EDUCATIONAL PROPOSAL

This proposal calls for creation of a "Video Web" to support student learning and is aimed at addressing the critical issue of preparation diversity in our upper-division chemistry laboratories. The proposed Video Web will be shared publicly on YouTube and will be available as a resource for other institutions and individuals.

Department Educational Issues and Priorities:

Development of new upper-division chemistry courses is underway at Saint Mary's College due to a contemporary redesign of the chemistry curriculum. In a strategic five-year plan, which will begin in Fall 2015, the department is adjusting its chemistry curriculum to deliberately provide students opportunity to apply disciplinary training to open-ended interdisciplinary projects. This change has been motivated by recent recommendations from the American Chemical Society that "graduates should be provided with an integrative experience that requires them to synthesize the knowledge and skills introduced across the curriculum" [44] as well as suggestion from the National Research Council that future careers in science, engineering, technology and mathematics (STEM) will require professionals who can apply their specific training to interdisciplinary problems.[45]

In Fall 2015, our curriculum change will begin with development of interdisciplinary classroom courses and a move from discipline-specific advanced laboratory courses (Analytical, Physical, Inorganic and Biological Chemistry) to a two-semester sequence of interdisciplinary project-based "**Pro-Labs**" in the students' junior or senior year. The name "Pro-Labs" comes both from the *pro*ject-based nature of the labs and from the expectation that students will apply their previous classroom and research experience to work collaboratively as science *pro*fessionals in these courses. In developing the Pro-Labs, recommended precautions[46, 47] are being taken to maximize desired outcomes while avoiding reported pitfalls of project-based integrated laboratories.

As courses are developed for this new curriculum, the faculty is collaborating to address fundamental principles of learning by adopting active-learning and technology-enhanced pedagogies.[48] As Saint Mary's College is a women's college with significant ethnic and socioeconomic diversity, the faculty are especially attuned to benefits of active-learning pedagogies for increasing performance of traditionally underrepresented groups in the STEM classroom.[49-51] Technology can further increase student learning by providing immediate feedback during problem solving and by helping students to visualize concepts, test models with simulated data, and connect concepts to real-world problems.[52] Strategic use of technology can provide additional benefits including customized student learning experiences.[53, 54]

My part in this curriculum transformation is to develop a new interdisciplinary course, Bioinorganic Chemistry and Materials (CHEM 342), and to develop an interdisciplinary research-based laboratory project as a part of the Pro-Lab sequence. I also propose to solve a pressing issue inherent to our new curriculum, stated below, by developing video tools to support customized student learning experiences, help students integrate disciplinary concepts into Pro-Lab experiences, and to empower students in Pro-Lab courses to *pro*actively take control of their education.

The Issue: Although the new chemistry curriculum will offer the benefits expected from interdisciplinary courses and from integrated project-based laboratories,[46, 47, 55] it will also increase the academic diversity of the student audience in each of the Pro-Lab courses. In the new curriculum, students may enroll in the two-semester Pro-Lab sequence either during their junior or senior year, and each student will take a different sequence and number of foundational and advanced courses prior to their Pro-Lab experience. **Saint Mary's College now has an issue of audience diversity in advanced lab courses; students enrolled in the Pro-Labs will have diverse preparation and experience with discipline-specific concepts.** Without a creative solution, bringing all students up to speed could take significant faculty resources, decrease the hands-on time in the laboratory, and may decrease the chances of the program's ultimate success.

Proposed Solution and Plan of Approach:

This proposal calls for creation of a "Video Web" to enable student self-preparation for Pro-Labs and to help students to integrate knowledge between classroom and laboratory experiences. I propose to create a series of "Pro-Lab Videos" to introduce each project-based laboratory sequence, as well as a multi-level series of "Concept Videos" that will introduce fundamental concepts related to each laboratory sequence. Pro-Lab Videos will be linked to Concept Videos using the YouTube Annotations feature to create a publicly available Video Web.

