Integration of Inquiry-Based Learning with Real -World Problem-Solving

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ABSTRACT

Our chemistry courses are focused on developing real-world problem solving skills. These real-world problem skills developed in our laboratory and field trips require students to acquire knowledge as researching the question to solve accordingly. As stated by Arthur L. Costa ""The critical attribute of intelligent human beings is not only having information but also knowing how to act on it." Our Inquiry-based activities/labs/field trips are organized, open-ended approach that promotes creativity, design of experiment, with testing and analysis which lead to solving the problem. Our students utilize inquiry-based learning skills and gather, critique, analyze, and interpret information; create working theories; pose new questions; bring forward evidence; integrate new technology to solve the problem. The main steps to successful IBL module involves 1) professor needs to start with a question , problem-based question; 2) students need to design a plan for the project; 3) students need to create a scheduled plan; 4) professor needs to facilitate the students; 5) professor needs to assess the outcomes and possibly continue the facilitation process; 6) professor needs to evaluate the experiences and how to improve the experience (reflection time). This paper will discuss the novel inquiry-based labs developed and discuss the pre- and post-test analysis data to illustrate the content gains in our chemistry courses. These novel inquiry-based labs require each student to obtain a different project/problem to solve. The novel aspect has prevented cheating and requires students to become independent thinkers and not looking for the answers on-line or from previous students that have taken the chemistry course in the past. The IBL example will be detection of acetaminophen, ascorbic acid and caffeine without the need to prior separation using a novel electrode sensor.

Keywords: Inquiry-based learning/problem-based technology, polymers, oxidation/reduction reactions, electrochemistry, analytical instrumentation, interdisciplinary- academia and industry.

1. INTRODUCTION

Constructivism is the new approach for instruction instead of the traditional style of lectures. However as shown historically constructivism has been around a long time. Socrates , Plato and Aristotle have shown aspects of constructivism theory when discussing on formation of knowledge in 470-320 B.C. In 354-430 A.D. St. Augustine was teaching in the search for truth people must depend on sensory experience. John Locke in 1632-1704 was teaching that no man's knowledge can go beyond his experience, and Immanuel Kant in 1724-1804 elucidated "the logical analysis of actions and objects leads to growth of knowledge and the view that one's individual experiences generate new knowledge." Jean Piaget from 1896-1980 was considered the father of constructivism. Constructivism is where humans construct meaning into their own experiences and ideas that are the result from an investigation to understand the content better. Constructivist classroom the teacher assists the students in the incorporation of new ideas into what they already know or think they know about the lesson being taught. Students are encouraged to ask questions that they may find the answer to themselves via discussion and exploration rather than lecture mode. Teachers become facilitators that guide the learning process to solve the problem. The lab module that was developed encourages a new atmosphere of learning the content. The students are more responsible for understanding the experiment and must collaborate with the lab partners and utilize literature resources in order to resolve all problems/lab parameters. Inquiry-based activities are founded in constructivist principles that teach science as a process rather than a defined method. Inquiry-based activities increase student engagement and learning and teaches science as a process rather than a defined method. Inquiry can happen in many different forms such as collaborative inquiry and guided inquiry. With collaborative inquiry our students work in groups together and are guided to solve the lab problems where the following processes are: observing, posing questions, examining other resources/journals, utilizing tools to gather , analyze and interpret data, proposing predictions, answering questions, explaining and communicating results, considering alternative experimentation and explanations, and developing critical thinking and problem-solving skills. In inquiry-based learning, the teacher becomes the facilitator and assist students to come derive the facts instead of just presenting the facts. The 5E model is carried out for inquiry learning which involves the 5 items of : 1) Engage, 2) Explore, 3) Explain, 4) Elaborate, and 5) Evaluate. 1) Engaging the students involves developing excitement about the topic related to real-world issues. 2) Exploring the lab experiment topic involves discussing the different aspects of the problem in small collaborative groups. 3) The collaborative teams will explain the discoveries made during the inquiry experiment. 4) The elaboration of the lab will be carried out farther to investigate the experiment further with more data compiled. 5) Evaluation of the experiment to assess what was learned in the experimental process. However, inquiry labs are more challenging and require more preparation time for the professor/teacher.

There is an evident need for change in the way college science courses are taught due to the fact that 40-60% of students are leaving science related fields to non-science areas of study. Typical teacher evaluations at the college level share a common complaint of poor teaching and faculty pedagogy in science courses.

The overriding goals of IBL (Inquiry-based learning) modules are :

1) To transform the first and second year chemistry courses into problem -based research intensive program that will lead students pursuit of additionally scientifically oriented training. The IBL mode will assist the student with adopting the scientific method as a lifelong problem solver in real-world issues.

2) To increase retention and graduation rates in STEM (Science, Technology, Engineering and Mathematics) fields.

3) To produce new knowledge in the chemistry field of study and share outcomes and results in a database.

Assessment is a vital part of learning to ensure students are gaining content knowledge and not just memorizing formulas accordingly. Therefore the inquiry-based experiment process needs to be assessed with a pre-test and a post-test to analyze and illustrate content gains. Normalized gains were calculated by: Post-test- Pre-test/ 100-Pre-test R.R. Hake states that a normalized gain greater than 0.7 means a high gain in content and less than 0.3 is an extremely low content gain. The low gain of 0.3 is typically found in cook book chemistry labs and high gains are found in Inquiry -based learning modules. The analysis of content gains can assist with improvements in lab modules development with problem solving skills to meet real-world issues such as detection of various pharmaceuticals/medicinal compounds without the need of prior separation. A post-survey about feedback on how the inquiry-based lab module could be improved and how the student felt about the IBL mode to assist in improvement was carried out. Various electrochemical techniques were utilized to determine the best modified sensor electrode and best parameters to detect and analyze everyday compounds such as acetaminophen, ascorbic acid and caffeine.

