

Summer Science Academy in Chemistry as a Gateway to STEM for Matriculating First-Generation and Other Underrepresented Students

Meishan Zhao*



Cite This: *J. Chem. Educ.* 2022, 99, 759–767



Read Online

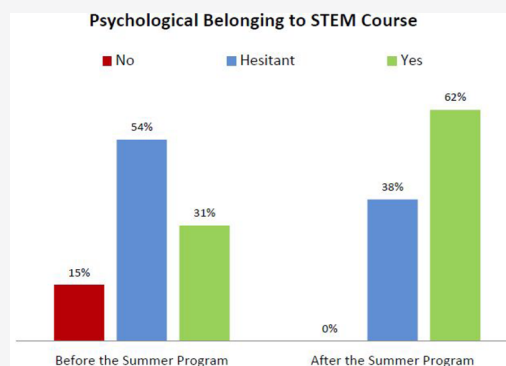
ACCESS |

Metrics & More

Article Recommendations

Supporting Information

ABSTRACT: We report a program for a summer science academy in chemistry, a section of the Chicago Academic Achievement Program (CAAP) at the University of Chicago, as a gateway to STEM for incoming first-generation students and other underrepresented student groups. Our program emphasized diversity in classrooms, students' psychological safety and a sense of belonging to STEM, increased knowledge base, and overall college readiness. On the basis of feedback from participating students, the reported summer science academy in chemistry successfully prepared and motivated the CAAP scholars toward a STEM career direction.



KEYWORDS: *First-Generation College Students, First-Year College Students, Underrepresented Student Groups, Minorities in Chemistry, Incoming College Students, Classroom Competition, Imposter Feelings, Diversity, Community Building, Collaborative Learning, Student-Centered Learning, Inquiry-Based Learning*

INTRODUCTION

First-generation low-income (FGLI) and underrepresented students of color (URM) face tremendous barriers in pursuing higher education, contributing to the problems of enrollment, graduation attainment, financial difficulties, worsening inequality, and discrimination in society.

Many contributory factors lead to social inequity, which is a cancer to society. Fortunately, there are signs of progress in this area, with active supporting organizations nationally and within most higher education institutions, especially in the past decade. Findings from the literature reveal pedagogies and activities that correlate to student success in college (e.g., refs 1–7).^{1–7} However, many of the underrepresented groups are disadvantaged from even enrolling in higher education, resulting in a significant equity gap that, in turn, is a potential source for social unrest. Figure 1 presents the results of a recent Axios-Ipsos poll in higher education.⁸ This poll was produced with 1,992 adult participants within the general population, aged 18 or older, including 761 White respondents, 510 Black respondents, 477 Hispanic respondents, and 205 Asian American/Pacific Islander respondents. We have updated the figure by normalizing each group to 100% by eliminating no answers, representing the current social sentiment in society.

We must make a concerted effort to achieve a successful and sustainable long-term reduction of inequality in society. The first phase for educators is to support a smooth transition of FGLI-

Pool of Higher Education in USA

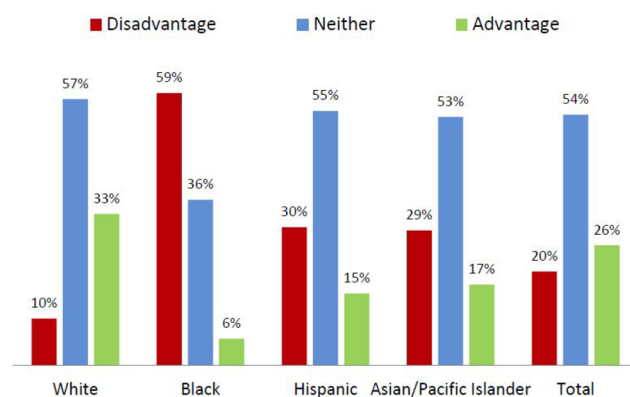
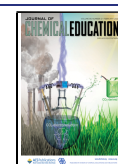


Figure 1. Updated reconstructed figure (normalized to total 100% in each group, poll number count 1992), showing contemporary social sentiment on inequality, data from “Axios-Ipsos poll: Higher Ed’s Coming Clashes, Aug 21, 2021—Politics & Policy”.

Received: September 4, 2021

Revised: January 4, 2022

Published: January 20, 2022



URM students to higher educational attainment, setting them up for long-term academic success and, broadly, career success after graduation. Diversifying the talent pool of students from multiple cultural backgrounds by stimulating the cohort to careers in science, technology, engineering, and mathematics (STEM) will ultimately yield positive dividends to society at large. It is imperative to produce more highly trained STEM scientists and engineers from various social groups since STEM careers are associated with higher income.

FGLI-URM college students face numerous economic and social obstacles that make completing college education more difficult than for other student groups. Multiple factors have noticeably hindered these students from going into STEM careers, e.g., precollege experiences, the traditional campus culture of the higher education institutions, and personal academic goals. These issues lead to a significant social-economic consequence because STEM occupations earn higher salaries compared to the median wage, contributing to the FGLI-URM students' achievement gaps in higher education and sustaining or exacerbating the existing economic inequality.^{7,9}

The challenges experienced by FGLI-URM students on campus have been studied and reported extensively.^{10–14} Often, the students would report feeling psychologically isolated. They may also sense the inconsistencies between their cultural experiences at predominantly white institutions, resulting in a feeling of devaluation, irrelevance, and exclusion, especially in STEM fields. In large STEM classes, students often feel discouraged by the lack of faculty–student interaction, peer integration, and proper preparation of the teachers.^{15,16} These cumulated experiences may also prevent disadvantaged students from actively participating in class activities or asking for help. Therefore, classroom diversity is necessary to help students of nontraditional backgrounds achieve their academic goals.

