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Remote Undergraduate Research to Increase Participation and Engagement in Community College Engineering Classes: Bridging the Research Opportunity Gap Between Community College and University Students

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Sophia Barber is a second year Molecular and Cell Biology major at Pasadena City College with a 4.0 GPA. She currently works at Pasadena City College tutoring Biology, Chemistry, and Physics, is the External Vice President of the Pi Club, the Vice President, Event Coordinator, and ICC Representative for the Caduceus Club, is an active member of the Alpha Gamma Sigma Honors Society, is a Student Research Mentor, is a Dean's Honors student, and also serves her community by sitting on the Academic Commission Committee, the Student Services Committee, and the ICC Funding Committee. Additionally, in her free time, Sophia decided to teach herself Python and is now leading the research project Studying Statistics in Python. In the future, she hopes to become a physician-scientist studying preventative measures for Alzheimer's disease and treatments for Charcot-Marie-Tooth (CMT) disease.

Ms. Sophia Isabella Ibargüen, Pasadena City College

Sophia Ibarguen is a first-generation college student of immigrant parents, who is majoring in Biology and minoring in Biomedical Research. She is a Dean's Honors student, Student Research Mentor, a hospital volunteer, Internal Vice President of the Pasadena City College Pi Club, an Academic Commission Committee Member, and an active member of PCC's Alpha Gamma Sigma Honors Society. In the fall of 2021, Sophia will continue pursuing a Bachelor of Science degree at the University of California, Los Angeles. In the future, she hopes to become a physician-scientist studying tumor immune microenviornments.

Ms. Chloe Sharp, Pasadena City College

Chloe Sharp is a Junior in High School at the Mississippi School for Mathematics and Science. She is the graphic design leader for Mississippi Youth Against Sexual Violence, an active member of the Mississippi High Schoolers for Biden campaign, a performer in the Mississippi School for Mathematics and Science Drama Club, a member of the Mississippi State Superintendent's Student Advisory Council, and a volunteer for the Elizabeth Gwin Special Needs Session at Camp Tik-A-Witha. In the future, she hopes to attend a university where she will major in Environmental Engineering and minor in either Spanish or Theatre.

Dr. Aaron Reedy, DataClassroom

Dr. Aaron Reedy is an evolutionary biologist, entrepreneur, and former high school science teacher. Reedy studies the evolutionary dynamics of sex differences in aging. He recently founded DataClassroom to produce the DataClassroom web app to facilitate the teaching of quantitative skills in science education.

Dr. Tanya Faltens, Purdue University, Main Campus

Tanya Faltens is the Educational Content Creation Manager for the Network for Computational Nanotechnology (NCN) which created and manages the open access nanoHUB.org cyber-platform. Her technical background is in Materials Science and Engineering (Ph.D. UCLA 2002), and she has several years' experience in hands-on informal science education, including working at the Lawrence Hall of Science at UC Berkeley. While a faculty member at Cal Poly Pomona, she introduced nanoHUB simulation tools into the undergraduate curriculum in materials science and engineering and electrical engineering courses, mentored student capstone research projects and taught their first year engineering course, which employs a student development philosophy.

Much of her work has focused on introducing STEM concepts to broad audiences and encouraging students, including women and others in groups traditionally under-represented in STEM, to consider graduate school in STEM fields. She currently manages the NCN Undergraduate Research Experience (URE) program, which introduces undergraduates from 2-year and 4-year colleges to computational nanotechnology research projects each summer.

Dr. Yu-Chung Chang-Hou, Pasadena City College

Yu-Chung Chang-Hou obtained her Ph.D. in mathematics from UCLA in 1991. During her postdoc at New York University and at Caltech, she co-developed a very effective level-set method for computing multi-phase flows, which has generated a lot of excitements in the computational fluid dynamics community. Besides teaching mathematics at Pasadena City College, she has devoted herself to developing effective teaching and learning strategies.Encouraging students to showcase their STEM learning with real life applications, she has initiated and led the annual Pi Day Student Conferences at Pasadena City College since 2013. She also joined the Undergraduate Research program at PCC to enhance student learning outcomes with active learning in STEM fields and bridge the gap between the undergraduate research opportunities provided to community college and university students.

