
<td>73%</td>
</tr>
</tbody>
</table>
Student satisfaction with various aspects of MACES increased in most areas in Year 2, although changes were not statistically significant (Table 6).

Table 6. Overall Student Satisfaction with MACES – Year 1 and 2

<table>
<thead>
<tr>
<th>% Satisfied / Very satisfied</th>
<th>Year 1</th>
<th>Year 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>The quality of research conducted at MACES</td>
<td>83%</td>
<td>89%</td>
</tr>
<tr>
<td>The MACES research experience</td>
<td>75%</td>
<td>83%</td>
</tr>
<tr>
<td>Interactions with MACES graduate students</td>
<td>83%</td>
<td>89%</td>
</tr>
<tr>
<td>Interactions with MACES undergraduate students</td>
<td>92%</td>
<td>72%</td>
</tr>
<tr>
<td>Interactions with MACES faculty</td>
<td>67%</td>
<td>83%</td>
</tr>
<tr>
<td>MACES overall</td>
<td>83%</td>
<td>94%</td>
</tr>
</tbody>
</table>


<table>
<thead>
<tr>
<th>N</th>
<th>12</th>
<th>18</th>
</tr>
</thead>
</table>

↑↓ Significant difference to p≤0.05

Students offered the following suggestions to improve MACES, ranging from issues around specific research abilities, to increased interactions, to more industry exposure:

“Require training for students in instruments like SEM, TGA, AFM, etc. Also, more engagement from the MACES faculty board would be nice, however I understand they are busy.”

“I think MACES could provide more help on the independent aspect of research. One possible solution is to encourage grad students to give small but meaningful tasks to undergrads.”

“It would be great to have help in preparing for Research manuscripts and etc.”

“My graduate mentor was a little too controlling and most of the time wasn’t able to do work on my own. It would help to allow undergraduates to have a bit more freedom with projects and lab work.”

“I would have a graduate/undergraduate research symposium, and maybe an award/incentive for undergraduates and graduates. Also, the faculty might benefit from an award for the best collaborator.”

“Please continue to encourage collaboration. I believe that it will pay off in the coming years. Also please streamline/clarify the internship process. There is so much time wasted at NASA getting plugged into a lab, finding out where and what safety trainings are necessary, and getting a badge. I don’t think that you...”
can rely on the internship teams there to provide much of the necessary information to help students get started. Also I believe that the faculty in the MACES program are extremely talented, but that talent is tucked away in their labs. Could you possibly facilitate a panel where faculty discuss the skills that personally benefitted them in graduate school? I believe that sharing those skills will immensely help the graduate students in the MACES program succeed.”

“It would be beneficial if MACES could arrange more activities that involve industry or national lab visits, in order to provide more opportunities for networking. Furthermore, higher availability of potential internships in industry or national labs would be a significant step towards accomplishing career goals.”

Summary of Recruitment and Educational Impacts

The gender and racial diversity of MACES undergraduate and graduate students reflects the Center’s recruitment efforts and commitment to broadening participation. More than half of the students are either women or underrepresented minorities.

Both undergraduate and graduate students report that MACES has had a positive impact on their intellectual development by increasing their STEM knowledge and their confidence in STEM abilities and by helping them develop critical thinking skills. The majority of students agree that MACES is creating an interdisciplinary learning environment that provides them with opportunities for interdisciplinary collaboration and team work, to communicate with researchers trained in different disciplines, and to apply approaches from multiple disciplines to research.

Participating in MACES has increased graduate and undergraduate student interest in STEM careers and increased undergraduate student interest in going to graduate school in a STEM field, suggesting that MACES is helping to increase the STEM workforce and also diversify the STEM workforce (since the majority of MACES students are from groups underrepresented in STEM).

Student satisfaction with their MACES experience is very high. The majority of students report being “satisfied” or “very satisfied” with the quality of research being conducted at MACES, the MACES research experience, interactions with students and faculty, and MACES overall.
3.3 NASA Summer Internship Program

In partnership with NASA, MACES students were chosen through a merit-based selection process to participate in a 10-week summer internship at NASA. Students were provided with an opportunity to learn about the research being conducted at NASA, enhance their research and technical skills, learn about careers at NASA, and establish connections with NASA scientists and engineers that may lead to future collaborations.

