Early Career and Remote Undergraduate Research Experiences as Catalysts for More Impactful Community College STEM Opportunities

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 bringing 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.

Prof. Jillian L Blatti, Pasadena City College

Jillian L. Blatti is a chemistry professor at Pasadena City College. She was part of the algae biotechnology community as a graduate student at the University of California, San Diego, and her current research focuses on sustainability outreach and education, as well as teaching creative problem solving in science.

Prof. Marcial Gonzalez, School of Mechanical Engineering, Purdue University

Dr. Marcial Gonzalez is an Assistant Professor in the School of Mechanical Engineering at Purdue University since 2014. He is affiliated with the Center for Particulate Products and Process (CP3), the Purdue Energetics Research Center (PERC) and the Ray W. Herrick Laboratories. He was a Research Associate at Rutgers University with an affiliation with the Mechanical and Aerospace Engineering Department and with the NSF Engineering Research Center for Structured Organic Particulate Systems. He received his Ph.D. in Aeronautics, with a minor in Materials Science, from the California Institute of Technology in 2010. He is a Mechanical Engineer from the University of Buenos Aires, Argentina, and received a MS in Aeronautics from Caltech. His research sits at the interface of virtual-physical particulate engineering, and it focuses on developing predictive modeling, simulation, and characterization techniques, at and across different scales, to further the understanding of microstructure formation and evolution in confined particulate systems, with an emphasis in manufacturing processes and the relationship between product fabrication and performance.

Ms. Melanie T. Hacopian, California State University, Long Beach
Danyal Nicole Pereyda Cave
Mrs. Isabel Bojanini
Mr. Esteban Bautista, California State University, Northridge

I am currently a senior studying Biochemistry at California State University, Northridge. Beginning in Fall 2020, I will pursue a Chemistry Ph.D. at the University of California, Irvine.

Dr. Veronica I. Jaramillo, Pasadena City College
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Jared Ashcroft, Veronica Jaramillo, Jillian L. Blatti, Marcial Gonzalez, Pablo D. Zavattieri, Janelle Wharry, Danyal N. P. Cave, Esteban Bautista, Isabel Bojanini, Melanie T. Hacopian

Abstract

This paper presents a successful model of preparing community college students for summer Undergraduate Research Experiences (UREs) that may be of interest to other community college faculty. Over the past four years, the Network for Computational Nanotechnology (NCN) summer URE program at Purdue large research University has created URE opportunities for community college students. This paper describes a 4-year partnership between faculty at Pasadena City College (PCC), which consists of 55% of students from underrepresented populations, and research groups in Engineering Schools at Purdue.

During the URE summer program, community college students worked side-by-side with both fellow undergraduate student researchers and graduate student mentors on a research project. Interviews and surveys demonstrated that students had a positive experience in pre-summer research experience and that performing research in advance of the summer URE better prepared them to work in the more advanced laboratory at Purdue. Several students and faculty mentors will share their individual experiences as part of this paper. Overall, ten students have participated in the URE partnership. Of these, eight have transferred to 4-year universities and seven have continued performing research, with five being co-authors on peer-reviewed science-based research publications. Furthermore, four are currently enrolled in graduate school after graduating from their 4-year program.

Looking forward, the PCC - Purdue partnership will evolve to include remote learning. To further increase the program impact, faculty and students from Purdue and research faculty and students from PCC will meet remotely during the academic year to discuss aspects of the projects. This learning experience will involve a higher greater number of community college student participants in this Remote Undergraduate Research Experience (R-URE) and better prepare them to participate in the summer URE.

