Creating an Equilibrium Between Teaching and Research in a General Chemistry Curriculum: Students Reinvent Lab Modules

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Abstract

In this presentation we outline the design of an electrochemistry project based on research conducted at our university using a solar powered electrolytic water remediation system to introduce electrochemistry and heterogeneous catalysis in the context of green chemistry in the second semester general chemistry laboratory sequence. The project was designed to be a part of a project based cooperative green chemistry curriculum for freshman chemistry laboratories. Moreover it represents our educational model where students are first introduced to catalysis in teaching lab and are then invited to join undergraduate research projects based on the ideas they were introduced in the lab and which then tie to departmental or broader research in the same theme.

The development team incorporates young undergraduate students who completed the first semester of the pilot laboratory implementation of the new lab curriculum as students and showed interest in being involved in the project as co-designers and facilitators. In this presentation we will summarize the outcomes of one of these research projects based on research conducted at Northeastern University (PROTECT project). The team is working on coupling the electrochemistry system generating H_2O_2 to a heterogeneous polymer based system containing a nature inspired catalyst (FeTAML)[1] rendering it heterogeneous and reusable with use in a portable water remediation system.

The team incorporates students with various majors (engineering, health science, biology, chemistry) to create interdisciplinary approach into the design of the system and in incorporating these core ideas into teaching laboratory modules. We are presenting here (a) the pedagogical design of the laboratory curriculum where this exemplary electrochemistry project will be implemented (b) lab parameters, design and results of the electrochemistry project (c)the function of the student curriculum team framed within a peer mentoring model in collaboration with the faculty involved in this effort (d) preliminary learning outcomes of these efforts in our curriculum.

Design of the Curriculum

This student laboratory curriculum was designed to accomplish three main goals:

I. Introduce students to cooperative lab learning with emphasis on experimental design, data processing and reaching conclusions in an inquiry environment.[2]
II. Provide means to master key laboratory techniques and get introduced to the 12 principles of green chemistry.[3]
III. Facilitate a pathway from lab learning to undergraduate research by providing explicit and viable research links from classroom learning to departmental research to pursue novel, student-led projects based on interest in collaboration with faculty as in the case of the RAISE project.

RAISE

An Integrative Approach to Chemistry Education

The Research Alliance in Science and Engineering investigates novel approaches to environmental issues.

Students complete general chemistry labs and are invited to join undergrad led research projects under faculty mentorship. RAISE is the flagship research project and fosters a natural turnover system as students complete coursework, join the project, and become leaders.

Founding and Funding

The RAISE project was established by students following the redevelopment of the chemistry lab curriculum at Northeastern University.

Internal university grants have supported research expenses, such as chemicals and equipment. Students are directly involved and are team mentored for earning these grants.

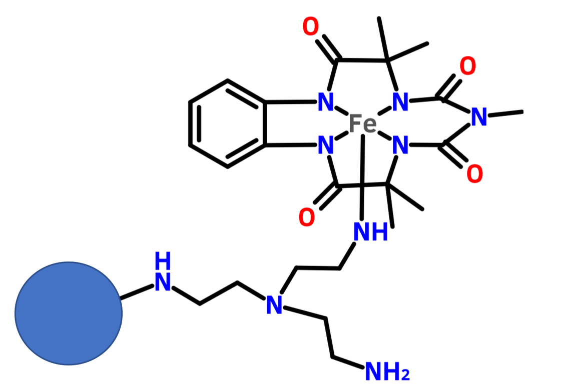
Recruitment

Lab member present to other students in lectures and clubs to recruit new members.

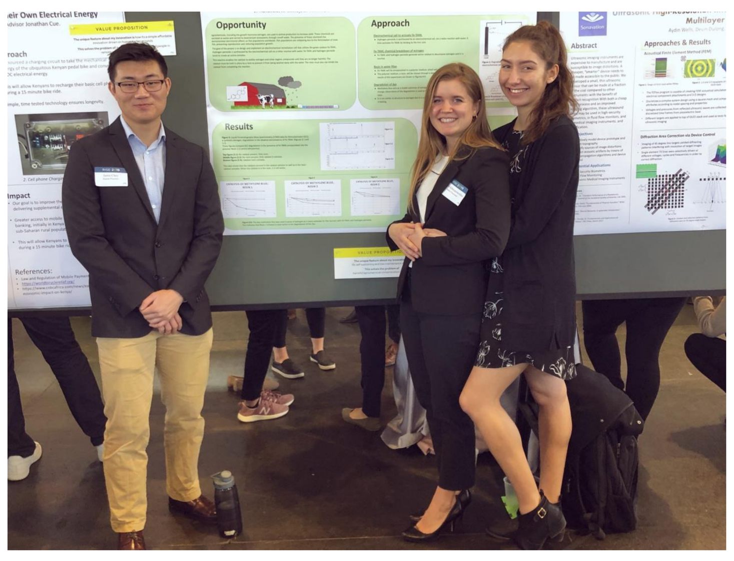
Students who complete general chemistry coursework are invited to join RAISE or other similar projects to continue their education beyond the classroom.