These Concept Videos will also support classroom courses. Concept Videos will cover both foundational and advanced concepts and will be linked to each other to help students advance from foundational concepts to more advanced concepts. In this way, the videos will serve as a resource for learning and as a map for integrating discipline-specific concepts into interdisciplinary laboratory experiences.

In preparation for laboratory, students will be asked to complete a problem set and will watch Pro-Lab Videos. Students will decide which linked Concept Videos to watch based on their previous experience and confidence with each concept (see illustration in Fig. 4). The students will be able to follow their interests and to fill in knowledge gaps by clicking on appropriate links provided in a "just in time" approach. For example, if a student is preparing for Pro-Lab and has not taken biochemistry, she may not be familiar with concepts necessary to solve problems about the roles of metal ions in biology. When prompted, the student might click on the *Protein-Metal Interactions* video, which will prompt her to watch the *Levels of Protein Structure* and *Structural Metals* videos. When she is able to answer the questions in the problem set, she will have reinforced concepts that will facilitate engagement in the laboratory. A similar strategy has recently been successful for increasing student performance and student perceptions of course support in my General, Organic, and Biochemistry course (CHEM 118). Although the audience in CHEM 118 is different than that of the Pro-Lab courses, online Video Webs address the common issue of preparation diversity and empower students to take control of their education.

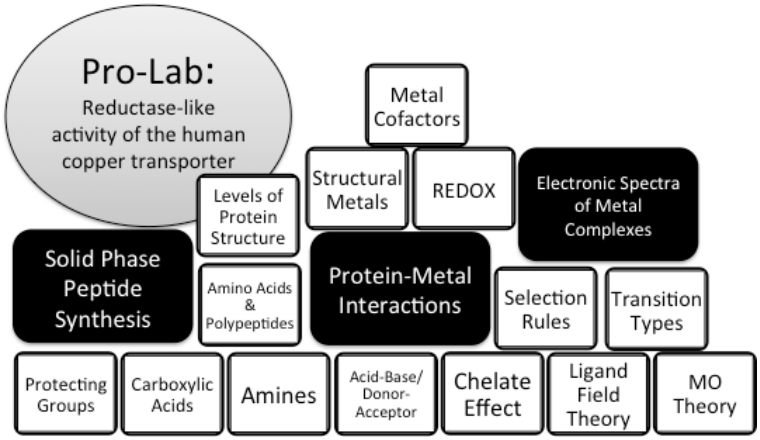

Figure 4. Visual illustration of a selected example of the Video Web. Each Pro-Lab Video (grey oval) is supported by several Concept Videos (rectangles). Concept videos will cover foundational (white rectangles) and advanced (black rectangles) concepts to introduce students to concepts and to help them recall previous experience with concepts.

Plan for Video Development and Implementation:

In the context of the Video Web, the first year of the Pro-Lab sequence (2015-'16) will be an information-gathering stage. As Pro-Lab courses are introduced in this first year, critical concepts will be identified and prioritized through regular feedback from students and faculty in the form of online surveys. Production and implementation of Pro-Lab videos and high-priority Concept Videos will begin in 2016-'17. Videos will be produced using equipment and software available at Saint Mary's College. Selected videos will be produced using the Lightboard at the University of Notre Dame, although Lightboard technology is not essential to this plan. Assessment results will be used to guide optimization of existing videos, production of new videos, and expansion of the Video Web over the next two years (2017-'18, 2018-'19). Concept Videos will be available to students and instructors for support of classroom courses and a strong effort will be made to produce concise videos that are less than eight minutes in length. We expect that the Pro-Lab Videos will be updated regularly and revised to complement current topics in the Pro-Lab Courses. Well-designed Concept Videos will endure over time, but new videos will be added to the public library and revised as necessary.

This plan will solve a critical issue at Saint Mary's College, stated above, and will help students to integrate knowledge between lecture courses and their Pro-Lab experience. A long-term goal of this plan is to expand the Pro-Lab Video Web and to link it to other videos and "webs" already being created by the PI and other STEM faculty at Saint Mary's College and at other institutions. This web will allow students to integrate knowledge between chemistry courses (short-term goal) and between STEM disciplines (long-term goal). In addition, this strategy will allow faculty to link their videos and guide students to trusted outside resources.

