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# COMMENTARIES

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## Undergraduate Research as a High-impact Practice for Engaging Students of Color in Ecology

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### Introduction

The number of Hispanic, African American, Alaskan Native, and American Indian students who graduate in science disciplines and find employment in science careers is unacceptably low, as are the retention rates of the small number of students of color who matriculate into graduate-level science programs. While approximately 25,000 PhDs in STEM disciplines are awarded each year by universities in the United States, students enrolled as underrepresented minorities (predominantly Black and Hispanic) earn less than 5% of those degrees despite comprising ~30% of the total population (Fabio et al. 2008, National Science Foundation 2018). Students of color face many obstacles and barriers to science engagement, including cultural differences and lack of exposure to mentors and role models (Hall and Post-Krammer 1987, Maton et al. 2000, House 2000, Armstrong et al. 2007). These barriers limit the ability of underrepresented minorities to succeed in STEM pathways.

Such small numbers of students of color in these areas can have a variety of negative impacts on issues that range from the US economy and the conceptualization of graduate degrees to careers that some students consider as realistic options. Diverse mentors/role models are critical for successful science recruitment and retention programs (Council of Graduate Schools 2003). If science faculty

of color are a rarity, how are undergraduate and graduate students of color able to find role models? Likewise, if persons of color are a rarity among the ranks of science professionals, how are recent graduates of color able to find role models in science careers? This situation may partially be caused by the cultural and family values of persons of color, which may lead to decreased participation in STEM fields from the start. In order to change this trend and move traditionally underrepresented students into graduate programs and, ultimately, senior positions in science disciplines, we need to establish a pipeline of programs that support the engagement of students of color in science education.

The essential role of faculty mentor contact and engagement is a common theme across models for student engagement and retention (Tinto 2012). Engagement methods that have been shown to improve retention include faculty-mentored research, virtual reality, active learning, internships, and reverse classroom structures (Ryan 2019, Sultan et al. 2019, Stranford et al. 2020, Cottone 2020). Faculty-mentored research is an ideal engagement strategy because it gives students a tangible, hands-on application of classroom concepts while also preparing them with practical problem-solving skills (Kardash 2000, National Research Council 2000, Boyd et al. 2009). The intersection between theory (introduced in the classroom) and practice (obtained through mentored research experiences) improves learning outcomes and an early definition of career goals (Kuh 2011). Through research experiences, a student's first-hand exposure and response to real-world problems, along with real-time reflection upon the products of their actions, facilitate the development and evolution of knowledge across their discipline (National Research Council 2000). Undergraduate research is particularly well suited for bridging intersecting disciplines in highly complex fields like ecology (Itin 1999, Kuh and Kinzie 2018, Emery et al. 2019, Hernandez et al. 2018, Martinez et al. 2018, Chelberg and Bosman 2019, Morton 2020). At Colorado State University (CSU), as highlighted below, mentored research has proven especially effective at increasing academic performance, retention, and realization of career opportunities for science students of color. This underscores the value of undergraduate research as a high-impact practice for engaging students of color in ecology.

### Discussion

In 2009, CSU established its first all-university office for undergraduate research. At that time, university surveys indicated that fewer than 1400 of CSU's approximately 26,000 undergraduates participated in faculty-mentored research. Starting as early as freshman year, the office invites undergraduates to participate in faculty-mentored research, presents students with the benefits of undergraduate research, and works with students and faculty to place students in research positions. The number of undergraduate researchers at CSU is now pushing 6000, despite research remaining voluntary for all students. Notably, the increase in participation of CSU students of color in research has significantly outpaced that of the general student population by a margin of 560%, compared to 326%, respectively. More importantly, science students of color participating in formal research programs at CSU far outperform other students of color and the general student population based on several key metrics, including STEM persistence, retention, and entry into STEM graduate programs and/or careers. While it is possible that the students that opt for extracurricular research experience may not be a true "random" sample of the general student population, it remains true that CSU's increased emphasis on student research has provided greater opportunity for all students and that retention has also increased. Participants of CSU's Rocky Mountain Scholars Program (RMSP), which provides participants with

cohort-based research placements, place emphasis on the recruitment and success of STEM students of color. Since 2011, participants have had a 100% rate of retention in higher education and a 99% rate of persistence in STEM programs. These rates are dramatically higher than our institutional average of 68%. Among the graduates of this program, 89.6% have either elected to pursue a STEM graduate degree or have entered the STEM workforce.