Research has shown that student diversity also enhances the power of student learning.^{17–20} Differential perspectives in STEM classes enrich the classroom learning environment, benefiting all students involved in the conversation. Meanwhile, teaching from diverse perspectives leads to more student activities in critical thinking, challenging biases potentially presented in the environment. Students achieve improved educational outcomes by nurturing the classroom diversity climate to support intellectual engagement and active thinking.^{17,21,22} For example, a safe space for addressing diversity in STEM classes contributes to diminished discrimination, creates an inclusive and supportive classroom climate, improves the retention rate of the underrepresented students, and allows them to progress at the same speed toward higher educational levels as other students groups. With more positive STEM classroom experiences, FGLI-URM students will be more likely to continue their studies for STEM careers.^{23–35}

For our FGLI-URM students, the values of community and collaboration are usually strong compared to their continuing-generation peers. They might have had limited familial guidance for navigating higher education and experienced more difficulty adapting to college. They might earn lower grades and drop out of college at higher rates.^{36–40} Many students intend to pursue STEM careers but quickly abandon these goals when confronted with evidently competitive STEM courses that often pit students against each other. The seemingly interpersonal competition in STEM classes could be especially detrimental for the FGLI-URM students because the perceived classroom competition culture may exacerbate the issue of belonging, potentially

resulting in imposter syndrome among FGLI-URM students in STEM education.⁴¹

Arguably, the most important factors identified in predicting the students' academic performance are motivation and belonging.^{42–51} Negative stereotypes of the FGLI-URM students on campus promote adverse psychological experiences of the students.⁵² Fink, Frey, and Solomon⁴² reported a thorough study of students belonging in general chemistry classes with a survey of 739 first-year students and predicted student success and attrition rate through a biannual general chemistry class sequence. These researchers found that psychological belonging is an essential indicator for student success in general chemistry. Non-belonging leads to imposter syndrome and a lack of psychological safety. Thus, creating an environment of psychological safety within the classroom is more critical now than ever. Research showed that perceived classroom competition was associated with daily in-class imposter feelings, especially in FGLI-URM students.⁵¹ In turn, it influenced their class attendance, engagement, assignment performance, dropout rate, and course grades. Instead of enhancing a sense of belonging, these negative imposter feelings can cause psychological damage to students, one of the undoubtedly crucial factors and an overlooked barrier in promoting FGLI-URM students for STEM careers.^{1,51–53}

This report presents a summer science academy in chemistry, a section of the Chicago Academic Achievement Program (CAAP) at the University of Chicago.²¹ We established the summer science academy in chemistry (SSAC) as a gateway to STEM for first-generation, low-income, and other underrepresented student groups coming to the college. Our program aims to prepare students with college readiness, enhance the students' knowledge base, promote diversity in classrooms, and ensure students feel a sense of psychological safety and belonging to STEM. We attempted to achieve the goal by developing students' critical-thinking skills, confidence and community building, student-centered collaborative learning, inquiry-based class discussions, and stimulating students from passive participants into active learners.

■ SUMMER SCIENCE ACADEMY IN CHEMISTRY

The summer science academy in chemistry is a subprogram of the CAAP at the University of Chicago,²¹ supporting first-year students for a smooth transition from high school to college life. The Odyssey Scholarship Program at UChicago provides support and service to first-generation and lower-income students. All CAAP scholars are also the Odyssey scholars, and many of them are first-generation college students from low-income family backgrounds or other underrepresented groups.

The program is free of charge to relieve any added financial burden for students in the summer to attend the summer academy. Additionally, the college provides full financial support to students in the program, including a stipend, books, and other needed materials for attending the program.

The CAAP scholars meet their peers during the summer academy to develop social networks. They will participate in several college core-level courses, learn about the campus and resources, connect to the local neighborhoods, and prepare for overall college readiness. Besides mathematics and humanity classes, students will take at least one of the following science classes, i.e., biology, chemistry, computer science, and physics. The chemistry class is rigorous, runs about eight weeks before student enrollment, and instills college readiness for the scholars to STEM courses.

CAAP Chemistry has the following goals through the summer academy: (i) enhancing students' knowledge base for college chemistry, (ii) promoting diversity in the classroom, (iii) confirming students with psychological safety and belonging to STEM, and (iv) ensuring students for college readiness. Over the past many years, there have been about 50 students per year on average. We had 65 students in 2019, 64 in 2020, and 53 in 2021. There are about 20–25 in CAAP Chemistry in a typical year. Table 1 shows the ethnicity distribution in 2021, which is representative of the program, and Table 2 shows the distribution of gender and other underrepresented student groups.

Table 1. 2021 Ethnicity Distribution of CAAP Scholars and in Chemistry

race/ethnicity	CAAP	chemistry
Black	28%	29%
Latinx	38%	50%
AAPI ^a	6%	7%
White	9%	7%
Multiracial	19%	7%

^aAAPI: Asian Americans and Pacific Islanders

Table 2. 2021 First-Generation, Other Underrepresented Groups, and Gender Distribution

first-gen	others	female	male	mixed gender
53%	47%	48%	48%	4%

We inspire students throughout the summer academy in chemistry to remember the teaching by Dr. Martin Luther King, Jr., "Whatever your life's work is, do it well. A man should do his job so well that the living, the dead, and the unborn could do it no better."

Psychological Safety and Belonging

The first step in our summer chemistry academy was to welcome the students into the community and build trust. We wanted to get to know each of our students and let the students get to know us. This initial natural process would allow us to understand the students better and their strengths and needs, preparing us to build a safe and secure learning environment.

In the next step for establishing the psychological safety and belonging of the students, we communicated to the students our vision, their potential career paths with STEM, and ultimately the beneficial social consequences of increasing diversity in STEM. Building on the trust and strong relationships with participants, we encouraged students to come to us with any questions or concerns via an open-door policy. We made ourselves available for the students whenever they would like to talk.

Overall, retaining proper strategies and modeling to create a psychologically safe community and classroom environment offered students better chances of succeeding and growing in and out of the classroom.

Promoting Diversity in Classroom

Our class intended to activate the students' maximum potential by discussing different perspectives for diverse student groups. Although it is challenging to engage diversity in STEM classes, a classroom with diverse student experiences usually reaches higher levels of discussion, providing students valuable insight and a more profound understanding of the discussed topics.

This discussion can also serve as a leading step toward greater openness in the classroom.

In the chemistry academy, we defined a safe-space classroom as a place where students can openly, honestly, and respectfully speak their ideas and not be afraid to disagree with one another. Students were encouraged to express themselves naturally and freely discuss their thoughts and ideas. We also held community-building activities, panel discussions, and community awareness sessions outside the chemistry classroom and discussion groups.²¹ These activities created a safe space for peer support and advocacy for STEM education and career advising.

We are willing to face and address inequality, disagreement, and conflict through discussions and community activities in the summer academy in chemistry. We believed that these discussions were positive and healthy, such as how discrimination and inequality affect people at all levels of society. We emphasized integration with our local communities and appropriate language in class, promoting positivity, avoiding stereotypes, and modeling inclusion and acceptance to all students. Our actions signaled that we have zero tolerance for discrimination in our community.

We make a determined effort to connect the chemistry topics in the classroom to students' personal and cultural experiences, e.g., geography, culture, or popular interests. These connections with the subject matter are an excellent strategy to motivate student engagement in the class activities and promote dialogue among students and teachers. We also engaged former CAAP scholars who went through the summer science academy to serve as teaching assistants (TAs) to help lead the students getting inside the door.