Dr. Jared Ashcroft, Pasadena City College

Jared Ashcroft graduated with a BS in Chemistry from Long Beach State in California and subsequently attended Rice University, where he worked for Dr. Lon J. Wilson, developing carbon based nano-bio immunoconjugates for use in medical applications. After earning his doctorate in Chemistry from Rice, he moved to Berkeley California to work in Dr. Carolyn Larabell's National Center for X-ray Tomography at the Lawrence Berkeley National Lab. Currently, he is a Professor of Chemistry at Pasadena City College and runs an undergraduate research program attempting to infuse active learning in conjunction with remotely accessible microscopes into K-12 and university science curriculum. He is actively involved in bring micro nanotechnology technician programs to Community College campuses being a part of the Remotely Accessible Instruments in Nanotechnology (RAIN) Network and the Nanotechnology Professional Development Partnership (NPDP) Program. Dr. Ashcroft is currently the Principal Investigator for the National Science Foundation Advanced Technological Education Micro Nano Technology Education Center.

Remote Undergraduate Research to Increase Participation and Engagement in Community College Engineering Classes: Bridging the Research Opportunity Gap Between Community College and University Students

Sophia Barber*, Sophia Ibargüen*, Chloe Sharp, Daisy Kim, Yu-Chung Chang-Hou, Jared Ashcroft, Tanya Faltens, Aaron Reedy

Abstract

A collaborative effort between the Micro Nano Technology Student Scholars Research Program at Pasadena City College and the Network for Computational Nanotechnology at Purdue University created an undergraduate research program that invited students in STEM fields to partake in a unique remote undergraduate research experience. In this remote environment, interaction among students and faculty was conducted completely through online tools such as email, text messaging, and Zoom meetings. This model requires minimal funding and eliminates geographical barriers, allowing students throughout the United States to participate in undergraduate research opportunities without a need to relocate.

In the 2020-21 academic year, this innovative research opportunity focused on creating distance education STEM modules on statistical analysis and graphing, two pivotal skills needed for success in engineering and science courses that are often neglected in STEM laboratory curricula at this level. Remote research, coupled with outreach and mentoring of high school students, has never before been conducted by community college students on the national scale and is a step forward in working to promote engineering and other STEM fields collectively, while also bridging the gap between the undergraduate research opportunities provided to community college and university students. Data will be shared on the effectiveness of and increased student engagement created through the remote undergraduate research experience.

Introduction

Community colleges are cost-effective and positioned to provide personalized academic experiences in comparison to established baccalaureate universities. However, community college students are at an acute disadvantage in terms of attaining undergraduate research experiences, which are often reserved for elite students at baccalaureate universities [1, 2]. This disadvantage can be attributed to a lack of funding, proper equipment, lab space, and dedicated research faculty [3-5]. In addition, research is not a key component of community college educational master plans. Rather, the ultimate goal of community colleges is to prepare students for transfer or employment through certified technical education programs [6-8].

Undergraduate research has proven to be a high impact practice that helps students increase their academic performance, build confidence, and develop critical thinking skills and STEM identity [9-11]. These traits are necessary to become a successful scientist, engineer, or educator in these fields— thus it is imperative that research experiences are provided in the early stages of STEM students' educational journeys [12, 13]. Undergraduate research has also been a driving force in the pursuit of STEM equity. Underrepresented students experience an increased success rate in STEM when participating in research opportunities [14-17]. The lack of research opportunities in community college STEM programs inhibits students from applying to highly competitive programs [1]. A community college student surveyed in this work reported that they had "never even considered pursuing [undergraduate research] at this stage in [their] education" (Student Testimonial). Students who apply but who are not selected due to their

minimal previous research experience are further discouraged. This reduces their likelihood of pursuing other undergraduate research opportunities, which in turn diminishes their preparation when eventual transfer occurs [18], resulting in transfer students being considerably less competitive in comparison to their peers when seeking coveted upper-division research opportunities [19].

In recent years there has been a push to provide community college students with opportunities to develop research skills through course-based undergraduate research experiences (CURES) or by conducting independent research projects [20, 21]. Due to the unexpected circumstances created by the COVID-19 pandemic, however, the education system transitioned to a remote format that could not support many of these research opportunities. With fewer opportunities for community college STEM students to engage in undergraduate research, an open discussion about methodologies to improve this concerning situation is imperative.

