Integration of Instrumentation & Technology-Based Instructional Materials Into Targeted Chemistry Curriculum

Sabbatical Project Report

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ACKNOWLEDGEMENTS

I wish to acknowledge the invaluable support that my faculty colleagues provided during my 2019-2020 “sabbatical leave”. First and foremost, I greatly appreciate the college administration and the Salary and Leave Committee for granting me the opportunity to produce this sabbatical product that expands and improves our Chemical Laboratory curriculum. I thoroughly enjoy working at an institution that is strongly committed to academic excellence and fully supported professional faculty development.

The new laboratory manual developed through this sabbatical project required effort and expertise from many incredibly supportive people. First of all, I would like to express my appreciation for my retired colleague and dear friend, Professor Eileen DiMauro. She allowed me permission to work on and develop a number of challenging experiments included in her previously authored CHEM 20 laboratory manual. I am indebted to Dr. Ginevra Clark at the University of Illinois, Chicago, who allowed me to adapt several of her experimental activities and to include these into our curriculum. Three of these experiments: Distillation of Organic Liquids, Dialysis of Dyes in the Presence of Albumin, and Aspirin and Oil of Wintergreen Syntheses and Properties were adapted from her published work in the *Journal of Chemical Education*. I am also grateful to my colleague, Professor Dhaval Doshi, for the insightful editing of the drafts of all of the experiments.

Finally, I greatly appreciate the unwavering support from Matt Judd, Dean of the Natural Sciences Division, during my sabbatical leave. His encouragement, along with the support from my Department colleagues, made this project an example of the shared commitment of providing a quality instruction to our students. To all of my colleagues in the Chemistry Department, I sincerely appreciate your support and it is a pleasure and an honor to work with all of you.

ABSTARTCT

Rapid advances in technology coupled with developments in new and innovative pedagogies demand continuing upgrading of curriculum and changing the way we teach. Twenty-first Century learning puts the emphasis on the students' roles as *active discoverers* who take ownership of their experiences by dealing with situations that require something other than a memorized response. As educators, we have to respond to this emphasis in order to properly prepare and train our students to have the necessary skills to meet the demands of the 21^{st} Century job market. The central goal of this sabbatical project is to further enrich the student learning experience in the Chemistry Department by creating an improved learning environment that encourages the students to be creative, active learners and collaborators. This will further develop critical thinking, reasoning and communication skills. To accomplish this goal, the project proposes an original approach to research, develop and produce quality classroom instructional materials that: i) are instrumentation and technology-based, ii) are discovery-based and collaborative in nature, and, iii) expand, enhance and strengthen the laboratory curriculum in the Chemistry Department.

STATEMENT OF PURPOSE

Over the past years, as a result of several individual and collaborative efforts from many dedicated faculty, the Chemistry Department has been extremely successful in securing external funding from the National Science Foundation (NSF) for several educational projects. The funds from these projects have been utilized to provide a high-quality instructional program to our students to enhance their learning experiences through the utilization of the latest technology, instrumentation and innovative pedagogical approaches in instruction. Some of the changes made in our curriculum were also the direct beneficial results of past sabbatical projects, such as *incorporating molecular modeling computations* in our laboratory curriculum (my first sabbatical project) and converting the entire organic chemistry lab curriculum to *green chemistry* (my second sabbatical project). The purpose of this sabbatical project is to build upon these strong foundations to develop additional instrumentation and technology-based instructional materials to expand, enhance and strengthen the laboratory curriculum in the Chemistry Department.

Three distinct objectives form the foundation of this project. Briefly, they are:

1. To complement, enhance and upgrade the laboratory curriculum of our CHEM 20 Course, Introductory Organic and Biochemistry taken primarily by nursing majors, to include improved and safer experiments plus develop and incorporate computational modeling experiments in place of molecular-kit modeling activities.

2. To expand the use of our state-of-the-art instrumentation, the Nuclear Magnetic Resonance (NMR) and the Infrared spectrometers (IR), in the CHEM 20 laboratory. Additionally, introduce green chemistry concepts such as the principles of green chemistry and identification of waste and hazard reduction into the curriculum.

3. To develop few integrated lecture/lab, computation - instrumentation based learning modules that bridge general and organic chemistry in order to provide students with the fundamental knowledge needed to successfully begin and succeed in organic chemistry.

OVERALL APPROACH

In the original proposal, I had envisioned that the myriad of activities I proposed to achieve the project's objectives to be carried out over three phases:

Phase I: Research and Investigation

Phase II: Compilation and Development of Activities/Experiments

Phase III: Conducting Experiments and Writing Protocols/Modules

I proposed to work mostly on the Phase I and II activities that were related to the first two objectives (CHEM 20) in the fall semester and leave most of the work on Phase III plus completing activities for the third objective for the spring semester. In reality, once the sabbatical project began, it was very difficult to follow such an exact schedule. As it happened often, the right timing for some project activities occurred earlier or later than what was originally planned and thus those activities were carried out either earlier or later than originally proposed. The COVID-19 pandemic situation and closing of Mt. SAC also made a big impact on the conduct and timing of a number of the activities proposed in the original proposal. The situation limited adequate consultation and communication with colleagues, prevented testing/vetting of the new and/or modified modeling and wet experiments with actual students enrolled in courses in spring semester and foiled conference attendance and workshops to enable gathering of additional ideas for experiments and projects. Regardless of that, I am extremely satisfied with the successful completion of my proposed sabbatical project during these unprecedented times and I take great pride in the product I have produced. I am confident that the new laboratory materials developed through this project would enhance and strengthen our curriculum and would enrich the student learning experience in chemistry through integration of discovery learning, molecular modeling and advanced instrumentation into the lab curriculum. The rest of this report provides a somewhat chronological but brief explanation of activities undertaken to achieve each of the projects' individual objectives. And, the "**Project Product"** submitted with this report include the newly developed lab activities, experiments and modules, together representing the culmination of this year-long sabbatical endeavor.

SABBATICAL PROJECT ACTIVITIES

I. Research and Investigation

A significant amount of time early on during the sabbatical project was devoted to a comprehensive research of online publications, contacting colleagues at other institutions, examining resources collected from attending different conferences and workshops in the past and reading the *Journal of Chemical Education (JCE)*, which is the official journal of the Division of Chemical Education of the American Chemical Society (ACS). In chemical education community, JCE is regarded as the premier chemical education journal as it publishes topics in all areas of chemistry education such as computation, modeling, laboratory experiments, instructional methods and different pedagogies. In searching for appropriate lab activities, particular attention was paid on ways to introduce "discovery-based" learning, technology and green chemistry into the curriculum, and also look, in particular, for biochemistry lab activities that utilize the collection of instruments and software the department has such as Spartan Molecular Modeling, Nuclear Magnetic Resonance (NMR) and Infrared (IR) instrumentation. An additional focus of the search was to find ways to enrich the curriculum with those *concepts related to healthcare,* in a chemistry course for pre-nursing students. All the experiments in the current CHEM 20 lab curriculum were also thoroughly evaluated to consider which ones can be modified and what new experiments need to be developed.

II. The New Curriculum

A. CHEM 20 Laboratory (Objectives 1 & 2)

The laboratory curriculum of our CHEM 20 course consists of two types of lab activities; modeling activities (dry labs – 2 hours per week) and wet lab experiments (4 hours per week). Following the thorough research investigation as stated above, and in consultation with my colleagues who regularly teach the same course, the following "*Modeling Lab Activities*" were developed:

1. Introduction to Spartan
2. Lewis Structures
3. Intermolecular Forces (Reading Assignment)

4. The Structure and Nomenclature of Hydrocarbons
5. Polarity and Polar Organic Compounds
6. Organic Compounds and Hydrogen Bonding
7. Structures and Reactions of Alcohols
8. Addition to a Carbonyl Group
9. Amines
10. Structure of Carbohydrates
11. Structure of Proteins
12. Structure of Lipids
13. Nucleic Acids
14. Replication, Gene Expression and Protein Synthesis

And, following a careful evaluation of all the experiments in the current CHEM 20 lab curriculum, the following new and/or modified lab experiments were developed:

1. Polarity
2. Organic Laboratory Techniques - IR
3. Properties of Hydrocarbons - NMR
4. Identification of an Unknown Hydrocarbon
5. Properties of Oxygen-Containing Compounds
6. Identification of an Unknown Oxygen-Containing Compound
7. Distillation
8. Properties of Esters
9. Extraction and Separation of Plant Pigments
10. Reactions of Carbohydrates

11. Saponification Reaction

12. Properties of the Enzyme Catalase

13. Dialysis of Dyes – Drug Absorption

14. Aspirin and Oil of Wintergreen

The following appendices (to the new lab manual) describing the procedures for operating and making measurements using the simple instrumentation used in the experiments, and one on introducing the *green chemistry* principles were also prepared.