Among a range of focus areas, the RMSP added an Ecology Cohort in 2019 that provides undergraduate research opportunities. The current project for this cohort of 15 students (ranging from freshman to seniors) involves a cross-disciplinary study that spans ecological health, animal health, and public health. Briefly, the project samples regional honey and pollen samples from a network of managed beehives to identify contaminants, including heavy metals, trace metals, insecticides, fungicides, and herbicides. In silico modeling is conducted to predict broader impacts on bee health, ecological health, and human health. For participants, what begins as in-field sampling later leads to chemical analyses, pollen identification, computer modeling, and, ultimately, cell-based studies of the impacts each identified adulterating agent (both individually and combinatorically) has on human breast, colorectal, and hepatic cells using proliferation and tumorigenicity assays. Thus, participants are able to focus on a specific aspect of this project while being exposed to a wide range of meaningful procedures in studying the cascade of intersecting impacts related to interconnected ecosystems. These are highly impactful, career-defining experiences for most participants.

Sustainability- Define and assist self-efficacy survey results  
(Bowser et al. 2014)

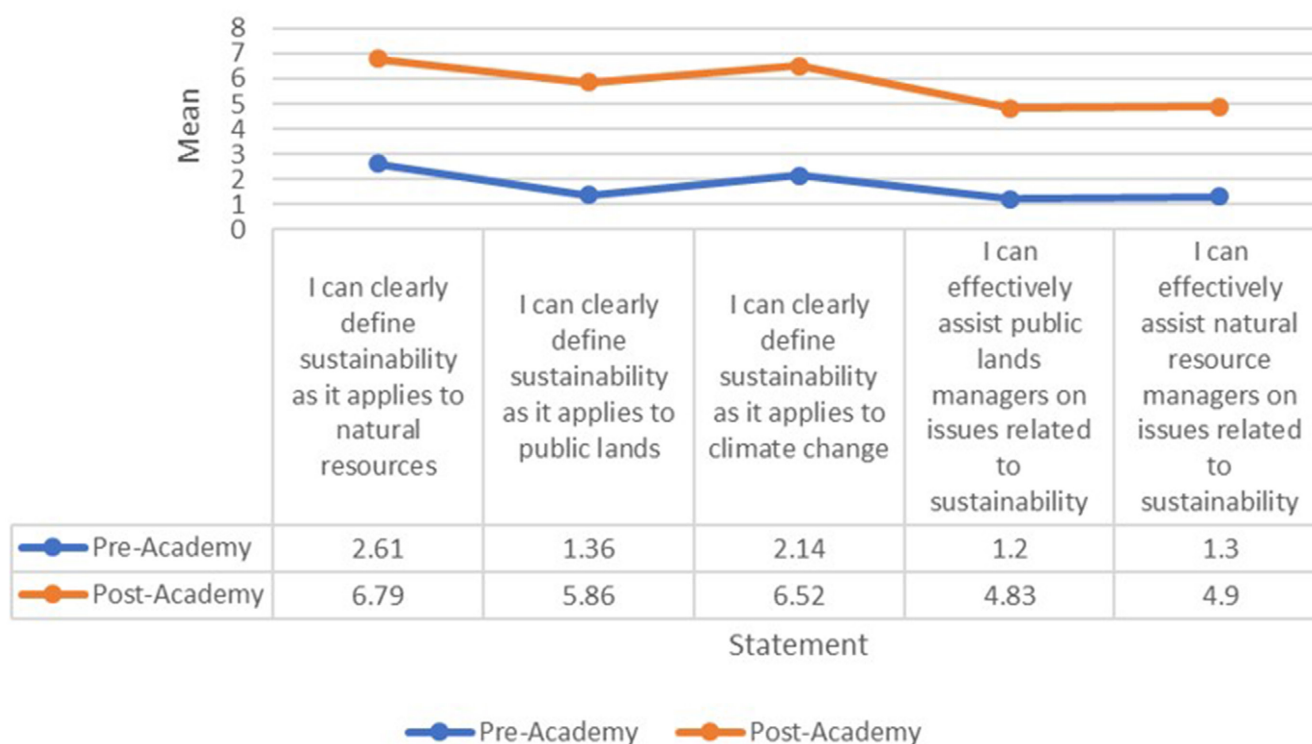


Fig. 1. Sustainability: Define and assist self-efficacy survey results (Bowser et al. 2014).

Among CSU's formal undergraduate research programs, the RMSP is a program that emphasizes the engagement of students of color in ecology-focused experiential learning that has shown some of the most profound impacts. The Rocky Mountain Science and Sustainability Network (RMSSN) was established at CSU based upon the overarching vision to help train the next diverse generation of public lands leaders. The year-to-year average of students of color in the RMSSN is approximately 75%. Based on a battery of self-efficacy measures, as well as a range of qualitative indices (Davis et al. 2012, Bowser et al. 2014, Gretzel et al. 2014, Halliwell et al. 2020), the RMSSN now includes a network of hundreds of program graduates who are rapidly ascending the ranks of public lands agencies throughout the world. Figs. 1 and 2 below manifest a shift toward stronger self-efficacy following the experience of RMSSN Academy. In Fig. 1, the collected student responses after engaging with the RMSSN activities reveal the shift toward more confidence in defining and assisting with global environmental sustainability. In Fig. 2, the collected responses after the academy experience display a significant shift toward confidence, scientific knowledge, and the ability to define, explain, or assist in climate change efforts. According to student surveys, the leading and overarching cause of these positive results was research experience, although mentorship and cohort support also played a role.