Introduction

Recent studies show that STEM degrees awarded to underrepresented minorities (URM) comprise 14.7% of all Bachelors, 12.6% of all Masters, and only 8.3% of all U.S. Doctorate degrees awarded, even though URMs are 29.3% of the U.S. population [1]. It is imperative that science educators increase awareness and interest in STEM to our students. It is no longer enough to rely solely on in-class instruction. Instead, effective informal STEM experiences can be organized. These informal experiences have shown to have positive impact on the recruitment and retention of young students in STEM [2]. Increasing effectiveness of informal science learning can be accomplished by providing students with unique undergraduate research experiences utilizing course-based undergraduate research experiences (CUREs) as well as by
supplementing in-class learning with hypothesis-driven undergraduate research programs. These early UREs are a High-Impact Practice [3] that have been shown to increase STEM learning gains [4] and are especially significant for students from underrepresented communities [5, 6]. PCC has developed a program, the Early Career Undergraduate Research Experience (eCURe), which aims to formalize undergraduate research at a two-year college through a tiered approach (Figure 1). The Community College students first participate in the year-long Early Career Undergraduate Research Experience (eCURe) program that trains them in skills and techniques needed for the summer URE. Specific activities vary by student but have included mentorship from faculty on the importance of scientific research, computer programming, working in a laboratory, critically thinking through a scientific problem, and sharing outcomes through presentations at regional and national conferences.

![Design of Undergraduate Research Program: a tiered approach](image)

**Figure 1:** Tiered approach to undergraduate research at Pasadena City College; **Tier 1:** Course-based Undergraduate Research Experiences; **Tier 2:** Authentic Research with Community College Mentor; **Tier 3:** Summer URE; **Tier 4:** Student-led Mentoring using Remote Research Capabilities.

The eCURe program was developed with three targeted goals:

1. Increase student success and retention in STEM fields through collaborative and interdisciplinary research projects in basic science.
2. Inspire enthusiasm for scientific research by introducing students to research projects with a broader impact in terms of energy, the environment, and emerging scientific technologies.
3. Provide students with the opportunity to participate in all aspects of a scientific campaign, including research experience (laboratory work, literature review) and communication of scientific data (oral presentations, poster presentations, writing of manuscripts/peer-review process).
**Tier 1: Research methods/skill development**

The first tier of eCURe involves recruitment and initial preparation of needed STEM skills through CUREs within existing General Chemistry coursework or a one-unit Research Methods course in either Physical or Biological Sciences. The goal of this initial tier is the development of needed research skills, including soft skills, such as working in a team, communicating within a group, how to problem solve using critical thinking, and what it takes to be a professional scientist. During these course-based instruction experiences, students will also be introduced to STEM specific skills needed in chemistry, biology, physics or biology projects. This training in both soft and hard skills using a more active learning approach increases excitement for science, promotes scientific literacy and prepares students for the rigor inherent in the STEM academic pathway.

Over the past five years, students at PCC have participated in this active learning approach to STEM. Hispanic students in their first semester of General Chemistry increased success by 35%, including an 11% greater progression success in their second semester of General Chemistry. These students in second semester General Chemistry also transferred to a four-year university 11% more (51.7% verse 40.6%) from CURE-based courses [7]. Internal data also shows that these classes have no equity gap between male and female students. Female students in the CURE courses continue within the STEM pathway at an 18% greater rate. **Table 1** shows the overall success observed by the Course-based undergraduate research experience chemistry course compared to the traditionally taught general chemistry classes.

**Table 1**: Success, Progression and Progression Success (General Chemistry II) for Course-based Undergraduate Research Experience (CURE) classroom and traditional General Chemistry I course.

<table>
<thead>
<tr>
<th></th>
<th>Number of Students</th>
<th>Success</th>
<th>Progression</th>
<th>Progression Success</th>
<th>Completion Success</th>
</tr>
</thead>
<tbody>
<tr>
<td>CURE</td>
<td>194</td>
<td>94%</td>
<td>58%</td>
<td>76%</td>
<td>59%</td>
</tr>
<tr>
<td>Traditional</td>
<td>667</td>
<td>71%</td>
<td>48%</td>
<td>79%</td>
<td>55%</td>
</tr>
</tbody>
</table>

