Integration of
Discovery Learning, Green Chemistry and Instrumentation Into the Chemistry Lab Curriculum

Sabbatical Project Report

Fall 2018 – Spring 2019

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Acknowledgments

I would like to acknowledge the invaluable support that many people have provided during the course of my sabbatical leave from Mt. San Antonio College. First and foremost, I am enormously grateful to the college administration and leadership, as well as the Salary and Leaves Committee for granting me this wonderful opportunity to work on the project. On both professional and personal levels, it is very exciting for me to see that the idea of integrating discovery learning, green chemistry and instrumentation into the chemistry lab curriculum at Mt. SAC is well received and supported. I deeply appreciate working at an institution that is strongly committed to academic excellence and fully supports faculty professional development.

I am also very grateful for the continuous and unwavering support from both the Natural Science Division and the Chemistry Department. To all of my colleagues in the Chemistry Department, I sincerely appreciate your support for my sabbatical project and your shared commitment to providing quality education to our students.

Abstract

The goal of this sabbatical project is to complement, enhance and strengthen the current lab curriculum by creating a learning environment to allow the students to be creative, become better learners, more responsible citizens, and to develop critical thinking skills. To accomplish this goal, a comprehensive research and investigation on the best practices in teaching the chemistry lab curriculum was conducted by closely examining current literature, lab manuals, journal articles and websites, as well as by attending conferences. This sabbatical project provided the enormous opportunity for an excellent learning experience for professional growth and enrichment. More importantly, innovative classroom instruction materials for integrating discovery learning, green chemistry and instrumentation into the chemistry lab curriculum have been developed for implementation.

Statement of Purpose

This purpose of this sabbatical project is to propose an innovative approach to effectively enrich the student learning experience in chemistry, by integrating discovery learning, green chemistry and instrumentation into the lab curriculum. The eventual goal is to complement, enhance and strengthen the current curriculum by creating a learning environment to allow the students to be creative, become better learners, more responsible citizens, and to develop critical thinking skills. Ultimately, this project seeks to produce high quality classroom instruction materials, with the intention of incorporating them into the current lab manuals.

To accomplish this goal, the first imperative step, phase I, of the sabbatical project is to conduct a complete and thorough research and investigation on the current best practices in teaching chemistry lab curriculum, focusing specifically on the topics of discovery learning, green chemistry and instrumentation.

The second important step of the sabbatical project, phase II, is to use the important findings from phase I to select appropriate activities, with the specific focus on incorporating elements of discovery learning, green chemistry and use of new instruments into the current lab curriculum. The approach here is to modify the current lab experiments or add new components to enhance and strengthen, and not to replace.

The last crucial step of the sabbatical project, phase III, is to use the major findings from phase I to develop new laboratory modules that fully embrace discovery learning, green chemistry and instrumentation. The approach in this step is to design lab modules that allow students to be creative, to become better learners, to become more responsible citizens by making green chemistry choices, and to develop critical thinking skills.

Sabbatical Project Activities

Phase I: Research, Investigate and Learn

Research Design and Methods of Investigation

To learn effective teaching pedagogy, best practices and innovative applications for the topics of discovery learning, green chemistry and instrumentation in chemistry lab curriculum, a comprehensive research and investigation has been conducted. This comprehensive research consists of the following components, each with a specific objective:

- Read books on the topics of discovery learning and green chemistry. The objective here is to learn more about each specific topic and to gain a better understanding of the overall picture of how these are applied in various disciplines, since effecctive, innovative pedagogy practices are never limited to just one discipline.
- Examine current published lab manuals. Since most colleges and universities adopt a published lab text or manual for their chemistry laboratory courses, then these lab manuals can be considered as the standards for how chemistry lab curriculum is taught. The objective in this search is to investigate to what depth and breadth these topics are addressed in most chemistry lab curriculums nationwide.

- Search the Journal of Chemical Education. For chemistry, this is the most important journal that addresses the various aspects of chemical education, from effective teaching pedagogies in the classroom to innovative new lab experiments. The objective in this search is to really widen the scope of the research to go beyond the national level, to identify successful practices and novel experiments that have implemented discovery learning, green chemistry and instrumentation into their lab curriculum from educators in different places of the world.
- Explore the various open education resource websites. In recent years, there is a wealth of information available online on various chemistry topics, especially in the area of green chemistry. The objective here is to take advantage of these valid websites, such as the American Chemical Society's Green Chemistry Institute and Green Chemistry Education Network, to learn what resources are available for possible adoption. In addition, an online search on the different types of lab instruments will be conducted to determine which ones may be appropriate for instructional use and are available within a reasonable budget.
- Attend conferences and workshops. Often times, these conferences provide the best opportunities to hear about novel ideas, see demos of the newest modern lab instruments, dialogue with experts in the field, and network with other educators that share the same professional goals.

Once the comprehensive search and investigation phase is completed, the results are summarized and analyzed to draw conclusions for phases II and III.

Project Activities

In the original proposal, the first twelve weeks of the fall semester (last week in August to the 2^{nd} week in November) were dedicated to this learning, research and investigation phase. In reality, once the sabbatical project began, it quickly became apparent that this phase requires far more time and effort than these twelve weeks. There is just a plethora of information out there and the scope is so wide; consequently, to be comprehensive, this learning and research phase actually continued well into the spring semester, especially in the area of journal articles as new issues continued to come out. It is very difficult to resist the urge to read the newest issues, to see if any new ideas have been proposed. Since the project activities in phase I are so crucial to the quality of materials to be developed in phases II and III, the extra time spent on phase I is both necessary and beneficial to the successful completion of the project.

To learn more in depth about the topics of discovery learning and green chemistry and to gain a broader perspective on how to apply these concepts in the lab curriculum, the following books were read and studied:

- *Green Chemistry: Theory and Practice*. Anastas, P.T., Warner, J.C.
- *Green Organic Chemistry and its Interdisciplinary Applications*. Kolb, V.M.
- *Chasing Molecules: Poisonous Products, Human Health, and the Promise of Green Chemistry*. Grossman, E.
- *Green Organic Chemistry: Strategies, Tools, and Laboratory Experiments*. Doxsee, K.M., Hutchison, J.E.
- *Greener Approaches to Undergraduate Chemistry Experiments*. American Chemical Society.
- *Introduction to Green Chemistry*. American Chemical Society.
- *Real-World Cases in Green Chemistry*. Cann, M.C., Connelly, M.E.

- *Real-World Cases in Green Chemistry Volume II.* Cann, M.C., Umile, T.P..
- *Open to Questions: The Art of Teaching and Learning by Inquiry.* Bateman, W.L.
- *A More Beautiful Question.* Berger, W.
- *The Book of Beautiful Questions.* Berger, W.
- *Organic Chemistry, A Guided Inquiry, 2nd Ed.* Straumanis, A.
- *Guided Inquiry Activities for an Integrated Approach to General, Organic, and Biological Chemistry.* Frost, L.
- *Introductory Chemistry Modules, A Guided Inquiry Approach.* March, J., Caswell, K., Lewis, J.
- *Laboratory Inquiry in Chemistry.* Bauer, R.C., Birk, J.P., Sawyer, D.J.

To gain a better understanding of the current standards on how chemistry lab curriculum is taught in many colleges and universities, it is necessary to closely examine the various published lab manuals for the different chemistry courses. In particular, special attention is given to the area of instrumentation and lab techniques, as in which instruments are commonly employed and to what extent they are utilized in the different courses. The following lab textbooks and lab manuals were read and investigated:

- *Making the Connection, A How-To Guide for Organic Chemistry Lab Techniques, 3rd Ed.* Padias, A.B.
- *Macroscale and Microscale Organic Experiments, 7th Ed.* Williamson, K.L., Masters, K.M.
- *A Microscale Approach to Organic Laboratory Techniques, 6th Ed.* Pavia, D.L, Kriz, G.S., Lampman, G.M., Engel, R.G.
- *The Organic Chem Lab Survival Manual, A Student's Guide to Techniques, 9th Ed.* Zubrick, J.W.
- *Laboratory Techniques in Organic Chemistry, 4th Ed.* Mohrig, J., Alberg, D., Hofmeister, G., Schatz, P., Hammond, C.N.

- *Exercises for the General, Organic & Biochemistry Laboratory.* O'Neal, W.G.

- *Exploring General Chemistry in the Laboratory.* Craig, C.F., Gunnerson, K.N.

- *Laboratory Experiments for General Chemistry.* Block, T.F., McKelvy, G.M.

- *Investigating Chemistry through Inquiry.* Volz, D.L., Smola, R.

- *Chemistry with Vernier, 4th Ed.* Holmquist, D.D., Randall, J., Volz, D.L.
- *Chemistry with Vernier, 4th Ed.* Holmquist, D.D., Randall, J., Volz, D.L.

- *Advanced Chemistry with Vernier, 4th Ed.* Randall, J.