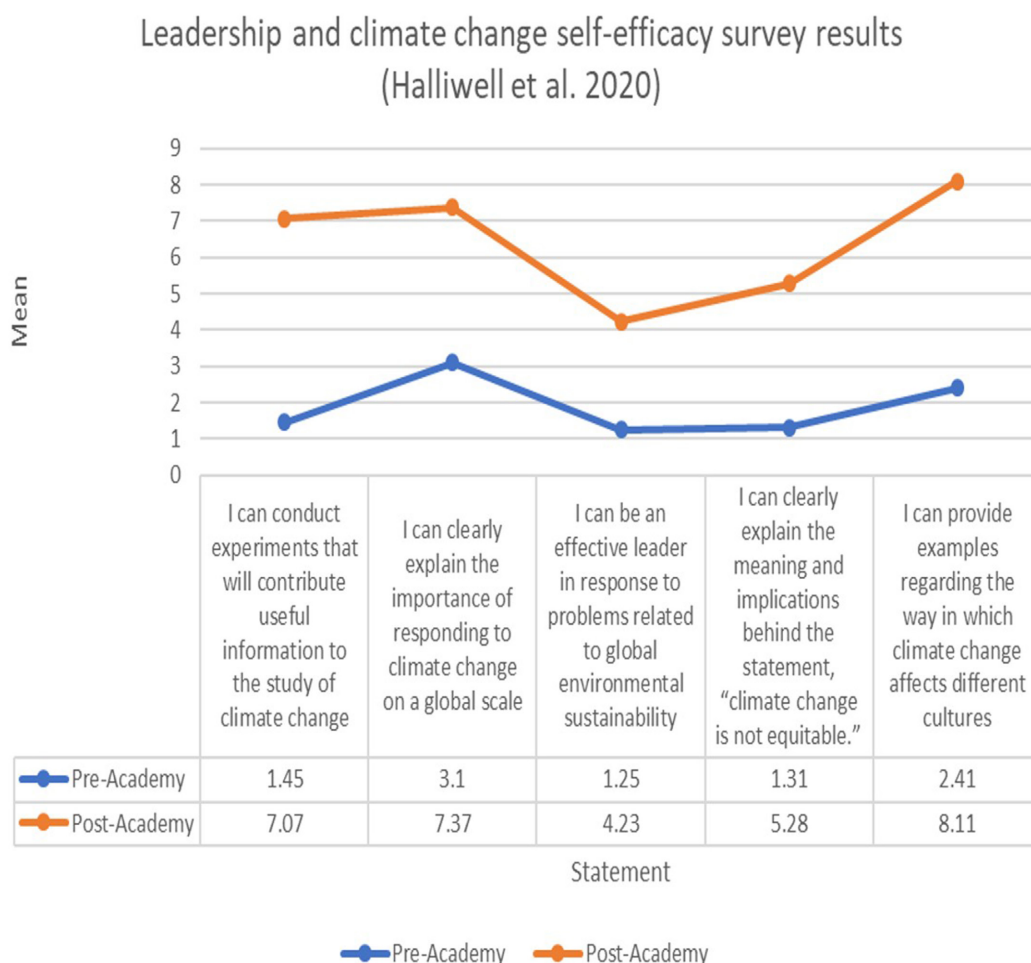


Fig. 2. Leadership and climate change self-efficacy survey results (Halliwell et al. 2020).

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## Conclusion

Underrepresentation of students of color in the ecological sciences has far-reaching socioeconomic impacts and severely limits the diversity and breadth of influence and experience brought to bear on ecological issues. Student engagement is a powerful tool for both recruitment and retention, and it is the most important factor in retention programs for undergraduate students of color (Upcraft et al. 2005, Pascarella et al. 2008, Tinto 2012). Undergraduate research has been previously proven to have the most positive outcomes, among all high-impact practices, with regard to promoting student engagement, and we have repeated those results through a combination of formal and informal programs at Colorado State University. In particular, the RMSSN provides a framework for implementing mentored research as a high-impact practice in undergraduate ecology education.

For more information about RMSSN or the Rocky Mountain Scholars Program, see <https://rmssn.wordpress.com/> and <https://tilt.colostate.edu/OURA/RMSP>.

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