The eCURe program provides access to students to enroll in a research methods course in either Physical or Biological Sciences. These research methods course enables students to design authentic research proposals using the Scientific Method. Students learn how to formulate a hypothesis based on scientific literature, followed by designing and analyzing experiments. Each student in the course must disseminate their project through a research poster or presentation at a regional or national conference. This course-embedded research project allows for a more natural transition to tier two of eCURe or it better prepares the students for applying and participating in a summer URE program.
Tier 2: Hypothesis-driven research

The second tier of eCURe allows students the opportunity to work with a faculty mentor and academic peers, which has been shown to be an effective strategy for community-based STEM undergraduate research [8]. Students are trained in the scientific method. They learn how to ask scientific questions, form a hypothesis, collect data, and, most importantly, present their conclusions through presentations and publications. Students in the eCURe program have thus far published experimental design papers in using Remotely Accessible Instruments in Nanotechnology (RAIN) [9]-[12], STEM-based chemistry experiments [13], [14] and effective STEM teaching and outreach programs [15], [16]. Additionally, over 40 eCURe students have presented their work at regional and national conferences, including at the Council for Undergraduate Posters on the Hill in Washington, DC (Figure 2). The further development of research skills and design, alongside the Research Methods courses, is critical to prepare the students for applying and participating in undergraduate research experiences at four-year colleges, non-profit organizations and national laboratories.

Figure 2: Vanessa Wolf Student from PCC Presenting at Posters on the Hill

Tier 3: Internships and Undergraduate Research Experiences (URE)

Tier 3 of eCURe is supporting students’ applications and acceptance into REU programs either as summer interns or through year-long collaborations that provide students access to more complex science questions and instrumentation. As a community college, research experiences are limited due to lack of funding and research space that allows for advanced experimentation. Therefore, providing students opportunities in four-year university labs that do allow for more complex questions will further benefit the students’ STEM understanding and build on critical thinking research skills. Table 2 lists the number of students that participated in UREs over the past five years.
Table 2: Pasadena City College student REU experiences

<table>
<thead>
<tr>
<th>URE Institution</th>
<th>Number of Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>California State University Northridge</td>
<td>23</td>
</tr>
<tr>
<td>Oak Ridge Institute of Science</td>
<td>18</td>
</tr>
<tr>
<td>California Polytechnic State University, Pomona</td>
<td>11</td>
</tr>
<tr>
<td>Purdue University</td>
<td>10</td>
</tr>
<tr>
<td>Huntington Medical Research Institute</td>
<td>9</td>
</tr>
<tr>
<td>Jet Propulsion Laboratory</td>
<td>2</td>
</tr>
<tr>
<td>University of Southern California</td>
<td>2</td>
</tr>
<tr>
<td>Norfolk State University</td>
<td>1</td>
</tr>
<tr>
<td>Oak Ridge National Laboratory</td>
<td>1</td>
</tr>
<tr>
<td>Pennsylvania State University</td>
<td>1</td>
</tr>
<tr>
<td>University of Nebraska</td>
<td>1</td>
</tr>
</tbody>
</table>

The aim of eCURe is to increase passion and interest in STEM with an optimal goal of having each eCURe student continue their STEM studies by transferring to a four-year university. Ninety percent of students that complete all three tiers of the eCURe program have transferred or are currently applying to a four-year university STEM program. For students attending Pasadena City College, the California Community Colleges Student Right-To-Know Disclosure data shows a transfer rate of 9% and a completion rate of 37% [17]. Completion of the eCURe program showed a three times improvement in success.

Purdue University and PCC Partnership

The most successful eCURe Tier 3 experiences occur when partnerships between PCC and the research institution are formed. Therefore, for many of the above experiences, collaborative projects were developed so that students at the community college interact and learn about the four-year university projects before the URE begins. Specifically, Purdue University and PCC designed a program in which community college students discuss their summer research projects with their faculty mentor. Four Purdue engineering faculty and ten PCC students participated in the summer program (Table 3). It is worth noting that 60% of the students (in bold letters in Table 3) completed their undergraduate education in six years. In contrast, the national average for community college transfer students is only 42% [18].

