Integration of Teaching and Scholarship in the Chemical Sciences

Robert M. Hughes Ph.D., Associate Professor of Chemistry, Department of Chemistry, East Carolina University

Abstract

Since 2016, I have taught introductory and advanced courses in chemistry at East Carolina University while maintaining an active research laboratory with a blend of undergraduate and graduate research assistants. These activities have become intertwined in several ways, including the transition of independent research projects into classroom-based activities and the production of new scientific knowledge from classroom-based research activities. This poster presentation includes several examples of how the educational and institutional environment at ECU has promoted the intersection of teaching and scholarship and how their convergence has influenced my approach to higher education. Examples include:

- The implementation of a biocatalysis-focused course-based undergraduate research experience (CURE) for first and second semester organic chemistry students. This course was based on independent research from a graduate student.
- The creation of a 3D-printed labware course module for engineering students, based on independent research from an undergraduate student.
- The creation of a senior capstone course for bioprocess engineering students, also based on undergraduate and graduate research from our group.
- A seminar for Honors College students, based on a personal long-standing interest in the history of the chemical sciences.

Biocatalysis/Organocatalysis CURE

- Independent research funded by the ACS Petroleum Research Fund and performed by ECU Chemistry graduate student Mitul Patel (Patel, et al 2020) was the basis for this CURE, in which organic chemistry students investigate new methods for the asymmetric synthesis of pharmaceutical compounds. In the current version of the CURE, the focus on the synthesis of warfarin, a commonly prescribed anti-coagulant. Manuscripts based on student work are currently submitted (Wurz, et al 2024) or in preparation.

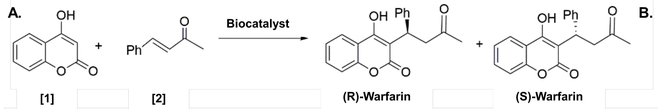
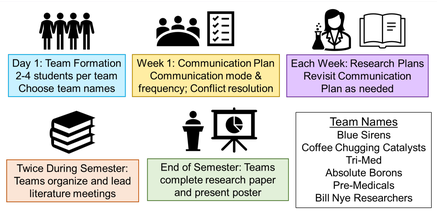
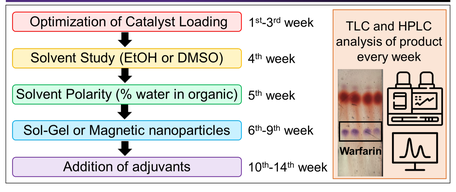


Figure 1. Reaction scheme of Warfarin synthesis. A. 4-Hydroxycoumarin [1] reacts with Benzylideneacetone (BZA) [2] with assistance of a biocatalyst to produce the enantiomers (R)- and (S)-Warfarin. **B.** Racemic Warfarin crystals.

TEAM SCIENCE APPROACH



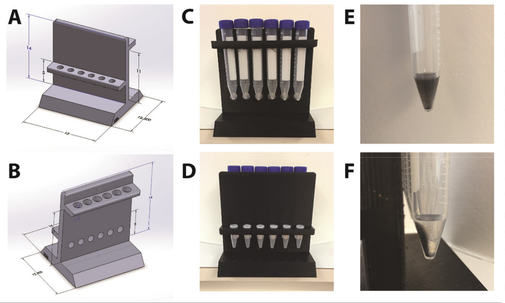
RESEARCH APPROACH & TIMELINE



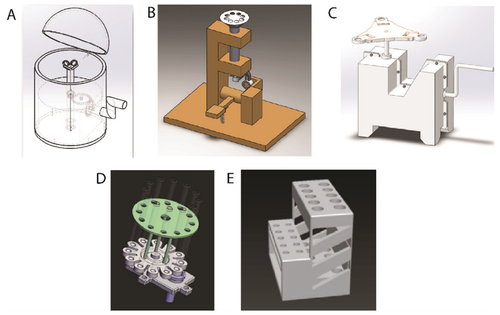
CHEM 2753 and 2763 students working in CURE lab on the Warfarin project (images shown at right): Marissa Smith and Gauri Patel (top); Cora McQuaid and Kayleigh Nieves (middle); Robert Hughes, Alexis Owens, Lovens Paul, Manjot Singh.

3D Printed Labware Course Module

- Independent research performed by ECU Bioprocess Engineering major Ethan Quinn (Quinn, et al 2023) was the basis for this course module led by Dr. Brian Sylcott (ECU College of Engineering), in which students working in teams were asked to design 3D-printable chemistry labware based on design prompts.



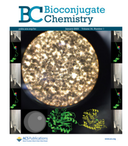
3D Printed Labware Designed and Created by UG Research Student Left panels show design created with the SOLIDWORKS modeling program. (A) The 1.5 mL tube side and (B) the 15 mL conical tube side. Dimensions are in centimeters. (C) Printed design with 15 mL conical tubes installed. (D) Printed design with 1.5 mL tubes installed. (E) Solution of superparamagnetic nanoparticles suspended in solution. (F) Solution of superparamagnetic nanoparticles installed on magnetic separation rack.



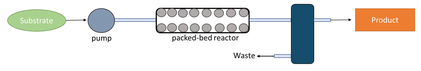
Designs from Engineering Students' Team-Based Projects (ENGR 2000) Schematics of student designs for hand-cranked (A, C) and foot-pedal powered (B) centrifuges. (D) Schematic for a lab tube rotator. (E) Schematic for a multilevel column holder for chromatography applications.