My experience in creating educational videos and my interdisciplinary training will facilitate development of a broad range of Concept Videos to support the Pro-Lab courses. I have already created a "web" similar to that proposed here that has received over 2,000 views on YouTube in the last year.[56] These videos are effective pedagogical tools and are valued by students according to institutional student surveys. For concepts outside of my range of expertise, local experts at Saint Mary's College and the University of Notre Dame will serve as consultants to ensure high fidelity of information propagated by the proposed Video Web.

Synergistic Educational Activities:

The courses below employ active-learning pedagogies and video tools that I have developed over the past three years. Over 80 educational videos are available on my YouTube channel, which over the last one year has received over 2,000 views and over 15,000 minutes watched.[56]

Advanced Inorganic Chemistry, CHEM 431: I have developed this course for advanced chemistry majors using a flipped-classroom model. This course covers fundamental concepts including periodic trends, symmetry and group theory, molecular orbital theory, and crystal field theory. These concepts are applied to understand absorbance spectroscopies, vibrational spectroscopies, properties and reactivity of inorganic complexes. The course culminates in a capstone project where students explore and present frontier topics in inorganic chemistry research. The original videos created for this course are ~20-60 minutes long, thus are not ideal for the Video Web project. Shorter videos are preferable according to student surveys. However, the videos created for this course are publicly available on YouTube and on the Virtual Inorganic Pedagogical Electronic Resource (VIPeR): A Community for Teachers and Students of Inorganic Chemistry. My experience gained through this work will be applied to create more concise videos for implementation of the proposed Video Web.

General, Organic, and Biological Chemistry, CHEM 118: I have developed this course for freshman pre-health nursing majors. This course covers fundamental concepts of atomic structure, bonding, functional group reactivity, structure and properties of biological molecules, cellular structure, and metabolism. The course is delivered using guided inquiry and group problem solving approaches. I have developed daily problem sets and short videos to support student learning in the lecture portion of this course. I have developed the laboratory portion of the course to engage students in a local collaborative research project between Saint Mary's College, led by Dr. Toni Barstis, and the University of Notre Dame, led by Dr. Marya Lieberman, on the development of Paper Analytic Devices (PADs) for detecting counterfeit drugs. Students use their knowledge of functional group chemistry to test prototype PADs for authenticating commonly counterfeited medicines. This activity advances the PADs research and engages students in real-world application of chemical concepts. Students responded positively to the laboratory and video components of this course on student evaluation of teaching surveys.

Bioinorganic Chemistry and Materials, CHEM 342: I am developing an interdisciplinary course on Bioinorganic Chemistry and Materials, which will cover fundamental concepts in coordination chemistry, biochemistry, and spectroscopy. Students will apply these concepts to explore the roles of metals ions in biological systems and will analyze how chemists use knowledge of complicated biological systems to engineer new materials. CHEM 342 will be offered for the first time in Fall 2015, and will be supported with short, online videos and in-class group problem solving. Videos created for this course will also support the Pro-Lab Courses as Concept Videos in the proposed Video Web.

Pro-Lab, CHEM 361 & CHEM 362: This is a two-semester project-based, upper-division integrated laboratory sequence. I have collaborated with the faculty to develop a strategic plan for implementing this course, its structure and policies. I am developing one six-week project sequence based on the proposed research project (above) on characterizing the reductase-like activity of Ctr1 and Histatin 5 model peptides, and an additional four-week experiment that will integrate research on peptide-functionalized gold nanoparticles from the Schultz Lab at the University of Notre Dame.