In recent years, there has been an abundance of open education resources online, addressing various chemistry topics. These additional resources are important, since for many educators, sharing online is perhaps the easiest and quickest method of communicating new ideas. To explore the wealth of information available online, especially in the area of green chemistry, a thorough search was conducted and only valid, reliable resources are included here:

- American Chemical Society's Green Chemistry Institute
  www.acs.org/greenchemistry

- Green Chemistry Commitment
  www.greenchemistrycommitment.org

- Beyond Benign
  www.beyondbenign.org

- GCEdNet – Green Chemistry Education Network
  http://cmetim.ning.com/

- University of Scranton Greening Across The Chemistry Curriculum
  http://www.scranton.edu/faculty/cannm/green-chemistry/english/drefusmodules.shtml

- Carnegie Mellon University Institute for Green Science
  http://igs.chem.cmu.edu/

In addition to these online resources, a significant amount of time during the sabbatical project has been devoted to reading the *Journal of Chemical Education*, which is the official journal of the Division of Chemical Education of the American Chemical Society. In chemistry, this journal is regarded as the world's premier chemical education journal as it addresses topics in chemical content, activities, laboratory experiments, instructional methods and pedagogies. As part of the sabbatical project activities, all issues of this journal for the past five years have been scrutinized closely to look for novel ideas and relevant experiments in discovery learning, green chemistry and incorporating instrumentation. To appreciate how much work and time this requires, each year has 12 issues, which totals up to about 2300 pages just for the year 2018.

Besides learning through books, lab manuals, websites, and journal readings, this sabbatical leave also provided a tremendous opportunity to attend conferences and workshops. I totally enjoy and appreciate having the time to attend various conferences and workshops to just learn, some of which may not have been directly related to chemistry, but definitely all provided opportunities for professional growth and enrichment, and will certainly help me to become more effective in teaching. Here are some of the highlights:

- 2YC3 (Two-Year College Chemistry Consortium) Conference on *Student Success – It's Not Just a Game: Promoting Scientific Curiosity*, 2-day national conference at University of New Mexico, Valencia.
- Training from the Back of the Room (2-day workshop)
- Inspired Teaching Conference: Exploring Experiential Education
- Inspired Teaching Conference XVIII: Ready, Set, Engage!
- Introduction to Emotional Intelligence and Diversity

- The Neuroscience of Decision-Making in Higher Education
- Dynamic Presentations Using an Interactive Whiteboard
- Top 5 Ways to Use Doceri to Increase Classroom Interaction

Important Findings and Conclusions

The first phase of the sabbatical project serves as an excellent learning experience for professional growth and enrichment, and certainly accomplished the purpose of learning the pedagogy, best practices and innovative applications for discovery learning, green chemistry and instrumentation. Important findings for each topic will be summarized here.

For both introductory and general chemistry courses, the trend observed is that most lab experiments still adhere to the traditional approach, where students would follow the same step-by-step procedure and are expected to arrive at similar answers. For lab report writing, the format is usually fill in the blanks in the data tables provided in the lab text, performing data analysis calculations as requested by specific prompting questions, and answering any post-lab questions. The students are left with very little opportunities to practice critical thinking skills and express their creativity. The common lab techniques students have to learn include conducting chemical reactions, titration, calorimetry, preparing solutions, filtration and thin layer chromatography. In terms of instrumentation, the common lab instruments utilized are limited to spectrophotometer, pH meters and some form of digital data collection device.

For the more advanced organic chemistry courses, the experiments are more challenging in nature. Since they are more focused on the training of specific lab techniques, the glassware setup is much more complicated and unique for each technique.

Although the students still follow the same procedure, the procedure is often written in paragraph form in the lab text. Students need to demonstrate a certain level of understanding of the experiment in order to translate that procedure into the step-by-step format on their laboratory notebooks. There are many lab techniques that students have to learn, including melting point, boiling point, crystallization, extraction, separation, simple distillation, fractional distillation, vacuum distillation, column chromatography, and thin layer chromatography. Most of these techniques require specialized glassware. The common instrumentation include infrared spectrometer, nuclear magnetic resonance spectrometer, gas chromatography instrument, mass spectrometer, and high-performance liquid chromatography instrument. However, the extent to which the students actually gain hands-on experience with these instruments, if any, is highly dependent on the institution since these instruments are very expensive, so very few colleges/universities actually allow the students to work closely with these instruments.

Most of the green chemistry experiments for general chemistry are similar in context to traditional experiments, with the exception of choice of reagents, where hazardous chemicals are avoided and replaced with greener alternatives or less toxic chemicals. Benefits of this approach ranges from lower initial purchasing cost to reduced cost for waste disposal. For organic experiment, greener design often involve solvent-less reactions, to eliminate waste from the beginning. There are not too many completely green experiments that are appropriate for the teaching organic laboratory, instead, the approach is to choose less toxic chemicals, especially greener solvents to work with, in the attempt to reduce waste.

In the literature, the concept of discovery learning in chemical education is often regarded as comparable to the notions of inquiry based learning and guided inquiry, and these topics are often discussed interchangeably. Regardless of the exact chosen words, the approach is similar, and that is to remove the traditional recipe style procedure and allow the students to take ownership of the experiment. The role of the professor is to be a resource and to guide or provide the students with the necessary resources to develop their own experimental protocols. The purpose is to foster experimental problem solving skills, develop critical thinking skills and encourage collaboration. The variation is that guided inquiry or inquiry based learning often suggests more guidance or direction from the professor to start with, whereas discovery learning is more open ended, where the students are allowed to explore a wider latitude of options. In that context, the trend observed is that guided inquiry may be conducted by replacing only one experiment in the curriculum, whereas in some advance courses and institutions with smaller class settings, an entire lab course is structured around discovery learning by utilizing a tailored problem-based learning approach.

To conclude, the intended outcomes of gaining a deeper and better understanding of discovery learning and green chemistry, as well as attaining valuable insights on which instruments may be appropriate for our lab curriculum, have been achieved. More importantly, the necessary knowledge to move forward and continue to phase II and phase III is attained.

Phase II: Modify the Current Curriculum

Overall Approach

Upon completion of phase I of the project, the next phase is to apply these valuable knowledge and resources to modify the current lab curriculum. In the past decades, the Chemistry Department already has a proven record of utilizing the latest technology and innovation for lecture delivery and laboratory instruction. This sabbatical project seeks to further enhance the curriculum by finding appropriate areas where discovery learning, green chemistry and instrumentation can be integrated. Rather than selecting a few experiments to focus on, the approach here is to examine all the experiments in the current lab curriculum with specific efforts focused on:

- Integrating discovery learning into appropriate portions of the experiments;
- Applying the green chemistry concepts to choose less hazardous reagents and to reduce waste; and
- Incorporating the use of new instruments in the current experiments.

Project Activities

In the original proposal, the next ten weeks of the academic calendar (last four weeks in the fall semester and first six weeks of the spring semester) were dedicated to this phase of modifying the curriculum. In reality, once the sabbatical project began, it is very difficult to follow such an exact schedule, because sometimes the right timing for certain project activities occur earlier than originally planned. For example, in October, after attending the Two-Year College Chemistry Consortium Conference in New Mexico where I had the opportunity to try some of the new instruments first-handed, I was excited to envision the possibilities for our Department. Upon returning, I shared this sabbatical project at a department meeting, with the purpose of discussing with my colleagues the initial ideas of developing experimental protocols for the new Vernier and Pasco instruments and identifying the experiments for possible implementation. Shortly after the meeting, I began working on developing these experimental protocols, which according to the original proposal, is not scheduled to take place until March.

For the new instruments, experimental protocols have been developed for the Vernier temperature probes and the Pasco spectrometers. Since one of the project goals is to integrate instrumentation at all levels of chemistry lab curriculum, these experimental protocols are very different in design from the tradition chemistry lab instructions, in that they are written with the visual learners in mind and are intended to be very easy to follow, even for the introductory students with no previous chemistry background. These protocols were then tested by two sections of CHEM 50 (General Chemistry I) students, along with the current MeasureNet technology, for "Copper Concentration" and "Calorimetry" experiments. A short student survey was conducted to evaluate the effectiveness of the new approach and to obtain student feedback on their perception of the learning experience. The questions on the survey ranged from user experience such as ease of use, data collection, data analysis to set-up time and preference of which instruments to use. Overall, the student feedback were very positive for the new Vernier instrument and provided valuable insights on what works well for our current student population. In addition, the accuracy of the collected data with the new instruments were discussed with colleagues and compared with previous semester data, with the results shown to be very precise. For reference, the instrumentation lab protocols and the student survey with feedbacks are attached in Appendix B.

Similar to the instrumentation testing process, most of the efforts during phase II have been focused on: (1) examine the waste collection data from the stockroom technicians to identify which experiments generate the largest amounts of chemical waste and should be modified with greener alternatives, (2) discuss these ideas with colleagues to decide on the most appropriate choices, (3) gather the required chemicals, materials, glassware and instruments to test the new ideas, (4) evaluate the collected data, and (5) to summarize these proposed modifications.