For example, when discussing acid–base chemistry, we connected it to the natural universal indicators, e.g., purple cabbage, maple tree leaves, and others. We asked students to find other universal indicators from their familiar geographical environment. Then, students would discuss how materials they found work and why they work. In the discussion group, we would apply the so-called popcorn-style discussions, where one-by-one, each student would discuss, building on the earlier debate.

Students may examine the related environmental issues within the same topic, e.g., acid rain. We allowed the students to discuss whether natural rainwater was acidic or basic, even before the industrial revolution. Students may use the costless acid–base indicator to test rainwater, the water from their geographical background, and the various soft drinks on the market that may come from their home state. These discussions can be assigned as group projects or even as the end of the lecture questions. Instead of the recap by the class lecture, we can ask questions and summarize the feedback from student discussions at the beginning of the following class meeting. In the group discussion, we would provide opportunities for all students to contribute. We could suggest or ask students to volunteer to take on different roles that fit their strengths. For example, some students may act as notetakers in discussions, and others may facilitate the meetings or vice versa.

These seemingly modest topical discussions promoted interactions among students and connected to the geographic and cultural background of the students, which led to the establishment of a vibrant atmosphere to incubate a positive learning experience and explore the significance of different historical and social traditions.

Preparing Students for College Readiness

We want to use chemistry in the summer academy to prepare students for college readiness and introduce students to STEM classes and potentially STEM careers. We attempt to achieve this by reconfirming the students' knowledge base and establishing a healthy learning environment in the classrooms, i.e., promoting diversity in the academy, establishing students' psychological safety and belonging to STEM. Over the past years, we have modified what we do from the lessons learned through student feedback by the end of each summer chemistry.

Chemistry Class Materials

The summer science academy in chemistry is at the college core-course level, so it is fast-paced, rigorous, and content-rich and engenders college readiness for students taking chemistry courses in the upcoming academic year. Perhaps, the biggest challenge is providing information-dense class content in a meaningful learning experience for students for their first college-level STEM class in a relatively short time.

A closely related, equally crucial challenge is balancing the level of the class materials for a cohort with diverse STEM backgrounds. The [Supporting Information](#) contains a sample syllabus in the initial design. The topics were selected on the basis of our experience teaching general chemistry, balancing mindfulness of diverse mathematics and chemistry backgrounds with rigor in preparing the students for college-level chemistry. For example, the topic of measurement is to reaffirm that students are ready to handle lab measurements and the measured data. The subject of atoms next is to start with the atoms-first approach and ingrain students with a solid physical principle in chemistry. Then, we may discuss stoichiometry, switching back to chemical reactions. The following topics are arranged similarly with bonding, gases (and chemical reactions), etc., alternating physical principles and chemical reactions. From our experience, one of the most confusing yet exciting topics for students in chemistry is chemical equilibrium, including acid and base equilibria, common ion effects, and solubility equilibria, due to the complex mathematical operations involved in problem-solving. Overall, we have selected these topics with a combination of stimulating students to STEM and preparing students for college readiness, building on our philosophy of a trial approach in the hybridization of atoms-first and reaction-first approaches. On the basis of constant feedback from the students, the materials covered in the classroom are tweaked and adjusted regularly throughout the program, including the difficulty level of the materials that will challenge students without overwhelming them. To meet diverse learning needs, we had two homework sets with different levels of the mathematical knowledge base in each discussed topic. This approach allows us to lessen the pressure on students with diverse STEM backgrounds while still teaching them the requisite material.

Student feedback is critical in improving our teaching style and providing proper class materials to fit students' needs.

We used the Canvas discussion board to establish discussion threads for each topic going through the course to facilitate fundamental chemistry discussion. Members of the class community, teachers or students, could ask and answer questions, raise concerns related to the class, make suggestions, or raise new discussion threads. These online discussions stimulated student learning with many unforeseen questions and answers and increased the understanding and confidence of the students.

We do not take it for granted that all students could take off-class time to view and study. To ensure equal access to extracurricular study opportunities, our dedicated TAs^{54,55} organized student groups for discussion. As with discussion-based lectures, many questions and discussion topics were open-ended to encourage student engagement. Students were pressure-free to express themselves at these discussion sessions because there would be no absolute answers. Students were encouraged to feel that each of their responses was valuable. Notably, these stimulated group discussions increased student interaction. They also led to an enhanced understanding of the chemical concepts, collaborative learning in the community, team-based collective answering, and critical-thinking skills for students. Notes from these activities would be available to students for further studies. These activities provide excellent service to activate diversity within the chemistry class and the summer academic academy.

Oftentimes, we would not end class meetings by summarizing the lecture. Instead, we would end the class with questions, especially those raised or resolved from discussions with the point of contention or contradiction, which could often generate more questions. We would set particular assignments in collecting the answers from students credited with completion, none right or wrong. Similarly, for each class assignment, we would ask students to generate a question raised for the materials when they did their work. These questions would be shared with all students and posted to Canvas, which had stimulated student discussions and enhanced the students' critical-thinking skills.

The lecture materials were helpful for students to study and review. After each class meeting, the lecture notes, lecture video, and experiment demo videos, generated by the instructor(s), would be posted to the class website on Canvas. Students may take their time to view, think, ask questions, and provide more feedback, especially the perspective regarding if we had reached the goals of the course.

Concerning the weekly homework assignments, we included some problem-solving tasks requiring mathematics as a base and problem-solving techniques; some practices also emphasized chemical concepts. Each homework set had about 20 problems for concept practice, randomly selected by the computer system from an extensive problem database. For each new trial, the system would randomly select 20 problems from the database, where some overlapped problems from an earlier practice are possible but not guaranteed. After each new set of exercises, students would receive their updated scores, and they could do it again and again until they were satisfied with their received scores. The class also included a weekly lab assignment similar to a regular general chemistry course.

In teaching general chemistry, there are two competing approaches currently available. Many instructors prefer the so-called atoms-first instead of the reaction-first approach. The atoms-first usually start with the smallest chemistry particles: the elements, the atoms, the bonding to build molecules, and chemical structures. This approach jumps on the physical principle, focuses on conceptual understanding, and benefits students with critical-thinking and problem-solving skills. However, it may or may not stimulate students in chemistry because of the theoretical mathematics and physics without the traditional hands-on chemistry practical lessons, for instance, involving colors and smells. The reaction-first approach is the conventional chemistry approach starting with a reaction instead of the microstructure of the elemental particles. Each strategy

has pros and cons. In the summer science academy in chemistry, we applied a combined approach of the two. We discussed in detail the physical interpretation of the elements and molecules. Meanwhile, we do reactions in class that are closely related to people's life. Therefore, we could sometimes complement the class meetings with exciting chemical reaction demonstrations closely associated with everyday life, stimulating students for discussion and relating to their geographical background if possible.