2. EXPERIMENTAL

Bioanalytical System Epsilon potentiostat in a three electrode compartment cell was utilized to carry out controlled potential electrolysis, Differential Pulse Voltammetry and Differential Pulse Anodic Stripping Voltammetry. The three electrode compartment cell utilized a Ag/AgCl reference electrode, platinum wire as the auxiliary electrode and working electrodes (carbon, gold and platinum , 1.6 mm diameter). All working electrodes were cleaned with alumina polish before modifying with the polymer lignin by controlled potential electrolysis at +1.0 V for 5 minutes. Standard samples of ascorbic acid, acetaminophen and caffeine were made to be tested. All safety precautions were carried out under a fume hood when mixing the solutions and all protective garments were worn such as gloves, safety goggles, and lab coats.

3. RESULTS/DISCUSSION

The detection of acetaminophen, ascorbic acid and caffeine without the need of prior separation with quick analysis times and inexpensive techniques are vital for real-world assessment. The various types of working electrodes carbon, gold and platinum were examined to determine which exhibited the optimum electrocatalytic activity to detect everyday pharmaceuticals such as acetaminophen in the presence of common interferences ascorbic acid and caffeine. It was found the carbon material exhibited the best bare electrode to utilize for the development of a sensor modified electrode due to the enhanced electrocatalytic ability on the detection of acetaminophen, ascorbic acid and caffeine. However, these three compounds were not successfully detected by bare carbon electrode simultaneously as a mixture (only acetaminophen and ascorbic acid) and the caffeine was not detected. Therefore the lab required determination of a modified polymer such as lignin which is inexpensive and simple to utilize due to its catalytic activity on the electrode surface. The polymer lignin was grown onto the carbon working electrode by the controlled potential electrolysis technique at +1.0 V for 5 minutes and thus determined by various experimental steps. The technique DPASV (Differential Pulse Anodic Stripping Voltammetry) was utilized with the bare carbon response to a mixture of acetaminophen, ascorbic acid and caffeine and compared to the modified lignin carbon electrode with the mixture. It can be seen in the figure A., below the 0.2 V ascorbic acid, 0.5 V acetaminophen and 1.3 V caffeine were all detected with the modified lignin carbon electrode and the bare carbon electrode was not successful at detecting all three compounds (no detection of caffeine).

The Post survey on the IBL module in detection of pharmaceuticals (acetaminophen, ascorbic acid and caffeine) was carried out to assist in improving IBL learning modules.

Post Survey questionnaire

1. What did you like the most about your experiences with this IBL module on detection of acetaminophen, ascorbic acid and caffeine utilizing electrochemistry?

2. What did you like the least about your experiences with this IBL module on detection of acetaminophen, ascorbic acid and caffeine utilizing electrochemistry?

3. What would you do to improve the IBL module in the next implementation of an inquiry-based lab experiment?

4. Has the IBL module increased your interest in chemistry to take more chemistry courses or pursue research in chemistry?

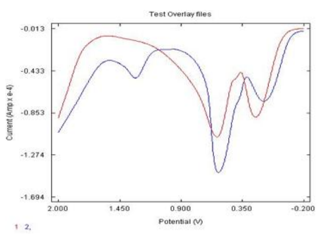

Figure A. DPASV of 1) bare carbon versus 2) Lignin carbon electrode in detection of acetaminophen, ascorbic acid and caffeine without prior separation.

4. CONCLUSION

In the past most science was taught where a summary of facts needed to be memorized in order to succeed in the course while real comprehension was not emphasized nor rewarded. IBL learning occurs when students seek the information by asking questions and constructing novel knowledge. The development of critical thinking skills and problem solving skills is more discovery based learning (IBL modules). Critical thinking skills happen when a student can determine the reason for a change in a variable and how the variable affects the changes of other variables in an experiment. Critical thinking allows for integration of information from different sources to explain and predict outcomes. The collaborative learning in small groups with IBL labs develop critical thinking and problem -based thinking skills by negotiating ideas and realizing that no set of answers exists to the given questions, there may be other polymers besides lignin to modify the electrode surface. This forum of learning aids (IBL modules) students real world problem skills throughout their life experiences.

The students involved in this IBL have participated in an inquiry-based lab module which reflects upon a real -world application detection of pharmaceuticals/medicinal compounds without the need of prior separation. The students come to see why important to understand this type of chemistry because relevant outside the classroom. The lab module has put a novel and stimulating twist on studying oxidation and reduction reactions as students study acetaminophen (Tylenol), ascorbic acid (Vitamin C) and caffeine with electrochemical techniques. A few students that were involved in the IBL module have gone on to pursue research as an undergraduate student.

The IBL modules were to provide inquiry-based experiments involving oxidation and reduction reactions in a chemistry course that was teaching both problem solving skills and critical thinking skills to detect all three chemicals simultaneously (acetaminophen, ascorbic acid and caffeine). Many chemistry students do not have the opportunity to work with real-world medicinal /pharmaceutical compounds and the IBL modules allow real-world sample analysis. This experiment was developed to bring an interest to the students chemistry studies and hopefully engage them to stay in STEM fields. The IBL lab module introduces students to using electrochemical techniques such as controlled potential electrolysis, cyclic voltammetry, differential pulse voltammetry and differential pulse anodic stripping voltammetry integrated creating a sensor (lignin) while incorporating real world detection of pharmaceuticals such as acetaminophen. The pre- and post-test questions were to assess the students gain as well as a project survey to get the students' feedback for the lab module. The pre/post-test results from the IBL module showed a normalized gain of 0.71 indicating a high gain. The gain in content knowledge illustrates the students were successful at understanding the inquiry lab module.

5. REFERENCES

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