# EDUCATIONAL PROPOSAL

According to recent US census information, only ca. 30% of the population 25 years+ old holds a bachelor's or an advanced degree.<sup>18</sup> Extensive data analysis shows that success in pursuing and earning a degree is strongly correlated to the educational and income level of the parents,<sup>19</sup> putting underrepresented, low-income and firstgeneration students at a distinct disadvantage. Indeed, in spite of a steady growth in the number of underrepresented minority college and PhD graduates, their participation remains very low.<sup>20</sup> The economic and social repercussions of the ongoing COVID-19 pandemic, and the intrinsic challenges of remote learning are expected to exacerbate this gap.

Among chief challenges contributing to low participation of underrepresented, low-income or first-generation students in Science, Technology, Engineering, and Mathematics (STEM) fields and obtaining advanced degrees among are a lack of family and social support, and conflicting messages about belonging (i.e. impostor syndrome). Further, traditional teaching practices have been shown to



disproportionately disadvantage underrepresented students, and discourage them from pursuing STEM careers.<sup>21</sup> Low performance in STEM courses is one of the principal reasons why students of all backgrounds switch to non-STEM majors or drop out of college altogether, and this is compounded for members of underserved communities.



To reduce achievement gaps, promote equity and increase retention of underserved students in STEM careers, my educational program integrates a multi-pronged approach, including active learning, mentorship, engagement in research and immersion into the scientific community at the University of Washington (UW; **Figure 6**). I seek to accomplish this in a sustainable way, that leverages local strengths at the UW to address current shortcomings.

# Evidence-based teaching for improved learning

The transition to an online classroom forced by the outbreak of the COVID-19 pandemic has not only called into question traditional teaching strategies but also necessitated the implementation of updated, evidence-based teaching practices to engage and retain students into STEM fields. Indeed, a recent study from UW revealed that *active learning* is a *critical* component in narrowing the achievement gaps in STEM studies for underrepresented undergraduate students, and in increasing their retention in STEM majors and careers.<sup>21</sup> My commitment to cultivating effective learning in the classroom is reflected in the increasing inclusion of applied learning experiences in graduate and undergraduate level courses I have taught thus far. This transition has correlated with increased participation in lessons and quality of learning, as self-reported by students and reflected in exams and other course evaluation metrics. Driven by a commitment to empower students, I have led the instruction of several courses outside of my primary responsibilities, designed to enhance students' scientific *Writing* (Chem 500), and introducing a new undergraduate course *Chemistry Frontiers* (Chem 500, vide infra)).

Especially transformative to my growth as an educator has been teaching *Inorganic Chemistry* (Chem 312) in my first quarter as an assistant professor at a large public institution. This course brings together ca. 60-90 nonchemistry majors in their junior and senior year. It quickly became apparent that a fascination with abstract scientific concepts or even the topic of inorganic chemistry was not a prerequisite for enrollment. During a short 10 week quarter, I was determined to engage students with the material and enable them to learn it while also helping them answer "why should I care about this"? To address these goals, I began introducing authentic learning experiences into my teaching, and emphasized those exposing students to real-world applications of the fundamental concepts covered. For example, learning symmetry and its application to molecular orbitals is extremely challenging to most students taking this course. Using its application in vibrational spectroscopy, and explicitly tying it to real-world applications, greatly improved the learning outcomes and retention of the material. High-stakes midterm exams

were replaced with weekly quizzes, which had the benefit of providing a real-time metrics to student performance, reporting on areas where they struggled. I also introduced in-class collaborative problem-solving exercises, and the use of primary literature as a glimpse into the process of research and discovery (e.g. connecting bonding in organometallic complexes with scientific report on the isolation of ferrocene, and the subsequent work assigning its correct structure).

The next phase of implementing active learning experiences in my teaching will focus on de-emphasizing traditional direct teaching, in favor of increased in-class individual and collaborative problem-solving activities. Short videos (5-15 min) will be created and available to watch before, and after the lectures, in which key concepts will be introduced and explained. The newly gained lecture time will be dedicated instead to in-class problem solving, and small team projects. Increased interaction with students and between students via in-class problem solving and team projects seeks to alleviate the isolation of remote learning during the pandemic. Course assignments will also be redesigned to contain team project work. To achieve the desired effect strong adherence to evidence-based improvements and gradual implementation is required. Specific strategies that achieve this have been proposed to include:<sup>21</sup> i) extensive and focused efforts geared to improve performance (*i.e.* focused work on the most relevant tasks, such as learning and internalizing new concepts by solving problems); ii) problem and projects designed to address specific deficits in understanding or skills (i.e. determining symmetry or point groups "Inorganic Chemistry"); iii) immediate feedback (i.e. discuss solutions in class; weekly guizzes for low-stakes, real-time feedback), and iv) repetition. To effectively accomplish my in-class teaching goals, I will enroll in the Evidence-Based Teaching Program at UW. This local program offers extensive and qualified support from teaching and technology consultants and UW faculty, and provides a collaborative network of peers to enable participants to correctly implement research-based teaching strategies in the classroom.

