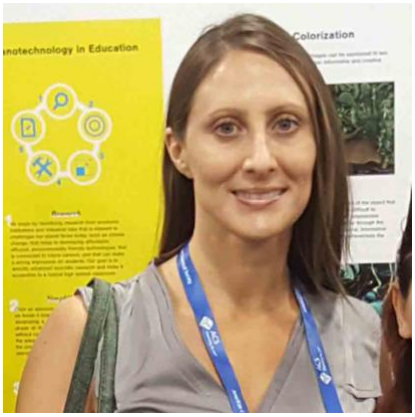

Invited Letter: Undergraduate research as a means to build a creative, resilient, and highly skilled biomanufacturing workforce

Keywords: NSF, ATE, future manufacturing, biomanufacturing, STEM education, workforce development, synthetic biology, DNA nanotechnology, outreach, teacher education, undergraduate research, art in science, green chemistry, systems thinking, active learning, equity in education

As a principal investigator of an undergraduate research group at Pasadena City College (PCC) for the past ten years, I have witnessed the profound impact that the research experience has had on our students. I have observed students as they develop the ability to carry out authentic research projects from the inception to dissemination, design and carry out thoughtful experiments, write meaningful conclusions in light of relevant literature, and present science to peers and at conferences. Undergraduate research gives students the opportunity to work in a laboratory setting early in their career and collaborate with scientists as they learn how to do science themselves. It lays the foundation for future experiences in research; it informs their decision to pursue science; it excites, motivates, and inspires them; it contextualizes what they learn in courses and applies interdisciplinary scientific concepts to emerging technologies.

Currently, as Co-Principal Investigator of an NSF Future Manufacturing grant in collaboration with UCLA, UCSB and Caltech entitled “DNA & RNA Condensate Droplets for Programmable Separation and Manufacture of Biomolecules,” I lead the education and workforce development aspect of this effort. Through this undergraduate research program in DNA nanotechnology, PCC students are trained in research methods, laboratory techniques and scientific theory to prepare them for the future biomanufacturing workforce. They apply this knowledge to authentic research projects, exploring aspects of DNA nanotechnology while developing important character traits and skills that will enable their success as students, scholars, and technicians. As advisors in undergraduate research, we have the privilege of serving as mentors to students, and mentorship can have a significant and lasting impact on students’ lives and careers.

Creative ideas are the centerpiece of my research program at PCC that focuses on bio/nanotechnology. We have made natural paints through green chemistry, biodiesel from algae, nanostructures using DNA origami, and we are now working with DNA nanostars and DNAzymes. Artistic themes permeate our scientific research, which inspires creativity in the students and allows them to learn complex scientific concepts in a fun and engaging way. We love to create art through microscopy, craft paintings with themes at the art-science interface, and use graphic design to illustrate scientific concepts. Students pursue their passions and interests, which motivates and inspires them. Throughout the research experience, students collaborate with professors, graduate students and post-docs, attend seminars, and carry out scientific work; they begin to identify as scientists as they develop confidence in their application of the scientific method and in their ability to communicate effectively. Students learn how to think through problems, troubleshoot instruments, and persevere through challenges. They cultivate important characteristics, such as resilience, ethics, and leadership, and skills such as critical thinking, creativity, and collaboration, which are desirable traits to any future employer.

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Course-based undergraduate research affords research experiences for a wider range of students, and it is an equitable, effective way to teach science that engages students from diverse backgrounds. My research group has designed lesson plans to teach students about green chemistry, sustainability, and renewable energy; and we are working to translate our current research into projects focused on DNA condensates. PCC researchers teach these engaging and interactive lessons with me in outreach to underrepresented communities and as learning assistants in my courses, and this experience inspires everyone involved. Excellent science teachers are necessary in the development of a creative and resilient future workforce, and providing opportunities for students to engage in science teaching can identify talent and passion for teaching science and technology. In summary, undergraduate research is a highly impactful experience for students, and equitable opportunities must be created for more students to participate in the research process.

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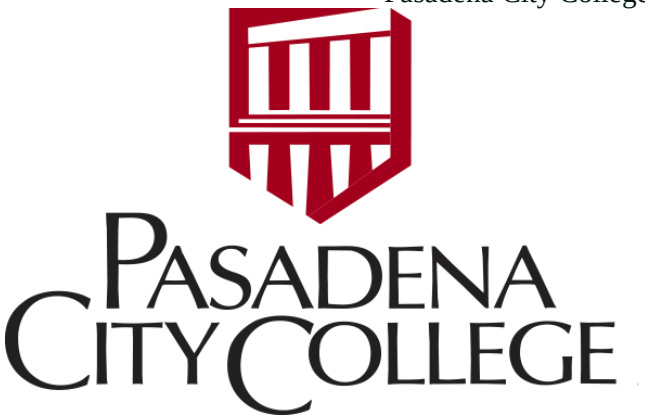

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