Education outside the classroom: As a mentor, I have been effective in encouraging women to pursue further study in chemistry through providing undergraduate research opportunities in my lab and through collaborations with researchers at other institutions. I seek out students early in their career in order to provide in-depth multi-semester research experiences in my lab and cater to student interests through collaborative opportunities with excellent mentors at other institutions. Over three years at Saint Mary's College, I have mentored five students in undergraduate research. Three of these students have graduated. Of two 2015 graduates, one has received an Orr Fellowship, and the other has received an NSF Graduate Research Fellowship and is pursuing her Ph.D. in chemistry at Dartmouth College. A 2013 graduate is pursuing a Ph.D. in chemistry at Purdue University and is a co-author on a recent submission to *Journal of Inorganic Biochemistry*. Of the two current students, one is a rising junior and is co-author on our recent article in *Inorganic Chemistry*. A rising senior researcher is preparing a draft for a future fellowship application and will present her work at the upcoming Bioinorganic Chemistry Gordon Research Seminar.

ASSESSMENT PLAN.

The effectiveness of video tools and learning outcomes of this new curriculum will be assessed using several surveys and the YouTube Analytics feature. In addition to our institutional student evaluations, we will use two established external survey tools. Assessment of the Pro-Lab courses will begin in Fall of 2015 using the Student Assessment of Learning Gains (SALG)[57] online survey, and the Classroom Undergraduate Research Experiences (CURE)[58] online survey tools. These online survey tools will be offered to students before and after each Pro-Lab course in order to assess learning gains, integration of discipline-specific knowledge, student confidence in research-type projects and student perceptions of the laboratory experiments in each semester. Our faculty will evaluate the results of the SALG survey and Dr. David Lopatto, creator of CURE and Professor of Psychology at Grinnell College, will analyze the CURE survey results externally. Results of CURE and SALG will be shared with all members of the Chemistry and Physics department at Saint Mary's College. Results of these surveys will inform design of subsequent versions of the Pro-Lab, the Video Web, and supporting courses.

Online learning materials produced for the Video Web are expected to facilitate student preparation for and active learning in Pro-Lab courses. Video tool assessment will be built into the SALG survey as part of classroom and laboratory courses. Results from institutional course evaluation and from YouTube Analytics features will provide further internal and external assessment. In addition, instructors will be surveyed to assess faculty perceptions of video tool effectiveness in facilitating classroom and laboratory learning. These assessment tools will inform development and design of future videos or alternative pedagogical methods.

The Video Web produced through this work will be publicly available on YouTube and will also be disseminated through VIPeR and the National Science Digital Library. The Video Web pedagogy and assessment of our integrated curriculum will be disseminated through conferences and peer-reviewed chemical education literature. I aim to present results of the Video Web project at the Biennial Conference on Chemical Education (BCCE) in 2018, which will be held conveniently at the University of Notre Dame. The BCCE is a biennial meeting of educators in chemistry and is an ideal venue for sharing and receiving external assessment of this new methodology. Results from the Video Web assessment will also be disseminated through education journals, such as the *Journal of Chemical Education*, *The Chemical Educator*, or the *Council on Undergraduate Research (CUR) Quarterly*.

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.

Toni Barstis, Professor of Chemistry, Department of Chemistry & Physics,
Saint Mary's College, 168 Science Hall, Notre Dame, IN 46556; tbarstis@saintmarys.edu.
Collaborator in development of Pro-Lab courses and consultant for Concept Videos on Physical Chemistry.

Chris Dunlap, Associate Professor and Chair of Chemistry, Department of Chemistry & Physics,
Saint Mary's College, 178 Science Hall, Notre Dame, IN 46556; cdunlap@saintmarys.edu.
Collaborator in development of Pro-Lab courses and consultant for Concept Videos on Analytical Chemistry.

Jennifer Fishovitz, Assistant Professor of Chemistry, Department of Chemistry & Physics,
Saint Mary's College, 162 Science Hall, Notre Dame, IN 46556; jfishovitz@saintmarys.edu.
Collaborator in development of Pro-Lab courses and consultant for Concept Videos on Biological Chemistry.

James Parise, Associate Teaching Professor of Chemistry, Department of Chemistry & Biochemistry,
University of Notre Dame, 416 Jordan Hall, Notre Dame, IN 46656; james.parise@nd.edu.
Will provide access to Lightboard technology at University of Notre Dame for creating selected Concept & Pro-Lab Videos. Dr. Parise is currently creating videos for his organic chemistry course that may be incorporated into the proposed Video Web.

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