The Micro Nano Technology Student Scholars Research Program

The Micro Nano Technology Student Scholars Research Program (MNT-SSRP) is a remote, interdisciplinary, multi-component project, with the overall goal of increasing the number of underrepresented students, such as African Americans, Latinx, women, and veterans, that enter the STEM workforce. The program stemmed from Pasadena City College's Early Career Undergraduate Research Experience (eCURe) program and is a component of the Micro Nano Technology Education Center (MNT-EC), which is located at Pasadena City College and has both community college and research university partners [22]. MNT-EC is an NSF Advanced Technological Education (ATE) center dedicated to increasing community college micro nanotechnology programs and providing students with pathways to professional workforce jobs in micro nanotechnology.

Table 1: Student Demographics

Gender	
Male	2
Female	12
Other	0
Prefer not to specify	0
Race/ethnicity	
Hispanic/Latino	4
Black/African American	1
Asian/Pacific Islander	3
White/Caucasian	2
Biracial	4
Other	0
Prefer not to specify	0

Utilizing a remote research format provides an avenue to serve not only students at Pasadena City College, but also students at community colleges and high schools across the nation by providing opportunities to conduct research in both the educational and the micro nano technology fields. The expansion of this program to include students located outside the greater Los Angeles area allowed more collaboration and exposed students to different cultures and perspectives seen in different parts of the nation. This program successfully attracted a diverse group of students in 2020-21, as shown by the Student Demographics reported in Table 1.

Students in this program believe that remote undergraduate research programs "give opportunities to students all over the country to participate in research projects …. without having to live in the same location"; "[collaborating] with people from different backgrounds …. enhance[s] the research process"; and "[Diversity] is important to gain an extrinsic understanding of how our work can impact others, so by promoting diverse collaboration, it also improves the work itself" (Student Testimonials).

The active outreach to high school students allows undergraduate community college researchers to take on high school mentees. This serves to lessen the gap between undergraduate researchers and high school students, who have even fewer opportunities for research. Additionally, by not requiring a minimum GPA to join this program, the research opportunities become open to students who may have been detrimentally impacted by their personal and socioeconomic backgrounds yet are still driven to learn and to succeed.

This first of its kind community college research opportunity allows students to collaborate from a number of different states, representing various ethnicities and backgrounds on projects ranging from understanding coloration of *Blue Morpho* butterfly wings through natural selection, chemistry, physics, and nanotechnology to the Student Engagement and Statistical Analysis Project, which employs at-home labs in combination with graphing and statistical analysis using DataClassroom [23] and Python coding in Jupyter Notebooks in nanoHUB [24] and Google Colab [25] to not only increase student engagement in remote classes but also increase statistical analysis skills in undergraduate students, which is essential for many STEM disciplines and technical workforce needs, yet undervalued in teaching pedagogies.

The MNT-SSRP is a community college student-led experience, providing seasoned student peer-to-peer mentoring. In essence, community college students act as mentors, allowing the STEM faculty to act as facilitators within the program design. In this manner, the community college mentors are afforded the ability to practice and improve their leadership and communication skills, which are essential for success in future education or employment endeavors after transfer. Students are granted independence to choose when and how they conduct their research, which strengthens the critical thinking and analysis skills necessary for them to be competitive applicants for both future undergraduate research opportunities at a baccalaureate-granting institution as well as future job opportunities in the STEM workforce [26]. Additionally, the MNT-SSRP allows "students with multiple commitments (school, work, children, etc.)" to conduct research "that they would not have otherwise participated in" (Student Testimonial).

Table 2: Program Inputs & Outcomes

Student count [a]	14
Primary faculty mentors [b]	3
Secondary mentors	2
Student mentors	2
Students with Publications [c]	6
Students with Presentations	7
Student Leadership Roles	7

[a] Includes only active members— does not include student auxiliary members.
[b] Includes program principal investigator, Purdue University Educational Content Creation Manager, and Pasadena City College statistics professor.
[c] Includes accepted and in-progress manuscripts authored or co-authored by MNT-SSP scholars.