## "Chemistry Frontiers": curriculum development

In Spring of 2020, I developed a course entitled *Chemistry Frontiers* (Chem 196), designed to fill a critical gap in the undergraduate 1<sup>st</sup> and 2<sup>nd</sup> year students curriculum at UW. The core questions this course addresses are: *why and how is chemistry relevant in our society? what can chemistry research look like in the lab? what opportunities to engage with research in chemistry exist on campus, and how do you go about them? what is graduate school?* Importantly, the class aims to provide a low-stakes opportunity to meet and interact with research active faculty and students in the chemistry department at UW, in a relatively informal setting. As a Caltech undergraduate I had

abundant access to finding research internships. I was surprised to find this was not the case for many promising students at UW, who find themselves in their junior or senior year realizing graduate school is a path they would like to pursue, but are held back by no prior research experience, and little time to compensate for it. This is especially true for underserved communities of students.

Chemistry Frontiers is designed to be taught by a professor/student(s) team from the Department of Chemistry at UW, and includes a description of the big picture scientific goals by the PI followed by an interactive presentation or demo conducted by a student within the group on the scientific methods employed in the research. Additional benefits of this structure include i) potential for scalability, and ease of implementation in other departments that could benefit from it (i.e. physics), and ii) provides a career-development opportunity for students in research groups to grow their science communication skills. In Spring 2020, the class spanned cutting edge research topics and methods in biological, physical, inorganic, organic and theoretical chemistry. This first iteration of the course coincided with the onset of the COVID-19 pandemic, which, among other challenges, introduced a short timeline to move the course to an online format and reduced enrollment. Still, Chemistry Frontiers

"The topics in the class were interesting and wonderfully diverse. I really appreciated the format of the class and how we got to hear from grad students as well as professors"

"I thought the class was stimulating in that it introduced us to a wide range of different chemistry topics and subfields. It was eye-opening to see how certain parts of chemistry apply to parts of our everyday lives/society."

"The lectures from the graduate students contributed a lot. I also really liked having recordings to look back at and rewatch; hopefully, when the class is taught in person it can continue to be recorded."

"I was previously not aware of how undergraduates could be involved in this kind of high-level research and helped me understand that as a freshman there are still opportunities for me."

"I thought it was great that the researchers often made their topics more digestible for us students (especially since many of us are first-years) and were very open to answering our questions. It was also helpful that the grad students described their research experiences, especially since I'm a freshman who wants to apply for but has not done any research yet."

"[learning about quantum dots] was really cool to me because [...] I have seen Qled tv's and monitors, so it was tangible to me. It was really cool to me to learn exactly how that process of high definition resolution and bright colors actually worked based on chemistry."

**Figure 7.** Excerpts from student evaluations and comments from "Chemistry Frontiers" (CHEM 196, Spring 2020).

was a resounding success. Excerpts from student evaluations and comments are included in Figure 7.

Having demonstrated a proof-of-concept successful iteration of *Chemistry Frontiers* in a limited enrollment setting, I next seek to expand student participation, targeting particularly underserved undergraduate students. To accomplish this, I formed partnerships with the Chemistry/Biochemistry Undergraduate Advising Office at UW, the Louis Stokes Alliance for Minority Participation (LSAMP) office, and the Office of Minority Affairs & Diversity (OMA&D). *June Hairston-Summers*, the director of LSAMP is an important partner in my educational efforts, as her office addresses unmet needs in the recruitment and retention of underrepresented minority students in STEM majors. *Todd Sperry* (Assistant Director of the McNair Scholars Program, OMA&D) is another critical partner to my efforts in the chemistry department; the McNair program that he represents is a Ph.D. preparatory program for eligible first-generation, low-income, and/or minority undergraduate students. With their combined support and guidance in bettering our approach, Chemistry Frontiers and related efforts (vide infra) will be assimilated into the curriculum of first-generation, low-income, and/or minority undergraduate students.

# Connecting with Mentors and hands-on science demos

*Power Hour Mixer in Chemical Sciences*: Set to kickstart in Spring 2021 (delayed due to COVID-19), this platform, that I designed with the support of LSAMP and the Clean Energy Institute (CEI) Outreach Office, will provide an informal venue to connect underserved students at UW with faculty and research active student allies and mentors, in chemistry and clean energy related disciplines. In addition to networking, this recurring in-person or, need be, virtual event will expose include hands-on science demos and data analysis mini-projects. To increase student/researcher (student and PI) interactions, the event will include structured one-on-one or small group workshops (15-20 min) with suggested activities. My vision for this platform is for it to evolve into a structured mentorship network for underserved students.

