EXTERNAL EVALUATION MEMO

MERCED NANOMATERIALS CENTER FOR ENERGY AND SENSING (MACES)

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Submitted By:

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Introduction

This memo summarizes the external evaluation activities undertaken for Merced Nanomaterials Center for Energy and Sensing (MACES) between March and June 2018. The focus during this evaluation period was an assessment of the undergraduate educational experience and the outreach activities. During this period, the following evaluation activities were completed:

- Developed and distributed an online survey for undergraduate students
- Analyzed data from the pre-post paper and pencil evaluation forms to assess the impacts of the modules presented to high school students
- Analyzed data from an undergraduate field trip to NASA

1. Undergraduate Student Survey

The annual undergraduate survey was conducted in May, 2018, at the end of the spring semester. Ten students were invited by the external evaluator to complete the online survey and eight students did so, for a response rate of 80%. The survey addressed the key educational goals of the grant in the areas of enhancing students’ intellectual development and STEM knowledge, preparing students for STEM careers, and providing an interdisciplinary learning environment.

1.2 Enhancing Learning - Intellectual development and STEM knowledge

As shown in Figure 1, students reported that MACES enhanced their learning and intellectual development. All students “agreed” or “strongly agreed” that MACES increased their STEM knowledge. Almost all “agreed” or “strongly agreed” that MACES helped them develop critical thinking skills, increased their confidence in their STEM abilities, and that their mentors and/or research advisors were available for help when needed.
1.3 Workforce Preparation – STEM career perspectives

When asked to reflect on their career interests, 86% of students “strongly agreed” or “agreed” that MACES increased their interest in a STEM career and 83% of students reported that MACES increased their interest in going to graduate school (Figure 2).
1.4 Interdisciplinary Learning Environment

One of the goals of MACES is to increase students’ interdisciplinary learning by creating opportunities to conduct research in different disciplines. The survey results (Figure 3) show that more than half (57%) of the respondents “strongly agreed” or “agreed” that MACES provided them with multidisciplinary training (Figure 3). Almost all students agreed that MACES provided them with opportunities to work on an interdisciplinary team (83%), communicate with researchers trained in different disciplines (86%), and to communicate research to a general audience (88%).

![Figure 3. MACES’s Impact on Students’ Interdisciplinary Learning](chart)

1.5 Student Satisfaction, Gains and Challenges

All the student respondents were “very satisfied” or “satisfied” by the research experience gained from MACES, their interactions with the MACES faculty and the MACES program overall (Figure 4). Most students were satisfied with the quality of research conducted under the MACES groups (75%), with the interactions between undergraduate students (75%), and the mentoring received from their respective MACES advisors (88%). Student satisfaction was lowest in terms of interactions with MACES graduate students, with about two-thirds reporting being “satisfied” or “very satisfied.”

MACES External Evaluation Memo
In open-ended questions, students were asked to reflect on the ways they benefitted from participating in MACES. They described a range of benefits, such as improving research skills, participating in internships, access to mentors, and opportunities that they would not have had otherwise:

“I benefited a lot from participating in MACES because it allowed me to improve my research skills. For instance, I learned how to read and interpret scientific articles and how to practice safety lab procedures when conducting an experiment. I also secured an internship for the summer.”

“REU especially. If it wasn’t for MACES and letting me intern at NASA I wouldn’t have gotten the chance to intern at LLNL, thanks for everything.”

“I was able to create a resume I am proud of, and with the help of my mentor, I was able to obtain a paid internship... However, the main way I benefitted from MACES was the access to faculty who genuinely care about this group of students. It is a life-changing experience in that it instills confidence and faith in reaching one's goals.”

“It provided me with a strong letter of recommendation for graduate school. In addition, I benefitted from having a fellowship on my CV for applying to graduate school.”
“MACES helped by giving me an opportunity to strengthen my research skills. I gained great mentorship as well and made good networking through MACES. I have also been offered more internship opportunities after this MACES year.”

