EDUCATIONAL PROPOSAL

STATEMENT OF THE PROBLEM, SIGNIFICANCE OF THE PROBLEM, AND YOUR PLAN OF PROCEDURE*. Describe identified educational priorities in your department and explicitly detail how your plan fits. State clearly the problems or issues you wish to address and how they relate to any ongoing work. Cite precedent. Carefully outline the importance of your plan and the impact it may have on your undergraduate and/or graduate students. A viable approach should be given, including examples from your own prior experience and/or from the literature. Indicate ways in which the completion of this work has a broader impact. Use Arial 11 point font. Limit to three pages.*

Targeted issue: Science is increasingly important in public policy. From environmental sustainability to homeland security, policymakers routinely make decisions that require input from, and have impact on, the chemical community. Yet scientists often lack the expertise to successfully engage in the policy process, and policymakers typically do not have the scientific training to communicate efficiently with the scientific community. The purpose of my Educational Proposal is to develop **an interdisciplinary course to engage both STEM and non-STEM undergraduate students by examining the challenges relevant to the incorporation of science in public policy and everyday modern life**. For example, teaching future generations of policy makers and scientists to communicate effectively with each other as a single community is vital if society is going to benefit from nontoxic and lower carbon-footprint scientific solutions that impact everyday modern life.

Educational Goal: My overarching educational goal is **to enhance communication between scientist and policymakers** who advance public policy, through a **new community of undergraduates with the professional, scientific, critical analysis, and life skills to fully contribute to the policy process**. The expected outcome from my Educational Proposal is multiple cohorts of students at the University of Arizona (UArizona) who experience an interdisciplinary, problem-solvent curriculum between the **Colleges of Sciences** and **Law** based on analyzing and debating broad, interconnected issues in science and public policy.

Motivation: As a father of two, my concern about what world is left for future generations is a driving force to my scientific interests in sustainable chemistry, renewable energy, and energy storage. Yet, scientific discovery is only a portion of societal evolution. Without appropriate support from governments, sufficient changes are not foreseeable. Fortunately, science and technology are becoming increasingly important in public policy. From environmental sustainability to homeland security, policy makers make decisions that require input from, and have impact on, society.[42,43] However, in order to form rational judgments on the complex challenges society encounters today, one must possess both an understanding of the underlying scientific and technical issues and an appreciation for relevant economic, political, legal, historical, and ethical dimensions.[44,45] Yet only 5% of the members of U.S. Congress have backgrounds in science and engineering. Likewise scientists often lack the opportunity and expertise to successfully engage in the political process. I perceive this gap between disciplines as a miscommunication that can be partially remedied by training scientists and policy makers (nonscientists) to behave as a single community—starting at the college education level.

Currently, many universities, including UArizona, have programs on public policy and science. However, commonly these programs target a specific audience of students at the Master's level who are already aware of the communication gap and aspire to become involved in the environmental public policy. In contrast, my new interdisciplinary class differs by targeting **undergraduate students** in their 2nd, 3rd, or 4th year who are either in chemistry/biochemistry or law/public policy programs. In the proposed curriculum, my colleagues and I (see below) bring students from these different disciplines to address societal topics in an interdisciplinary manner. The topics chosen are the platforms on which **students have the opportunities to learn how to interact effectively with experts from drastically different backgrounds**. Indeed, developing a curriculum that can improve the dialogue between science and policy has been one of my longtime objectives. Already before being an assistant professor at UArizona, I discussed the need of such a class when attending the 67th Lindau Nobel Laureate meeting.[46]

Course description in its current pilot format: In Fall 2019, I offered the first pilot of this class at UArizona with my collaborator in the College of Law. For this pilot, the enrollment was limited to 10 students with science or engineering majors, and 10 students with law or public policy majors. STEM and non-STEM students mixed in small groups of four to promote and encourage interaction. Science majors led discussions on the science part of the topic, while non-STEM students led discussions for the regulations and policies.

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When offered in the Fall 2019, the course was first divided into four topical units each for three weeks. The last three weeks of the course were for the final projects (vide infra, **Figure 7**). During each topical unit a societal challenge was investigated as a main topic. The *first week* of each unit focused on the science aspects of the topic. The *second week* focused on relevant laws, regulations, and/or public policies. The *third week* synthesized the knowledge acquired from both fields. The four unit topics presented were:

Unit 1 – global warming – introduced greenhouse gases and climate change concepts, and tools and data that record the human-made impact on climate. A climate prediction model showed the intricacy between scientific data and policy impact. For the legal portion, students discussed climate regulations from local municipalities to international treatises. An invited guest speaker, State Rep. Kirsten Engel, succinctly discussed these issues and answered students' questions. Finally, students drafted a state regulation for the Unit 1 project. The final day had in-class "elevator pitch" presentations of these proposed state regulations.