Summary and Conclusions

All the experiments in the current chemistry lab curriculum have been evaluated to consider which ones can be modified. The chosen experiments are all in the area of introductory and general chemistry, since the current organic chemistry curriculum is already consist of all green experiments.

To apply the green chemistry concepts, the following experiments can be modified to have certain chemicals with high toxicity or reactivity replaced with greener alternatives that are less hazardous, which would also reduce chemical waste disposal:

- *Titration of Vinegar*: replace phenolphthalein indicator with pH paper or litmus paper, which would eliminate majority of the chemical waste collected.
- *Single and Double Displacement*: replace barium chloride with calcium chloride.
- *Copper Concentration*: replace copper (II) nitrate with color dye, which would eliminate the need to collect any chemical waste for the majority of the experiment.

- *Calorimetry*: replace magnesium and hydrochloric acid with acetic acid (vinegar) and sodium bicarbonate (baking soda), which will not generate chemical waste.
- *Solubility and Stoichiometry*: replace barium chloride with calcium chloride.

There are many experiments in the current lab curriculum that can incorporate the use of new instruments. The following table clearly shows that for each type of instrument, which experiments would be appropriate and can benefit from utilizing that instrument:

Type of Instrument	Experiment
Pasco spectrometer	*Solutions and Dilutions* *Light, Electron Configuration, and Periodic Trends* *Atomic Emission* *Kinetics of Acetone Triiodide* *Equilibrium of a Metal Complex Ion*
Vernier probes	*Properties of Gases* *Copper Concentration* *Calorimetry* *pH and Hydrolysis* *Titration* *Electrochemistry and Cell Potentials* *Buffers*

Many of the current experiments can be modified to integrate elements of discovery learning into the experiment, since most experiments have multiple parts in the experiment where one part can be converted to discovery learning. For example, in "Calorimetry," the students can follow the given procedure for the first part, but instead of repeating the experiment for more reactions, the students can be given different types of foods, where they can design their own procedure to determine the calorie content. In a different experiment, "Qualitative Analysis of Household Chemicals," prior to identification of the unknown, the students can be asked to write a procedure to determine the acidic or basic properties of the household chemicals, which would assist them in the identification process later.

Phase III: Develop New Laboratory Modules

Overall Approach

Upon completion of phase I and phase II of the project, the final phase, the last ten weeks of the spring semester, is to develop new laboratory modules that fully embrace discovery learning, green chemistry and instrumentation. Thus, efforts will be devoted to narrowing down the many exciting possibilities to choose topics that are most appropriate for our students and to complement the existing lab curriculum.

Project Activities

In the process of narrowing down the choices, certain trends in the current chemistry lab curriculum became obvious. First, it is evident that for both the introductory and general chemistry courses, there have been a lot of collaborative efforts from various faculty to work on improving the lab curriculum. Consequently, there are more experiments in the pool than what can be fitted into a semester schedule, which allows the faculty the flexibility to choose a different experiment on the same topic. This is beneficial to both the students and the faculty. Second, while there are lots of experiment choices available, very few, if any, are designed to be discovery learning or inquiry based. This is understandable given that for each course, there are over 15 sections offered each semester and a lot of the sections are taught by adjunct faculty, which can change from semester to semester. It is extremely difficult for a new adjunct to walk into a course and be expected to conduct discovery learning experiments, which require a lot of training and preparation. The last trend observed in the department is that for the most advanced organic chemistry courses, there is only one set of experiments. Again, this is comprehensible since organic chemistry lab is highly challenged in technique mastery and often requires specialized training on the part of the faculty to just teach the course well.

In phase III, while many of the project activities will be similar to those conducted in phase II, the biggest difference is that there is no preexisting framework or confinement to limit the imagination. Nonetheless at the same time, the selection of topics for the new laboratory modules to develop should be made with the above trends in mind, to properly address the needs of the department. The approach in developing the new lab modules is very simple and straightforward, to begin with green chemistry design in choosing less hazardous reagents and reactions, and utilize various instruments as tools to allow discovery learning to occur. The last part of the project activities is devoted to developing, testing and writing the new lab modules. This is an extremely time consuming process and requires utilizing all the literature resources from phase I. Whenever possible, parts of experiments from various valid resources such as Journal of Chemical Education publications, with permission, are adopted and adapted to fit into the new lab modules.

Summary and Conclusion

To address various topics in introductory, general chemistry to organic chemistry courses, here is a list of the new lab modules that have been developed along with a short description of each module:

- *Acids, Bases and pH Indicators.* Students will be introduced to the concept of using various natural pH indicators, such as red cabbage juice, beet juice and blueberry juice to determine the acidic or basic nature of common household items. In addition, the students will determine which natural indicator will be most suitable for use in acid-base titrations.
- *IR Spectroscopy Activity Using Spartan.* Most students struggle with grasping and understanding the 3D shapes and the bonding structure of molecules. This inquiry-based activity will allow the students to gain hands-on experience with IR (infrared) spectroscopy, connect specific IR frequencies to types of bonds, and be able to visualize that frequency on 3D structures in Spartan.
- *NMR Spectroscopy and Structure Templating.* Using guided inquiry and Mnova software, the students will predict and generate NMR (nuclear magnetic resonance) spectrum, to make the correlation between organic structures and ^{1}H, ^{13}C NMR. Also, the students will have the option of conducting the wet chemistry part of this.
- *Lipase-Catalyzed Esterification.* The students will apply the principles of green chemistry to design a solvent-free reaction where students will determine which ester they want to synthesize, plan a procedure, conduct the experiment and share the results with peers.
- *Quantifying Compounds in Thin Layer Chromatography (TLC) Experiments.* TLC has been a very useful analytical tool in chemistry to analyze mixtures of compounds. With a new software or an online webapp, students can obtain

quantitative information from a developed TLC plate, allowing the students to analyze and compare various samples.

- *Buret Chromatography, a HPLC Analogue.* High performance liquid chromatography (HPLC) instrument is usually very expensive to purchase and to maintain. This approach, using a buret and spectrophotometer, the students can separate and analyze various liquid mixtures.
- *Gas Chromatography (GC).* GC instrument is usually very expensive, but now with the benchtop version, the students will analyze different fragrant compounds and use the GC instrument to demonstrate the principles of chemical quantitation.

The common theme that all of these modules share together is that it allows the students to be creative, to be more responsible learners and to develop critical thinking skills as they employ different instruments as tools to decipher and to explore their own reaction mixtures. No two students will arrive at the same answer. These modules are not ready for classroom implementation yet because of one important reason. In the original proposal, the proposed activities did not include preparing teaching notes for faculty. Once the modules have been developed, it became apparent that teaching notes are necessary to allow other faculty to teach these lab modules. Unfortunately, because of the open nature of the experiments, writing these instructor notes will be very time consuming to address the various possible reactions and outcomes. The current plan is to continue to work on them, even though they are not mentioned in the original proposal and the sabbatical leave has finished.

Conclusions

<u>Sabbatical Project Summary</u>

I am extremely satisfied with the successful completion of my proposed sabbatical project, and deeply grateful to Mt. SAC for this wonderful opportunity to work on such an exciting project. As reflected by this sabbatical report, I take great pride in achieving the stated goal for this project – to complement, enhance and strengthen the current curriculum by creating a learning environment to allow the students to be creative, become better learners, more responsible citizens, and to develop critical thinking skills. This sabbatical project proposes an innovative approach to effectively enrich the student learning experience in chemistry, by integrating discovery learning, green chemistry and instrumentation into the lab curriculum. Each phase of the project has been completed with immense effort and meticulous attention to every detail to accomplish its intended purpose and expected outcomes.

For phase I of the project, a comprehensive search and investigation has been conducted on the topics of discovery learning, green chemistry and instrumentation by focusing on books, lab manuals, websites and journal readings, as well as attending conferences and workshops. The collective efforts and the knowledge attained from phase I serve as the solid foundation for phase II and phase III of the project. In phase II, green chemistry concepts have been applied to selected experiments to replace highly toxic or reactive chemicals with greener alternatives while reducing chemical waste production. In addition, experimental protocols for new instruments have been developed and tested in the classroom, with student feedbacks collected and analyzed on the new approach. For phase III, new lab modules have been developed for various courses from introductory, general to organic chemistry. These modules begin with green chemistry design in choosing less hazardous reagents and reactions, and utilize various instruments as tools to allow discovery learning to occur, enabling the students to be creative, to be more responsible learners and to develop critical thinking skills.

Benefit and Value of the Sabbatical Project to the College

Professional Growth and Enrichment

As an educator, my professional goal and passion in life are to contribute excellence to science education and to provide exceptional learning experience to students. This sabbatical project has provided a truly outstanding opportunity for me to learn the best practices from the successful implementations nationwide, dialogue with experts in the field, and gain the vital knowledge necessary to develop high quality classroom instruction materials at Mt. SAC. It has been such an absolute joy to be like a student again, to be immersed in the field of chemistry, to attend conferences and workshops, to learn about so many novel ideas, state-of-the-art instrumentation and just soaking in all the knowledge. The scope of the finished project pleasantly exceeded my initial expectation and planning (as outlined in the original sabbatical proposal); moreover, the entire duration of the sabbatical leave has been an exciting, enriching and rewarding learning experience. I am deeply grateful that this project has allowed me to gain expertise in an areas that I strongly believe will shape the future direction of science education. I look forward to the coming academic year with a refreshed, invigorated attitude and an eagerness to contribute to the instructional program at Mt. SAC.

