Inter-disciplinary Inquiry-Based Science Experiences for the 21st Century

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ABSTRACT
Inter-disciplinary Inquiry-Based Science Experiences that have Science Technology Engineering and Mathematics (STEM) in the undergraduate learning experiences are the learning experiences needed for the 21st century. The laboratory research experiences for my undergraduate science education students working on development of sensors to analysis of field samples changes a typical traditional classroom into a highly interactive learning environment. The inquiry-based labs are required to engage students into problem solving with the process of critical thinking skills. These problem-based skills enable students to generate, evaluate and share their research findings for their sensors developed. The students are required to design the sensor to analyze a sample collected on a field trip. The sensor(s) developed to the samples collected on a field trip are analyzed by technology such as cyclic voltammetry (CV), differential pulse voltammetry (DPV), square-wave anodic stripping voltammetry (SWASV), Scanning Electron Microscopy (SEM), Fourier Transform Infrared Spectroscopy (FTIR), X-Ray Fluorescence (XRF) and Raman Spectroscopy [1-3]. The results of the SWASV will be shared to show the students success at learning how to utilize and develop novel sensors in this talk related to heavy metal detection in water sampling.

INTRODUCTION:
The traditional laboratory experiments are often isolated and ineffective use of learning time and students can fail to understand the content and relevance of the lab. Also, traditional labs do not allow the integration of different disciplines and various instrumentations into one experiment. The old and typical technique for teaching undergraduate chemistry lab is to have a pre-lab lecture followed by a lab to validate the pre-lab lecture given with limited technology

and instrumentation skills developed. This can be referred to as the cookbook technique for teaching undergraduate students chemistry. Guided inquiry-based methods of teaching are useful and allow students to explore the lab problem and proceed to problem solve the lab with guidance by the teacher. Bodner et al., have suggested that guided inquiry-based learning has allowed students to learn better and be more interested in their chemistry studies. [4] The successes of guided inquiry-based experiences have brought about the inter-disciplinary chemistry lab experiences for our undergraduates at our university. These guided inquiry experiences will engage students into the needed technology of studying and understanding various type of instrumentation utilized from not only chemistry but also the field of environmental science/geology, biology, mathematics and engineering aspects.

GUIDED INQUIRY EXPERIMENT EXAMPLE; DISCUSSION/RESULTS:

One of the latest experiments developed was a guided inquiry-based experiment in the detection of heavy metal detection will be discussed in detail. Detection of heavy metals in the low parts per billion (ppb) concentration levels will be displayed. The most recent news from journals published by the *American Chemical Society* are discussing the need for a novel sensor that can detect low detection limits (ppb) range for heavy metals due to the humanitarian disasters in areas such as China, Bangladesh and Vietnam. Typical detection of heavy metals in water samples are utilizing methods such as chromatography, spectroscopic methods and Inductively Coupled Plasma Mass Spectrometry (ICPMS). However, due to the serious problems with heavy metal poisoning to human life there is the need for on-site sampling, in the field sensors that are portable and easy to utilize unlike the methods such as ICPMS. Therefore, electrochemical sensors are ideal for the detection of the heavy metals since this is an environmental concern and in high concentrations naturally in the soil and water in Asian countries.

The electrochemical technique Square wave anodic stripping voltammetry (SWASV) that is easily portable for real-world analysis and inexpensive as well to detect heavy metals was a guided inquiry based lab recently developed to enhance students' instrumental skills and electrochemistry content. The heavy metals are pre-concentrated on bare electrodes such as gold, silver and carbon electrodes via electrochemical reduction for a specified length of time then the electrochemical stripping from the bare electrodes surface results in the faradaic signal which is used to determine the concentration present. The current due to the heavy metals oxidation is featured as peaks with heights proportional to the concentration of the heavy metal present. The focuses of the lab were determining the optimum electrochemical technique such as cyclic voltammetry or SWASV. Also, the pH level that the optimum value to detect the heavy metals and the SWASV parameters on the bare electrodes such as frequency, amplitude, deposition potential and deposition time were analyzed.

The successes of the students' detection of heavy metal detection at the different bare electrodes by SWASV illustrated such low detection in the ppb range. The pre-and post-tests assessment of the students content

knowledge was an overall gain of n=0.73; which illustrated a high gain according to R.R. Hake method. [5] This lab can be further expanded into more guided inquiry by more in-depth development of the sensor to detect lower than ppb levels of heavy metals in water; down to the ppt levels. This study of the morphological surface of various modified electrodes with polymers to possible sol-gel materials could achieve even lower detection limits (ppt levels) in a real-world analysis sample on site with limited contamination issues of fouling electrode surfaces. Therefore, this lab can be further continued as a guided inquiry experience, which has gained interest of students while engaging their problem solving skills to detect these heavy metals. [6-7] The successes of the electrochemistry experiments in an inquiry-based mode will be shared to show how the 21st learning is vital to meet the needs of todays research endeavors while integrating electrochemistry with technology such as CV and SWASV (BASi-instrumentation).

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Keywords: Hands-on/Inquiry-based learning, Professional Development, Inter-disciplinary Science, and Informing via Research.

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