1. Melting Point
2. Boiling Point
3. Refractive Index
4. Introduction to Green Chemistry

Drafts of all these experiments were reviewed by my colleague, Professor Dhaval Doshi, who regularly teaches the same course and his insightful editing were incorporated into the final drafts of all of the experiments included in the final product.

B. CHEM 20 Lecture (Objectives 1 & 2)

A significant portion of my time on research was also devoted to investigating ways to increase the use of technology in the lecture portion of the course. Along the way I became familiar with ***Chem 101*** platform. From some preliminary reading and research I became interested in this program and subsequently participated in a few zoom workshops offered by its publisher to learn more about different ways that chemistry faculty at other institutions use it in their courses. It soon became evident that Chem 101 has quickly grown in popularity in chemistry education community and is now adopted by faculty at over 250 two-year and major four-year institutions such as UC Irvine, Carnegie Melon University and Columbia University to name a few. The program's approach focuses on discipline-specific interactive assessment tools, such as molecular structure drawing, Lewis structure, writing chemical reactions and practicing organic nomenclature that triumph over traditional generic multiple choice tools. As such Chem 101 has shown to promote student engagement and improving student outcomes. The program has an extensive question library with over 5000 questions to assign homework, in-class activity and quizzes in a synchronous or asynchronous manner. Every Chem101 question contains targeted instructional feedback that provides students with helpful hints when they submit incorrect answers. When students run out of attempts, they are presented with a step-by-step detailed solution that fully explains how to solve the problem. Chem101's authoring tool also allows the instructor to easily write, save, and assign his/her own questions with targeted instructional feedback. For in-class assignments, instructors receive results in real time as students submit answers. The three most common mistakes are provided for each problem so that the instructor get feedback on levels of student understanding and easily launch into class discussions. Students and instructors can access the Chem101 app from any iPhone, iPad, or Android Device. Additionally, the platform is fully accessible with any Mac, PC, or Chromebook. All these key features make Chem 101 an excellent choice to utilize in our CHEM 20 course.

C. Integrated Lec-Lab Modules (Objectives 3)

The third distinct objective of this sabbatical project was to reinforce fundamental *concepts* and *tools* that build a solid foundation for success in organic chemistry. The approach proposed for achieving this goal in the original proposal was to develop few integrated lecture/lab, computation - instrumentation based learning modules that bridge general and organic chemistry in order to provide students enrolled in general chemistry (CHEM 50 & 51) with the fundamental knowledge needed to successfully begin and succeed in organic chemistry.

As discussed in the original proposal, the so-called "*structure-reactivity*" relationship is fundamental to the learning of organic chemistry. Yet, it is shown that majority of students move through general chemistry without acquiring sufficient critical reasoning skills or a deep understanding of this highly abstract and other related foundational concepts. Studies have shown that lack of retention of structure-reactivity related concepts such as electron density, resonance, and electron distribution in molecules and molecular polarity (which are covered in general chemistry and are key for success in organic) has caused many students (including ours) to struggle and drop out. The difficulty toward comprehending these abstract concepts lies in students' ability to "*visualize*" them in the "*3-dimensional microscopic*" world of atoms and molecules. In recent years, however, the availability of fast, low-priced computers equipped with student-friendly modeling software such as *Spartan* has provided a creative way to carry out exciting "*Molecular Modeling*" experiments to reinforce student understanding of bonding concepts and help them visualize these concepts that are so important, particularly, in organic chemistry.

Modern instrumentation such as IR and NMR, and molecular modeling computational activities are foundational to understanding these "organic structure and reactivity" concepts and are routinely used in organic labs, yet many general chemistry students do not have access to this modern instrumentation. To succeed in organic chemistry, students must acquire working skills with the above instrumentation and learn to do/interpret molecular modeling now routinely used in organic labs as an integral part the curriculum. Availability of this modern instrumentation at Mt. SAC, coupled with this sabbatical project provided the opportunity to develop the following four integrated lecture-laboratory modules for adoption into our general chemistry curriculum:

1. Molecular Structure & Resonance
2. Molecular Orbital Theory and Molecular Orbitals
3. Introduction to Infrared (IR) Spectroscopy
4. Introduction to ^{13}Carbon-NMR and DEPT Spectroscopy

The content of the four modules were developed based on the collective experiences of the faculty who regularly teach organic chemistry. The first two modules are appropriate for adoption in our first semester general chemistry lab curriculum (CHEM 50) and the last two for adoption in our second semester general chemistry lab curriculum (CHEM 51).

III. Key Features of the New Curriculum

In the original proposal, I had proposed to upgrade the laboratory curriculum of our CHEM 20 Course to include improved and safer experiments, use technology such as molecular modeling and state-of-the-art instrumentation NMR and IR, introduce green chemistry concepts such as the principles of green chemistry and identification of waste and hazard reduction and, to the extent possible, relate the new materials to healthcare. Additionally, I had proposed to develop few integrated lecture/lab, computation - instrumentation based learning modules that bridge general and organic chemistry in order to provide students with the fundamental knowledge needed to successfully begin and succeed in organic chemistry. I believe I have successfully achieved all of the objectives. The listing of the new lab experiments and modules developed through this project are included on pages 7-10 of this report and the activities are all included in the "Project Product" submitted with this report. What follows is brief discussion of the ways that the proposed key features are incorporated into these lab activities.

i. Technology

Technology is introduced in different forms in the upgraded curriculum. For example, the first nine computational modeling lab activities use the modeling program, Spartan. Student build and optimize many molecules and manipulate the output files to measure characteristic features of the molecule such as bond length, bond angle, display electron density surfaces, polarity, molecular orbitals, etc. None of these investigations would have been possible with the molecular-kit activities currently used in the laboratory. Integration of Chem 101 platform also provides CHEM 20 students with the opportunity to use technology more at home or in lecture. The first two modules developed for CHEM 50 will also provide students enrolled in general chemistry with hands-on experience using molecular modeling Spartan.

ii. Instrumentation

Beyond Spartan, students in CHEM 20 will get hands-on experience with advanced instrumentation, NMR and IR. They will learn about and use this instrumentation for the first time in few lab experiments to determine structure of simple organic compounds. Students in CHEM 51 will also get to work with modern NMR and IR instrumentation as the last two modules developed for bridging the general chemistry and organic chemistry utilize these instruments.

iii. Discovery-Based Learning

The primary goal of discovery-based learning and/or guided-inquiry learning is to remove the traditional recipe style procedure and allow the students to take ownership of the experiment they are to do. The role of the professor is to provide guidance and the necessary resources to help students develop their own lab activity protocols. The purpose of this approach is to foster experimental problem solving skills, develop critical thinking skills and encourage collaboration by utilizing a tailored problem-based learning approach. The newly developed modeling lab activities (first 9) in CHEM 20 are all designed to be discovery-based and worked on as a group so that students can share ideas and discuss computational results. The concepts discussed in the four general chemistry modules closely relate to "structure-reactivity" relationship and these modules are also designed to be discovery-based and collaborative in nature. Although students are asked what molecules to build and optimize, most of the questions included in those activities require students to apply what they have learned in the previous activities and think about what else they need to do in order to answer the questions. Through performing the new NMR and IR experiments, students will also hone their critical thinking and problem-solving skills as well. Numerous published studies suggest that *early* introduction of NMR in curriculum offers pedagogical advantages and also help students develop reasoning and critical thinking skills.

iv. Green Chemistry (GC)

Application of green chemistry into the CHEM 20 laboratory curriculum was approached from several fronts. First, combustion test of organic compounds done in a few of the current experiments was replaced by carbon and DEPT NMR in those experiments. Students used combustion, a simple observation of the flame characteristics like color, smoke and amount of soot produced to get an idea about the nature and possibly the size of the organic molecule being tested but this test was often inconclusive. The advantage of switching to NMR is positive on many levels. Firstly, there is no combustion smoke and soot product and the experiment is safer. Secondly, more accurate data is produced and students get the opportunity to work with an advanced instrument. Thirdly, MRI is the same technique as NMR. Since CHEM 20 serves students who will be future nurses, radiologists and other health professionals, this introduction would help students better relate what they learn in the lab to what they will be doing in the future and encourages deeper understanding and comprehension of the concept.