To collect data about the summer internship experience of the interns and the mentors, two online surveys were developed (one for mentors and one for interns). The external evaluator and the MACES staff sent emails to students and mentors to invite them to complete the online surveys. Four reminders were sent to students and mentors by the external evaluator and MACES staff also sent a reminder to complete the surveys.

3.3.1 Interns

A total of six male students participated as interns at NASA in the Summer of 2016. Of the six students, three were undergraduate students from UC Merced and three were graduate students from UC Santa Cruz.

Of the six students who completed summer internships, three completed the online survey to inform the evaluation.

The majority of summer interns responding to the survey reported the internship provided STEM research and career opportunities, increased their interest in careers in STEM and at NASA, and increased their knowledge about NASA-related research (Figure 8). Two out of three students “strongly agreed” that the NASA internship provided the opportunity for them to sharpen their research skills and provided the opportunity to learn what skills they would need to develop to pursue a career at NASA. All three students who completed the online survey “agreed” or “strongly agreed” the internship increased their confidence in their STEM abilities.
Overall, students reported very positive experiences with their NASA mentor (Figure 9). In particular, the level of agreement was highest with statements that the mentor offered a research topic and welcomed their research ideas. Moreover, most students reported being “very satisfied” with the mentoring they received (Figure 10).
In addition to their overall satisfaction with the mentoring they received, the majority of students reported being “very satisfied” or “extremely satisfied” with the research they participated in, the skills and knowledge they gained, and the NASA intern experience as a whole (Figure 10).
One student consistently reported not being satisfied with his intern experience on items throughout the survey, but the responses of the other two students indicate very high levels of satisfaction.

In open-ended comments, students reported the intern experience was helpful for gaining independence, exposure to the “real research environment,” and that they appreciated the opportunity to meet scientists and engineers working at NASA.

Suggestions for improvement provided by the interns included: more information about the project and equipment beforehand to help them better prepare for what they will be doing during their internship and more group activities on weekends.

3.3.2 Mentors

Four NASA researchers served as mentors for the six interns. Of the four mentors, three completed the online survey to provide feedback about their experience as mentors.

The three mentors reported very positive mentoring experiences (Figure 11). All three “agreed” or “strongly agreed” they were satisfied with the mentoring experience overall. Agreement was also high that the expectations for mentors were clearly communicated and that the intern(s) learned new knowledge, were well-prepared for meetings, and had an adequate base of knowledge and skills to participate in the research.

![Figure 11. "To what extent do you agree..." (Bar Chart)](image-url)

- You were satisfied with the mentoring experience
- Expectations for mentors were clearly communicated
- The intern(s) learned new knowledge during the internship
- The intern(s) were well-prepared for meetings
- The intern(s) had an adequate base of knowledge and skills to participate in the research

<table>
<thead>
<tr>
<th>Number of Mentors</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Neither Agree nor Disagree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td></td>
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<td>1</td>
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<tr>
<td>2</td>
<td></td>
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<td></td>
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<tr>
<td>3</td>
<td></td>
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</tbody>
</table>
The positive experience of the mentors was reflected in the open-ended comments, such as, “Really enjoyed working with them. Excellent students!”

Suggestions for improvement offered by the mentors included: the need for documentation such as mentor signing intern time sheets; documenting the intern’s accomplishments in a poster or presentation, plus a final report; and enhanced coordination and communication between the MACES program and the interns. One mentor also mentioned the preference for graduate students for enhancing the continuity of research for the long run and enhancing the collaboration between the UC system and NASA.

**Summary of NASA Summer Internship Impacts**

The NASA Summer Internships helped advance the MACES goal to enhance student learning experiences and prepare them for careers in STEM fields. The majority of students who completed the post-internship survey reported they were either “very satisfied” or “extremely satisfied” with the research they participated in, the skills and knowledge they gained, and the mentoring they received. The majority of students reported they “agree” or “strongly agree” the internship provided opportunities in the following areas: to sharpen their research skills, learn what skills they need to develop to pursue a career at NASA, and establish connections that may lead to future collaborations or a job at NASA. All students also reported the internship increased their confidence in their STEM abilities and most reported the internship increased their interest in pursuing a career in STEM and pursuing a career at NASA. The positive experiences reported by the mentors reinforce the benefits of the program.

