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Broader Impacts Cumulative Exam Proposal

The traditional undergraduate chemistry curriculum consists of the standard core courses encompassing general chemistry, organic, inorganic, analytical, biochemistry, and physical chemistry[1,2]. Recently there has been increasing criticism of these divisions. Critics highlight the chemistry field is becoming more interdisciplinary while undergraduate curriculum remains disjointed[3]. There has been much focus on a new approach to teaching chemistry that sets a better foundation of fundamental concepts that build through higher courses[2,4–6].

Most curriculum changes propose teaching in themes so students learn how to solve chemical problems rather than memorize specific chemical topics[1,2,7,8]. This need is reinforced by the 2015 ACS guidelines for undergraduate curriculum, which state the need for an integrated approach to teaching that covers multiple foundational themes[9]. The chemistry department at the College of Saint Benedict and Saint John's University (CSB/SJU) proposes a focus on structure, reactivity, and quantitation for both lecture and laboratory work[1]. Emory University has proposed similar work building on CSB/SJU's themes with their *Chemistry Unbound* curriculum. Both emphasize a structure-focused introductory course.

These themes have also been a focus for high school chemistry. The ACS guidelines for high school curriculum include "motion and stability: forces and interactions" as a core idea[10]. Emphasizing this in high school connects to many concepts that would be covered in a structure-based introductory course in college and creates a stronger foundation early in student education.

The first broader impact of this proposal uses these themes to continue improving STEM education in high school and general chemistry. This will be done by developing an integrated, interdisciplinary module activity with hands-on experiments. The module will be conducted with early high school students focusing on intermolecular forces and the movement of molecules in solution.

Within the module students will be guided through each activity by completing a laboratory workbook. The material is presented through experiments and symbols first, then an explain of the chemistry at a microscopic level is given. Through this strategy, students exercise deductive reasoning and critical thinking skills to reach a conclusion on their own, as opposed to a more passive lecture-based approach[11] which has been shown to result in greater student success in STEM courses[12]. By utilizing guided-inquiry structured workbooks and hands-on experiments, students will discover the concepts by experiencing them in the activity.

Additionally, this module will expose students to lesser-highlighted sub-divisions of chemistry early in their education. The *Chemistry Unbound* curriculum stresses this as beneficial to show non-majors the potential in chemistry as well as help majors make an informed decision when selecting upper-division courses[5].

The second broader impact is to increase the participation of underrepresented groups in STEM fields. Through partnering with the University of Oregon Summer Academy to Inspire Learning (SAIL), the module will be directed at low income, first-generation high school students. SAIL has been providing students from these groups with resources and mentors to make higher education more accessible 14 years. The Department of Chemistry and Biochemistry has been involved with SAIL for five years. By introducing chemistry to these students through hands-on critical thinking activities they are further engaged, as a process-oriented approach has shown positive effects on student attitude in the chemistry learning environment[13]. Through this module these underrepresented students will experience chemistry in a positive, engaging environment to encourage their future pursuit of chemistry in college.

Materials and Methods

The proposed module will be two hours in length and consist of three experiments in the fields of surface and electrochemistry. It will focus on three specific learning goals. First, students will gain a basic understanding of electronegativity and be able to identify polar and nonpolar characteristics in a molecule. Second, they will be able to recognize intermolecular forces and identify hydrophilic and hydrophobic interactions. Finally, they will understand diffusion as movement from high to low concentration and identify this movement at the electrode of an electrochemical reaction.

The first activity focuses on environmental remediation of oil spills and uses electrocoagulation to disrupt oil emulsions in water. The second shows the interactions between surfactants and fat emulsions by showing the movement of dish soap in milk. The third teaches electron transfer and solution diffusion through the electrolysis of water. Each experiment will focus on specific learning objectives but incorporate similar concepts relating to other learning goals throughout, facilitating connections between all three. The materials required for the module are common materials already found in most general chemistry labs. Any additional materials can be easily obtained at a minimal cost.

To evaluate student learning, the module will be assessed from three perspectives. First, the students will be given a worksheet to complete at the end of the module. This worksheet consists of summary questions highlighting the main learning objectives of the module. At the end of the week students will also be given a survey to assess their overall perception of the module. Second, instructors assisting with the module will give written feedback on their perceptions of student engagement, retention of information, and overall success of the module. Third, an additional instructor will attend the module as an external observer. This member will also submit written feedback on their perception of student retention and module success. To evaluate the increased involvement in chemistry, a survey will be given at the beginning and end of the week assessing student interest in a future college major or career in chemistry.

All materials for the module will be made publicly accessible through the broader impacts website. These include the workbook, an instructor edition of the workbook with a discussion guide and materials list, and PowerPoint slides used for discussion. The module is customizable and can be repeated in similar outreach settings or incorporated into a general chemistry laboratory curriculum.

Conclusion

Through this interdisciplinary module, low income and first-generation high school students will gain laboratory experience and early exposure to fundamental structural chemistry themes. They will also be introduced to surface and electrochemistry as two of many sub-divisions within chemistry. The chemistry concepts introduced will start a foundation for future general chemistry courses to build on. Further, the materials produced enable other outreach programs or schools to integrate the activity for future applications.

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