Second, changes were made to the procedures of few of the experiments, when possible, to use much smaller quantities of chemicals, thus, "*greening*" the experiments. For example, in the new Aspirin and Oil of Wintergreen experiment only half as much chemicals are used, the heating period is much shorter than in the current experiment and naturally less chemical waste is produced. This type changes open the door to introduce students to the "twelve principles of green chemistry".

Third, to further apply the green chemistry concepts in a proper way into the lab curriculum, it became necessary to write a short introductory document that covers the green concepts, the twelve principles of GC and the green terminology that students can quickly refer to when needed (included as an appendix in the new lab manual). The American Chemical Society (ACS) has a publication that includes "Industrial Case Studies in Green Chemistry". Each article in the publication deals with an industrial research case dealing with green chemistry and it demonstrate how green chemistry has played a role in the research conducted. The articles are suitable for integration in lower-level chemistry courses to introduce the role that GC plays in chemical research. As an example, the old method of industrial *ibuprofen* synthesis that includes 12 steps and the new green method of the synthesis that consists of only 4 steps, and thus resulting in far less waste being produced is included as a case in the publication. This case relates well with healthcare being the focus of CHEM 20. Cases like ibuprofen synthesis and similar ones found at other sites like the Environmental Protection Agency (EPA) make them excellent assignments to use for "lab final", student group-research activities to further introduce the GC principles in the curriculum. It is my plan to incorporate a few of these cases in this fashion in our CHEM 20 lab curriculum.

v. Relationship to Healthcare

I have been teaching CHEM 20 course for the past three years. As I was carefully evaluating all the experiments in the current curriculum keeping in mind that the course serves students who will be future nurses, radiologists and other health professionals, it became obvious to me that although present sporadically at different places, most of the experiments either do not adequately relate to healthcare or the relationship is not clear in the experiment. For example, although "intermolecular forces, IMFs", play a major role in determining the physical state and properties of organic compounds and in biology to maintain the 3-D structure of all proteins, the function of all cells and cellular membranes and holding nucleotide bases together in nucleic acids, DNA and RNA as discussed in the lecture portion of the course, they were not adequately addressed in laboratory. As for another example, although we have an experiment to synthesize and characterize aspirin in the current lab curriculum, the mechanism by which aspirin is absorbed and digested in body is not part of the current experiment and students fail to see the biochemical connection between the experimental results and the way drug is absorbed and functions in body. Acid-base concept plays a major role toward this function but it is not discussed in the course.

To address this deficiency in the laboratory curriculum, a number of activities was undertaken and new lab materials were created for this purpose. The following objectives were achieved as the result of these activities embarked on during the course of this sabbatical project.

- A short handout briefly describing the three major types of intermolecular forces and their significance in chemistry and biology (please see the Project Product/Modeling Activities/pages 10-12).
- The new modeling labs developed using Spartan all include questions asking students to relate the computational results to the physical properties of the compounds being investigated.
- A new laboratory experiment, titled "Distillation: Separation and Purification of Organic Liquids, Exp. 7 in the manual", was adapted from the *Journal of Chemical*

Education. In this experiment, students obtain experimental data on the relationship between the physical properties (boiling point) of a compound and the strength of its intermolecular forces. No such experiment exists in our current CHEM 20 laboratory curriculum.

- A new laboratory experiment, titled "Dialysis of Dyes in the Presence of Albumin" Exp. 13 in the manual", was adapted from the *Journal of Chemical Education.* In this experiment, students investigate drug distribution and mechanism of drug action in body.
- The old "Aspirin Synthesis" experiment was replaced with the new "Aspirin and Oil of Wintergreen" experiment, again adapted from the *Journal of Chemical Education.* The new experiment is safer and greener as it uses half as much chemicals thus reducing the chemical waste produced in the experiment. Like the current experiment, students synthesize and characterize aspirin but also will perform several additional tests to investigate the solubility of *aspirin* and *oil of wintergreen*, another closely structured product of salicylic acid, in aqueous and organic solutions at different pH values. Students will use the results of these tests to compare and contrast the solubility of aspirin and oil of wintergreen in biological fluids and learn how, in general, drugs that are taken orally pass from the digestive system to the blood stream.
- (*Uncompleted Task*) Another new experiment titled, "Urinalysis and Prenatal Health" was also in plan for adaption. This experiment had just been published in the *Journal of Chemical Education* in February 2020. The experiment was brought to my attention by the primary author of the article whom I had me at the Biennial Conference on Chemical Education (BCCE) held at the University of Notre Dame in 2018. In this experiment students in a health science filed like nursing conduct a number of simple experiments that demonstrate how organic functional groups that they study earlier in the course is relevant to nursing and to their vocational goals. Chemicals for testing this experiment had been ordered when the COVID-19 pandemic situation caused closing of the campus and left this task uncompleted. It is still my plan to test this experiment and potentially adapt it in our CHEM 20 lab curriculum when the campus reopens.

IMPLEMENTATION PLAN

The plan for implementing the new experiments into our CHEM 20 lab curriculum has somewhat changed due to the COVID-19 pandemic situation that caused closing of the campus. The initial plan was to vet the new modeling activities and the new experiments in spring 2020 semester in at least one of the two sections of CHEM 20 course and make changes needed, if any, based on the students' feedback. Mt. SAC closing ruled out this option. At the time of writing this report (July 2020), it is my plan to coordinate scheduling with my colleague, Professor Doshi who teaches the other section of the course, to implement as many of these new activities and experiment as possible in fall semester. The new modeling activities require students' remote access to Spartan that needs to be provided if students cannot be physically present at the campus. I will offer the four modules to my colleagues who teach CHEM 50 and 51 honor courses to consider adopting them as the first step of integrating them into our general chemistry curriculum.

CONCLUSIONS

Sabbatical Project Summary

I am extremely satisfied with the successful completion of my proposed sabbatical project, and deeply grateful to Mt. SAC for granting me this wonderful opportunity to work on this exciting project. I take great pride in successfully achieving all of the stated objectives for this project. I feel confident that the new activities and experiments developed through this sabbatical project will complement, enhance and strengthen our current curriculum by encouraging the students to be creative, become better learners and to develop critical thinking skills. Although I ran into some unexpected challenges due to the closing of the campus, each phase of the project was completed with massive effort and careful attention paid to every detail to accomplish its intended purpose and expected outcomes.

For phase I of the project, a significant amount of time was devoted to a comprehensive investigation of online publications, contacting colleagues at other institutions, examining resources collected from attending past conferences and workshops and searching the *Journal of Chemical Education* (JCE) for new ideas and potential activities for adoption into our curriculum. Particular attention was paid on ways to introduce "discovery-based" learning, technology and green chemistry into the curriculum, and for biochemistry lab activities that utilize advanced instruments and software our department has such as Spartan Molecular Modeling, Nuclear Magnetic Resonance (NMR) and Infrared (IR) instrumentation. The research also focused on finding ways to enrich the lab curriculum with those *concepts related to healthcare* in our CHEM 20 course that is taken by primarily pre-nursing students. The collective efforts and the knowledge attained from phase I served as the solid foundation for phase II and phase III of the project activities.