The following individual accounts are from Summer URE faculty mentors and students on their participation in the eCURe Collaborative Research College Partnership.

Table 3: Purdue mentors and PCC students in NCN sponsored summer research experience

<table>
<thead>
<tr>
<th>Purdue Mentor</th>
<th>Pasadena City College Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dr. Marcial Gonzalez</td>
<td>Melanie Hacopian, Isabel Bojanini, Danyal Cave, Felix Monje, Paul Beckwith, Vidal Lopez</td>
</tr>
<tr>
<td>Dr. Pablo Zavattieri</td>
<td>Ashley Min</td>
</tr>
<tr>
<td>Dr. Janelle Wharry</td>
<td>Esteban Bautista</td>
</tr>
<tr>
<td>Dr. Tim Fisher</td>
<td>Daniel del hoyo Torres</td>
</tr>
<tr>
<td>Dr. Edwin Garcia</td>
<td>Anthony Varellas</td>
</tr>
</tbody>
</table>
**Purdue Mentor:** Dr. Marcial Gonzalez, Assistant Professor, School of Mechanical Engineering

Over the past four years, Professor Gonzalez hosted and mentored a total of six underrepresented minority students from Pasadena City College, and one from Ivy Tech Community College, who had demonstrated the desire and ability to pursue graduate studies in STEM fields. During the URE summer program, community college students worked side-by-side with both fellow undergraduate student researchers and graduate student mentors on a research project, namely the fabrication of particulate products by powder compaction, with applications to a variety of industries ranging from pharmaceuticals to propulsion. This research project is under the umbrella of the Center for Particulate Products and Processes and trains students on powder technology, modeling of manufacturing processes, and implementation of these models in the NSF-sponsored nanoHUB online platform [19-22, 32]. Every summer, before the URE begins, students and Dr. Gonzalez discussed the project using the simple schematic depicted in **Figure 3**. Given students’ prior successful eCURe and consolidated understanding of what any research project entails, the proposed project schematic effectively conveys how both experimental and computational components are intertwined and what the role of the community college student is within a more extensive research effort.

![Figure 3: Schematic used by Dr. Gonzalez to discuss the details of the proposed summer URE with community college students who already have had successful eCURe.](image)

The URE projects were structured through a research contract and involved regular supervision from graduate student mentors and one-to-one weekly meetings with Dr. Gonzalez, as well as periodic attendance to professional development and research seminars offered by the NCN Network and an oral presentation at an end-of-summer Research Symposium. These interactions helped create a more inclusive and culturally competent climate among the summer students by motivating them to interact across barriers of difference. After the confidence-inspiring and
resume-building summer experience, six students have transferred to four-year institutions, and three of them are currently pursuing undergraduate research. Impact of this 3-tier approach to undergraduate research is put into perspective by research conducted by the National Student Clearinghouse which shows that only 15% of all community college students complete a four-year degree in less than six years—with far more daunting numbers for underrepresented and low-income students. The reach of this program is evident in the diversity of students hosted and mentored by Dr. Gonzalez, i.e., two military veteran, three female, and three Hispanic students.

Purdue Mentor: Dr. Pablo Zavattieri, Professor, Lyles School of Civil Engineering