We approached the class with a short talk about the importance and usefulness of each newly introduced topic instead of jumping immediately to theory and problem examples, leading to input and discussions in class and promoting classroom diversity.

For example, on solubility equilibrium, when discussing the sparingly soluble metal complexes, e.g., AgCl, we related them to mining and the metallurgical industries, closely related to the metals around our daily lives. Students could articulate the ores and minerals produced in their familiar background, again stimulating discussions. Through the topic discussions, we could reconfirm the students' pride in their family background, foster self-confidence, and promote learning from each other.

ASSESSMENT OUTCOMES

To learn what we have achieved and what to improve, we have assessed the summer academy in chemistry for how much improvement students have made through the chemistry class. The significant components in this assessment include evaluating student psychological belonging in STEM classes via promoting diversity in the classroom, preparation for STEM classes through chemistry knowledge building, and overall confidence in college readiness.

To help students pass the psychological imposter barrier and create STEM classroom belonging, both the instructor and the TA worked together as the leaders in classrooms, facilitating a psychologically safe classroom environment with multiple perspectives on strategies and eliminating the fears of embarrassment, rejection, or punishment for asking questions.

As discussed in the last section, the regular periodic feedback (usually weekly) from students for class operations combines conversations with students in discussions, office hours, and class surveys through the Canvas class website.

In the chemistry program, we had 46 students in 2020–21 (30 in 2020 and 16 in 2021; one high school student in class but not yet matriculating to the college) with the current assessment. The evaluation was anonymous on Canvas, collected and analyzed by the CAAP program administration, where the summer chemistry academy in chemistry is a subprogram. The central CAAP program administration designed the final assessment questions with input from the corresponding class instructors; i.e., the chemistry questions were from the chemistry instructors. We set the chemistry-specific questions as anonymous surveys on the chemistry Canvas site.

The following are some typical comments from students:

"It was also a great review in chemistry and helped me identify what topics to review before my chemistry class this fall. It also gave me a greater understanding of how I can improve my studying habits."

"I believe this course has contributed to my education by reminding me that even subjects I am not as intrigued by still have a lot to offer in terms of thought-processing."

"Trying to problem-solve on my own."

"This class has taught me to control my education a bit more."

"It improved my understanding of chem and made me consider taking gen chem for the science core."

"It has made me decide to try out chemistry this fall."

"Taught me more about chemistry than I learned in high school."

"It provided a decent review in chemistry."

"It (definitely) helped strengthen the chemistry knowledge I have and prepared me for the intensity of a UChicago chemistry course."

"It has given me a general understanding of what chemistry will look like in the Autumn Quarter."

*"Even with the trials and tribulations of this course, I *do* know more chem than I did before taking this course and have a strategy for succeeding in chemistry now. Honestly, it's better that I had this experience prior to the school year so that I didn't have to struggle as badly."*

"It refreshed my memory in basic topics I had not touched upon since sophomore year in high school."

"I improved a few skills to comprehend the topics, and through this class, I felt confident about majoring in premed."

"It helped provide me with a background in chemistry."

"This course has taught me the foundations of chemistry. I feel confident in starting my first quarter chem class!"

"This course has taught me that going to discussions and office hours are vital! I have learned new topics that will allow me to succeed in comprehensive chemistry when I arrive on campus."

"I'm so, so excited for honors chemistry this fall! Professor XXX has instilled me with a newfound confidence in chemistry, and I'm ready to put in the work necessary to succeed in the sequence."

"I feel a bit more prepared for chemistry now!"

"This course has helped me gauge what to expect in my Chemistry course during the year."

"This course has taught me that I have the potential to do well. However, I might not follow the path I intended to follow in the first place."

Figure 2 displays the survey response to the statements, "I feel belonging and fitting well into STEM classes in the college before/after the summer CAAP", showing the psychological

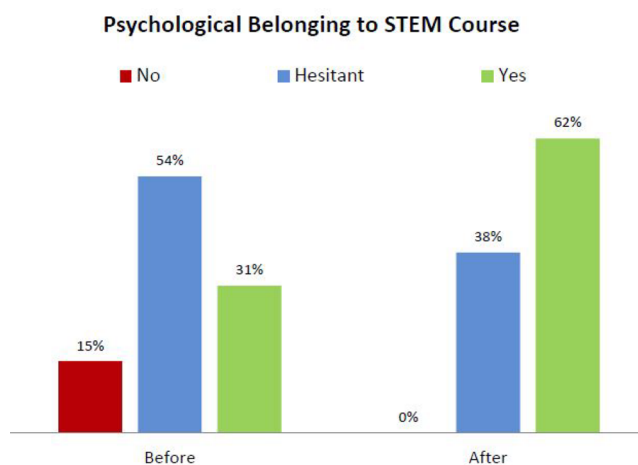


Figure 2. Confidence level of students in psychological belonging to STEM classes before and after the summer academy in chemistry.

improvement after the summer CAAP chemistry classes. It shows that remarkable progress has been made for students to overcome pre-existing psychological barriers to pursuing a career in STEM. After the summer science academy, 62% of the participants firmly set themselves in the STEM community. While there are still 38% who are hesitant, notably, no students feel hopeless in STEM. Even though it has always been challenging to implement modeling and utilize strategies to create a psychologically safe classroom environment, our program has undoubtedly instilled confidence in STEM in our participants, allowing them the best chance to succeed.

Figure 3 shows the confidence level of students for STEM classes responding to the statements, "I feel belonging and fitting

Preparation for STEM Course (Chemistry)

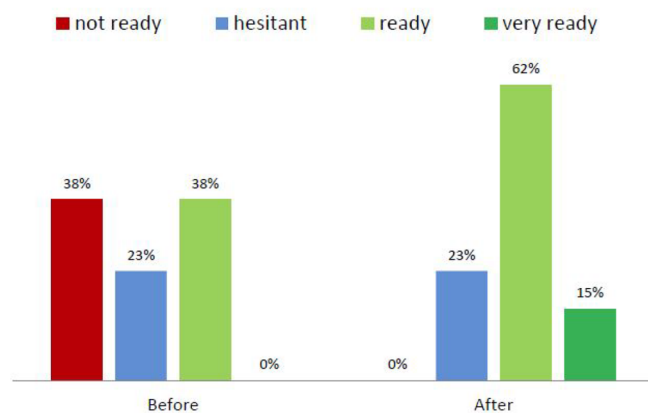


Figure 3. Confidence level of students for STEM classes before and after the summer academy in chemistry.

well into STEM classes in the college before/after the summer CAAP", a remarkable success to achieve one of the program's goals.