In phase II and phase III, all of the CHEM 20 experiments, both modeling activities and lab experiments, were carefully evaluated. Modifications were made to almost every experiment that was retained. The type of changes made includes adding new questions, changing the procedure to improve it, rewriting report pages for more clarity and adding additional text and descriptive images to the experimental write-ups to bring in the biochemical connection to the experiment, when possible. For example, the action of detergents in the "Saponification" experiment was compared to that of bile acids that are powerful "detergents" themselves and play an essential role in emulsifying dietary lipids. To the extent possible, discovery-based learning was also incorporated into the new activities and experiments. Changes were also made to a few of the experiments to make them greener and safer as well. Combustion test done in a few of the current experiments was replaced with NMR and IR implementation, resulting in safer experiments and students getting more accurate and reliable data. Several new experiments published in the JCE that relate the chemistry concepts discussed in the course to vocational careers of students in a health science field were tested and their procedures were rewritten in a format suitable for adaption into our new curriculum. Four modeling/instrumentation-based modules that bridge general chemistry and organic chemistry were also developed and are ready for adoption into our general chemistry curriculum. It is my hope that the collection of these new activities will enable the students to be creative, develop critical thinking skills and to be more responsible learners.

BENEFITS AND VALUE OF THE SABBATICAL PROJECT TO COLLEGE

Professional Growth and Enrichment

This sabbatical has been a very gratifying experience for me. As a lifetime educator, my professional goal and passion have always been to provide exceptional learning experiences to students and to contribute excellence to science education beyond just the classroom. This sabbatical project has provided a wonderful opportunity for me to delve into my passion. The project allowed me to expand my knowledge in the field of chemical education and enabled me to develop high quality technology and state-of-the-art instrumentation based instructional materials that would complement and strengthen our curriculum here at Mt. SAC. The change of pace from the responsibilities of everyday teaching to the flexibility demands of working on the projects' activities was refreshing, energizing and stimulating. I am returning back to the classroom excited and invigorated about the projects' outcomes and look forward to work with my colleagues to implement these new activities into our curriculum. It was truly a pure joy working on this project and the finished product satisfyingly exceeded my initial expectation and planning as discussed in my original proposal.

NSF Award: During the months of late November through mid-February while working on my sabbatical project, I also wrote and submitted a proposal to the National Science Foundation (NSF), titled " Preparing a Skilled Technical Workforce through Utilization and Assessment of Undergraduate Research". I am proud to report that the proposal was funded for the full requested amount of $953,432.

This funded project builds upon the evidence that early immersion in mentored experiential learning, such as an authentic undergraduate research experience, increases student persistence in STEM, completion of STEM certifications, and entry into the technical workforce. These research experiences are unfortunately very limited at many two-year college campuses and students at these institutions do not benefit from expanded opportunities to engage in such authentic research experiences. Working in collaboration with the University of California, Irvine (UCI), the project will provide authentic research experiences to a large number of Mt. SAC STEM students, four (4) annual cohorts with 20 students recruited in each cohort, to help strengthen their interest in STEM careers and gain professional skills that are critically important in the technical workplace. The selected students will each receive close to $ 5,000 research scholarship to engage in summer-long research in the laboratories of leading STEM researchers at UCI. Students enrolled in various AS Technology/technician programs at Mt. SAC are also eligible to apply. Although two-year college students have participated in undergraduate research in the past, this project is unique in its design in the way that it also plans to broadly assess the impact of these experiences from both the students and the mentors' perspectives, something that has not been done before. The technical resources and the services of an experienced leading researcher in undergraduate education at SUNY-Buffalo State will be used to evaluate and assess the impacts of the program. The abstract of this award is attached as an appendix to this report for further information. I am very excited about the NSF support of this project and anxiously look forward for Mt. SAC to reopen to start working on the project.

Benefits to the Department, Instructional Program and Students

The Chemistry Department provides a quality instructional program led by the dedicated faculty in the Department. Through the collective efforts of this faculty over many years, the Department has continuously enhanced the quality of education it offers to all students going through the chemistry program by utilizing the latest in technology innovations and pedagogy. Beyond the College's support, the Department's has a stellar record of success securing external funding from the NSF and other external funding agencies that have made it possible to develop and implement many of these quality instructional programs. This sabbatical project follows the Chemistry Department's commitment to excellence philosophy and directly benefits the Department by complementing and enhancing the current curriculum. The new activities and experiments developed through this sabbatical project expand the use of the Department' state-of-the-art instrumentation in the current curriculum. Through these experiments, the students will gain valuable hands-on instrumentation experience, get introduced to green chemistry, practice discovery learning and collaboration, and develop critical thinking skills. Collectively, these experiences will increase the students' level of preparation for pursuing and meeting their educational goals in life.

Benefits and Value to the College

The activities of this sabbatical project are directly correlated to and promote Mt. SAC's mission and vision statements:

- *"The mission of Mt. San Antonio College is to support all students in achieving their educational goals in an environment of academic excellence."* The central goal of this sabbatical project is to enrich the student learning experience in the Chemistry Department by creating an improved learning environment that promotes critical thinking skills and encourages the students to be creative, active learners and collaborators. The project has successfully produced quality classroom instructional materials that support this goal by providing the students with opportunities to practice these essential 21st century skills and be better prepared for their future careers (please see the "***Sabbatical Products***" submitted as separate PDF files with this report).

- *"Mt. San Antonio College strives to be regarded as one of the premier community colleges in the nation. We will be viewed as a leader in community college teaching, programs, and services."* The quality classroom instructional materials developed through this project are instrumentation-based, technology-based and discovery-based and are collaborative in nature. Successful implementation of these activities will expand, enhance and strengthen current lab curriculum and could also serve as a model for other community colleges to follow.

- *"As a premier community college, we will provide access to quality educational programs and services, focusing on student success within a climate of integrity and respect."* Although not planned in the original proposal, the timing flexibility during this sabbatical period provided an excellent opportunity to write and submit a proposal to the NSF that will directly benefit a large number of students enrolled in different STEM disciplines and various technology programs at Mt. SAC. The project will provide significant financial support to the students to engage in either authentic undergraduate research projects at UCI or take part in an industrial internship related to their vocational majors. These experiences will increase the students' level of preparation for transfer to four-year institutions and/or entering a technology career. Successful implementation and outcome of this project will undoubtedly strengthens Mt. SAC reputation as a premier community college in the nation dedicated to implementing innovative paradigms in education in an environment of academic excellence (please see the Professional Growth & Enrichment section and Appendix B for more information about this NSF-funded project).

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Integration of Instrumentation & Technology-Based Instructional Materials Into Targeted Chemistry Curriculum

Sabbatical Project Proposal

2019 – 2020

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Abstract

Rapid advances in technology coupled with developments in new and innovative pedagogies demand continuing upgrading of curriculum and changing the way we teach. Twenty-first Century learning puts the emphasis on the students' roles as *active discoverers* who take ownership of their experiences by dealing with situations that require something other than a memorized response. As educators, we have to respond to this emphasis in order to properly prepare and train our students to have the necessary skills to meet the demands of the 21st Century job market. The central goal of this sabbatical project is to further enrich the student learning experience in the Chemistry Department by creating an improved learning environment that encourages the students to be creative, active learners and collaborators. This will further develop critical thinking, reasoning and communication skills. To accomplish this goal, the project proposes an original approach to research, develop and produce quality classroom instructional materials that: i) are instrumentation and technology-based, ii) are discovery-based and collaborative in nature, and, iii) expand, enhance and strengthen the laboratory curriculum in the Chemistry Department.