Ashley Min joined the Multi-Scale Mechanics and Materials by Design Laboratory in the summer of 2018. Ashley worked with two undergraduate students under the supervision of two Ph.D. students and Professor Zavattieri. Their primary research was to develop a computational simulator on nanoHUB. This simulation tool could predict the mechanical response of a new architected material, Phase Transforming Cellular Materials, which can undergo large deformation, dissipate energy, but remain elastic. The mechanical behavior of PXCMs was already studied by graduate students and the basic computational code was written in MATLAB. Ashley worked with the other two students to design the user interface of the simulator and modify the code in the format which is compatible with nanoHUB. Although Ashley did not have strong background in mechanics or engineering, she was able to understand the fundamental mechanism of the materials. She managed to discretize the research problems into small tasks which she could solve using the fundamental knowledge she had. For instance, without strong background in mechanics, Ashley was able to understand basic mechanics of the materials concepts as well as the mechanical function of code. As a result, she was able to modify the code and interpolate them into a graphic user interface. In addition, she was willing to gain new skills to complete the task. For example, when Ashley was working on design outlook of the interface, some new schematic can explain the function of tool were required. Ashley learned a new graphic design software online, and designed a clear cover schematic with the other two undergraduate students.

In addition to the computational skills that Ashley obtained, she also conducted a variety of mechanical experiments. She conducted cyclic loading tests for various structures of interest, specifically structures capable of buckling instabilities leading to energy dissipation. With the direction of the supervising graduate students, Ashley designed experiments with the desired boundary conditions as well as operate the appropriate machinery required to conduct the cyclic loading experiments. The cyclic loading experiments involved loading and unloading of samples to obtain a characteristic load-displacement curve, which could quantify the energy dissipated by the structure of interest. Ashley trained to use a formlab 3D printer for fabrication, which she utilized to create several experimental samples. She understood the various defects that were possible during this particular fabrication process, which included small voids (‘air bubbles’), layer orientation, and printing failures. Additionally, Ashley was able to understand the differences between the results from the computational simulations that she ran with code and the results obtained from the experiments, which were mostly a consequence of these fabrication errors. Ashley was able to understand each portion of the research process in Professor Zavattieri group, which fundamentally proceeds as follows: initial design and proof of concept using numerical simulations, fabrication of experimental samples, and experimental validation.
**Purdue Mentor:** Dr. Janelle Wharry, Assistant Professor, School of Nuclear Engineering

PCC student Esteban Bautista’s summer research will have long-lasting impact, as it represents one of the first steps toward qualifying alloys fabricated by powder metallurgy with hot isostatic pressing (PM-HIP) for use in the nuclear power industry. During his summer at Purdue, Esteban studied two corrosion-resistant Ni-base alloys and compared thermal aging effects in their PM-HIP versions to their conventionally prepared (e.g. forged) versions. He carried out thermal aging of these four materials, each over three temperatures for two lengths of time. In order to carry out these studies, he had to become proficient with metallographic specimen preparation, etching, light optical microscopy, microstructure quantification, and microhardness testing. Esteban is now a co-author on two peer-reviewed journal articles we have since published, based on the work he did at Purdue.

Prior to his summer research experience at Purdue, Esteban had never been away from home and his family for an extended period of time. Further, he is the only one in his immediate family to have ever left home for such an extended period—in fact, his family doubted that his research internship offer from Purdue was real, until he physically began working in the lab! This was a unique aspect of working with Esteban—because of his background, he did not take anything for granted. But he was a quick study and seemed to gain confidence over the course of the summer. He later told me that his growth and confidence came from being outside of his comfort zone—both geographically, and research-wise. Esteban’s unique background and research interests (heavier in chemistry than most of the other students in my research group) provided a rich learning experience for all students in my research group.

**Student Experience:** Esteban Bautista, California State University, Northridge

“I guess you’re not cut out to be a scientist, you should change your major to something less competitive.” Regrettably, I listened to my professor and I changed my major from Biochemistry to Nutrition. Although this is the type of messaging I received throughout my education and was a major setback in my undergraduate education, I decided I wanted to become a researcher. My research experiences at PCC and Purdue resulted in tangible academic outcomes that include publishing five peer-reviewed manuscripts, presenting my research at local and international conferences, and obtaining various scholarships.