Benefits to the Department, Instructional Program and Students

The greatest benefit of this sabbatical project to the students is the excellent quality education that they will receive by incorporating discovery learning, green chemistry, and instrumentation into the chemistry lab curriculum at Mt. SAC. The Chemistry Department continuously provides a quality instructional program that utilizes the latest technology and innovation for lecture delivery and laboratory instruction. 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 students will gain valuable hands-on instrumentation experience as they complete the various chemistry courses, along with expanded knowledge in green chemistry which will encourage them become more responsible citizens. The discovery learning will allow the students to express creativity and develop critical thinking skills. Collectively, these experiences will increase the students' level of preparation for transfer to four-year institutions and in other academic endeavors.

Benefits to the College

This sabbatical project has the potential to bring some direct cost benefits to the College. In phase II of this sabbatical project, green chemistry principles will be applied to specific experiments that typically generate large amount of chemical waste, with the intention of replacing the more toxic or reactive chemicals with greener alternatives and thereby reducing chemical waste. For the current fall semester, there are a total of around 65 sections of chemistry courses offered, so any attempts at reducing chemical waste can translate into a large difference in decreasing the total cost for waste disposal.

In addition, the project activities are directly correlated to and promote Mt. SAC's mission and vision statements:

- *"College is committed to providing quality education, services, and workforce training so that students become productive members of a diverse, sustainable, global society."* The goal of this sabbatical project is to create a learning environment to allow the students to be creative, become better learners, more responsible citizens, and to develop critical thinking skills. By improving the quality of their learning experiences and providing the students with the opportunities to practice these essential 21st century skills, the students will be better prepared for their future careers.
- *"We will be viewed as a leader in community college teaching, programs, and services."* This project has the potential to significantly enhance and strengthen the current lab curriculum, to provide better learning experiences for all the students in the program. Successful implementation of the project activities could also serve as an inspiring model for other community colleges to follow.

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Green Chemistry Commitment
www.greenchemistrycommitment.org

Beyond Benign
www.beyondbenign.org

GCEdNet – Green Chemistry Education Network
http://cmetim.ning.com/

University of Scranton Greening Across The Chemistry Curriculum
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Appendix A:

Sabbatical Leave Proposal

Integration of Discovery Learning, Green Chemistry and Instrumentation Into the Chemistry Lab Curriculum

Sabbatical Project Proposal

2018 – 2019

Jenny Chen, Ph.D.

Chemistry Department

Abstract

With the rapid advances in technology, the world around us has changed drastically in the past decades. To properly prepare and train our students to have the necessary skills to meet the continuously changing demands of the 21st century job market, it is inevitable that our curriculum and how we teach have to change. This sabbatical project proposes an innovative approach to effectively enrich the student learning experience in chemistry, by integrating discovery learning, green chemistry and instrumentation into the lab curriculum. The goal is to complement, enhance and strengthen the current lab curriculum by creating a learning environment to allow the students to be creative, become better learners, more responsible citizens, and to develop critical thinking skills. Through this sabbatical project, Dr. Chen would be able to learn the current best practices, dialogue with experts in the field, and gain the vital knowledge necessary to develop quality classroom instruction materials for Mt. SAC courses to provide excellent learning opportunities to students.

Introduction

With the tremendous advances in technology, the world around us has changed drastically in the past decades. In this digital age, the availability of vast information at the touch of our fingertips and the impact of social media have forever changed our society and how we live. Consequently, our students have changed in how they learn and interact, as our students today are very different from the past generations. More importantly, with the rapid pace in the change of technology, the job marketplace has become unpredictable. Jobs in the future are not so easily defined. For example, some of the fastest growing jobs in technology today did not even exist a decade ago. To properly prepare and train our students to have the necessary skills to meet the continuously changing demands of the 21st century job market, it is inevitable that our curriculum and how we teach have to change.

Of the many skills considered to be essential for the 21st century workplace, most educators agree that the crucial areas for development of learning skills are:

- critical thinking
- creativity
- collaboration
- communication

Many education reformers argue that the traditional curriculum is not preparing the students adequately to be competitive in the global economy, and changes are necessary.

Over the years, as a result of the collaborative efforts from many dedicated faculty, the Chemistry Department has been very consistent in providing a high-quality instructional program to our students. These efforts have allowed the Department to continuously enhance the student learning experience in both lecture and laboratory settings through the utilization of the latest technology and innovation. Some of these changes were the direct beneficial results of past sabbatical projects, such as implementing electronic data collection system in general chemistry and green chemistry experiments in organic chemistry. With the current advances in technology, what was considered to be impractical years ago is now practical, what was conducted as standard protocol before now requires updates, and new innovations present many exciting possibilities. This sabbatical project seeks to build upon these strong foundations in the Chemistry Department and to develop instructional materials to expand, enhance and strengthen the current lab curriculum.

Project Goal, Design and Rationale

Project Goal

This sabbatical project proposes an innovative approach to effectively enrich the student learning experience in chemistry, by integrating discovery learning, green chemistry and instrumentation into the lab curriculum. *The goal is to complement, enhance and strengthen the current curriculum by creating a learning environment to allow the students to be creative, become better learners, more responsible citizens, and to develop critical thinking skills.* The decision to choose these three specific components to incorporate came after much contemplation and assessment of what our student needs are, what would be most beneficial to the Chemistry Department and College, as well as to my professional growth.

Discovery Learning

At the undergraduate level, the traditional approach to teach laboratory is expository where students often would follow the same step-by-step procedure to arrive at similar answers. While this approach is very effective in teaching the students the fundamental lab techniques and utilization of lab equipment, it is not conducive for developing critical thinking skills and creative thinking. In the ideal world, the best laboratory experiences would be similar to the research activities that scientists engage in. Research at the undergraduate level is widely recognized as a powerful pedagogical tool that significantly enhances the quality of undergraduate science education. Many studies suggest that undergraduate research plays a pivotal role in science students' success to graduation and their choice to pursue careers in sciences. In the real world, within the limitations and restraints of the teaching laboratory setting, discovery learning can be very effective in simulating the research environment where the questions are more open ended and students can learn to come up with their procedures to allow for various possible correct answers.

It is not necessary to change the entire lab curriculum, since the Chemistry Department already has a high quality program. Instead, the discovery learning approach is really all about changing the way we teach to affect how our students will learn, by making modifications to certain components. For example, our students are so accustomed to finding information on the web and almost cannot survive without the internet. With discovery learning, we can teach the students to become better learners by analyzing the flood of information online to search for valid scientific sources. At the same time, we are also encouraging creativity and critical thinking skills by having the students choose what they consider to be the best experimental method by anticipating the type of results they will obtain. With different methodologies, students will obtain different results, which takes away the boredom, creates interest and generates excitement from the sense of ownership. After conducting the experiment, the students can work on their communication skills by sharing their results with the class, and collaborate together to determine which methodology was the best approach. This is the type of laboratory learning experience that will truly help to train our students to better prepare for their future careers.

Green Chemistry

In very simple terms, green chemistry is really just a different way of thinking about how chemistry and chemical engineering can be done in a sustainable manner, to protect our environment. On a broader level, this sustainability concept can be applied to the design, development and implementation of chemical processes in both academics and industry. The difficult challenge is to find creative and innovative ways to reduce waste, create alternatives for hazardous substances, conserve energy, prevent pollution, and generate renewable energy sources.

The field of green chemistry is wide open for innovation and development of new ideas. Therefore, as educators, we must teach our students to become familiar with green chemistry principles and allow them the opportunity to explore these concepts. With the discovery learning approach, as the students are searching for and figuring out the best experimental procedure to conduct their experiment, green chemistry principles such as prevention, designing safer chemicals and utilizing less hazardous chemical syntheses can be applied. Rather than teaching a course on green chemistry that may reach only a limited audience, the eventual overarching goal should be to strive to incorporate the concept of green chemistry and sustainability in every course, every laboratory experiment that we teach. This is the future of chemistry, and we have the responsibility of training our students to become informed and responsible citizens, to make better choices in designing for the future.

Instrumentation

In the chemistry laboratory, most experiments require the extensive use of lab equipment and instruments to collect meaningful data. Thus, providing hands-on training for the most common as well as advanced instruments is a crucial component in the lab curriculum. As the students progress from introductory level courses to upper level courses, the demand for advance (and usually more expensive) equipment increases significantly also.

