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Work in Progress: Classroom Glucose Spectroscopic Analyzer Learning Module Implementation Revision

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Prof. Bernard J. Van Wie received his B.S., M.S. and Ph.D., and did his postdoctoral work at the University of Oklahoma where he also taught as a visiting lecturer. He has been on the Washington State University (WSU) faculty for 43 years and for the past 29 years has focused extensively on novel team-interactive hands-on learning with miniature Desktop Learning Modules that represent physical equipment used in industry. Van Wie and his cross-disciplinary team have shown markedly enhanced learning of concepts at higher Bloom's levels and student motivation through use of these modules. He has about 100 publications in engineering education journals and ASEE full-length publish-to-present archives.

Introduction

For twenty-eight years, our group has worked to promote hands-on learning in chemical engineering education (1). Chemical engineering is a multidisciplinary field with a wide breadth of topics to cover in a four-year program, so learning should be both efficient and immersive to train a large population of prospective engineers (2-4). To facilitate this transition, our group worked to eliminate obstacles preventing professors from adopting hands-on learning tools and developed ultra low-cost physical models dubbed the Low-cost desktop learning modules (LCDLMs) to cover topics like heat exchange and fluid mechanics (5-6).

Beginning in 2018 and through the present, we promoted and propagated the LCDLMs at other universities for testing, and the preliminary data both on student comprehension and motivation have proven positive. Moving forward, we would like to expand the number of topics that can be covered by the LCDLM program, leading to the new module described in this paper: the Classroom Glucose Spectroscopic Analyzer. The module is a rudimentary spectrometer setup explored in these similar experiments (7) intended for students to gain a comprehensive understanding of basic analytical chemistry. Much like the other LCDLMs developed by our team, the module is designed such that it is simple to assemble and use while providing enough data for students to map hands on experiences to various theoretical topics, including stoichiometry, enzyme turnover rate, and beer's law. It also provides opportunities for student learning outside of the main experiment, such as the fluid mechanics which allow the module to function as a passive mixer. This paper will provide a brief description of how the model works, what topics we intend to cover with it, and our implementation strategies for the classroom, with the intended goal of presenting classroom data this coming summer at the Annual conference.

Description

The Classroom Glucose Spectroscopic Analyzer (CGSA) is a 12 x 12 cm set of acrylic panels held together by a UV cured adhesive. The middle panel has a quarter inch thickness (0.635 cm) and features a y-shaped channel laser cut into it which facilitates the experiment. During measurements, students would load the sample and reagent solutions into separate reservoirs at the top, then mix them together by feeding the two liquids through a serpentine static mixing channel via gravity. To prevent early mixing, loading occurs with the module on its side, holding the liquid in place with surface tension and a lip found at the entrance of each reservoir. The mixture solution would then collect at the bottom, allowing students to take rudimentary spectroscopic measurements using a flashlight, a green filter, and a cellphone camera.

Figure 1. Left: Cardboard frame used for light isolation. Right: Main Module with y-shaped chamber and offset reservoirs for on demand mixing.

This simple experiment is meant to teach students about the basics of spectroscopy by demonstrating the importance of complimentary colors in the use of Beer's law. The reaction selected, a glucose colorimetric reaction, leads to the production of red-violet dye, so students will measure the amount of green light allowed to pass through the sample using a software (apple ColorAssist, requires iOS 16.0, 50x50 pixel target area, android currently untested) that performs pixel measurements. This will allow students to collect data and construct a calibration curve by hand, as well as make estimates about the reaction rate by measuring the change in color over a set period. This will lead in to the other topics, such as reaction stoichiometry and reaction kinetics.

Implementation

Students will be given two fifty-minute class periods to collect data by completing two guided experiments. The first will focus on the reaction kinetics of the probe reaction, which generates the color from glucose present in the sample. The second will go over the entire colorimetric reaction process, step by step, to go over the stoichiometric requirements of the test and have students search for the rate constants. Students will be given background information in the form of a brief description of the experiment and the reaction taking place before being asked for predictions on the graphical representation of the data. They will then proceed to collect data on a set of samples with known initial concentrations to generate a graph and answer a set of homework questions. Note: This is an experiment intended for undergraduate students with minimal lab experience. Students are assigned a concentration to measure and are guided through the experiment.

During the first experiment on day 1, they will be given samples of aqueous hydrogen peroxide and estimate the initial rate by tracking how the absorbance changes over a thirty second period. Students will be divided into groups to test one concentration multiple times, then share their measurements with the other groups. This will allow them to construct a rudimentary Michaelis-Menten graph with more data points than they would normally be able to achieve in a fifty-minute period. Outside of class, students will linearize the Michaelis-Menton rate equation and plot the data-related parameters in the linearization and use the graph to find the probe reaction rate constants, the Michaelis constant, and the maximum reaction rate (8).

$$R_{probe} = d[dye]/dt = r_{max}[H_2O_2]/K_M + [H_2O_2]$$

R_{probe}- Rate of the probe reaction, $[H_2O_2]$- Hydrogen peroxide concentration in the sample, r_{max}- maximum rate of the probe reaction, K_M- Michaelis constant