**4) Outreach and Dissemination**

**4.1 High School Student Modules**

During June 2016, MACES faculty, staff, and graduate students led a workshop for six high school teachers to create instructional materials to be used with their students during the 2016-17 school year. (Evaluation of the workshop was included in the Year 1 External Evaluation Report.)

Graduate students implemented the following modules to local high school students during the 2016-17 school year:

- Renewable Energy Sources Study of Water Splitting Module
  
  **Student Learning Outcomes**
  
  - Gain knowledge of how chemical reactions can be used to produce energy in nature
Understand how chemical reactions have been studied and used in devices such as batteries, fuel cells and solar cells

- **Surface Effects at the Nanoscale Denture Cleanser Module**
  
  **Student Learning Outcomes**
  
  - Identify the explanatory variables (factors), response variable, treatments, and experimental units of an experiment
  - Collect data and form an exploratory analysis
  - Discover the relationship between surface area and volume with reaction times of Alka Seltzer

- **Crime Lab Module**

  **Student Learning Outcomes**
  
  - Use of Biosensors
  - Measure pH
  - Measure sugar levels

Students were given brief (2-5 question) pre- and post-module paper and pencil evaluation forms to assess change in knowledge and assess student interest in the module and interest in STEM. Data from the evaluation forms were entered into an Excel spreadsheet by the MACES team and provided to the external evaluator for analysis.

### 4.1.1 Surface Effects at the Nanoscale Denture Cleaner Module

On the pre- and post-module evaluation forms, students were asked to self-rate their level of knowledge for two topics: (1) Surface area to volume ratios and (2) Rate of reactions. Figure 12 shows the students self-reported level of knowledge before and after the module for key learning objectives. The percent of students reporting they were either “knowledgeable” or “very knowledgeable” increased from 20% to 82% for surface to volume ratios and from 24% to 89% for rate of reactions (increases statistically significant, p \( \leq 0.05 \)).
On the post-module evaluation form, students reported how interesting they found the Denture Cleaner Module. The wording of the question about module interest varied between the Fall 2016 and Spring 2017 module post-test and results are shown separately. In the fall module implementation, almost all students (89%) reported the module was “interesting” or “very interesting” (Figure 13). In the Spring 2017 implementation, all students “agreed” or “strongly agreed” the module was interesting for them (Figure 14). Although the question was phrased slightly differently than in the Fall 2016, overall the results are very similar with high interest in the module.

As shown in Figure 14, almost all students (92%) reported that the module increased their interest in STEM (not asked in Fall 2016).
This presentation was interesting to me

- Strongly Disagree: 31%
- Disagree: 69%

The presentation increased my interest in STEM

- Neutral: 19%
- Agree: 73%
- Strongly Agree: 8%

N = 26

4.1.2 Renewable Energy Sources Study of Water Splitting Module

Students who participated in the Water Splitting module reported becoming more knowledgeable about chemical reactions, with the share of those feeling “knowledgeable” or “very knowledgeable” increasing from 55% to 80% (Figure 15). Knowledge of water splitting (measured in Spring 2017 only) also increased after the module. In the pre-lab, 80% of students reported they were “not knowledgeable” about water splitting; by the end of the module, 72% of students reported being either “knowledgeable” or “very knowledgeable.”

Figure 15. Renewable Energy Sources Study of Water Splitting Module - Impact: Fall 2016/Spring 2017

- Chemical Reaction: Pre Lab 20%, Post Lab 80%
- Water splitting*: Pre Lab 20%, Post Lab 64%

* Spring 2017 data only

Significant increase from pre-test to post-test (p≤0.05)
As was the case for the Denture Cleaning Module, the question about student interest in the module was phrased slightly differently in Spring 2017 than in the Fall 2016. As shown in Figures 16 and 17, student interest in the module was quite high. In the Fall 2016 implementation, almost all students (91%) found the module “interesting” or “very interesting” and in the Spring 2017 implementation, 92% agreed or strongly agreed the presentation was interesting to them. For three quarters of students, the module also increased interest in STEM (this question was not asked in Fall 2016).