The MNT-SSRP provides its participants with ample opportunities to present their findings to their peers as well as to respected experts in various fields. Students appreciate "how everyone is given an opportunity to contribute their ideas and have active discussions" (Student Testimonial). These opportunities range from oral presentations at national conferences [27-29], to posters exhibited on a number of online platforms [30,31], to publications that would allow them to be listed as authors in peer-reviewed journals. This extremely difficult and distinguishable feat at the undergraduate level further sets them apart as applicants for future opportunities. Table 2 lists the number of students in 2020-21 with publications and presentations, along with other program inputs and outcomes.

Outreach

The MNT-SSRP places a strong emphasis on student outreach to all applicable grade levels. Although the current circumstances caused by the COVID-19 pandemic placed obstacles to promote such a

program to students at the community college level, the faculty, staff, and program participants have successfully recruited students from around the country to join the MNT-SSRP via online interactions. Prior to the transition to a remote format, several program participants were invited to join the program in person by faculty mentors— specifically, those who teach courses in chemistry, mathematics, and computer science. Others were made aware of the program's existence through other organizations on their community college campuses such as the Honors Transfer Program at Pasadena City College which advertises the MNT-SSRP as a means by which students can conduct research during their time at Pasadena City College, for which they can earn honors credit. This credit could ultimately lead to gaining priority admission to a number of University of California and California State University campuses [32].

The MNT-SSRP has also been promoted by students and faculty at various local and national conferences ranging from the Pasadena City College Pi Day Student conference to the National Science Foundation Advanced Technological Education (NSF ATE) Principal Investigators Conference. Both made an impact on the interest of prospective program participants. There have also been informational meetings to which students and educators from across the country were invited. These meetings allow the program's faculty to share the program's missions and they enable student scholars to share their experiences as well as information about the projects they are currently working on. These meetings have been vital to the program's overall outreach efforts and have been effective in recruiting high school students as well as students from other geographic regions such as Texas and Mississippi. Surveyed high school students find the MNT-SSRP valuable because it allows them to "learn how to [conduct] undergraduate research before even entering college" (Student Testimonial).

These collective outreach efforts have built an online MNT-SSRP community of 60 auxiliary members and 20 active student and faculty members from across the country. The continuation of these outreach efforts aims to expand this community to an international scale. This expansion would provide the program participants with the opportunity to interact with students and faculty from different backgrounds, cultures, and educational systems around the world, which would not only call for a greater emphasis on collaboration in research efforts across international borders but would also allow students to ultimately adopt a greater worldview.

Program Initiatives

The MNT-SSRP places a great emphasis on students using their voices to convey what opportunities they would like to receive during their involvement in the program. On a survey with a 5-point rating scale, students were asked what activities they would like to see incorporated into program meetings and workshops sponsored by the MNT-SSRP, and their responses are shown in Figure 1.

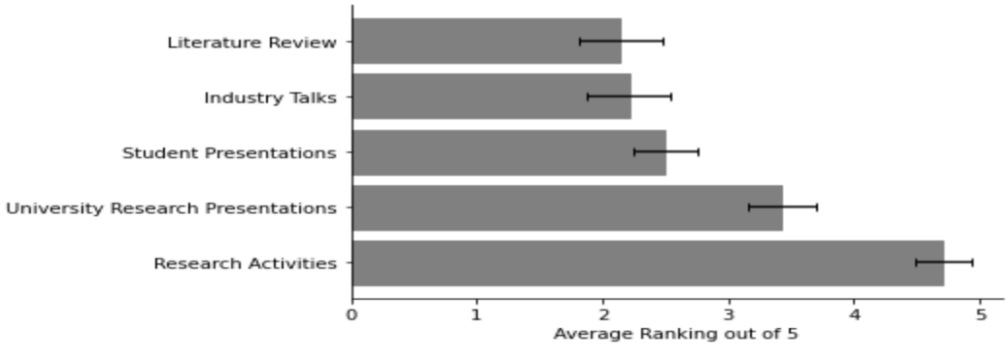

Figure 1: Programs Student Preferred in MNT-SSRP. Sample size=14. Mean rankings shown with ±1 Standard Error of the Mean..

The program prioritizes providing community college students with research opportunities, which introduce students to novel disciplines and knowledge that facilitate their prospective journeys into STEM fields. Thus, it was expected that research activities would be the most highly requested activity for the MNT-SSRP, followed by university research presentations. Surprisingly, student presentations, rather than industry talks or literature review skill development, were the next most requested. Student presentations would allow the scholars' peers and student mentors to share both their previous and current work with the group, and also share their own experiences as well as advice they may impart to their fellow students.