Although the technical experience gained in a research laboratory is of extreme importance to become a successful researcher, some of the most impactful and life-changing lessons were learned outside of the technical laboratory setting. One of my most significant research experiences was at Purdue. After a difficult first couple of weeks—I was not accustomed to researching for over 40 hours a week, and I felt a bit homesick—I overcame the challenges I faced. Specifically, I became accustomed to my settings and expectations and was able to push out a substantial amount of work and eventually contributing to the writing and editing of two manuscripts. The objective of our research was to compare the fabrication methods of heat-treated, Nickel-based alloys and how they varied in yield strength and grain structure size.
My three other published manuscripts were on the reduction of the gender and achievement gap and the interconnection between remote access technologies and chemistry experiments in K-12 classrooms and college classrooms. Participants were predominantly from low-income minority communities and students indicated increased interest in scientific practices and careers in over eight hundred students across twenty-one classrooms. This research was impactful because of my own experience as a first-generation, low-income, student of color. In these classrooms, I felt I was making a difference and it further motivated me to apply to Chemistry and Engineering Ph.D. programs. More importantly, through this education research project, I discovered my passion and ultimate goal: teaching.

Whether it was when my professor told me to change my major or when I was struggling to maintain a job and my academics, I could have used a role model that looked like me or understood what I was going through. Because of the absence of racial, ethnic, and class diversity among so many of my own courses, my goal is to become a university professor at an institution with a diverse student body. Because of my research experiences at PCC and Purdue, moreover, I know that I want to conduct research for the rest of my life. I learned about the patience, diligence, and sacrifice required to be a successful researcher, doctoral student, and leader to push forth the next generation of diverse scientists.

**Student Experience:** Danyal Cave, Pasadena City College

The undergraduate research that I experience at PCC and the summer internship at Purdue has impacted me in a way that allowed me to figure out what I wanted to do with my potential career. It helped me realize that I enjoy doing research and want to continue learning as much as possible, and that I want to pursue a STEM graduate degree to continue doing what I love.

At PCC, it was my first time I have ever conducted research. I first gained the experience inside a classroom working with other students inside a lab. It piqued my interest and later on I joined a research group where I stayed in that group for a long period of time and worked with different types of people. To me, this was where the real research experience developed, as nearly everything was led by students in order for the research to continue. This experience helped me develop commitment, working in groups, and how to conduct research properly. This was when I started to think about graduate school and possibly continuing doing research.

The experience I gained in the classroom and in the research group helped me at the summer internship at Purdue because I knew what to expect. Although, the experience I gained was different from what I had gotten from PCC. I experienced new people in a completely new environment and the people I met were like no other that I have met before. This helped me learn from other people’s point of view on how they did their research and the experiences they gained from their schools. Learning these new techniques and meeting those people helped me engage better in my research. Another thing I learned was that the majority of the time I was alone in doing the research, even though I had guidance, it was up to me on how to do it. It helped me mature by developing my time management and priority skills. After this experience I now knew for sure I wanted to continue doing these types of things as my future.
Both these experiences offered me a real taste of what the culture of research is like and what the life of a scientist is going to be like. It also helped me decide if research is the life for me. It also helped me decide if researching in these particular fields is something I would love to pursue later on when I want to apply to graduate school, and if the investment in graduate school is worth the time and if I want to continue my studies. Besides that, it helped me express my love of learning, interacting with people of different backgrounds, and discovering topics that could help impact the world. It helped me develop the skills that are needed in graduate school by showing commitment, interest in learning, construct and developing plans on how to research and do a specific topic, curiosity, work ethic, and reliability to the potential graduate schools that I am ready for their research and to help impact the world positively. All the aside, in order for me to be able to do what I truly want to do, the career requires me to get a graduate degree.