The students were asked to name the greatest academic challenges they experienced during the school year and how MACES helped prepare them for these challenges. The primary challenge students faced was balancing coursework and research. They expressed appreciation for their mentors and described how their mentors were instrumental in guiding them and helping them overcome these challenges:

“Creating a poster or slide show presentation and presenting the content itself have always been things I struggle with. After two semesters of being awarded a MACES position, I learned the most efficient ways to summarize my data and information, and lessened my fear of public speaking. I now feel very comfortable relaying my research results through presentations to various audiences. This extends to my overall performance in research as I understand things quicker now that I am able to reduce my stress prior to deadlines.”

“The faculty and graduate students are a great help and influence to all undergraduate students.”

“I was struggling with my senior thesis presentation throughout this academic year. However it was thanks to the feedback of my MACES mentor that I was able to make it the best it could be.”

“I struggled keeping up with coursework and research at the same time because it was my first exposure to research. I had a hard time devoting my time to both but through mentoring I was able to manage my time and get things done.”

“Greatest challenge I experienced was time management whether it was being there for countless hours for my experiment or sometimes I would have to balance that with an exam.”

“School in general...classes are quite tough especially with the [addition] of research.”

When asked for suggestions for improving MACES, most students recommended increasing opportunities to interact with MACES faculty and students, additional professional development opportunities (such as presentations, travel, speakers), and support resources.

“It would be beneficial to students if MACES could provide traveling opportunities. Perhaps a research conference outside Merced, or support students in a visit to a graduate school.”
“I would suggest having more social events for MACES students to make connections with one another; I only ever really spoke with the other people in my lab or those I’d already known prior to the MACES fellowship.”

“Perhaps more chances to present, some optional field trips and some guest speakers would be nice, too.”

“The faculty and staff that guide students through the program are always available and very helpful. However, I would like to see more one-on-one between these mentors (apart from just the supervisors and undergrads) to work on any weaknesses they might catch. Reviewing presentations and giving feedback would be appreciated as we all highly respect the faculty and staff, and would value their opinions. Finally, surveys like these can be collected after every workshop to work on any small concerns or suggestions students might have, and improve on future ones.”

“[The Organic Chemistry series] are very difficult and it was hard at times to get a full understanding of the material. It would be great if MACES could provide a separate resource for MACES undergrad fellows to help with their success in their classes.”

“I think for some students who maybe need a bit more financial help it may be good to increase their stipend so that way they don’t have to worry about life and they can just focus on school.”

1.6 Summary

Undergraduate students reported that MACES had a very positive impact on their intellectual development by increasing their STEM knowledge, helping them develop critical thinking skills, and increasing their level of confidence in their abilities. Students learned important interdisciplinary skills, such as the opportunity to work in a multi-disciplinary team and to communicate their research to those in other disciplines and to a general audience. For almost all students, participating in MACES increased their interest in STEM careers and in going to graduate school.

All students were “satisfied” or “very satisfied” with MACES overall, the MACES research experience, and their interactions with MACES faculty. Satisfaction was also very high in terms of the mentoring they received, interactions with undergraduate students, and the quality of research conducted. Students were least satisfied with their interactions with graduate students, yet almost two-thirds reported being “satisfied” or “very satisfied.” Students reported a variety of ways they felt they benefitted from participating in MACES, including improved research
skills, internship opportunities, access to mentors, and personal development, as these comments reflect:

“I am glad I got to be part of the MACES program because it allowed me to learn more about myself and what I want to do in the future.”

“I would like to thank MACES for the opportunity it provided for me to conduct research and [apply background knowledge in my field]. This program allowed me to think critically.”

“Was a great experience”

Students’ primary challenges were in the areas of time management, specifically balancing their research with coursework, but students credited their mentors with pivotal guidance in addressing these challenges. Suggestions for improving MACES focused on providing more opportunities to interact with MACES faculty and students and additional professional development opportunities.