Besides ensuring psychological wellbeing and building confidence, we provided rigorous chemistry materials, weekly homework assignments, and lab experiments to supplement the foundational knowledge of our students before taking the college STEM classes. Most students offered positive or very positive feedback on the assessed questions, e.g., the helpfulness of the videos, the feedback on student assignments, the fairness of grading, and the course requirements. In contrast, up to 17% of the students expressed that they were neutral to a couple of questions, suggesting there is still room for future improvement. The feedback from the students on class presentation and homework assignments seemed reasonable and encouraging, as presented in Figure 4.

We also assessed the lab assignments on coordination with the course presentation and the materials' usefulness, as shown in Figure 5. Of the students, 15% believed that we could have coordinated it better; other than that, the students provided positive and very positive feedback.

Concerning the overall material provided in class to prepare the students' readiness to enroll in college soon, it is similar to the assessments for homework and lab assignments. Approximately 80% of the students felt they were well-prepared and ready to enroll in STEM classes, and about 20% felt otherwise, as shown in Figure 6.

Proper training for professional TAs is vital for academic teaching programs. In running our summer academy in

Presentation and Assignment Evaluation

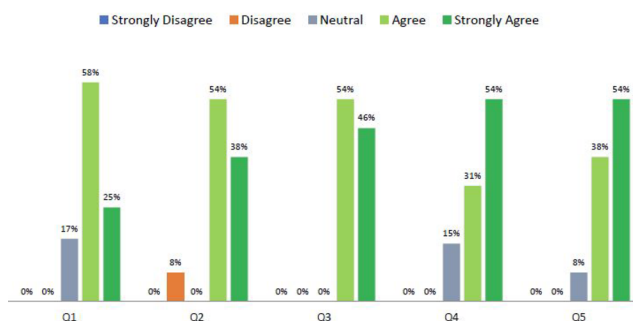


Figure 4. Q1: The videos were helpful. Q2: The feedback on assignments was timely and valuable (helpful). Q3: Assignments graded fairly. Q4: The course requirements were appropriately and proportioned to course goals. Q5: The course requirements contributed to achieving the (class) goals of the course.

Coordinated Lab Work Evaluation

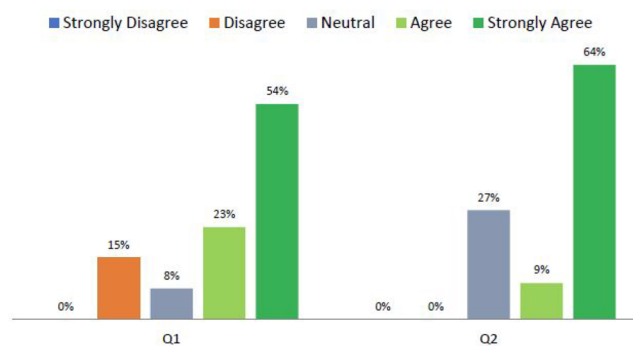


Figure 5. Q1: Laboratories were well coordinated with the course and contributed to it. Q2: Provided well-designed materials.

Overall Course Material Evaluation

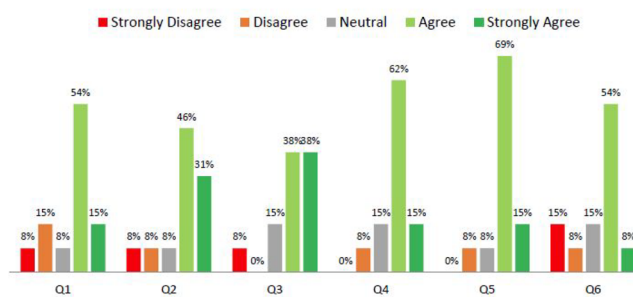


Figure 6. Q1: Met my expectations. Q2: Provided me with new insight and knowledge. Q3: Provided me with valuable skills. Q4: The class content was at an appropriate level. Q5: I put my best effort into this course. Q6: The class had a high level of enthusiasm.

chemistry, the teaching assistants played a significant role in its success.^{54,55} We also recognized that TAs who reflected diversity in the classroom would help students build confidence. We employed and trained the former CAAT scholars to act as TAs for the summer science academy. In prior years, these scholars went through the same summer academy, understood the students from similar family backgrounds, provided empathy and comfort to students with issues, and showed potential success using their own experience. Without any doubt, invoking help from the earlier years' CCAP scholars as TAs is one of the

most successful practices of the summer academy, as given in Figure 7, which shows that 90–100% of the feedback from students was positive or, better, very positive.

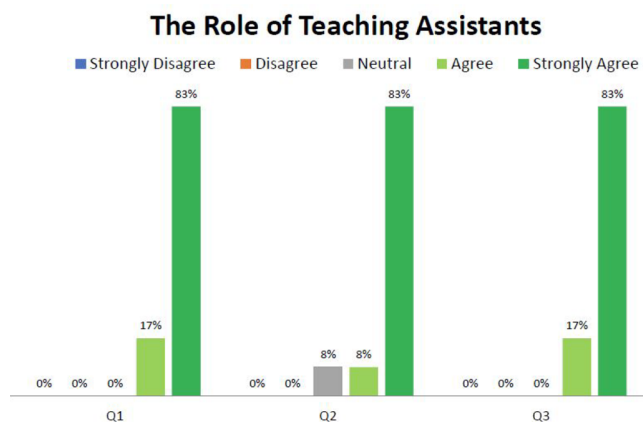


Figure 7. Q1: Was available outside of class. Q2: Was helpful with assignments. Q3: Coordinated problem sessions well.