Developing literature review and presentation skills are both vital [33]. These results may indicate students misunderstanding and inexperience of the research process, demonstrating the need for early research opportunities to increase students' familiarity with research while simultaneously building student confidence in their ability to review literature and present research talks [34, 35]. The ability to efficiently review literature is important for advancing students into the STEM workforce [36, 37]. Therefore, although literature reviews landed fairly low on students' priority ratings, the program will continue to place a strong emphasis on this topic, in addition to creating more meetings and workshops with the three most requested activities as their main focus.

Discussion

Active members of the MNT-SSRP were asked in a survey to rank their determination of how this program has impacted their research skills (**Figure 2**). This determination was prompted by questions asking how likely they are to agree with a given statement on a rating scale of one to five.

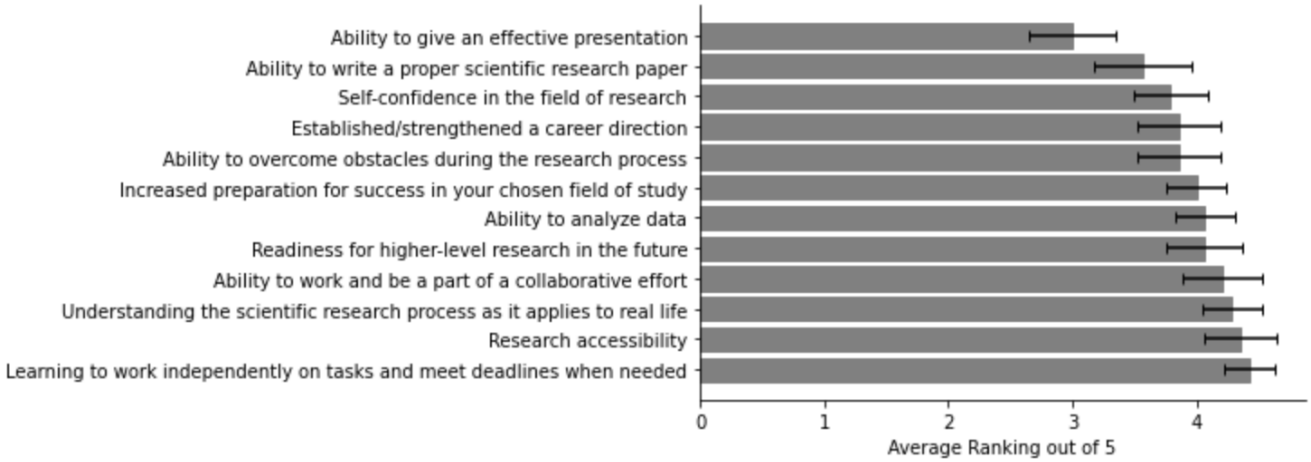

Figure 2: Ranked MNT-SSP Impacts. Sample size=14. Mean rankings shown with ±1 Standard Error of the Mean..

Responses ranked the skills that surveyed students have gained throughout their participation in the MNT-SSRP during their community college and high school experiences. The surveyed students felt that time management skills and efficiency improved, as well as reporting having a more in-depth understanding of the scientific research process as it applies to real life applications. From the start of the program, an emphasis was placed on the objective of improving students' collaborative and data analysis skills. The students' responses not only acknowledged this emphasis, but also affirmed the overall effectiveness of the program's effort.

An additional emphasis was placed on strengthening students' abilities to construct a scientific paper and successfully execute oral presentations, two important skills for students aiming to enter the STEM workforce [38-40]. Many of the surveyed students have refined their writing and presenting skills, improvements which can be attributed to the numerous local and national conferences as well as publication opportunities they had. Students wholeheartedly agree that it is "the meticulous organization," "inclusiveness," and "flexibility," that are core to this program (Student Testimonial).

Finally, students also reported both a notable increase in their readiness to partake in higher level research in the future and an increase in their problem-solving skills, which are necessary throughout the research process [41-43]. A student's time at a community college is extremely valuable but relatively short. During their two years at a community college, students endure the transfer process in addition to juggling their coursework and extracurricular activities. It is a challenge for them to also take on undergraduate research experiences.