While discovery learning is the pedagogical approach that enables the students to solve problems creatively and develop critical thinking skills, instrumentation is one of the necessary tools that allow this process to occur. The students need to have access to a variety of instruments to enable them to explore different methodology in conducting experiments and to obtain meaningful data. In addition to acquiring valuable hands-on experiences, the students will also gain further opportunities to sharpen their analytical and critical thinking skills in evaluating the collected data to interpret results correctly. With advances in technology comes possibilities, for example, a gas chromatography instrument that typically cost $150K – $200K now comes in a benchtop version that is in the range of a few thousands, much more budget friendly for community colleges. In the context of teaching, this translates into having another important analytical tool to use in current experiments and the possibility of adding new experiments that utilize gas chromatography to our lab curriculum. This is an example of some of the exciting options that I will contemplate and explore in this project.

Project Activities, Timeline and Expected Outcomes

The goal of my sabbatical project is to complement, enhance and strengthen the current lab curriculum by creating a learning environment to allow the students to be creative, become better learners, more responsible citizens, and to develop critical thinking skills. To achieve this goal, project activities will be conducted in three phases. The three phases of project activities will be described in details, along with an estimated timeline and expected outcomes.

Phase I: Research, Investigate and Learn

The first crucial step for this project is to conduct a comprehensive research and investigation on the topics of discovery learning, green chemistry and instrumentation. The purpose is to learn the pedagogy, best practices and innovative applications for each topic. The main components are data collection and compilation of useful information that can be utilized in phases II and III. Specifically, project activities will include a thorough study of available resources such as books, textbooks, open education resources, and journal articles from Journal of Chemical Education. I also plan to attend relevant conferences and workshops to learn the current best practices and to dialogue with the experts in the field. Examples include the "22nd Annual Green Chemistry & Engineering Conference" in June 2018 and the NSF-sponsored Chemistry Collaborations, Workshops and Community of Scholars (cCWCS) faculty workshops in summer 2018. Unfortunately, since the dates for these workshops actually occur outside of the two semester dates, I will not be including the attendance in the project timeline, but the compilation and evaluation of data from these workshops will occur during the semester.

Month	Week	Proposed Project Activities
August	4th	*The first five weeks will focus on the topic of discovery learning.* Project activities will include: ➢ Read books on the topic, such as "Thinking through project-based learning: guiding deeper inquiry," "Scaffolding science inquiry through lesson design," and "Best practices for teaching science: what award-winning classroom teachers do" to learn about the topic. ➢ Examine current published lab manuals to find relevant experiments on this topic. ➢ Peruse the Journal of Chemical Education to see the various ways of how this topic has been implemented in classroom setting. ➢ Search the various open education resource websites to find relevant experiments on this topic. ➢ Gather new ideas from conferences and workshops. ➢ Prepare a written summary of the important findings, as part of the sabbatical report. The expected outcomes of these activities are: ➢ To gain a deeper understanding of what discovery learning means and to learn the best practices of how to implement it into the curriculum from others.
September	1st 2nd 3rd 4th	

		➢ Identify and compile a list of appropriate topics, experiments, and activities for moving forward to phases II and III.
October	1st 2nd 3rd 4th 5th	*The following five weeks will focus on the topic of green chemistry.* Project activities will include: ➢ Read books on the topic, such as "Green chemistry: theory and practice," "Green engineering: environmentally conscious design of chemical processes," and "Green organic chemistry in lecture and laboratory" to learn about the topic. ➢ Examine current published lab manuals to find relevant experiments on this topic. ➢ Peruse the Journal of Chemical Education to see the various ways of how this topic has been implemented in classroom setting. ➢ Search the various open education resource websites to find relevant experiments on this topic. ➢ Gather new ideas from conferences and workshops. ➢ Prepare a written summary of the important findings, as part of the sabbatical report. The expected outcomes of these activities are: ➢ To gain a deeper understanding of what green chemistry means and to learn the best practices of how to implement it into the curriculum from others. ➢ Identify and compile a list of appropriate topics, experiments, and activities for moving forward to phases II and III.
November	1st 2nd	*The following two weeks will focus on the topic of instrumentation.* Project activities will include:: ➢ Conduct a thorough search online on the various manufacture companies to learn about the types of instruments that are available now at a reasonable budget, with the focus on their capabilities and limitations. ➢ Peruse the Journal of Chemical Education to see the various ways of how a specific instrument can be utilized in different experimental settings.

		➢ Search the various open education resource websites to find relevant experiments on this topic. ➢ Prepare a written summary of the important findings, as part of the sabbatical report. The expected outcomes of these activities are: ➢ To gain a better understanding of which instruments can be incorporated into our curriculum, and perhaps in the not so distant future, into our new science building. ➢ Identify and compile a list of appropriate instruments, experiments and activities for moving forward to phases II and III.

Phase II: Modify the Current Curriculum

In the past decades, to continuously enhance the quality of education to our students, the Chemistry Department has utilized the latest technology and innovation for lecture delivery and laboratory instruction. Through the efforts of sabbatical projects and various proposals funded by the National Science Foundation (NSF), the Department has successfully implemented electronic data collection technology (MeasureNet) in general chemistry, incorporated nuclear magnetic resonance (NMR) spectroscopy and Spartan molecular modeling software into the lab curriculum, and introduced green chemistry to the organic chemistry curriculum. This sabbatical project attempts to further enhance and strengthen the current lab curriculum by integrating discovery learning, green chemistry and instrumentation. The purpose is to complement, as in finding appropriate areas in the curriculum that can benefit directly from this approach.

Upon completion of phase I of the project, one of the tangible products will be a compilation of appropriate experiments or activities that have the potential of being integrated into the lab curriculum. These findings will be shared with my colleagues, and together, we will evaluate, analyze and select the most appropriate activities to move forward into phases II and III. In phase II, efforts will be focused on:

➢ Integrating discovery learning into appropriate portions of the current experiments;

➢ Applying the green chemistry concepts to choose less hazardous reagents and to reduce waste; and

- ➢ Incorporating the use of new instruments as additional analytical tool in the current experiments.

<table>
<tr><th>Month</th><th>Week</th><th>Proposed Project Activities</th></tr>
<tr><td>November</td><td>3^{rd}
4^{th}</td><td rowspan="5">These ten weeks will focus on modifying the current lab curriculum to incorporate discovery learning, green chemistry and instrumentation.

<u>Project activities will include</u>:

➢ Discuss phase I results with colleagues to evaluate, analyze and select the most appropriate experiments to test.

➢ Work with stockroom technicians to identify the experiments that generate the largest amounts of chemical waste. Focus on modifying these experiments with green chemistry principles to reduce waste.

➢ Gather the required chemicals, materials, glassware and equipment to test the selected experiments. Work with my colleagues to order the missing items.

➢ Conduct each of the selected experiments in the laboratory. Analyze the collected data to determine the feasibility of each experiment.

➢ Work with student volunteers to have them conduct the experiments and obtain student feedback on their perception of the learning experience.

➢ Evaluate the collected data from students to determine if the required skills in the experimental procedure are level appropriate and if consistent data can be generated.

➢ Prepare a written summary of the important findings, as part of the sabbatical report.

➢ Write protocols for the experiments that were tested and produced satisfactory results, as part of the sabbatical report.

➢ Present these findings to my colleagues to discuss the results and how to best implement these experiments in the curriculum.

<u>The expected outcomes of these activities are</u>:

➢ Each of the selected experiments is tested in the lab, with the successful ones being tested by both faculty and students.</td></tr>
<tr><td>December</td><td>1^{st}
2^{nd}</td></tr>
<tr><td>February</td><td>4^{th}</td></tr>
<tr><td>March</td><td>1^{st}
2^{nd}
3^{rd}
4^{th}</td></tr>
<tr><td>April</td><td>1^{st}</td></tr>
</table>

		➢ Develop high quality classroom instruction materials to facilitate the implementation into the curriculum.

<u>Phase III</u>: Develop New Laboratory Modules

Upon completion of phase II of the project, efforts will be devoted to developing new laboratory modules that fully embrace discovery learning, green chemistry and instrumentation. Many of the project activities will be similar to those in phase II. The biggest difference is that there is no preexisting framework to limit the imagination, and there will be many exciting options to choose from. At the same time, with so many possibilities, it will require a lot of time to narrow the choices down. The difficult challenge here is to design lab modules that would work great right now, within the constraints of our current facilities, and at the same time would have the potential for growth in future new facilities.