# Hands-on experience with scientific research: undergraduate research and outreach

Undergraduate research is a proven method to integrate students into a community, reinforce confidence in science skills<sup>22,23</sup> and increase retention of underrepresented groups. Sustained research of 10 hours per week or more over several quarters is required to influence persistence in undergraduate researchers.<sup>24,25</sup> Many underrepresented, low-income or first-generation students don't have the luxury or foresight to volunteer to pursue research opportunities. While in our group we had 12 undergraduate researchers during the past 3 years, paid internships opportunities are limited within the department. As a first step to alleviate this, I negotiated a three-way pledge from with the Chemistry Department, LSAMP and the MRSEC center on campus to fund an additional two summer internships; while the pandemic has halted this effort, it will be revived in the next year. Creating more institutional and departmental opportunities to address this important gap is one of my educational goals.

Since 2017 my group has actively participated in numerous chemistry outreach events in our on and off-campus community to increase science literacy and interest in STEM. For example, my group regularly participates in the UW Discovery Days,<sup>26</sup> and more recently at the Pacific Science Center in Seattle (**Figure 8**). In partnership with the CEI, graduate students in our group (4 of 6 total) constructed a "product of lasting value" or broader impacts project which helps translate our research into the larger world. These projects range from kits, demos, wikis, videos, permanent building exhibits, and organizing of special events, and have a large and lasting impact. We are committed to continue our participation in outreach activities in the future. Importantly, in my research group we focus on using research to better ourselves as mentors and as science communicators. To best accomplish this, I encourage participation in training programs designed for this purpose, for example The Science Communication Fellowship (2019-2020,



Figure 8. Pacific Science Center, "Meet a Scientist": In an activity titled "Be a Nanoarchitect!", developed by Jon Kephart, both kids and adults learn about ways that we can design and study nanomaterials for clean energy and electronics on an atomic scale.

Pacific Science Center; J. A. Kephart, graduate student), Torrance Policy Analysis Program (2020-2021, CEI; B. S. Mitchell, graduate student) or the Evidence-Based Teaching Program (2020-2021; A. Velian).

In conclusion, my educational program seeks to interest, engage, enable underserved undergraduate students at the UW and in our community to successfully pursue STEM careers. My multipronged strategy involves implementing evidence-based teaching strategies, increasing access to research experiences, and facilitate finding peer, near-pear and PI mentors.

### EDUCATIONAL PROPOSAL (continued)

**ASSESSMENT PLAN.** Define expected outcomes of your educational plan. How will your evaluation design provide information to improve your project as it develops and progresses? How will you determine whether your stated project objectives are being met according to the proposed timeline?

### Active Learning Curriculum Development.

Data collected for this objective will include analysis of student performance in the course (written and verbal examinations, projects, etc), student satisfaction with course work and overall experience.

## Chemistry Frontiers Assessment Plan.

The metric for success of this initiative entails a) final quiz; b) course evaluation form; c) class attendance; d) inclass participation, e) conversion to finding an undergraduate research host. The latter will be determined by a survey at the end of the quarter. The feedback collected will be used to make appropriate modifications in future class iterations.

#### Hands-on Research Activities.

Electronic evaluation and surveys that already exist via the REU programs on campus will be used.

#### Power Hour Mixer.

Metrics of success will be collected by tracking participation, and by using verbal and written evaluations from the participants. Results will be used make modifications for future years.

Identify departmental or institutional colleagues who might play a role in this educational endeavor (as mentors, collaborators, etc.) as appropriate and describe the role they will play.

- June Summers Hairston, Ed. D (Director of the Pacific Northwest Louis Stokes Alliance for Minority Participation in STEM, University of Washington). In her role as the Director of LSAMP, Summers Hairston is a lead academic advisor to underserved minorities, and spearheaded numerous campus-wide activities to address increasing diversity, equity and alliance building, and narrow carrier disparities in minority students. In partnership with LSAMP, we seek to build a stronger mentoring network and pipeline for undergraduate students in chemistry.
- 2. Todd Sperry (Assistant Director of the McNair Scholars Program, Office of Minority Affairs & Diversity) is another critical partner to my efforts in the chemistry department. The McNair program that he represents, is a Ph.D. preparatory program for eligible first-generation, low-income, and/or minority undergraduate students.
- 3. Evidence-Based Teaching Program (University of Washington). This initiative offers collaborative peer support, as well as support from teaching and technology consultants, in cross-disciplinary groups facilitated by UW faculty. Importantly, this program uses evidence to improve teaching and learning, and supports faculty to implement research-based teaching strategies in the classroom.