Figure 8 shows the confidence level in their college readiness in answering the question, “How confident were you for the

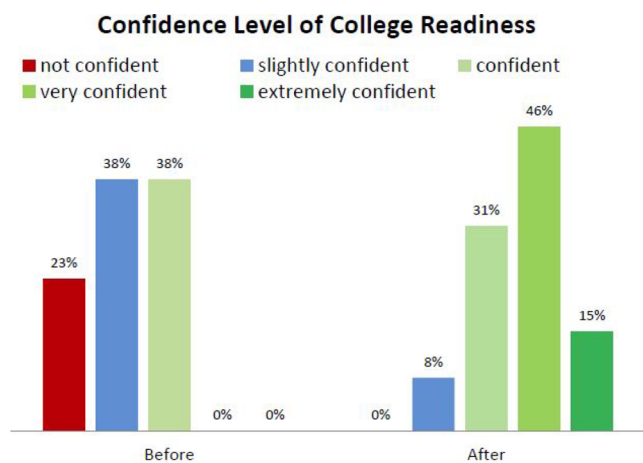


Figure 8. Overall confidence level of students in their college readiness before and after the summer academy in chemistry.

college before/after the summer CAAP Program?” From Figure 8, students showed a reasonably high level of enthusiasm and significant improvement for these two categories, similar to the psychological improvement.

FINAL REMARKS

In summary, the summer CAAP academy in chemistry was successful and boosted students’ morale in a diversified academic community, stimulated students to participate in the various confidence-building activities, and motivated the CAAP scholars toward a STEM-oriented career direction.

It is important to note some recent studies that showed the positive synergistic effects of concurrent enrollment of a preparatory course with regular general chemistry. The reported work included implementing a preparation course concurrently with the traditional chemistry course to replace the prerequisite for general chemistry,⁵⁶ using concurrent programs for first-year students.⁵⁷

Indeed, a proper transition from the summer academy to the regular academic year and continued student support will benefit students for continued success. Following the summer academy in chemistry, we provide ongoing support into the academic years. The first-generation and other underrepresented, low-income students are all Odyssey scholars, fully supported financially by the college. The CAAP program continues into the regular academic year to address psychological and financial needs for students and support students’ success.

We have two established chemistry programs for students transitioning from the summer chemistry academy to college chemistry. The program of collaborative learning in chemistry (CLIC) provides students with problem-solving sessions weekly.⁵⁸ Students register for CLIC classes with zero academic credit but a P/F grade. Given that the students are first-generation and historically underrepresented students in the college, we recognized the disparity of the educational background from different groups of students. We have three parallel general chemistry sequences: introductory general chemistry, comprehensive general chemistry, and honors general chemistry. Under this established scheme, the students in the introductory chemistry have additional problem-solving sessions to catch up additionally, if needed, after the summer program. After the first two quarters of introductory general chemistry, students will move to comprehensive general chemistry for the third quarter to finish the first academic year.

For the next step, it is critically important to keep supporting the students on track to graduation, especially in STEM classes concerning the imposter feeling and sense of belonging to the STEM community. The impact can be broadly significant to the advancement of our society because of the STEM human resource development for the next generation of scientists and engineers of the underrepresented community, which will reduce social inequality. Considering the future or near-future progress in science and technology, e.g., quantum information technology and quantum computing, artificial intelligence (AI), 5G (even 6G) telecommunication technologies, and biotechnologies, it is imperative to produce more and more highly trained STEM scientists and engineers.

To achieve the advancement and harmony of human society, we must make a concerted effort to work together to eliminate or, at the minimum, reduce inequality and discrimination, either racial or economic or other. In a recent editorial in *Nature Medicine* on Diversity in Science, McNutt and Castillo-Page⁵⁹ pointed out that promoting diversity and inclusion in STEM must start at the top. They argue that “a more diverse and inclusive scientific workforce and culture—along with a more inclusive approach to research—would better enable science to fulfill its obligations to society.” We hope that, by stimulating the first-generation college students and all other underrepresented students toward STEM careers, we advance our society to a much better social environment, leading to a higher level of advancement of humanity.

ASSOCIATED CONTENT

Supporting Information

The Supporting Information is available at <https://pubs.acs.org/doi/10.1021/acs.jchemed.1c00950>.

Sample syllabus and demonstration list (PDF, DOCX)

AUTHOR INFORMATION

Corresponding Author

Meishan Zhao – James Frank Institute and Department of Chemistry, The University of Chicago, Chicago, Illinois 60637, United States; orcid.org/0000-0001-6460-1786; Email: m-zhao@uchicago.edu

Complete contact information is available at:
<https://pubs.acs.org/10.1021/acs.jchemed.1c00950>

Notes

The author declares no competing financial interest.

ACKNOWLEDGMENTS

The author wants to thank Devon Moore, Director of Center for College Student Success, for some feedback data and statistics. Many thanks go to Nathaniel Martinez, the CCAP Chemistry TA, for doing an impeccable job supporting student success.