Unit 2 – water/soil contamination – introduced and discussed basic chemical concepts using examples from daily life, such as the main contaminants and properties of drinking water. The Clean Water Act, nuisance Law, Toxic Substances Contract Act, and CERCLA/Superfund were discussed by in-class case studies. As a final assignment for Unit 2, student groups acted as EPA or water control employees. Each student used a strip test at one on-campus and one off-campus location to analyze the level of common contaminants. Groups then analyzed their data and presented them as reports and class presentations.

Unit 3 – genetic engineering – provided backgrounds on biochemical and biological genes and gene editing. Week 2 focused on regulations applied to scientific research, genetically modified food (GMOs), and the use of gene therapy treatments in group discussions to promote interactions. The final week was a debate that opposed one-half of the class against the other over "do it at home" gene editing.

Unit 4 – renewable energy – discussed alternatives to a fossil fuel economy. For the legal portion, students discussed climate regulations in the context of renewable energy at scales from local municipalities to international treatises, oil and gas lobbying, government funding, risks and liability. The final project considered a renewable energy installation in a fictional town, and the multiple financial and planning aspects.

Findings from the pilot: It is critical to ensure that our students are learning to: 1) synthesize what they have learned from the two disciplines; and then 2) successfully transform that knowledge into policy and communicate it to each other. Thus, both the end-of-unit and final projects were used to assess these skills. For each unit, at the end of Science Week 1 and Law Week 2 the students completed online quizzes to ensure that the material covered in class was assimilated. Assessment was further performed at the end of each unit, as our students were asked to both turn in a written composition and participate in the in class oral activities, such as debates, defend their proposed regulations, or present their data on water contamination.

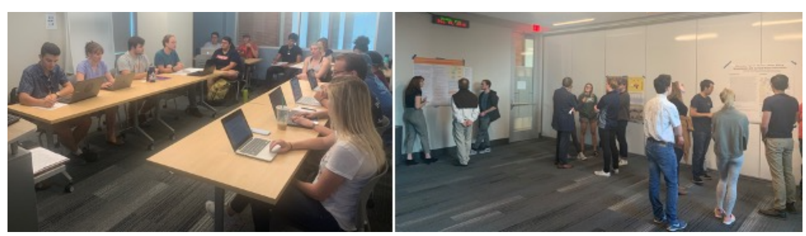

Figure 7. In class debate (*left*) and final projects poster presentations (*right*).

More importantly, the **final project was the main assessment and assignment that students had followed through the semester**. This final project further tested their written and oral communication skills, while ensuring that they were able to extrapolate what they have learned to topics outside the main focus of this course. Each group selected a scientific topic and examined the regulation and science involved. In the final report, students analyzed data that they found, drew conclusions, discussed the societal impacts, and proposed improved or new regulations accordingly. Their work was summarized in 10-page reports and they also presented their work during a poster session open to the public. The societally impactful topics chosen for Fall 2019 were: 1) vaping; 2) nuclear waste; 3) water control in Arizona; 4) Round-up pesticide and skin cancer; and 5) gun control in America.

Proposed changes: As a Cottrell Scholar, I will introduce new societal topics aligned with my current research on sustainable/organic base catalysis and the development of energy storage such as redox flow batteries, with content inspired by and connected to the Research Proposal and the underlying chemical principles.

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Such new topics will include: 1) light-harvesting organometallic molecules as an alternative for energy production and catalysis; 2) contaminated water from chemical plants that use toxic reductants and oxidants; 3) the environmental impact of mineral mining, for example the major copper mines in Arizona, Mexico, and near Native Nation lands (a topic that will help promote interest in this class from Hispanic and Native American students); 4) metal toxicity in drug discovery; and 5) current energy storage systems and their limitations. I will integrate my research into the unit discussions as an alternative to some of the issue raised within each topic. Some of the molecules synthesized by my group will be used for in-class demonstrations. The public policy and law aspects of these topic could in turn help my group to rethink the design of even better catalysts and redox flow batteries.

The current class design is for 20–25 students. Critically, our goal is to now expand and change this curriculum for a larger community of students. In Spring 2021, we will maintain 20–25 students while implementing changes to the course itself. Thereafter, we will target larger classes of up to 50 students and expand, with the involvement of more instructors, to two or three sections per semester. The goal is to offer this class to 100–200 students a year.

An important difficulty for this class is: "*How can we introduce fundamental yet basic knowledge to one portion of the class without being too redundant and uninteresting to the more experienced other half of the class—from both the science and law perspectives?*". To overcome this hurdle, we propose to use a hybrid class model (recorded videos, reading, and in class activities) that allows students to quickly move through familiar material and spend more time with the material from the other discipline. Critically, this will allow us to devote in-class time to interdisciplinary interactions. To assess the efficiency of this hybrids class, a brief quiz will follow each online material/recorded lecture for input on the basic knowledge of the topic's science and regulations. The in-class time will focus on classroom discussions, demonstrations, and problem-solving activities. This will allow us to introduce scientific demonstrations, such as small labs and activities that require data collection. The homogeneity of the class participation will further assess the class model.