**Student Experience:** Isabel Bojanini, University of California, Berkeley

During my sophomore year at PCC, I joined the research group of Dr. Khuloud Sweimeh through the Pasadena City College Early Career Undergraduate Research Experience (eCURe) program, designing “green” cosmetics by substituting toxic organic chemicals with natural substances to improve efficacy and safety of these products. This was the first experience in which I was allowed to work on my own and assess which components of the formula could be modified to improve the products. This experience was valuable because it taught me critical thinking and troubleshooting, but most importantly, I gained the confidence to be less reliant on my mentor and begin working independently. Through this experience I realized how much I enjoyed research and it led me to apply to the NIH BUILD PODER Undergraduate research program, a collaborative internship between PCC and California State University, Northridge. I was accepted and chose Dr. Jared Ashcroft as my mentor for the 2017-2018 academic year.

Through this program not only did I learn how to devise a research project and data analysis, but I was also in an academically and intellectually supportive environment. I began research with Dr. Ashcroft, developing methods of remediating soil samples of various heavy metals and nanoparticles using microorganisms, a project devised by the students in this lab. We also worked on a project developing K-12 teaching activities. The latter led to me being a co-author on a publication in The Journal of Laboratory Chemical Education, as well as presented at the HTCC Honors and Computer-Using Educators (CUE) conferences. These research experiences and opportunities to present my work were engaging and increased my passion for science and understanding of the amount of work, and persistence and discipline needed to conduct research.

During the following summer, I participated in the NCN-URE program at Purdue doing research in the Gonzalez lab in the mechanical engineering department. Having only done research in the life sciences field, I was nervous but excited to take on this challenge. The research program was designed to include engaging activities regarding how to conduct and present research in a professional setting, and it culminated in a poster presentation where the students were able to present the results obtained throughout the summer. While I had presented before, the information I learned in this program allowed me to become more confident in my science communication skills. During my time in this program I also learned to code in MATLAB. As a scientist, coding is extremely helpful, especially when large data sets are involved. Overall, my experience in this program was positive as I broaden my understanding of physical processes as well as learning a new skill that would make me a more well-rounded scientist.
After transferring to UC Berkeley and conducting research there, I can confidently say that these research experiences increased my self-confidence as a scientist. More importantly, it provided a solid foundation of science communication, research skills and methods that I currently put in practice as my research project is in the computational biology field. These programs helped me recognize how passionate I am for science and reinforced my desire to ultimately obtain a doctorate in this field.

**Student Experience:** Melanie Hacopian, California State University, Long Beach

While attending PCC as a biology student, I was determined to study science beyond the textbooks and in class lectures. I applied and was accepted by the NIH funded BUILD PODER program in collaboration with California State University, Northridge. BUILD aims to provide underrepresented students with the tools and support that is necessary to successfully pursue a career in research. I started working in a chemistry lab under the leadership of Dr. Jared Ashcroft in the Department of Chemistry. My research partner and I studied the impact of chemicals such as heavy metal nitrates and nanoparticles on plant growth and development. This project taught me valuable research skills such as how to operate SEMs, construct posters, and communicate scientific research at conferences. The results of this experiment emphasized the importance of preventing contamination of soils by industrial contaminants. More importantly, the research experiences I gained at PCC served as affirmations for my decision of pursuing research, and with the help of my growing network, I felt motivated to pursue opportunities outside of PCC.

My previous research with nanoparticles led to my application and acceptance to the Network of Computational Nanotechnology’s NSF funded undergraduate research summer internship at Purdue in a powder compaction lab under the mentorship of Dr. Marcial Gonzalez in the Department of Mechanical Engineering. This lab was geared towards compaction behavior and tensile strength of pharmaceutical tablets, which were embedded in an understanding of particle mechanics and micro-powder compaction technology. Working in a team, I created tablets composed of seven different mixtures of lactose and microcrystalline cellulose, two popular pharmaceutical excipients. I subjected the tablets to compaction and fracture tests, keeping records of compaction pressure and tensile strength. I presented this project at the 2018 Summer Undergraduate Research Symposium at Purdue. In addition, the results of these tests were used to calibrate a published online nanoHUB tool that simulates compaction when a user enters their desired parameters. This open-access tool, intended for pharmaceutical researchers, can potentially save money, time, and material. Through this experience I realized the importance of responsibility and time management since I decided my daily schedule. I also learned to seek support and guidance from graduate students in the lab, which was not a concept I could gain at PCC where there were no graduate students. In addition to this, the internship at Purdue taught me how to thrive outside of my comfort zone and contributed to my growth as an interdisciplinary scientist.