Month	Week	Proposed Project Activities
April	2nd 3rd 4th 5th	*These ten weeks will focus on developing new laboratory modules that fully embrace discovery learning, green chemistry and instrumentation.* <u>Project activities will include</u>: ➢ Discuss phase I results with colleagues to evaluate, analyze and select the most appropriate activities to bring together into modules. ➢ Gather the required chemicals, materials, glassware and equipment to test the selected experiments. Work with my colleagues to order the missing items. ➢ Conduct each of the selected experiments in the laboratory. Analyze the collected data to determine the feasibility of each component of the module. ➢ Work with student volunteers to have them conduct the entire module and obtain student feedback on their perception of the learning experience. ➢ Evaluate the collected data from students to determine if the required skills in the experimental procedure are level appropriate and if consistent data can be generated.
May	1st 2nd 3rd 4th	
June	1st 2nd	

		➢ Prepare a written summary of the important findings, as part of the sabbatical report. ➢ Write protocols for the modules that were tested and produced satisfactory results, as part of the sabbatical report. ➢ Present these findings to my colleagues to discuss the results and how to best implement these modules in the curriculum. The expected outcomes of these activities are: ➢ Each of the selected experiments is tested in the lab, with the successful ones being tested by both faculty and students. ➢ Develop high quality classroom instruction materials for the successful modules to facilitate the implementation into the curriculum.

Product of the Sabbatical Project

The tangible product of this sabbatical proposal has been described above, in the proposed project activities section for phase I, II and III, both as what will constitute the written sabbatical report and as expected outcomes. Essentially, the important findings from all three phases will be summarized in written form. These findings will be shared and discussed with my colleagues, to receive important feedback from them so that together, as a Department, we can make changes to enhance and strengthen our lab curriculum. In particular, the focus from phase I will be on identifying and compiling a list of appropriate a list of appropriate topics, experiments, and activities for moving forward to phases II and III. Phase II and III will emphasize the development and writing of modified experiments and new lab modules to produce high quality classroom instruction materials, with the possibility of incorporating them into the current lab manuals.

The intangible product of this sabbatical proposal is the value and benefits of this sabbatical project, which are described in details in the next section. The part of the intangible product that is difficult to describe and measure, but can be predicted is that we know that as we change the way we teach, this will have a direct influence on how our students learn. As proposed in this project, if we create a learning environment to allow the students to be creative, become better learners, more responsible citizens, and to develop critical thinking skills, this will have a long lasting positive impact on our students. While it is difficult to quantify this impact, but proficiency can only come with practice, so we must try to present these important and meaningful learning opportunities to our students.

Value and Benefits of the Sabbatical Project

Professional Enrichment and Growth

As an educator, my professional goal and passion in life are to contribute excellence to science education and to provide exceptional learning experience to students. Every day, I strive to do my best in teaching and preparing my students to do well not just in my class, but also to learn better habits, and to develop the important analytical and critical thinking skills, so that they will be successful in their future academic endeavors and careers. I consider it a privilege that what I do in the classroom and how I treat my students can have lasting positive impact on them. The irony is that often times, we get so wrapped up in our teaching and the extra things that we do for our students that we don't have the time to stop and reflect on what we do. Yet, it is very important to take the time to learn, to stay current in the field and to reflect on what we do to make changes, in order to continuously improve and excel in teaching.

This sabbatical project will provide an exceptional opportunity for me to continue to grow professionally, to become a student again, to learn about new concepts in depth, to explore ideas about how to change our teaching to better prepare our students for the 21st century workplace. There is a growing sense of excitement and joy, as I am pouring long hours, day after day, to prepare this sabbatical proposal. I am excited and eagerly look forward to finally have the time to attend more conferences, to read books on discovery learning and green chemistry, to find out about the latest advances in teaching technology, to reflect on new pedagogies and contemplate how I can incorporate these innovations back to the Chemistry Department, back to the students at Mt. SAC.

Through this sabbatical project, I would be able to learn the best practices from the successful implementations nationwide, dialogue with experts in the field, gain the vital knowledge necessary to develop high quality classroom instruction materials for Mt. SAC courses to provide exceptional learning opportunities to students.

Benefits to the Department, Instruction Program and Students

I am privileged to work in Chemistry Department, where my colleagues share the vision and passion to provide excellent learning experiences to students, and always seeking to utilize the latest technology and innovation for lecture delivery and laboratory instruction. This sabbatical project follows the Department's commitment to excellence philosophy and directly benefits the Chemistry Department, our students and Mt. SAC in the following ways:

- Enhance and strengthen the current Chemistry curriculum by incorporating discovery learning experiences and green chemistry applications.
- Increase the use of instrumentation in the various courses, providing additional valuable hands-on instrumentation experience for our students.
- Allow the students to have multiple exposures to discovery learning, green chemistry and use of instrumentation as they complete the various chemistry courses; this cohesion is essential in solidifying the development of critical thinking, creativity, collaboration and communication.
- Expand student interest in green chemistry and encourage them to become responsible citizens, as they learn in their courses how to make better choices for safer reagents and to reduce waste.
- Develop high quality classroom instruction materials, with the possibility of incorporating them into the current lab manual.

The goal of this sabbatical project is to complement, enhance and strengthen the current chemistry lab curriculum. To accomplish this goal, it requires a collaborative effort from the Chemistry Department, and not just one faculty's individual effort. Therefore, as described in the proposed project activities, the important findings from phase I will be shared with my colleagues to receive valuable feedback, and together as a Department, we will evaluate, analyze and select the most appropriate activities to move forward into phases II and III. In the past decades, the Chemistry Department has always welcomed, embraced and utilized the latest technology and innovation for lecture delivery and lab instruction. For example, as Co-PI of a National Science Foundation (NSF) funded project, a nuclear magnetic resonance (NMR) instrument (~$90K) was purchased for the Department, and we developed lab modules that successfully incorporated NMR spectroscopy technique into the organic chemistry curriculum.

Also, through the effort of another faculty's sabbatical project, green chemistry was effectively introduced into the organic chemistry lab curriculum. The innovative approach of integrating discovery learning, green chemistry and instrumentation, proposed in this project, is in perfect alignment with the Department's vision and commitment to excellence. The direct benefit of this sabbatical project will be to extend these quality learning experiences across the lab curriculum to the various courses, to impact more students.

In order for the outcomes of this sabbatical project to have a significant impact on enhancing and strengthening the current lab curriculum, it is imperative that these modified experiments and new lab modules can be conducted within the current facilities and budget restraints, while at the same time possess the potential for growth in the future new facilities. Therefore, parts of the proposed project activities in phases II and III involve working with the stockroom technicians and colleagues in the Department to analyze the collected data from phase I to determine the feasibility of each proposed experiment. For example, the experiments that currently generate the largest amounts of chemical waste will become the focus of applying green chemistry principles in the modified experiments. Also, the current instrumentation available in the Department are primarily used in organic chemistry lab curriculum. In the new lab modules, these instrumentation will be utilized in other courses, as tools to integrate discovery learning. The approach and vision of this sabbatical project is to develop high quality classroom materials that can be immediately incorporated into the current lab manuals, to serve the purpose of complementing, enhancing and strengthening the chemistry lab curriculum.

Benefits to the College

The proposed activities are directly correlated to and promote Mt. SAC's mission and vision statements:

- *"College is committed to providing quality education, services, and workforce training so that students become productive members of a diverse, sustainable, global society."* The goal of this sabbatical project is to create a learning environment to allow the students to be creative, become better learners, more responsible citizens, and to develop critical thinking skills. By improving the quality of their learning experiences and providing the students with the opportunities to practice these essential 21st century skills, the students will be better prepared for their future careers.

- *"We will be viewed as a leader in community college teaching, programs, and services."* This project has the potential to significantly enhance and strengthen the current lab curriculum, to provide better learning experiences for all the students in the program. Successful implementation of the project could also serve as an inspiring model for other community colleges to follow.

This sabbatical project has the potential to bring some direct benefits to the College. For this semester only, the Chemistry stockroom has already collected over 625 liters of chemical waste, as of beginning of November. For certain experiments, for example in CHEM 50, 181 liters of chemical waste was collected in October for just one experiment. In phase II of this sabbatical project, efforts will be focused on experiments such as this one, to apply green chemistry principles, to change the design of the experiment to safer reagents and to reduce waste. If successful, these green chemistry applications can directly benefit the College's sustainability efforts and significantly reduce the cost for chemical waste removal. Consequently, these financial savings for the College will allow the College to operate more effectively by using the available resources on other areas of need.

In a few years, the hopes for a new science building may become a reality. While there are still many uncertainties, it is never too early to dream big and start planning for the future. To design the ideal facilities for the future, we have to envision how we want to teach in the future. The innovative approach of integrating discovery learning, green chemistry and instrumentation into the chemistry lab curriculum, presented in this proposal, is perhaps setting the stage for this envisioning and planning for the future to begin.

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Appendix B:

Instrumentation Lab Protocols

Student Surveys and Student Feedback

PASCO Spectrometer

Calibration

1. Turn on the spectrometer. Use the USB cable to connect the spectrometer to your computer or wirelessly connect the spectrometer using Bluetooth.
2. Open the **Spectrometry** program to full screen.

3. Select **ANALYZE SOLUTION** from the menu at the top of the screen.

4. Select **CALIBRATE DARK** from the menu at the bottom of the screen. The spectrometer will turn off all of its lights and perform the calibration. *A check mark will appear when the calibration is finished.*

5. Put distilled water into a cuvette. This should be the same distilled water that was used as a solvent for the solutions being analyzed. Always handle the cuvette by the ridged sides. Wipe off any fingerprints using a lint free wipe (Kimwipes). Place the cuvette into the spectrometer so that the ridged sides are facing the violet and green light icons and clear sides face the white light and absorbance spectrum icons.
6. Select **CALIBRATE REFERENCE** from the menu at the bottom of the screen. A check mark will appear when the calibration is complete.