A challenge with choosing in-class demonstrations is to ensure that the experiments do not involve expensive or dangerous products and equipment. I am familiar with interesting yet safe science experiments that connect to the underlying chemical principles. During my graduate school, I participated in a program called *Bay Area Scientists in School* that develops science demonstrations and presents them in local public-school classrooms.[47] For example, we can order a toy car running on a fuel cell from Amazon. The hydrogen needed to power this car can be easily generated from vinegar and Zn dust in a reasonable experiment to demonstrate the use of renewable energy. Alternatively, we can demonstrate the greenhouse gas effect of CO_2 using a laser pointer, a thermometer, and dry ice. Such experiments could introduce more hands-on activities during class while following the online assignment at home. Similarly, opening in-class time will allow us to perform more case studies, include more field trips, and have guest speakers during the law and regulation part of Units 1–4.

Fit with Departmental and University Educational Priorities:

• UArizona is the only university in the country to offer a Bachelor of Art in Law. This unique undergraduate degree offers a distinct opportunity to develop this new interdisciplinary class at the undergraduate level at UArizona in a partnership between my department (Chemistry and Biochemistry, CBC) and the College of Law. This aligns with the vision of both academic parties to expand and cross-link their educational activities.

• Engagement is critical to the success of students, a central focus of CBC, and an essential part of the 5th pillar of the UArizona's strategic plan: *Institutional Excellence*. The new class promotes engagement by connecting students from different backgrounds and disciplines and encourages them to actively interact via group projects, in-class activities, and group presentations.

• Grand challenges is the 2nd pillar of UArizona's strategic plan, which mandates expansion of educational opportunities and addressing important societal challenges. The interdisciplinarity of the new class, its hybrid model, and the focus on societal topics perfectly align with the University strategic plan.

Broader impact: This multi-College curriculum will provide a supportive environment for students to learn how to work and interact across fields with different backgrounds and levels of expertise—to mutually solve societally important problems. Educating the future generations of policy makers and scientists in the importance of truly communicating with each other is of foremost priority to U.S. society.

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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?*

Expected outcomes: This course will establish a basic understanding of scientific topics often encountered in political discussions and decisions. It will also introduce the skills necessary to analyze scientific facts and data for students without STEM majors. Similarly, STEM students will learn basic knowledge about public policy, law, and regulations, and how policy is made. It is important to note that this course is not designed to turn STEM majors into politicians nor non-STEM majors into fully trained scientists—rather, students will build a foundation of mutual knowledge and respect as a basis for continued understanding and effective dialog. Our goal is sufficient background information to promote interactions and discussions, without overwhelming students. The class will encourage students to think critically about relevant problems regarding the interplay between science and public policy, and **become aware of how to interact as a <u>single community</u> with students from different fields, different backgrounds, and levels of expertise**. In-class activities will develop students who **learn how to work with nonexperts from the perspectives of their chosen field and solve important problems**. But above all, this class will help a generation of young students to be lifetime advocates as informed citizen for both science and public policy.

Evaluation: The pilot course in Fall 2019 received positive feedback. UArizona has an on-campus Office of Instruction and Assessment (OIA) that is freely available to faculty to design evaluations and assessments. Going forward, the critical information to gather and analyze with OIA during the next few years is: 1) "**How do students perform with learning material outside their expertise**?"; and 2) "**Are the students able to communicate efficiently with specialists in other fields**?". To that end, we will tabulate the quizzes and in-class presentations/participations used for grading in an Excel sheet and monitor throughout the semester to evaluate each student's progression and which subjects are the more challenging to learn. We will also collect information during each class, as well as a voluntary survey sent at the end of each Unit 1–4 to reveal the strengths and weaknesses of each class for discussions with OIA. Finally, a measure of the long-term impact of this course will be from keeping in contact with the alumni to establish the percentage of students who actively use the knowledge and skills they acquired.

Timeline and Feedbacks: Direct feedback from students will serve as an immediate assessment that we will integrate to improve the curriculum. After Year 1, we will determine if and how the topics and delivery methods align with the students' expectations. After Year 2, we will have additional data to optimize the in-class activities and scientific demonstrations. From Year 3 onwards, we will collect feedbacks from students who have graduated. Insights from these alumni will allow us to recalibrate the class.

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.

Alex Erwin, Lecturer at the College of Law, Dr. Erwin is my collaborator and has taught the pilot class with me in the Fall 2019. He will be developing and teaching the new version of this class.

Keith Swisher, Professor of Legal Ethics, Prof Swisher is the Assistant Dean for Finance and Administration at the College of Law and he has been the coordination point between my departmental administration and the college of Law to launch this class.

John Pollard, Associate Professor of Practice in Chemistry and Biochemistry, Prof. Pollard chemical education research revolve around interdisciplinary curriculum. In the Spring 2019 and 2020, he organized Faculty Learning Communities (FLC) around the development of interdisciplinary course. My collaborator and I participated in both FLC, which helped us developed the pilot class. Prof. Pollard is an invaluable mentor and advisor.

UArizona OIA. OIA will provide guidance on organization and structure to collect the assessment data, and will help administer the assessment of the curricula and teaching. OIA will also support the subsequent evaluation.