Introduction

According to the President's Council of Advisors on Science and Technology (PCAST) report, economic forecasts over the next decade point to a need for approximately one million additional STEM college graduates.[1] To address this need, a report titled "Discipline-Based Education Research, (DBER) Understanding and Improving Learning in Undergraduate Science and Engineering", recommends multiple possible approaches to meet this challenge.[2] These recommendations state that STEM student's need to: i) master a few major concepts well, and in-depth, ii) retain what is learned over the long term, iii) build a mental framework that serves as a foundation for future learning and, iv) develop visualization competence, including the ability to critique, reason, interpret, construct, and connect with physical systems. For improved comprehension, with the stated areas, DBER recommends involving students in *collaborative learning* activities. This can be accomplished by utilizing some existing performance proven student-centered instructional techniques. Many of these types of teaching techniques utilize *transformed courses* (i.e., courses in which instructors use student-centered approaches) that incorporate in class activities where students collaborate with each other through the utilization of either guided inquiry workbooks or open-ended problems. Several studies has demonstrated that student understanding has increased as a result of utilizing these techniques.[3-5]

With the rapid advances in technology in this Information Age and in alignment with the DBER report, it is inevitable that both our curriculum and how we teach have to change in order to properly prepare and train our students to have the necessary skills of the 21st century job market. One thing that defines 21st Century learning is the emphasis on the students' roles as *active discoverers* who take ownership of their experiences by dealing with situations that require something other than a memorized response.[6] Education reformers and proponents of 21st Century learning refer to the need to shift away from 3Rs - *reading*, *writing* and *arithmetic* - to developing skills in the 4Cs: *Creativity*, *Creative Thinking*, *Collaboration* and *Communication.* While the 3Rs emphasize repetition, memorization, and recall, the 4Cs focus on strengthening a student's ability to evaluate information and to combine that information with imagination and ingenuity to create something new and innovative.

Over the past years, as a result of several individual and collaborative efforts from many dedicated faculty, the Chemistry Department has been successful in securing external funding from the National Science Foundation (NSF) for several projects. The funds have been used to provide a high-quality instructional program to our students to enhance their learning experience in both lecture and laboratory settings through the utilization of the latest technology, instrumentation and innovative pedagogical approaches in instruction. Some of these changes were the direct beneficial results of past sabbatical projects, such as *implementing molecular modeling computations* in General and Organic lab curriculum (this author's first sabbatical project) and converting the entire lab curriculum to *green chemistry experiments* in Organic Chemistry (this author's second sabbatical project). This sabbatical project seeks to build upon these strong foundations to develop additional instrumentation/technology-based instructional materials to expand, enhance and strengthen the laboratory curriculum in the Chemistry Department.

Project Goal, Rationale and Need

<u>Project Goal</u>

The overarching goal of this sabbatical project is to further enrich the student learning experience in the Chemistry Department by creating an improved learning environment that encourages the students to be creative, active learners and collaborators, which will develop critical thinking, reasoning and communication skills. To accomplish this goal, the project proposes an original approach to research, develop and adapt quality classroom instructional materials: i) that are instrumentation and technology-based, ii) are for the most part discovery-based and collaborative in nature, and, iii) expand, enhance and strengthen the laboratory curriculum in the Chemistry Department.

My objective for selecting this project is three-fold:

1. Complement, enhance and upgrade the laboratory curriculum of our CHEM 20 Course, Introductory Organic and Biochemistry, to include enhanced, improved and safer experiments plus computation-based (*Spartan*) modeling experiments in place of molecular-kit modeling experiments. This course serves students interested in earning degrees in nursing or other allied-health disciplines.

2. Expand the use of our state-of-the-art instrumentation, the Nuclear Magnetic Resonance (NMR) and the Infrared spectrometers (IR), in the CHEM 20 laboratory in conjunction with the new experiments. Furthermore, introduce green chemistry concepts such as the principles of green chemistry, identification of waste and hazard reduction into the CHEM 20 laboratory curriculum.

3. Develop integrated lecture-lab, computation-instrumentation based learning modules to bridge General and Organic Chemistry. The intent is to reinforce fundamental *concepts* and *tools* that build a solid foundation for success in Organic Chemistry. The goal here is to provide students that are either enrolled-in or have passed General Chemistry with the fundamental knowledge needed to successfully begin and succeed in Organic Chemistry.

Rationale and Need for the Project

The decision to choose the above three specific objectives as the foundation of my sabbatical proposal came after much thought about what our student needs are, what resources we have in support of the project, what is the most beneficial in the Chemistry Department and College, as well as, what the project benefit is to my own professional growth.

Molecular Modeling (in support of objectives 1 & 3): Over the last two-three decades, molecular modeling has become a routine tool for educators and experimental chemists because desktop computers and laptops can now perform complex calculations that required main-frame computers not long ago. Plus, the exceptional *graphical display* of the calculations makes relating computational results to experimental data relatively easy to "**see**" by students. Shusterman argues that the understanding of reactivity and structural properties can easily be achieved through the visualization of *electron density surfaces* by even novice freshman students. [7] To help students understanding of *structure-reactivity* relationships, almost all organic textbooks and more recently several general chemistry textbooks have included electron density and other computer generated surfaces in their illustrations. The most useful information that a modeling experiment provides is the molecule's three-dimensional *structures* and its *energy*. Structure tells us what the molecule looks like, while the energy tells us something about the type of chemical reactions the molecule would undergo. This so-called *structure-reactivity* relationship is fundamental to the learning of organic chemistry. Molecular modeling is routinely used in our organic lab as an integral part the curriculum. The proposed integrated lecture-lab modules (Objective 3) will help students to learn about this fundamental concept as they prepare to enroll in organic chemistry.

Advanced Instrumentation (in support of objectives 2 & 3): It has been argued that students move through general chemistry acquiring basic problem-solving skills and rote memorization, without acquiring critical reasoning skills or a deep understanding of chemical concepts.[8] Furthermore, at many institutions general chemistry students do not have access to modern instrumentation such as IR or NMR, yet these instruments are foundational to understanding organic structure and helping students develop reasoning and critical thinking skills.[9-10] Since its inception in the 1950s, nuclear magnetic resonance (NMR) has become one of the most valuable tools, particularly in chemistry and biochemistry, for investigating structural and mechanistic problems. Parallel to research applications, NMR has found a central role in the undergraduate chemistry curriculum as evidenced by increasing number of publications in educational journals such as the Journal of Chemical Education. The ^{1}H- and ^{13}C-NMR methods are routinely used in organic labs as an integral part of product identification in synthesis reactions.[11-12] Numerous published studies suggest that *early* introduction of NMR offers pedagogical advantages.[13-16] NMR also provides an important stepping stone to a deeper understanding of organic chemistry.

Green Chemistry (in support of objective 2): Green Chemistry has been defined as: "*The utilization of a set of principles that reduces or eliminates the use or generation of hazardous substances in the design, manufacture, and application of chemical products. Rather than focusing on the reduction of chemical exposure and environmental contamination through controls such as gloves and fume hoods, green chemistry seeks to reduce or eliminate chemical hazards through the* <u>*replacement*</u> *of hazardous substances with less or non-hazardous substitutes.* An added benefit of the approach is that green chemistry will improve safety and provide an ideal context for the discussion of waste reduction and chemical safety in the laboratory. The field of green chemistry is growing rapidly and is open for development of new ideas. This year, the American Chemical Society (ACS) Committee on Environmental Improvement (CEI) has developed a "*green and sustainable supplement to the ACS Guidelines*". The supplement is an optional guidance document for educators to aid in the integration of green and sustainable chemistry concepts throughout the foundational chemistry courses. As educators, we must teach our students to become familiar with these green principles and provide them with the opportunity to explore these concepts.

Discovery Learning (in support of all objectives): Discovery learning is an inquiry-based, constructivist learning theory that takes place in problem solving situations where the learner (student) draws on his or her own past experience and existing knowledge to discover facts and relationships and new truths to be learned.[17] As a result, students may be more likely to remember concepts and knowledge discovered on their own in contrast to a traditional content-delivered learning. Proponents of discovery learning believe that that this pedagogy encourages active engagement, promotes motivation, collaboration, responsibility and independence and helps students to develop creativity and problem solving skills.

In one model of this theory called, Process Oriented Guided Inquiry learning (or POGIL), an activity guides students, by working in small groups, through an exploration to construct, deepen, refine, and/or integrate understanding of relevant disciplinary content.[18] Furthermore and after conducting an activity in this way, the students can work on their communication skills by sharing their results with other groups and with the entire class. This is the type of learning environment that will truly help to train our students to better prepare for their future careers. To implement this approach to some extent, it is fortunately not necessary to change the entire lecture or lab curriculum, since the Chemistry Department already has a high quality program. Instead, the discovery learning is all about changing the way we, the instructors, teach by making some modifications to certain lecture and laboratory components of the courses we teach.