At the end of a student's time in community college, and with the program, if they can say that their self-confidence in their research abilities has grown through their involvement, then the program has served its purpose. Students self-reported an increase in their self-confidence within a few months of participation in the MNT-SSRP. All the students active in the MNT-SSRP were awarded a summer internship. The continuous participation in undergraduate research will further increase their understanding of research and prepare students for graduate school or entrance into the STEM professional workforce.

Active student scholars were also surveyed on how likely they would be to recommend the MNT-SSRP to other STEM students looking for undergraduate research opportunities, how likely they would be to participate in another remote undergraduate research program after their involvement in this program, how beneficial the MNT-SSRP has been for them, and how much the MNT-SSRP increased their engagement in STEM **(Figure 3)**.

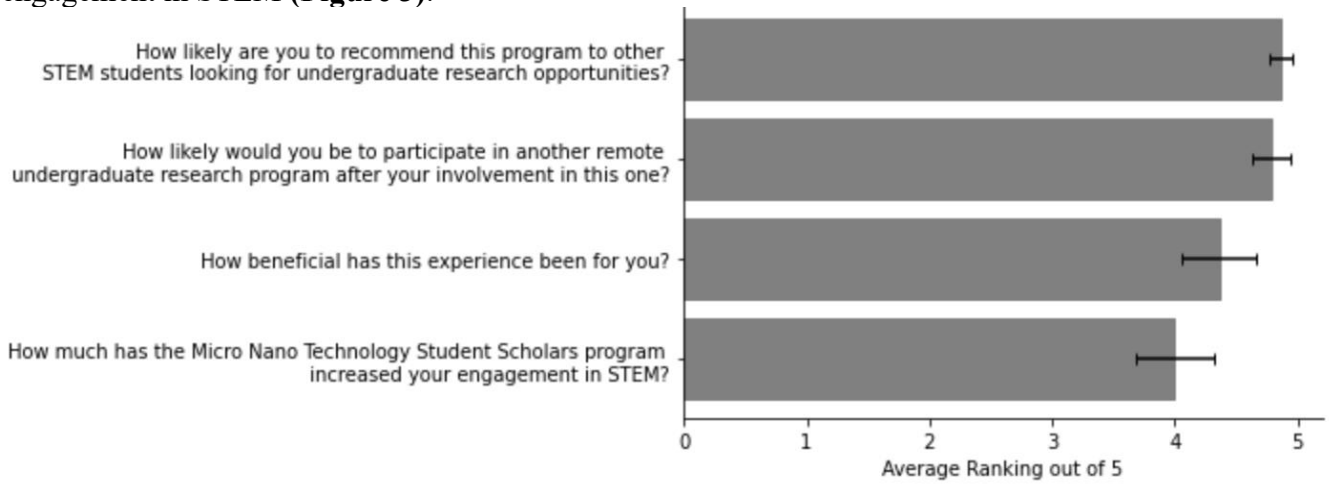

Figure 3: MNT-SSP Outcomes. Sample size=14. Mean rankings shown with ±1 Standard Error of the Mean..

These questions yielded a 97.2% average likelihood that students would recommend this program to other STEM students looking for undergraduate research opportunities, a 95.2% average likelihood that MNT Student Scholars would participate in another remote research program after their involvement in this one, and an 80% increase in their engagement in STEM. Additionally, the mean rank for how beneficial the MNT Student Scholars found this program to be was 4.36 on a 5-point scale. These results emphasize and affirm the assertions above, stressing the positive impact of remote undergraduate

research for the development of a well-rounded STEM student and highlighting the promise and continued demand for remote undergraduate research in the future.

The Micro Nano Technology Collaborative Undergraduate Research Network (MNT-CURN)
Growing on the foundation laid by the MNT-SSRP, Pasadena City College and the MNT-EC were recently awarded an NSF ATE grant for an academic-year remote undergraduate experience that includes a two-week summer capstone research experience. This online research experience will involve community college students and faculty mentors in partnership with baccalaureate research universities and industry partners from across the nation. MNT-CURN will focus on developing micro nanotechnology technical education skills and work with industry to support certification pathways. Students will gain hands-on experience in conducting experiments on a weekly basis, as well as participate in remote research group meetings, presenting their work and learning from faculty mentors in micro nano technology. Interested students and community college faculty can contact the MNT-EC or visit our website (micronanoeducation.org) for more information on joining this program.

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