![Figure 16. Interest in Renewable Energy Sources Study of Water Splitting Module (N=11) - Impact: Spring 2017](image)

![Figure 17. Renewable Energy Sources Study of Water Splitting Module - Impact: Spring 2017](image)
4.1.3 Crime Lab Module

The Crime Lab Module was introduced to students in Spring 2017. For all three topical areas, students' knowledge increased significantly (Figure 18): about half of students felt “knowledgeable” or “very knowledgeable” about biosensors and measurement of sugar levels in the post test, and two thirds (69%) felt “knowledgeable” or “very knowledgeable” about measuring pH levels.

![Figure 18. Crime Lab: Biosensors Module - Impact](image)

Most students (79%) “agreed” or “strongly agreed” that the crime lab module was interesting (Figure 19). For half of the students, the module also increased their interest in STEM.

![Figure 19. Interest in the Crime Lab Module and in STEM as a result of Module](image)
Summary of High School Module Impacts

The three modules introduced during the 2016-17 school year are having the desired impacts of increasing student topical knowledge. Students assess their own knowledge in the content areas as higher in the post-module evaluation than in the pre-module evaluation. Moreover, most students find the modules interesting and agree that the modules increased their interest in STEM.

5) Summary and Conclusion

MACES grant-related progress has continued into its second year. The groundwork laid during the first year is being carried forward into Year 2 and the team has been able to build on its strengths.

Significant accomplishments towards the grant’s key objectives in Year 2 include:

*Education*
- Recruitment activities such as outreach to local colleges and universities (many are Hispanic-serving institutions) appear to be successful for attracting a diverse group of undergraduate and graduate students. More than half of MACES students are either women or underrepresented minorities.
- The majority of students reported that participating in MACES has had a positive impact on their intellectual development by increasing their STEM knowledge, increasing their confidence in their STEM abilities, and by helping them develop critical thinking skills.
- The majority of MACES students report participation has increased their interest in a STEM career.
- MACES increased the interest of almost all undergraduate students in going to graduate school in a STEM field.
- Almost all graduate students agreed MACES has increased their knowledge of career opportunities at NASA and the NASA mission.
- Almost all students agreed that MACES is creating an interdisciplinary learning environment that is proving them with opportunities to collaborate with people outside their own discipline, work on an interdisciplinary team, communicate with researchers trained in different disciplines, and apply approaches from multiple disciplines to research.
- Graduate students are being provided with opportunities to enhance their communication skills by participating in the development and implementation of modules for high school students.
NASA internships benefited students by increasing their confidence in their STEM abilities, increasing their interest in a career in STEM and a career at NASA, and provided the opportunity to sharpen research skills. Students also increased their knowledge about NASA-related research and established connections with people at NASA that might lead to future collaborations or a job at NASA.

**Outreach and Dissemination**

Three modules developed during last summer’s professional development workshop with high school teachers were implemented during the 2016-17 school year. Self-assessed student knowledge in the key content areas increased for each of the three modules (with statistically significant increases from the pre-test to post-test, \( p \leq 0.05 \)). Almost all high school students found the modules interesting and reported the modules increased their interest in STEM.

The primary challenge in Year 2 experienced by students included balancing the rigors of classwork, research, and other requirements (although students pointed out that MACES helped in some ways, for example by providing funding so they did not need to TA).

**Recommendations:**

- Increase student opportunities for networking and interactions with industry, national labs, and MACES faculty.
- Enhance clarification about the NASA internship process, information about the project and equipment prior to the internship, and communication/coordination between MACES and interns.
- With the success of recruiting students from underrepresented groups, the Center is in a strong position to contribute to diversifying the STEM workforce. If the Center has not done so already, consider engaging with appropriate campus offices to provide information for faculty and students on ways to support an inclusive environment.

In conclusion, MACES has made meaningful progress in its educational and outreach goals in Year 2. MACES is providing opportunities for undergraduate and graduate students (many from underrepresented groups) to engage in interdisciplinary and innovative research, learn about NASA and participate in research with NASA scientists, and learn to communicate scientific ideas to high school students. High school students, undergraduate students, and graduate students report increased interest in STEM and STEM careers as a result of participating in MACES. The next evaluation report will address research goals.