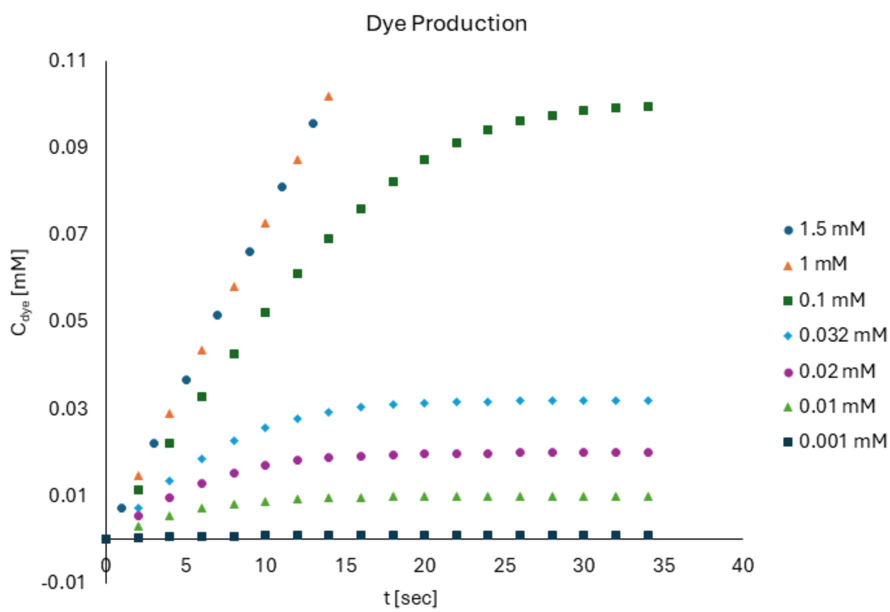

Figure 2. Example graph given to students in the homework activity, meant to illustrate the maximum rate of the reaction with the two higher concentrations, which are graphed with the same slope.

During the second experiment on Day 2, students will go over the preceding reaction, which supplies the probe reaction with hydrogen peroxide. Students will be briefed on the reaction mechanics, including oxygen dependency (8), and again will be asked to make predictions about how the graphical representation will trend before performing the experiment. Like day 1, students will be divided into groups and collect absorbance data on a sample, performing multiple trials. The primary difference is that the reaction will be allowed to go to its endpoint at approximately 5 minutes, leaving room for only a few trials of the same concentration. Again, students will pool their data and use it to form a calibration curve and look for trends before moving on to the reaction kinetics.

$$\text{D-glucose} + H_2O + O_2 = \text{D-gluconate} + H_2O_2$$

$$H_2O_2 + \text{4-AAP} + \text{p-HBS} = \text{Quinoneimine dye} + H_2O$$

4-AAP- 4-antiaminopyrine, p-HBS- p-Hydroxybenzene Sulfonate

If they had not already noticed during the debriefing, it should be clear that the dye concentration drops off as soon as the initial glucose concentration exceeds a certain point; that point being the saturation point of O_2 in room temperature water.

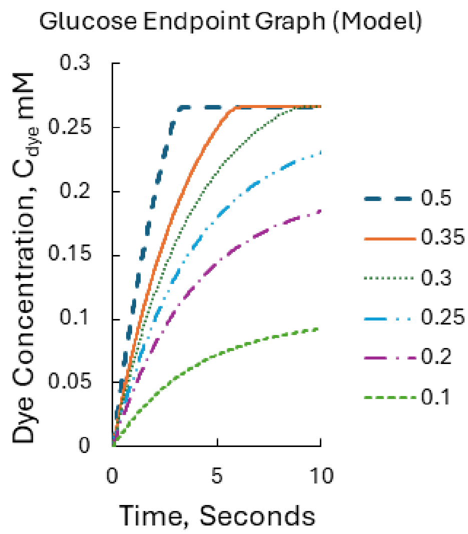

Figure 3. Endpoint example graph given to students to assist with the homework assignments to help them understand the linear range for the endpoint-based calibration curve.

Outside of class, students will have their data and a mathematical description of the first reaction kinetics, which they will then use to solve for some of the reaction rate constants by looking at the different conditions in the experiment, such as the rate at high and low glucose levels. They will then be asked to find the remaining rate constants graphically by fitting a polynomial to the data using Solver or MATLAB.

Future Work

Before implementation, students will be given an assessment on their chemistry knowledge to establish a baseline. After completing both experiments and the subsequent homework problems, students will be asked to complete a post-assessment to evaluate how much students comprehended the material. During assessment we will ask students conceptual questions about reaction kinetics rather than about the experiment itself to gauge their broader understanding. Example questions would include: What color is complimentary to red light? How does reactant concentration affect knowing the reaction is Michaelis Menten? What simplifications can be made to this equation if we assume reactant A is in excess? What graphical trend do you expect for the production of dye knowing the concentrations of A & B? By the end of the testing period, students should be able to prove they understand the underlying mechanics of Beer's law and the limitations brought about by reaction kinetics. More in depth computation, such as finding specific rate constants, will be recorded in the homework activities and collected at the instructor's discretion. Students will also be asked to provide feedback on the process. We want to evaluate not only retention but engagement levels. Students will be asked to voice complaints they had using the module, as well as suggestions for improvement, while surveying them about specific features, such as the cardboard frame's structure and its effects on observation.

To prepare for this, we have already drafted a worksheet to walk students through the experiments, provide background information and a space for students to record results, and where the homework problems will be posted. As of the writing of the Work-In-Progress manuscript, the assessments are still under development, but compared to the homework assignments, the assessments will be more straightforward, as they are meant to test retention of the concepts rather than the exact details of the experiment. Much like the other LCDLMs (1,6), our primary indicator of success is whether students are retaining conceptual knowledge demonstrated by the LCDLMs, and whether the results are significantly improved relative to a control group.

Acknowledgements

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