Learning Outcomes

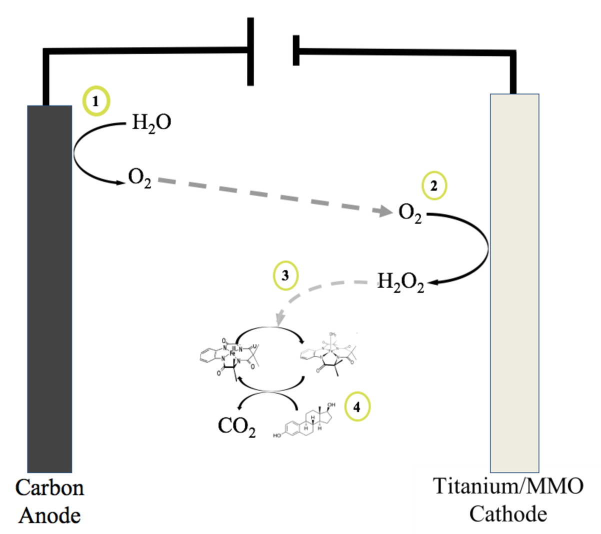
- Leadership and mentoring experiences for undergrads
- Presentations at international, national, and university conferences
- Development of standard protocols through experimentation and optimization
- Self-directed experimental design
- Scientific literacy through student led journal clubs
- Data interpretation and synthesis to support conclusions
- Lab safety and responsibility



Fe-TAML coordinated to a 2-aminoethyl amine covalently linked to a styrene divinylbenzene polymer bead



RAISE underclassmen presenting at a university research symposium



Electrolytic cell model describing generation of H_2O_2 for use in Fe-TAML oxidation reaction

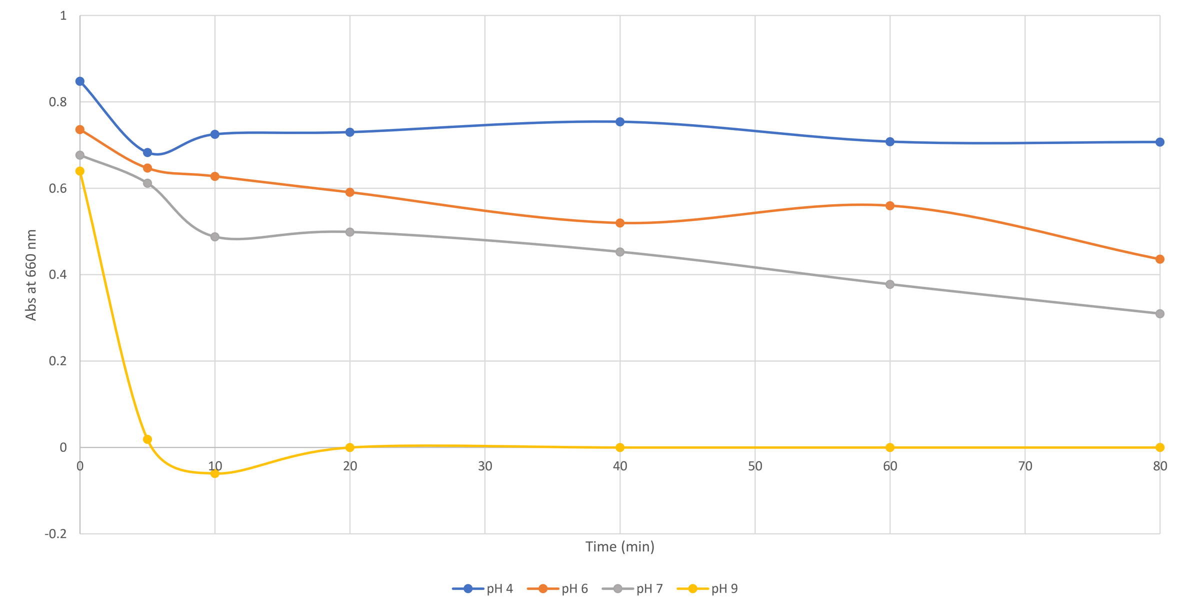
Outcomes from Pilot

After implementing cooperative green lab projects for two semesters in our multi-section honors labs the three main outcomes in our trajectory were the following:

- An establishment of peer mentoring to help support desired student learning outcomes in the labs (peer lab mentors steadily joining from the ranks of the freshman labs).
- Increase in recognition of application of the 12 principles of green chemistry and sustainability in chemistry.
- An exponential increase in expressed interest & involvement in green chemistry projects beyond the teaching lab. Four research project spinoffs from teaching laboratory work are funded by university grants. Students have built teams co-mentored and sustained by senior undergraduates in the projects. Students present their work in national and international conferences, author papers and seek outside funding.

Our Project

- Estrogenic compounds contaminant ecosystems downstream of cattle and dairy farms.
- Small concentrations (ppb range) can have effects on the surrounding wildlife by disrupting hormone processes
- Fe-TAML, a green catalyst, can oxidize organic compounds in the presence of H_2O_2
- By binding Fe-TAML to a solid phase support and generating H_2O_2 *in situ*, we theorize a sustainable method for degrading estrogens in a portable flowing water system prototype.



Degradation of methylene blue (a model contaminant) is measured spectroscopically. Rapidly decreasing absorbance at 660 nm under basic conditions shown above.

Research Outcomes

- Electrolytic cell generates H_2O_2 in suitable quantities for catalysis
- Fe-TAML uptake conditions optimized
- EE2 degradation seen, products to be investigated

Citations

[1] Brown, V. J. (2006). Fe-TAML: Catalyst for Cleanup. *Environmental Health Perspectives*, *114*(11), A656–A659
[2] (a) Anastas, P.T.; Warner, J.C. Green Chemistry: Theory and Practice; Oxford University Press: New York, 1998
(b) Beyond Benign Curriculum Home Page ttps://www.beyondbenign.org/curriculum/ (accessed July 6, 2019)
[3] Singer, S. R., Hilton, M. L.,Schweingruber, H. A., (Eds.), 'America's lab report', **2006**, Washington, D.C: National Academies Press

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