SciTrek: High School Inquiry Module on Electrochemistry and Glucose Detection

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Background and Goals

- Hands-on learning increases student interest (1).
- Scitrek, a UCSB outreach program, enhances critical thinking and improves attitudes toward science (2, 3).
- Real-world learning may have kept 81% of high school dropouts in school; linking science with practical applications boosts performance (4, 5).
- We developed an interdisciplinary glucose sensing module that combines electrochemistry and enzymology to address Diabetes mellitus, engaging students and enhancing their knowledge and critical thinking skills through hands-on experiments.

Research Question

How does an interdisciplinary glucose sensing module involving topics from electrochemistry, biochemistry, and medicine shape high school students' understanding of those topics, general science critical skills, and perception of science and its uses in the real world?

Methodology

Creating the Module

1. Develop experiments and questions using a glucose sensing apparatus that encourage critical thinking, inquiry, and hands on experiences

Module Preparations

1. Contact teachers and organize volunteers
2. Conduct teacher and volunteer orientation for the module
3. Organize boxes containing each required material for small groups to perform its own experiment.

4 Day Module

1. Administer pre-assessment
2. Conduct the Glucose Sensing Module in the classroom led. Includes three days of hands-on experimentation with the sensor and one day of poster presentation to demonstrate findings and conclusions.
3. Administer the post-assessment

Assessment Analysis

1. Grade student performance on pre and post assessments and statistically analyze the results to determine effectiveness of the module

Results

A paired-sample analysis of 19 students evaluated the glucose sensing module's impact. Pre-assessment scores (M = 5.1053, SD = 1.10024) were compared to post-assessment scores (M = 5.3158, SD = 0.82007) using a paired t-test. The mean difference of 0.21053 (SE = 0.21053) resulted in t(18) = 1.000, p = 0.331, with a 95% confidence interval of −0.65283 to 0.23177, indicating a non-significant increase. A moderate positive correlation (r = 0.577, p = 0.0165 one-tailed) showed that higher pre-test scores were associated with higher post-test scores. Although Cohen's d (≈0.918) suggests a large effect, this should be interpreted with caution due to the non-significant t-test and potential ceiling effect from high baseline scores.

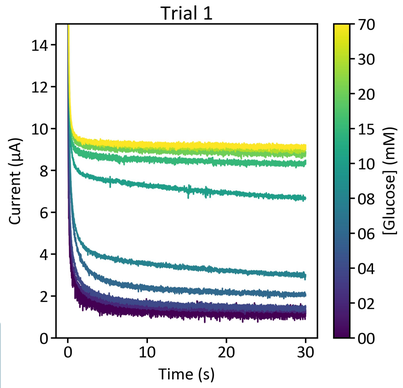

Figure 3: On Day 1, students collect the data that looks like the graph above using chronoamperometry, depicting current over time at a constant voltage of 0.5V to minimize side reactions. Recorded values vary depending on several factors.

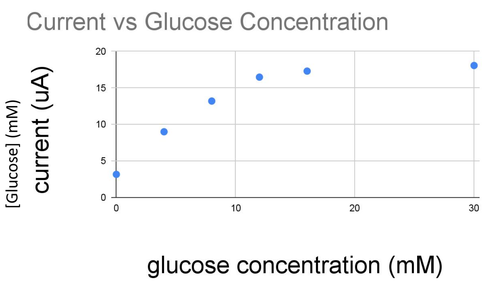

Figure 4: An example calibration curve students would make on Day 2. Recorded values for current may vary on several factors, like brand of potentiostat

Figure 1: Screen-printed glucose sensor strip with

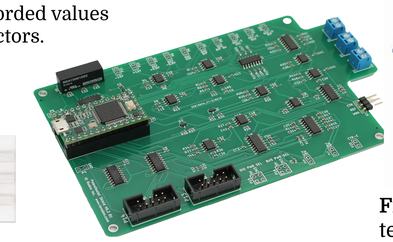

Figure 2. Potentiostat

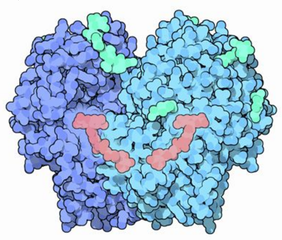

Figure 5: On day 3, high temperature permanently detached the flavin component, denaturing glucose oxidase.

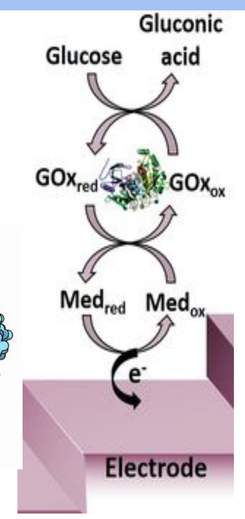

Figure 6. The reaction occurring on the electrode surface which uses Ferrocene Carboxylic acid as its mediator.

Assessment Questions

1. What is the main function of an enzyme in a chemical reaction?
2. What happens to a reaction when an enzyme's temperature is much above optimal in the presence of a large amount of substrate?
3. What is the importance of negative controls?
4. Why does current stop increasing even when more glucose is added at high glucose concentrations?
5. Why is important to do more than one trial when making scientific conclusions?
6. How do blood glucose levels of a person with diabetes compare to those without diabetes?

Figure 7: The assessment questions (paraphrased) asked before and after the module. Questions 1 and 2 test on enzyme function, questions 3 and 5 involve experimental design, question 3 tests on enzyme kinetics, and the last question tests understanding on diabetes

Discussion

- Students showed curiosity and enthusiasm during experiments.
- Pre- versus post-test scores increased but were not statistically significant.
- Future plans include:
  1. Comparing results with a control group (same surveys and teacher).
  2. Collecting assessments that measure student interest.
  3. Expanding participation to more schools and grade levels for deeper insights on the module's impact.

Module Details

This module utilizes a glucose sensor that we calibrated to detect physiological concentrations of glucose. Current is recorded, proportional to glucose concentration.

- **Day 1**: Students are introduced to key concepts and use the glucose sensor to record current at each glucose concentration (0,4,8,16,30 mM) . Then, build a calibration curve, reinforcing the concepts of negative control and substrate saturation of enzyme
- **Day 2**: Students use calibration curve to characterize an unknown sample of glucose as diabetic, prediabetic, or nondiabetic.
- **Day 3**: Students design an experiment to observe how changing temperature affects glucose activity, seeing optimization and denaturation firsthand
- **Day 4**: Students present their results to the rest of their class.

Figure 8: Haaris Mobin, Sophia Ramirez, and Jia Hu guiding students

References

1. Swarat et al., 2012;
2. Reich & Wang, 2024;
3. Helsel et al., 2022;
4. Bridgeland et al., 2006;
5. Hulleman & Harackiewicz, 2009

Acknowledgements

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