As a whole, the undergraduate student survey indicates that MACES is achieving its goal to enhance the undergraduate STEM learning experience and encourage students to pursue STEM careers and/or graduate study.
2. High School Student Modules

Modules developed at the workshop for high school teachers during grant year 1 were offered in Spring 2018 at three local high schools. MACES graduate students offered three modules (which were also offered in the preceding academic 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

Participating high school students were given brief pre- and post-module paper and pencil evaluation forms to assess change in knowledge, 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.

Findings from previous modules implemented during earlier grant years are mentioned in this report for comparison purposes (results are not shown, but can be found in prior external evaluation reports).

2.1 Surface Effects at the Nanoscale Denture Cleaner Module

This module was offered in April 2018 at Buhach Colony High School. 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 5 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 35% (pre-module) to 88% (post-module) for surface to volume ratios and from 33% to 90% for rate of reactions (increases statistically significant, p. ≤ 0.05).
This significant increase in self-reported knowledge is similar to previous editions of the module (Fall 2016 and Spring 2017; findings presented in prior external evaluation reports).

![Figure 5. Surface Effects at the Nanoscale Denture Cleaner Module - Impact: Spring 2018 Buhach Colony](image)

Legend:
- Very knowledgeable
- Knowledgeable
- Somewhat knowledgeable
- Not knowledgeable

N = 48

Significant increase from pre-test to post-test (p≤0.05)

On the post-module evaluation form, students reported how interesting they found the Denture Cleaner Module. The majority (86%) of students “agreed” or “strongly agreed” the module was interesting to them (Figure 6). This level of interest is similar to the previous edition of the module (Spring 2017) where all students found it interesting (with N=26).
Additionally, more than half (58%) of students agreed that the module increased their interest in STEM, although this proportion was lower than in previous edition (92% in Spring 2017).

2.2 Renewable Energy Sources Study of Water Splitting Module

The water splitting module was offered at three high schools in Spring 2018: Buhach Colony (March), El Capitán (April) and Golden Valley (May) high schools. In total, 105 students responded to the evaluation survey at Buhach Colony, 84 at El Capitán and 25 at Golden Valley.

Students who participated in the Water Splitting module reported becoming more knowledgeable about chemical reactions, with the proportion of those feeling “knowledgeable” or “very knowledgeable” increasing from 42% to 69% (Figure 7). Knowledge of water splitting also increased significantly after the module. In the pre-lab, 71% of students reported they were “not knowledgeable” about water splitting; by the end of the module, 57% of students reported being either “knowledgeable” or “very knowledgeable.”

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1 Pre and/or post test answer, partial or full
The impact on knowledge was observed in all three high schools similarly (increase in both areas, with generally lower pre-test knowledge in water splitting). These results are consistent with the previous editions of the module evaluations (Fall 2016, Spring 2017).

As shown in Figure 8, student interest in the module was quite high. The majority of students (83%) across the three high schools agreed or strongly agreed the presentation was interesting to them. For 66% of students, the module also increased their interest in STEM. As with impacts in the students’ knowledge, the level of interest in the module and in STEM afterward is similar across the three high schools, and consistent with results from Spring 2017 (N=25).
The presentation was interesting to me

The presentation increased my interest in STEM

Figure 8. Interest in the Water Splitting Module and in STEM as a result of Module: Spring 2018 Buhach Colony / El Capitan / Golden Valley

<table>
<thead>
<tr>
<th>Strongly disagree</th>
<th>Disagree</th>
<th>Neutral</th>
<th>Agree</th>
<th>Strongly agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>The presentation was interesting to me</td>
<td>1%</td>
<td>14%</td>
<td>55%</td>
<td>28%</td>
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<tr>
<td>The presentation increased my interest in STEM</td>
<td>2%</td>
<td>31%</td>
<td>46%</td>
<td>20%</td>
</tr>
</tbody>
</table>

N = 202 (total post-test)