Laboratory Resources (in support of all objectives): The laboratory component is central to our entire chemistry education program. We strive to provide laboratory activities where students have the opportunity to work with different instruments to acquire and analyze data, develop team-work skills, hone critical thinking skills, and practice written and oral communication. Our department has two Anasazi FT-NMR and two Shimadzu FT-IRs, equipped with an ATR accessory for ease in recording IR spectra of solid samples. We are also fortunate enough to have a computer lab facility that has a network of computers loaded with various programs including Spartan molecular modeling program for students' use.

This collection of *instruments and software* provides an ideal situation for carrying out this proposed sabbatical project. By integrating advanced instrumentation and computer modeling into this project, my professional goal is to create a learning environment in which students: (1) develop better laboratory skills by working with modern instrumentation and technology, (2) increase their reasoning and communication skills by working on assignments and experiments in small groups and presenting results and, (3) for students who enroll in organic chemistry to have less anxiety by being better prepared to succeed in the course.

Project Activities, Timeline and Expected Outcomes

To accomplish the three objectives of my proposed sabbatical, I envision the project to be carried out in three distinct phases. My plan is to work mostly on the first two objectives (CHEM 20) in the fall 2019 semester and on the third objective in the spring 2020 semester. It is likely however that work on the CHEM 20 objectives continue in the spring semester as well. The three interrelated phases of project activities are described in some details, along with an estimated timeline and expected outcomes for each of the three objectives.

Phase I: Research and Investigation

Why CHEM 20? After much thoughts and brainstorming of different ideas for my sabbatical project, I settled on focusing the major effort of the project on our CHEM 20 curriculum. The course, specifically the lab portion, needs significant upgrading from several fronts. For example, a few of the current experiments involve combustion of organic compounds. Although they are done safely in a hood, they can still be hazardous. These experiments will be replaced by introducing Carbon and DEPT NMR in these experiments. The advantage of this change is positive on many levels. First, there is no combustion smoke and soot product, safer experiments, more accurate data and students getting the opportunity to work with advanced instrumentation and technique. Furthermore, MRI is the same technique as NMR. When imaging methods using the NMR signal were first developed, the term ***NMR imaging*** was applied to them. In the mid-1980s, and at least partially because of patients' concerns over the dangers of *nuclear* energy, ***Magnetic resonance (MR) imaging***, or simply ***MRI***, became the preferred designation for this new radiologic technique. Since CHEM 20 serves students who will be future nurses, radiologists and other health professionals, this introduction would also provide an opportunity to apply what students learn in the lab to what they will be doing in the future and encourages deeper understanding and comprehension of the concept. Another example of the change in CHEM 20 will be to perform a few of the experiments using much smaller quantities of chemicals, i.e. "*greening*" the experiments. Not only will this change make the experiments safer and more efficient, but it would also open the door to introduce students to the concepts and principles of *green chemistry.* We also need to do more biochemistry experiments in the lab and bring in technology into the course. My goal is to examine the technology resources that have become more available for integration into the course and also develop appropriate Spartan molecular modeling experiments for incorporation into the laboratory portion of the course.

To accomplish the above and other projects' objectives (Objective 3), the first crucial step is, naturally, to conduct a thorough research on the topics related to the project's objectives to learn about the best practices used and the resources available that might potentially be adaptable to the proposed project. This will include studying and examining similar courses and programs at other institutions, reading journal articles on line and especially the Journal of Chemical Education, contacting colleagues at other institutions, visiting labs at nearby institutions and attending professional meetings and conferences. Following this research, along with meetings with my colleagues who regularly teach these courses, I will compile an appropriate list of activities and experiments that need to be developed in Phases II and III of the project.

<u>Phase II</u>: Compilation and Development of Activities/Experiments

Upon completion of Phase I of the project, the main outcome will ideally be an identified compendium of concrete ideas for assignments, lab upgrades and new experiments, both computational modeling experiments and wet experiments that need to be developed with potential for inclusion into our laboratory curriculum. This compendium will be shared with my colleagues who regularly teach the courses to both inform them about the project and ask for their feedback. Following this assessment, the major activity of this phase of the project will be to order new chemicals, reagents and specialty glassware, if needed, and then carry out the experiments myself. This will include developing computational experiments using Spartan, making the necessary modification to some labs as stated above and testing/developing new experiments with NMR and IR spectrometers. *This is the major and key component of the project.* Every effort will be made to integrate the "*discovery*" approach into the design of the new experiments. The activities of this phase will ensure if the experiments are appropriate and that they will conducted safely by students when integrated into the lab curriculum. This activity may still entail some traveling to other places if the need arises.

<u>Phase III</u>: Conducting Experiments and Writing Protocols/Modules

Upon completion of Phase II of the project, efforts will be devoted to edit the protocols of the modified experiments to include the modification done to the experiment and writing protocols for the new wet and computational experiments. Instrumental protocols or supplements focused on the basic theory and operation of the IR and NMR spectrometers and appropriate for CHEM 20 students also need to be written. I developed similar protocols for both our NMR and IR instruments as part of the "Integrating NMR in General and Organic Curriculum" project funded by the NSF a few years ago. I served as the Principal Investigator (PI) and my colleague, Dr. Jenny Chen served as the Co-PI of the project. These drafts will be revised into simpler versions for using in the CHEM 20 laboratory curriculum.

Estimated Project Timeline

<u>Fall 2019</u>: CHEM 20 (Objectives 1 & 2 Activities)

Month	Project Phase	Proposed Project Activities
September & October 2019	**I**	*The first few weeks will focus on primarily searching literature, reading and examining the resources available as related to the objectives 1 & 2.* <u>Project activities will include</u>: ➢ Search and read articles on the topics and works related to objectives 1 and 2 of the project. ➢ Read articles on guided-discovery pedagogy such as POGIL and others, identify best practices especially about how labs can be transformed from traditional format into guided-discovery. ➢ Search Chemistry Departments of other colleges and universities for similar lab offerings and, if available, examine their content. ➢ Examine published lab manuals and the various open education resource websites to learn identify, learn about and get ideas about new wet experiments for the laboratory. ➢ Contact different publishers of GOB textbooks to learn about and examine their technology resources for the lecture component of the course. ➢ Examine recent issues of the Journal of Chemical Education to find ideas implemented for similar courses at other institutions.

September & October 2019	**I**	➢ Time and budget permitting, attend conferences and workshops to gather new ideas for the laboratory. ➢ Consult with the Chemistry Department colleagues who regularly teach the course to gather new ideas for creating additional resources for the course. ➢ Prepare a written summary of the important findings, as part of the sabbatical report. <u>The expected outcomes of these activities are</u>: ➢ A deeper understanding of guided discovery approach, resources available and best practices of how to implement it into the laboratory curriculum from others. ➢ Identification and compilation of a list of modifications to the existing experiments, appropriate new wet experiments, and computational activities for moving forward to the development Phases II and III. ➢ A written summary of the important findings, as part of the sabbatical report.
October & November 2019	**I & II**	*This period will focus on modifying the current lab experiments as needed, testing potential new experiments that include instrumentation and development of computational experiments.* <u>Project activities will include</u>: ➢ Discuss Phase I results with colleagues to evaluate and get feedback on the most appropriate computations to develop, modifications to do, and experiments to test. When appropriate, focus on modifying the experiments with green chemistry principles to reduce waste. ➢ Work with stockroom technicians to order chemicals, reagents and glassware, if needed. ➢ Conduct each of the identified new experiments, test the modifications to existing experiments in the laboratory and create the computational experiments using Spartan. ➢ Work with student volunteers in CHEM 20 course to test the newly developed and/or modified experiments. ➢ Write drafts of protocols for the new experiments that were tested and produced satisfactory results, for the computational labs that are developed and write the modifications made to the existing experiments, as part of the sabbatical report.

October & November 2019	**I & II**	➢ Prepare a written summary of the important findings from this period, as part of the sabbatical report. The expected outcomes of these activities are: ➢ Selected wet experiments that were tested in the lab, improved and safer existing experiments and a brand new set of computational experiments. ➢ Drafts of protocols for the wet and computational experiments.
December 2019	**III**	*It is estimated that this period will complete the lab development activities related to objectives 1 and 2 of the proposal.* Project activities will include: ➢ Finalize, to the extent possible, the draft protocols. The expected outcomes of these activities are: ➢ Finalized drafts (ideal outcome) of the new experiments protocols ready for implementation into the CHEM 20 laboratory curriculum. ➢ A written summary of the important findings, as part of the sabbatical report.