The experience I gained from working in the lab of a four-year institution helped me greatly once I transferred to California State University, Long Beach. I applied and was accepted to the BUILD site there and I am currently working in the Department of Biological Sciences with Dr. Renaud Berlemont in the Bioinformatics Lab. In my current project, I employ data mining techniques to study the recruitment of cellulases for the bacterial cellulose synthesis (bcs)
operon, which encodes the enzymes necessary for bacteria to produce cellulose, a key structural component in biofilms. In this project, I programmed scripts in Bash and R to mine microbial genomes from a publicly available database. I then investigated the architecture and strain-specific potential of the \textit{bcs} operon using R. Similar to the Purdue internship, I work closely with graduate students in the lab for support. With the help of BUILD and my past research mentors, I applied to six Ph.D. programs and I am currently awaiting decisions. I am confident that my past experiences have prepared me to be an efficient graduate researcher. Although I did not know it when I started, getting involved in research is one of the smartest academic decisions I have made. In addition to the mentorship I received and the support system that encouraged me through tough times, the networking and communication skills I learned are tools I will apply for the rest of my life.

**Evolution of eCURe Tier 4: Remote Undergraduate Research Experiences (R-UREs)**

Future expansion of eCURe will entail strengthening the partnership between Purdue University and PCC. Effective UREs aim to (i) engage undergraduates in following protocol rather than interpreting results, (ii) increase duration and intensity of mentoring to strengthen impacts, and (iii) allow student opportunities to integrate evidence from their research to strengthen their identity as a scientist, and it takes up to a year within the URE to gain sufficient understanding to make sense of science practices and concepts in lab [23].

A newly established Tier 4 within eCURe will allow community college participants to meet on a biweekly basis with faculty, post-docs, and other graduate/undergraduate students at four-year universities utilizing remote software, such as Zoom. These quasi research groups will be led at PCC by students who have participated in the URE research experience at Purdue. These R-UREs will allow the student-led groups to develop, throughout the year, their research protocol and mentoring style amongst each other. The groups will be able to focus on the development of new research projects based on prior results. Initial engagements will be based on coding projects for simulation tools available in the nanoHUB Network, due to the easy remote implementation of simulation-based research remotely over Zoom. Future projects will be looked into as the program evolves and grows.

**Discussion**

Effective undergraduate research experiences are one of the most impactful practices for increasing success and persistence in STEM. Engaging students early in their STEM academic pursuit is vital and allows students ample time and opportunities to fully discover the STEM pathway they most enjoy. The Early Career Undergraduate Research Experience (eCURe) has successfully implemented a tiered research experience program that:

1. Has increased all student success in the STEM academic pathway through embedding research experiences within General Chemistry and Biology courses, with the most significant gain on underrepresented minority students.
2. Allowed access for students to further refine authentic research design within the framework of Biological or Physical Science Research Method courses.
3. Increased access to authentic research projects through hypothesis-driven research programs within the STEM program.
4. Provided 79 students acceptances into summer undergraduate research experience programs throughout the United States.
5. Enabled an avenue for students to increase their science engagement and passion through research.
6. Published 16 peer-reviewed articles that include 31 community college undergraduate students [7, 9-16, 24-30].
7. Performed over 100 national and regional conference presentations.
8. Developed two nanoHUB simulation tools [19, 31] and seven nano-based educational laboratory tools.

Evolving these research experiences using modern technologies, such as remote meetings will allow for more students, especially from two-year institutions to participate in research programs. This will greatly benefit community college students and lead to a more positive view and success from these oftentimes overlooked students.

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