2.3 Crime Lab Module

The Crime Lab Module was offered to students at Buhach Colony high school for the second time in Spring 2018 (March). For all three topical areas, students’ knowledge increased significantly (Figure 9): 40% of students felt “knowledgeable” or “very knowledgeable” about biosensors in the post test, 61% about measuring pH levels and 48% about measuring sugar. These impacts are very similar to those reported in the previous implementation of the module (Spring 2017).
Figure 9. Crime Lab - BioSensors Module - Impact: Spring 2018 Buhach Colony

Half of students (51%) “agreed” or “strongly agreed” that the crime lab module was interesting (Figure 10). For one third of the students, the module also increased their interest in STEM. This impact is lower than in the previous year’s implementation, where the presentation was interesting to 79% of students (n=129) and increased interest in STEM in 50% of the respondents.

Figure 10. Interest in the Crime Lab Biosensors Module and in STEM as a result of Module: Spring 2018 Buhach Colony

N=89
2.4 Summary of High School Module Impacts

The three modules implemented during the 2017-18 school year are having the desired impacts of increasing student topical knowledge. Students assessed 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. These findings are consistent with previous year module implementations, suggesting that MACES is accomplishing its goal to use the modules to enhance STEM learning and increase high school students’ interest in STEM.
3. High School Students Field Trip to NASA-Ames

In March 2018, MACES brought high school students on a field trip to NASA. At the end of the field trip, participants were asked to fill out a short evaluation survey. Thirty-eight participants responded to the survey in full or part; 36 were high school students, one was a high school teacher, and one respondent did not identify their status. Among the 36 respondents who self-identified as high school students, 61% were girls and 36% boys; 56% identified as Hispanic/Latina/o, 19% as White, 8% as Asian/Asian American and 17% as of more than one race/ethnicity.

Students overwhelmingly affirmed that they learned new information about NASA and that the trip was interesting (Figure 11). For 86% of students the trip increased interest in pursuing a career with NASA, and for 75% it increased their interest in a career in a STEM field. The level of interest in the field trip and its impact on considering a career in NASA or in STEM in general is very similar to that of students from the 2016 high school student field trip (results provided in previous external evaluation reports).

<table>
<thead>
<tr>
<th>Figure 11. Field Trip Interest Level and Impact on Career Orientation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Strongly disagree</strong></td>
</tr>
<tr>
<td>I learned new information about NASA today</td>
</tr>
<tr>
<td>Today's trip was interesting to me</td>
</tr>
<tr>
<td>Today's trip increased my interest in a career with NASA</td>
</tr>
<tr>
<td>Today's trip increased my interest in a career in Science, Technology, Engineering, or Mathematics</td>
</tr>
</tbody>
</table>

*Base: high school students (n=36)*

Overall, 44% of students reported being moderately or very interested in a career in space exploration and 83% in a career in STEM (Figure 12).
Figure 12. Interest in considering a career in ...

From students open-ended comments, a few themes emerged as most salient concerning the filed trip. Students commented on how interesting the visit to the wind tunnel was (22%, 8 mentions), as well as the presentation on the biological exploration of space (also 22%, 8 mentions). Students confirmed they enjoyed the NASA employee panel and generally hearing the scientists’ stories of how they came to NASA (19%, 7 mentions), as well as seeing the diversity of scientific disciplines and projects that were involved (17%, 6 mentions).

In terms of potential improvements, some students asked for more time to see facilities / explore (19%, 7 students) and more hands-on activities / seeing technology in action (also 19%). The one teacher participant responding to the survey also suggested more hands-on activities would improve the experience.

3.1 Summary

High school students found the field trip to NASA interesting and reported that the trip increased their interest in a career with NASA and in STEM. Most are interested in considering a career in STEM and/or space exploration. Students found the wind tunnel, the presentation on the biological exploration of space, hearing the stories of the scientists, and the diversity of projects especially interesting. The field trip to NASA is an important outreach activity for engaging high school students in STEM.