Senior Capstone Course for Engineering Students

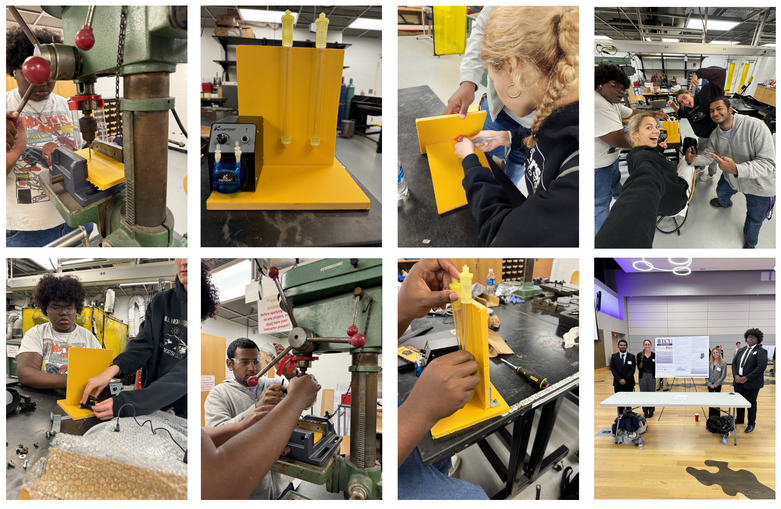
- Independent research performed by ECU Chemistry undergraduate and graduate students on the generation and application of immobilized enzymes (Norris, et al 2020; Deane, et al 2023) was the basis for this initiative, led by senior engineering students, to design and build a flow reactor for bioprocess chemistry.



Engineering Senior Capstone Project: Flow Reactor with Immobilized Enzymes

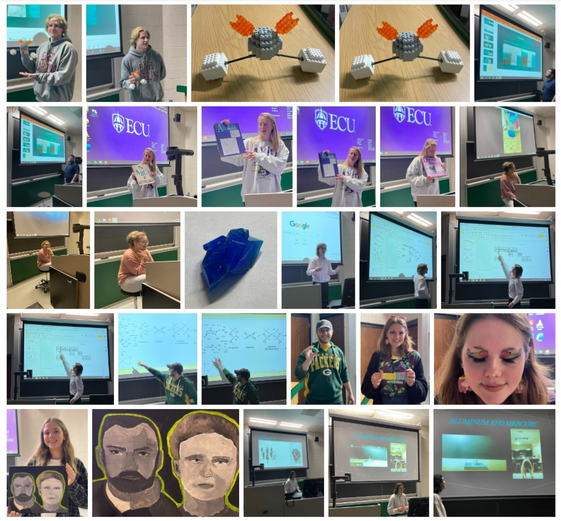


Senior Capstone students at work on the flow reactor project (images shown below): Team members are Marzuq Islam, Christina Leach, Cora McQuaid, and Xavier Wright.



History of Chemistry Honors Seminar

- In this course, an interdisciplinary approach to the history of the chemical sciences is utilized to present an overarching narrative of the discipline of chemistry from past to present. This course uses texts that emphasize the role of chemistry in world history (Napoleon's Buttons), chemistry as personal narrative (Uncle Tungsten), major personalities & contributors to the chemical sciences in the 20th century (Cathedrals of Science), and the history of the periodic table (The Periodic Table: Its Story and Significance). Students are challenged to develop creative projects using readily available resources (such as the Isley Innovation Hub).



Examples of past student projects and presentations are shown above (students pictured are Joshua Dail, Abby Ulffers, Fabiola Cabanas Hernandez, Will Wakeford, Austin Gates, Sarah Beth White, Hannah Umphlett, and Lily Szwejbka).

Acknowledgements

- Sincere thanks to all current and former members of the Hughes laboratory, current and former students of CHEM 2753 and CHEM 2763, students of ENG 2000, the 2023 – 2024 Senior Capstone Team, and current and former students of HNRS 2014.
- Thank you to all colleagues in the Department of Chemistry, particularly Drs. Joi Walker, Toby Allen, Anthony Kennedy, Brian Love, and Andrew Morehead and in the College of Engineering, Drs. Brian Sylcott and Loren Limberis.

References

Deane, D. T., Cope, T. A., Schulz, A. M., Bennett, E. T., & Hughes, R. M. (2023). Design, Heterologous Expression, and Application of an Immobilized Protein Kinase. *Bioconjugate Chemistry*, *34*(1), 204–211. https://doi.org/10.1021/acs.bioconjchem.2c00485

Norris, J. L., Patel, T., Dasari, A. K. R., Cope, T. A., Lim, K. H., & Hughes, R. M. (2020). Covalent and non-covalent strategies for the immobilization of Tobacco Etch Virus protease (TEVp) on superparamagnetic nanoparticles. *Journal of Biotechnology*, *322*, 1–9. https://doi.org/10.1016/j.jbiotec.2020.06.021

Patel, M. P., Green, N. T., Burch, J. K., Kew, K. A., & Hughes, R. M. (2020). Screening of biocatalysts for synthesis of the Wieland–Miescher Ketone. *Catalysts*, *10*(9), 1–13. https://doi.org/10.3390/catal10091063

Quinn, E. S., Sylcott, B., Green, N. T., Walker, J. P., & Hughes, R. M. (2023). 3D-Printed Laboratory Accessories as a Conduit for a Multidisciplinary Undergraduate Research Experience. *Journal of College Science Teaching*, *52*(4), 38–47. https://www.nsta.org/journal-college-science-teaching/journal-college-science-teaching-marchapril-2023/3d-printed

Wurz, A.I., Andersen, C. I., Walker, J. P., Hughes, R. M. (2024). Evolution of a Biocatalysis CURE for Organic Chemistry Students (submitted for publication)