REFERENCES

- (1) Cabrera, N. L.; Miner, D. D.; Milem, J. F. Can a Summer Bridge Program Impact First-Year Persistence and Performance?: A Case Study of the New Start Summer Program. *Research in Higher Education* **2013**, *2013* (54), 481–498.
- (2) Adams, G. M.; Lisy, J. M. The Chemistry Merit Program: Reaching, Teaching, and Retaining Students in the Chemical Sciences. *J. Chem. Educ.* **2007**, *84*, 721–726.
- (3) Rohrbaugh, M. C.; Corces, V. G. Opening Pathways for Underrepresented High School Students to Biomedical Research Careers: The Emory University RISE Program. *Genetics* **2011**, *189*, 1135–1143.
- (4) Peters, A. W.; Tisdale, V. A.; Swinton, D. J. High-impact Educational Practices that Promote Student Achievement in STEM. *Broadening Participation in STEM: Effective Methods, Practices, and Programs Diversity in Higher Education* **2019**, *22*, 183–196.
- (5) Center for First-Generation Student Success (NASPA). <https://firstgen.naspa.org/>.
- (6) First-Generation Students in Higher Education, The Postsecondary National Policy Institute. <https://pnpi.org/first-generation-students/>.
- (7) Fakayode, S. O.; Yakubu, M.; Adeyeye, O. M.; Pollard, D. A.; Mohammed, A. K. Promoting Undergraduate STEM Education at a Historically Black College and University through Research Experience. *J. Chem. Educ.* **2014**, *91*, 662–665.
- (8) Note: Contemporary Social Sentiment from “Axios-Ipsos Poll: Higher Ed’s Coming Clashes, Aug 21, 2021, Politics & Policy. <https://www.axios.com/higher-education-clashes-race-ideology-5c5ca360-fc7d-43ad-a52c-f2a19f089ec2.html>.
- (9) Hicks, T.; Wood, J. L. What Do We Know About Diverse College Students in STEM? A Meta-Synthesis of Academic and Social Characteristic Studies, First-Generation College Students in STEM Disciplines at HBCUs. *Journal for Multicultural Education* **2016**, *10*, 107–123.
- (10) Taylor, A.; Yochim, L.; Raykov, M. Service-Learning and First-Generation University Students: A Conceptual Exploration of the Literature. *Journal of Experiential Education* **2019**, *42* (4), 349–363.
- (11) Palmer, R. T.; Maramba, D. C.; Dancy, T. E. A Qualitative Investigation of Factors Promoting The Retention and Persistence of Students of Color in STEM. *Journal of Negro Education* **2011**, 491–504.
- (12) Hurtado, S.; Han, J. C.; Saenz, V. B.; Espinosa, L. L.; Cabrera, N. L.; Cerna, O. S. Predicting Transition and Adjustment to College: Biomedical and Behavioral Science Aspirants’ and Minority Students’ First Year of College. *Research in Higher Education* **2007**, *48* (7), 841–887.
- (13) Tsui, L. Effective Strategies to Increase Diversity in Stem Fields: A Review of the Research Literature. *Journal of Negro Education* **2007**, 555–581.
- (14) Hurtado, S.; Eagan, M. K.; Tran, M. C.; Newman, C. B.; Chang, M. J.; Velasco, P. We Do Science Here: Underrepresented Students’ Interactions With Faculty in Different College Contexts. *Journal of Social Issues* **2011**, *67* (3), 553.
- (15) Cabrera, A. F.; Nora, A.; Terenzini, P. T.; Pascarella, E.; Hagedorn, L. S. Campus Racial Climate and The Adjustment of Students to College: A Comparison Between White Students and African-American Students. *Journal of Higher Education* **1999**, *70* (2), 134–160.
- (16) Cabrera, A. F.; Colbeck, C. L.; Terenzini, P. T. Developing Performance Indicators for Assessing Classroom Teaching Practices And Student Learning. *Research in higher education* **2001**, *42* (3), 327–352.
- (17) Marin, P. The Educational Possibility of Multi-Racial/Multi-Ethnic College Classrooms. In *Does Diversity Make a Difference? Three Research Studies on Diversity in College Classrooms*; American Council on Education and American Association of University Professors: Washington, DC, 2000; pp 61–83.
- (18) Gurin, P.; Dey, E.; Hurtado, S.; Gurin, G. Diversity and Higher Education: Theory and Impact on Educational Outcomes. *Harvard Educational Review* **2002**, *72* (3), 330–367.
- (19) Moore, J. W. Diversity in Science. *J. Chem. Educ.* **2006**, *83* (6), 823.
- (20) Goethe, E. V.; Colina, C. M. Taking Advantage of Diversity within the Classroom. *J. Chem. Educ.* **2018**, *95*, 189–192.
- (21) Chicago Academic Achievement Program (CAAP) Program. <http://caap.uchicago.edu/>.
- (22) Wang, L. Undocumented Students Remain in the Shadows of the Chemical Sciences. *Chem. Eng. News* **2017**, *95* (16), 36–41. <https://cen.acs.org/articles/95/i16/Undocumented-students-remain-shadows-chemical.html>
- (23) Gurin, P.; Dey, E.; Hurtado, S.; Gurin, G. Diversity and Higher Education: Theory and Impact on Educational Outcomes. *Harvard Educational Review* **2002**, *72* (3), 330–367.
- (24) National Academy of Sciences. National Academy of Engineering, and Institute of Medicine. *Expanding Underrepresented Minority Participation: America’s Science and Technology Talent at the Crossroads*; The National Academies Press: Washington, DC, 2011.
- (25) Felder, R. M.; Brent, R. Understanding Student Differences. *Journal of Engineering Education* **2005**, *94* (1), 57–72.
- (26) Moore, J. W. Diversity in Science. *J. Chem. Educ.* **2006**, *83* (6), 823.
- (27) Goethe, E. V.; Colina, C. M. Taking Advantage of Diversity within the Classroom. *J. Chem. Educ.* **2018**, *95*, 189–192.
- (28) Women, Minorities, and Persons with Disabilities in Science and Engineering, National Center for Science and Engineering Statistics Directorate for Social, Behavioral and Economic Sciences; National Science Foundation. <https://nsf.gov/statistics/2017/nsf17310/static/downloads/nsf17310-digest.pdf>.
- (29) Wilson, Z. S.; McGuire, S. Y.; Limbach, P. A.; Doyle, M. P.; Marzilli, L. G.; Warner, I. M. Diversifying Science, Technology, Engineering, and Mathematics (STEM): An Inquiry into Successful Approaches in Chemistry. *J. Chem. Educ.* **2014**, *91* (11), 1860–1866.
- (30) Haslerig, S.; Bernhard, L. M.; Fuentes, M. V.; Panter, A. T.; Daye, C. E.; Allen, W. R. A Compelling Interest: Activating the Benefits of Classroom-level Diversity. *Journal of Diversity in Higher Education* **2013**, *6*, 158–173.
- (31) Milliken, F. J.; Martins, L. L. Searching for Common Threads: Understanding the Multiple Effects of Diversity in Organizational Groups. *Academy of Management Review* **1996**, *21* (2), 402–433.
- (32) Wink, D. J. Immigrant Students in the U. S. Chemistry Classroom: An Educational Opportunity and Challenge. *J. Chem. Educ.* **2015**, *92* (11), 1771–1772.
- (33) Villegas, A. M.; Lucas, T. Preparing Culturally Responsive Teachers - Rethinking the Curriculum. *Journal of Teacher Education* **2002**, *53* (1), 20–32.
- (34) G., Boutte, C., Kelly-Jackson, G. L., Johnson. Culturally Relevant Teaching in Science Classrooms: Addressing Academic Achievement, Cultural Competence, and Critical Consciousness. *International Journal*

of *Multicultural Education* **2010**, *12* (2). DOI: 10.18251/ijme.v12i2.343.

(35) Valentine, K.; Prentice, M.; Torres, M. F.; Arellano, E. The Importance of Student Cross-Racial Interactions as Part of College Education: Perceptions of Faculty. *Journal of Diversity in High Education* **2012**, *5* (4), 191–206.

(36) *Occupational Outlook Handbook*; US Department of Labor, US Bureau of Labor Statistics: Washington, DC, 2019.

(37) *Beginning Postsecondary Students Longitudinal Study 2012–2014 (Report BPS:12/14)*; US Department of Education, National Center for Education Statistics: Washington, DC, 2017.

(38) Terenzini, P. T.; Springer, L.; Yaeger, P. M.; Pascarella, E. T.; Nora, A. First-Generation College Students: Characteristics, Experiences, and Cognitive Development. *Research in Higher Education* **1996**, *37*, 1–22.