Winter Break:

Month	Project Phase	Proposed Project Activities
January & February 2020	**N/A**	Project activities will include: ➢ Enjoy winter break; reflect on the progress of the project. The expected outcomes of these activities are: ➢ Return energized, with refreshed attitude and excitement to continue with the project.

<u>Spring 2020</u>: Integrated Lecture-Lab Modules for Bridging General Chemistry & Organic Chemistry (Objectives 3 Activities)

Month	**Project Phase**	**Proposed Project Activities**
March & April 2020	**I & II**	*This semester will primarily focus on compiling ideas and developing computational activities and instrumentation experiments that are best suitable for bridging the General Chemistry and Organic Chemistry curricula. It will end with completing the project in June 2020.* <u>Project activities will include</u>: ➢ Finish the work on Objectives 1 and 2 (if work still to be done) from the fall semester. ➢ Finalize and present the experiments/modifications for CHEM 20 to my colleagues to evaluate and explore the feasibility of how to best implement them in the curriculum. ➢ Time and budget permitting, attend conferences and workshops to gather new ideas for related approach/small projects. ➢ Consult with my colleagues to discuss and compile a list of appropriate computational activities and instrumentation experiments that are best suitable for bridging the general and organic and to prepare our students for the transition.
April & May 2020	**II & III**	➢ Conduct the experiments and develop computational assignments using Spartan molecular modeling program. ➢ Write draft protocols, share with colleagues and edit/revise as needed based on their feedback.
June 2020	**III**	➢ Present the finalized drafts to my colleagues to explore the feasibility of how to best implement them in the curriculum. ➢ Compile all protocols. *Write a sabbatical report.* <u>The expected outcomes of these activities are</u>: ➢ Tested high quality classroom computational assignments and wet experiments ready for potential implementation into the curriculum. ➢ A sabbatical report detailing the project findings and the outcomes of the project.

Product of the Sabbatical Project

The tangible product of this sabbatical proposal has been described in some details above. I expect that at the conclusion, a new in-house laboratory manual that will include the new and modified experiments will be produced to replace our existing manual for CHEM 20 laboratory. Considering both the nature of developing new experiments (testing first, writing a draft protocol, piloting in the lab with students, editing and modifying, retesting, etc.) and the magnitude of the proposed work that needs to be done, it is likely that production of the new lab manual might extend beyond the one year duration of the project and at this time remains a longer-term outcome of the project but the experimental protocols will be ready for integration into the laboratory curriculum. As for the lecture-lab integrated modules for bridging general and organic chemistry (objective 3), the plan is to have them remain as individual modules ready for testing by individual instructors in either general chemistry laboratory or early at the beginning of the first semester of organic laboratory.

The intangible product of this sabbatical proposal is the value and benefits of this project to my own professional growth, to students and to College which are described in some details in the next section. The part of the intangible product that is embedded in the project's central goal but it is difficult to assess and evaluate is how and if the project will have a direct impact on how our students learn. This is the most difficult aspect of any new model, design or approach utilized in instruction. As educators, however, we can only predict and remain hopeful that a learning environment that promotes students' creativity, active learning and collaboration and encourages developing critical thinking, reasoning and communication skills, will have a long lasting positive impact on our students. This is the ultimate outcome of this sabbatical project.

Value and Benefits of the Sabbatical Project

I. Professional Enrichment and Growth

As an educator, my professional goal and passion in life has been to contribute excellence to science education by continuously learning and utilizing innovative, technology-based learning and new pedagogies into my instruction. Nothing is more rewarding than knowing that I have prepared my students well and ready for successful transition to a four-year university to continue on with their education. This sabbatical project will provide me with yet another great opportunity to continue to grow professionally.

Over my 26 wonderful years of teaching at Mt. SAC, I have attended many professional meetings and conferences, presented at those conferences and participated in and/or offered a large number of workshops, many sponsored by the National Science Foundation. Active engagement in these conferences and workshops has allowed me to continuously learn about the innovative pedagogies and approaches utilized in science education. I also learned significantly from my exceptional experience of serving for two years as a Program Officer in the Division of Undergraduate Education (DUE) at the National Science Foundation from 2001-2003. This unique experience provided me with yet another opportunity to travel extensively, both nationally and internationally, and learn first-hand from the leaders in science education. Collectively, these experiences led me to write and lead as the principal Investigator several successful grant proposals over the past 15 years to secure external funding to purchase advanced instrumentation for the Chemistry department and to help our students both academically and financially. The funds from these grants, amounting to nearly $1.7M total, allowed the Chemistry Department to purchase its first NMR Instrument (in collaboration with Dr. Chen as the Co-PI), bring computations using Spartan program (my first sabbatical leave outcome & with NSF grant and Prof. DiMauro as the Co-PI), convert the entire organic laboratory curriculum to *Green Chemistry* (my second sabbatical leave outcome), award summer STEM research scholarships to our students (in the amount of $3,500 each, awarded to over 65 students with NSF grants with Dr. Chen as the Co-PI) and award academic scholarships to students to persevere and succeed in completing majors STEM courses and transfer (over 140 in the amount of $2,800 each awarded to students from NSF grant and Dr. Chen as the Co-PI).

Our most recent NSF award titled "*Mt. SAC STEM Teacher Preparation Program or STEM TP2*" (with Dr. Newman as the Co-PI, a 4-year grant totaling $731K and currently in the final year) has allowed us to establish a successful partnership with the University of California, Irvine and with the Walnut Valley Unified School District with the overarching goal to recruit, advise, mentor and prepare Mt. SAC students that have a strong desire and passion to become future math and science teachers at the secondary level. The success of this unique program was recently recognized by the NSF. Pellet Production Company, a production company in Boston, secured an award from the NSF to produce a short educational video of our program that is now available for national dissemination at their website. This website lists and highlights successful NSF funded projects that are of national interest to the education community. The video can be viewed at *http://atetv.org/video/mt-san-antonio-college-stem-tp2-program/*. And just recently, our program also received the American Chemical Society Partners for Progress and Prosperity Award (ACS P3 award) recognizing its successful partnership accomplishments. The award was presented to us at the Western Regional Meeting of the American Chemical Society held at the campus of California Institute of Technology on October 27, 2018. These successes prompted us to submit another proposal to the NSF to continue and expand the program. I am grateful to Mt. SAC for providing resources and needed facilities in support of all these projects.

I have thoroughly enjoyed working on all these projects and bringing them to fruition. As an added benefit, these projects have provided me with multiple opportunities to work closely with my colleagues in the Chemistry department to move the projects forward and, above all, work closely with students. I have seen first-hand the impact these projects have had on students' transformation, maturity, and growth. It is very rewarding to hear from many former students writing to me or even coming back to visit, excited about the success at their new schools and letting us how well *we* have prepared them for their upper division classes.

I am also very satisfied with the outcomes of my past two sabbatical projects. Introducing molecular modeling computational experiments and activities into the General and Organic Chemistry curriculum was the focus of my first sabbatical leave. Since then computations with *Sparatn* molecule modeling program have become a significant part of the Organic laboratory curriculum and several of my colleagues also do it in general chemistry. The second sabbatical leave granted me an exceptional opportunity to learn about *Green Chemistry* from the leaders in the field at the University of Oregon and Hendrix College in Arkansas and as a result completely convert our organic laboratory curriculum into green. Through the activities of this sabbatical project I developed and adapted 17 green experiments that make extensive use of our advanced instrumentation like NMR, and also developed 11 computational experiments and with *Spartan*. These experiments were extensively vetted by myself and by my colleagues who taught organic laboratory at that time. Ultimately, these experiments, together with few additional resources I developed on green chemistry, IR and NMR theory and instrumentation, were compiled into two in-house laboratory manuals that replaced the laboratory textbook were using. This complete lab conversion to green has resulted in substantial savings to both the students (~$45 vs. $200+ for a lab textbook) and the College (reduction in waste) over the past several years. Furthermore, the new experiments are much safer that what we were doing prior to the conversion and not only they teach *students the traditional organic laboratory skills but at the same time they demonstrate, first hand, the benefits of an innovative approach that uses greener reagents and solvents, evaluates the efficacy of new synthetic procedures, and emphasizes environmental and green concepts.* This major accomplishment would not have been possible without the sabbatical opportunity granted to me by Mt. SAC. Following that sabbatical, I was invited back twice as a guest to participate at the University of Oregon week-long Green Chemistry Workshop to present our new green curriculum to participants from other colleges and universities who had similar interests. This proposed sabbatical project will provide yet another exceptional opportunity for me to continue to grow professionally, to become a student again, to gain additional expertise and to explore ideas about how to better prepare our students for the 21st Century job market. This sabbatical project will also enable me to produce additional high quality classroom instructional materials ready for potential implementation into the Chemistry Department laboratory curriculum.