Finding a Wavelength to Analyze

1. Place 4 mL of the most concentrated solution to be analyzed into a cuvette, or if cuvettes have been prepared in advance obtain the cuvette containing the sample of highest concentration. Always handle the cuvette by the ridged sides. Wipe off any fingerprints using a lint free wipe (Kimwipes). Place the cuvette into the spectrometer as you did in the calibration.
2. Select the red **RECORD** circle at the bottom left of the screen to start analyzing the solution. (It changes into a square while data is being collected.)

3. Select the red **STOP RECORDING** square to stop data collection.

4. Select **SCALE TO FIT** to rescale your data.

5. Use the **ADD COORDINATE** to locate a wavelength to analyze on the curve.

   a. A small hand will replace your cursor. Move it to the box that has appeared on the graph and drag the box slowly toward the curve. As you get near the curve an arrow will appear that indicates a specific wavelength on the curve. Releasing the box will snap the box to the point on the curve the arrow is pointing to.

b. Drag the box along the curve to find a desirable wavelength to analyze. This is usually a high point on the curve.

NOTE: If your curve plateaus near the top of the graph, the absorbance is too large in that area to be used for analysis and another wavelength near the plateau should be selected.

NOTE: A value of three indicates that the solution is too concentrated for the selected wavelength, and a different wavelength should be selected.

6. Once you have found a desirable wavelength, select the blue check mark to the rightt of the selected wavelength value.

Creating a Concentration-Absorbance Calibration Curve and Determining Unknowns

1. Select **CONCENTRATION** from the menu at the top of the screen . A table will appear on the left side of the screen that has columns for "Concentration" and "Absorbance."

2. Highlight the concentrations in the column titled "Concentration" and type over the given values with the concentrations of your prepared samples.
3. Select **RECORD** to start analyzing the solution.

4. Place the highest concentration sample into the spectrometer and look at the cell in the "Absorbance" column that corresponds to the respective concentration. *Once the absorbance stabilizes select the check mark next to the absorbance to record the value.*
5. Place the samples of lesser concentration into the spectrometer and record their absorbance values. Continue until all of the samples are analyzed.
6. Select **STOP RECORDING** to stop data collection.

7. You may wish to turn off **Show Live Scan Display**.

8. Use **SCALE TO FIT** to rescale your data.

9. Select **SHOW LINEAR FIT** to create a best fit line and display the equation for the line.

10. Place the cuvette containing a solution of unknown concentration into the spectrometer.
11. Select the box in the table titled "Determine Unknown Concentration" at the bottom of the screen under a column labeled "Absorbance."
12. Select **RECORD** to start analyzing the solution.

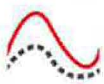
13. Once the absorbance stabilizes select the check mark next to the absorbance to record the value.
14. Select **STOP RECORDING** to stop data collection.

15. Repeat steps 10-14 with other unknowns, if needed.
16. Write down all the absorbance values into your lab notebook.

Vernier Go Direct® Sensor Temperature Probe

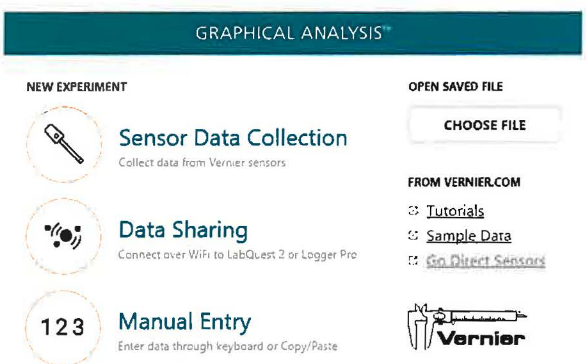
Connecting the Sensor Temperature Probe

1. Turn on your sensor temperature probe by pressing the power button once. The Bluetooth® LED will blink red.
2. Open the **Vernier Graphical Analysis** app on your computer, tablet or mobile device.



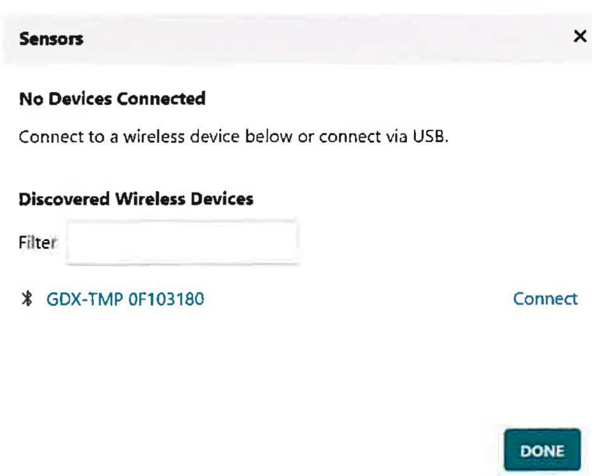
NOTE: Other names for this app include **Graphical Analysis 4** *and* **Vernier Graphical Analysis 4** *(but not the GW version) depending on the source of download.*

3. Select **Sensor Data Collection.**

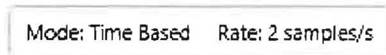


USB connection: Connect the temperature probe to the computer using the USB cable. Select **Done.**

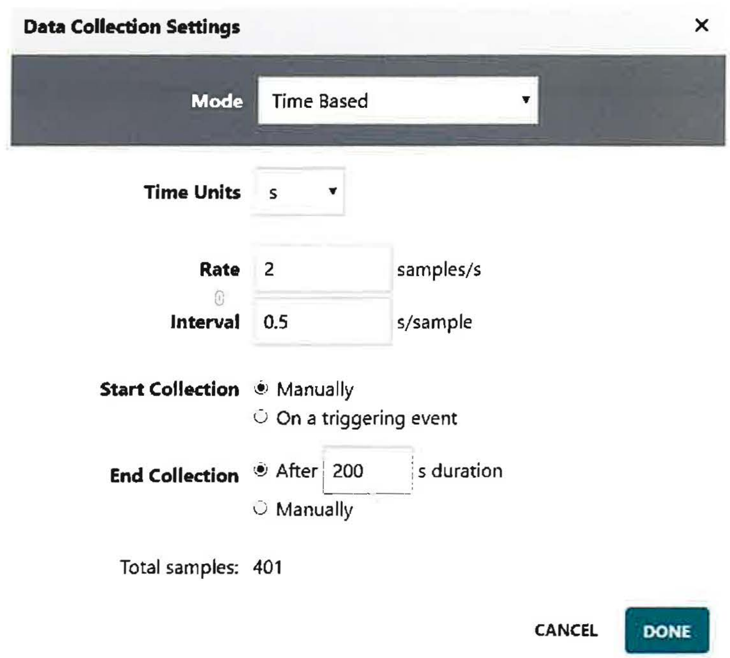
Bluetooth connection: Select your Go Direct sensor from the list of **Discovered Wireless Devices**. Your sensor's ID is located near the barcode on the sensor. The Bluetooth LED will blink green when it is successfully connected. Select **Done.**



Data Collection Settings

Select 

at the bottom left of the screen to input the following settings, then select **Done.**



Care and Cleaning of the Sensor Temperature Probe

- Before the experiment starts and during the experiment when the sensor is not in use, it can be placed flatly on top of a piece of dry paper towel.
- After each trial, the stainless steel portion of the sensor can be cleaned with tap water and dried with paper towel.

Data Collection

1. Select the view options button at the top right of the screen to change the display to **"Graph and Table."**

2. Once the sensor temperature probe is placed inside the calorimeter, select **Collect** button on top of the screen to begin data collection.

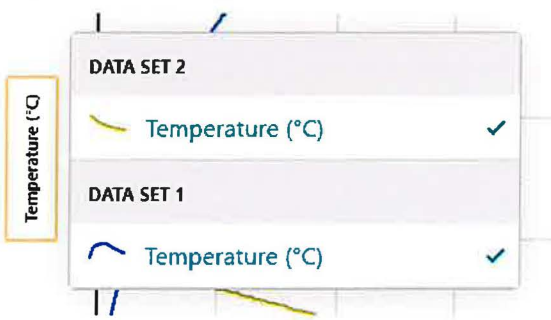
NOTE: Data collection will stop automatically after 200 seconds. To stop the experiment manually, press 

3. To conduct additional trials, select **Collect** button to begin the next trial.

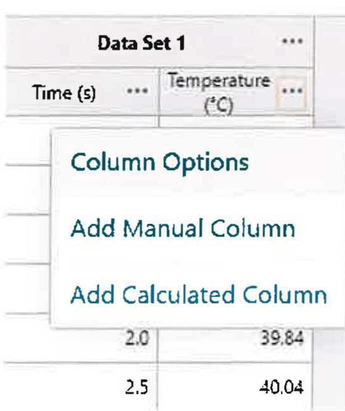
On the graph, the new trial data will be displayed. On the data table, you will see the second trial data under "**Data Set 2**."