(39) Holmes, D. L.; Slate, J. R. Differences in GPA by Gender and Ethnicity/Race as a Function of First-Generation Status for Community College Students. *Global Journal of Human-Social Science Research* **2017**, *17*.

(40) Redford, J.; Hoyer, K. M. *First-Generation and Continuing Generation College Students: A Comparison of High School and Postsecondary Experiences*; National Center for Education Statistics with American Institutes for Research, 2017. <https://nces.ed.gov/pubs2018/2018009.pdf>.

(41) Forrest Cataldi, E.; Bennett, C. T.; Chen, X. *First-Generation Students: College Access, Persistence, and Post-Bachelor's Outcomes*; National Center for Education Statistics Institute of Education Science, 2018. <https://nces.ed.gov/pubs2018/2018421.pdf>.

(42) Fink, A.; Frey, R. F.; Solomon, E. D. Belonging in General Chemistry Predicts First-Year Undergraduates' Performance and Attrition. *Chemistry Education Research and Practice* **2020**, *21* (4), 1042–1062.

(43) Fink, A.; Cahill, M. J.; McDaniel, M. A.; Hoffman, A.; Frey, R. F. Improving General Chemistry Performance Through a Growth Mindset Intervention: Selective Effects on Underrepresented Minorities. *Chem. Educ. Res. Pract.* **2018**, *19* (3), 783–806.

(44) Frey, R. F.; Fink, A.; Cahill, M. J.; McDaniel, M. A.; Solomon, E. D. Peer-Led Team Learning in General Chemistry I: Interactions with Identity, Academic Preparation, and a Course-Based Intervention. *J. Chem. Educ.* **2018**, *95* (12), 2103–2113.

(45) Ralph, V. R.; Lewis, S. E. Chemistry Topics Posing Incommensurate Difficulty To Students With Low Math Aptitude Scores. *Chem. Educ. Res. Pract.* **2018**, *19*, 867–884.

(46) Ralph, V. R.; Lewis, S. E. An Explanative Basis for The Differential Performance of Students With Low Math Aptitude in General Chemistry. *Chem. Educ. Res. Pract.* **2019**, *20*, 570–593.

(47) Ralph, V. R.; Lewis, S. E. Impact of Representations in Assessments on Student Performance and Equity. *J. Chem. Educ.* **2020**, *97* (3), 603–615.

(48) Xu, X.; Villafane, S. M.; Lewis, J. E. College Students' Attitudes Toward Chemistry, Conceptual Knowledge and Achievement: Structural Equation Model Analysis. *Chemistry Education Research and Practice* **2013**, *14*, 188–200.

(49) Villafane, S. M.; Lewis, J. E. Exploring A Measure Of Science Attitude For Different Groups of Students Enrolled in Introductory College Chemistry. *Chemistry Education Research and Practice* **2016**, *17* (4), 731–742.

(50) Lewis, S. E.; Shaw, J. L.; Heitz, J. O.; Webster, G. H. Attitude Counts: Self-Concept and Success in General Chemistry. *J. Chem. Educ.* **2009**, *86* (6), 744.

(51) Canning, E. A.; LaCosse, J.; Kroeper, K. M.; Murphy, M. C. Feeling Like an Imposter: The Effect of Perceived Classroom Competition on the Daily Psychological Experiences of First-Generation College Students. *Social Psychological and Personality Science* **2020**, *11* (5), 647–657.

(52) Tsay, C.-J.; Banaji, M. R. Naturals and strivers: Preferences and beliefs about sources of achievement. *Journal of Experimental Social Psychology* **2011**, *47* (2), 460–465.

(53) Aspelmeier, J. E.; Love, M. M.; McGill, L. A.; Elliott, A. N.; Pierce, T. W. Self-Esteem, Locus of Control, College Adjustment, and GPA Among First- and Continuing-Generation Students: A Moderator Model of Generational Status. *Research in Higher Education* **2012**, *53*, 755–781.

(54) Dragisich, V.; Keller, V.; Zhao, M. An Intensive Training Program for Effective Teaching Assistants in Chemistry. *J. Chem. Educ.* **2016**, *93* (7), 1204–1210.

(55) Dragisich, V.; Keller, V.; Black, R.; Heaps, C. W.; Kamm, J. M.; Olechnowicz, F.; Raybin, J.; Rombola, M.; Zhao, M. Development of an Advanced Training Course for Teachers and Researchers in Chemistry. *J. Chem. Educ.* **2016**, *93* (7), 1211–1216.

(56) Denaro, K.; Lo, S. M.; Holton, A. J. Effect of a Concurrent Enrollment Preparatory Course on Student Achievement and Persistence in General Chemistry. *J. Chem. Educ.* **2021**, *98* (9), 2820–2828.

(57) Xu, D.; Solanki, S.; McPartlan, P.; Sato, B. EASEing Students Into College: The Impact of Multidimensional Support for Underprepared Students. *Educational Researcher* **2018**, *47* (7), 435–450.

(58) Gemmel, P. M.; Goetz, M. K.; James, N. M.; Jesse, K. A.; Ratliff, B. J. Collaborative Learning in Chemistry: Impact of COVID-19. *J. Chem. Educ.* **2020**, *97*, 2899–2904.

(59) McNutt, M.; Castillo-Page, L. Promoting diversity and inclusion in STEMM starts at the top. *Nature Medicine* **2021**, 1864.

Recommended by ACS

A Pilot Graduate Student-Led Near-Peer Mentorship Program for Transfer Students Provides a Supportive Network at an R1 Institution

Audrey G. Reeves, Anne M. Baranger, *et al.*

NOVEMBER 10, 2022
JOURNAL OF CHEMICAL EDUCATION

READ 

Integrating Authentic Research, Peer Learning, and High-Impact Project Work into the General Chemistry Laboratory

Chelsea A. Barr, Destin W. Heilman, *et al.*

AUGUST 10, 2022
JOURNAL OF CHEMICAL EDUCATION

READ 

Training Tomorrow's Scientists: Embedding Professional Skills in the Physical Chemistry Curriculum with a Guided Grant and Laboratory Project

Andrea N. Giordano and David Styers-Barnett

MAY 23, 2022
JOURNAL OF CHEMICAL EDUCATION

READ 

The Open-Response Chemistry Cognitive Assistance Tutor System: Development and Implementation

Emily C. King, David J. Yaron, *et al.*

JANUARY 10, 2022
JOURNAL OF CHEMICAL EDUCATION

READ 

Get More Suggestions >