II. Benefits to the Department, Instruction Program and Students

The Chemistry Department provides a quality instructional program founded on the collective efforts of a dedicated faculty in the Department. These efforts have allowed the Department to continuously improve and enhance the quality of instruction it provides to students through the implementation of the latest technology, innovative pedagogy and advanced instrumentation into its curriculum. Integration of computer-based technology, Spartan Molecular Modeling, H-1 and C-13 NMR Spectroscopy, Process Oriented Guided Inquiry Learning (POGIL) pedagogy for lecture delivery, flipped classroom approach and use of clickers' technology in instruction are just a few examples of those efforts. This sabbatical project follows the Department's commitment to such excellence and directly benefits the Chemistry Department and our students in the following ways:

- Complements and improves the existing CHEM 20, Introduction to Organic and Biochemistry, laboratory curriculum.

- Expands the use of advanced instrumentation like the IR and the NMR spectrometers (currently NMR is used only in organic labs) into the CHEM 20 laboratory to provide for a more positive learning experience and training for our students.

- Introduces and implements molecular modeling into the CHEM 20 laboratory curriculum and integrates technology in the lecture portion of the course.

- Introduces green chemistry principles and collaborative/discovery learning to help students develop critical thinking, reasoning, creativity, collaboration and communication skills.

- Develops creative technology- and instrumentation-based modules to reinforce fundamental concepts and tools that build a solid foundation for success in organic chemistry and provide students with the fundamental knowledge needed to successfully begin and succeed in organic chemistry.

- Develop high quality instructional materials ready for incorporation into the curriculum.

- Strengthens the Departments' reputation as a leading two-year chemistry department in the nation in implementing innovation in science education.

These direct benefits of the proposed sabbatical project are well aligned with the Chemistry Department commitment to excellence and allow the Department to complement, strengthen and extend its quality instruction across the lab and the lecture curriculum to impact more current and future students at Mt. SAC.

Benefits to the College

The proposed projects' goals and objectives are directly correlated to the mission and vision statements of Mt. San Antonio College:

➢ *"College is committed to providing quality education, services, and workforce training so that students become productive members of a diverse, sustainable, global society."* The primary goal of this sabbatical project is to further enrich the student learning experience in the Chemistry Department by creating an improved learning environment that encourages the students to be creative, to be active learners and collaborators, and to develop critical thinking, reasoning and communication skills. The proposed project will research and produce quality instrumentation-, discovery- and technology-based classroom instructional materials that would enhance and strengthen the laboratory curriculum in the Chemistry Department and as a result provides the students with additional opportunities to gain and practice skills essential for entering the 21^{st} Century job market..

- *"To be viewed as a leader in community college teaching, programs, and services".* This project will enhance and strengthen the current Chemistry Department curriculum and provides improved learning experiences for all the students in the program, Mt. SAC and the community. The results from my previous sabbatical projects as well as those from our grant projects have been presented at several local, regional and national professional meetings and conferences such as the Two-Year College Chemistry Consortium (2YC3), the Biennial Conference in Chemical Education (BCCE) and the American Chemical Society (ACS) meetings.[19-21] Furthermore, I have sent numerous copies of our green experiments to participants at those presentations who were interested in adopting them into their own curriculum. These presentations have indeed highlighted Mt. SAC as *a leader in community college teaching, programs, and services.* The results and findings from this sabbatical projects will be shared with others in a similar fashion to further support this vision.

In conclusion, successful implementation of the project into the Chemistry Department's curriculum could serve as an inspiring model for other community colleges to follow and at the same time support the College in its quest to be regarded as one of the premier community colleges in the nation, and a leader in community college teaching, programs, and services.

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Award Abstract #2024276

Preparing a Skilled Technical Workforce through Utilization and Assessment of Undergraduate Research

NSF Org:	DUE Division Of Undergraduate Education
Initial Amendment Date:	May 7, 2020
Latest Amendment Date:	May 7, 2020
Award Number:	2024276
Award Instrument:	Standard Grant
Program Manager:	Paul Tymann DUE Division Of Undergraduate Education EHR Direct For Education and Human Resources
Start Date:	September 1, 2020
End Date:	August 31, 2025 (Estimated)
Awarded Amount to Date:	$953,432.00
Investigator(s):	Iraj Nejad inejad@mtsac.edu (Principal Investigator) Alvin Kung (Co-Principal Investigator)
Sponsor:	Mount San Antonio College 1100 North Grand Walnut, CA 91789-1399 (909)274-5417
NSF Program(s):	Advanced Tech Education Prog
Program Reference Code(s):	1032, 9178, SMET
Program Element Code(s):	7412

ABSTRACT

This project builds upon the evidence that early immersion in mentored experiential learning, such as an undergraduate research experience, increases student persistence in STEM, completion of STEM certifications, and entry into the technical workforce. Since research experiences may be limited at many two-year college campuses, students at these institutions would benefit from expanded opportunities to engage in authentic research experiences. Educating enough skilled technical workers who are prepared for advanced technology industries has become a national priority in the United States, and it is essential for the country to retain its global leadership in science and technology. Community and technical colleges play a vital role in meeting this demand, especially for preparing students who are well qualified to enter the technical workforce or transfer to a four-year university to earn STEM baccalaureate degrees. An efficient and rapid way to produce the STEM professionals that the nation needs would be to increase community college student persistence in STEM fields. This project proposes to achieve that goal by providing more undergraduate research experiences to community college students. The research experiences are expected to help students gain deeper STEM knowledge and skills, to increase their academic success, and to enable them to develop the highly valued professional skills needed to enter the STEM technical workforce.

The project will build on three distinct goals: (1) providing authentic undergraduate research experiences to a large number of STEM students to help strengthen their interest in STEM careers and gain professional skills that are critically important in the technical workplace; (2) modifying an assessment tool, EvaluateUR, for use in shorter (8-week) summer research experiences; and (3) implementing EvaluateUR to assess the intellectual growth and development in the students? disciplinary and professional skills acquired through participating in the undergraduate research experiences. The project is aligned with the goals of the Advanced Technological Education program and leverages the vast research facilities and resources at the University of California, Irvine, together with the technical resources and support for modifying and implementing EvaluateUR available through SUNY-Buffalo State and the Science Education Resource Center at Carleton College. Four cohorts of 20 STEM students will be recruited and engaged in an undergraduate research experience. Student and faculty mentors will be assessed using the modified EvaluateUR tool. This tool has been shown to measure a broad range of desirable outcomes that include both content knowledge and the outcomes that are critically important in the workplace, including communication skills, ability to solve obstacles, problem solving skills and critical thinking. The project will work to ensure educational equity through activities that support the recruitment of women, veterans, first-time college students, racial and ethnic minorities; these groups represent an important, talented STEM pool for growing the nation's technological workforce. The project outcomes will be published through a dedicated website, presentations at local and regional conferences, including the ATE Principal Investigators Conference, the American Association of Community Colleges annual convention, and the Council on Undergraduate Research Conference. The lessons learned while implementing this project will likely be of interest to all community colleges and other academic institutions with an interest in engaging students in similar research experiences. This project is funded by the Advanced Technological Education program that focuses on the education of technicians for the advanced-technology fields that drive the nation's economy.

This award reflects NSF's statutory mission and has been deemed worthy of support through evaluation using the Foundation's intellectual merit and broader impacts review criteria.

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