*NOTE: You can rename any of the Data Set by selecting the ··· button next to it and select "**Rename Data Set**" to enter a different name.*

*NOTE: To view and compare the graphs from different trials, select the "**Temperature (°C)**" button on the y-axis of the graph to choose which trial or trials to display.*



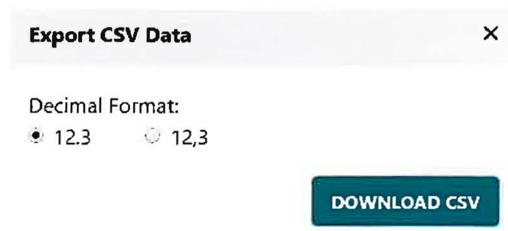
*NOTE: To view the temperature data in two decimal places, select the ··· button next to "**Temperature**" to choose "**Column Options**" to change the display.*



Exporting Data, Saving Data and New Experiment

1. To save data directly to your device or an accessible cloud storage location, select File Menu button on the top left of the screen and choose "**Save As...**" option.

2. To export the data to Excel for data analysis, select File Menu button on the top left of the screen and choose "**Export**" option. Select **.CSV** file option and decimal format.



3. To begin a new experiment, select File Menu button on the top left of the screen and choose "**New Experiment**" option, followed by Data Collection steps.

End of the Experiment

- At the end of the experiment, turn off the sensor temperature probe by pressing and holding down the power button for a few seconds. The LED light should be off.
- The stainless steel portion of the sensor should be cleaned with tap water and dried with paper towel.

CHEM 50 Student Survey and Results for Vernier Probe

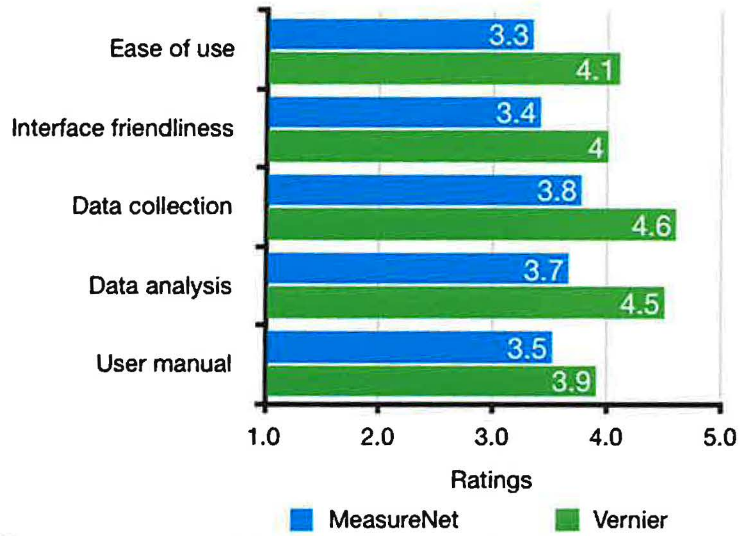


Figure 1. The ratings are scaled from 1 through 5. 5 being very good and 1 being not so good. Average of 27 student's response. Total number of students in the lab is 29 for Fall 2018.

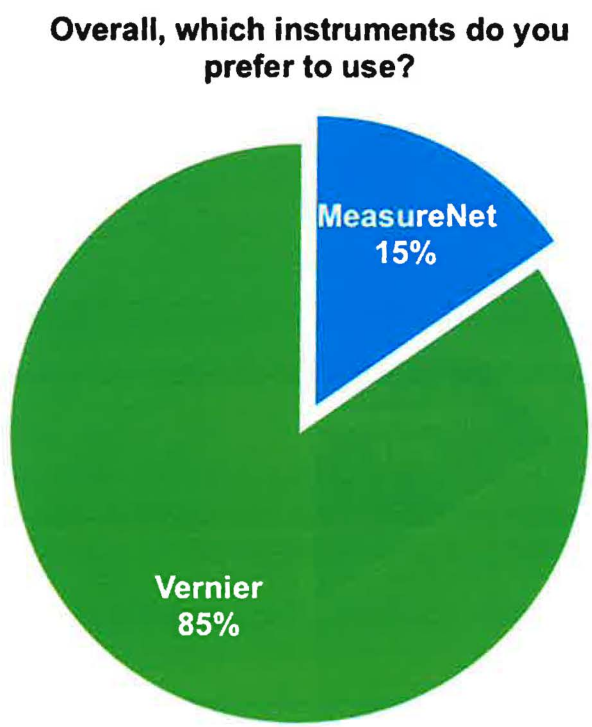


Figure 2. The percentages were determined from 26 student's opinion.

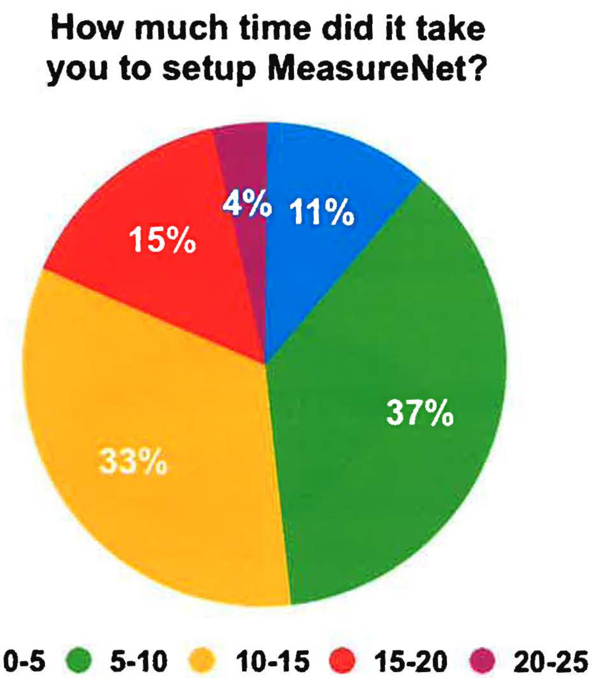


Figure 3. Students were asked how long did it take them to setup the instrument (in minutes). A total of 27 responses out of 29 students in the class.

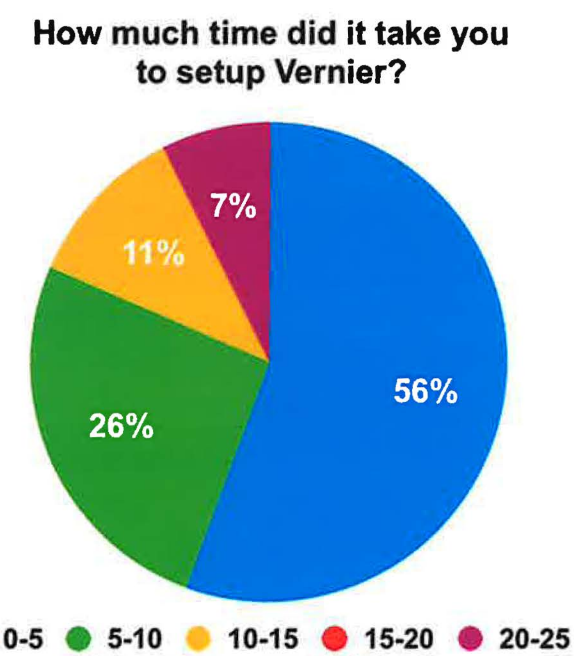


Figure 4. Students were asked how long did it take them to setup the instrument (in minutes). A total of 27 responses out of 29 students in the class.

What did you like about Vernier?

- It's user friendly and it shows all data and graphs
- Its interactive, up to date, highly customizable from labels to what you view while its recording data
- It's on the phone
- No cords to deal with
- I like how all the data was displayed on the same page and how easily it can be adjusted.
- Easy to read
- I could scroll through and find exact data after the experiment ended.
- This is easier to use, sometime
- I could download the graph straight to my phone
- Instant graph
- It was very easy to use
- Update/modern, easy access, easy and consistent tool
- It was very easy and convenient. The calibration isn't necessary. Very intuitive and easy to use.
- It user friendly and easily accessible through the phone.
- Easy to use
- Data collections are clear
- It's easy and take less time to operate
- A lot simpler to use
- Its more "up to date"
- I like the clarity of the graph and the overall clarity of the display.
- It was super easy to use and produced fast results that were accessed easily.
- The friendly user interface.
- Convenient
- It is very easy to setup. It does not need

What did you not like about Vernier?

- Nothing, everything is fairly simple
- Everything was fine, but I would like to know how to download from phone to laptop?
- Nothing
- Nothing, it worked perfectly
- I don't want to have to download an app on my phone.
- I don't like the fact that I need an app on my phone to use this device.
- I like everything about it!
- No, it's good!
- The file it saved can't not open with excel or word. It can only be open in Vernier app.