



Hands-on Tabletop Units for Addressing Persistent Conceptual Difficulties in Continuity & Bioengineering

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Introduction

With the increasing importance in economic development of chemical engineering and biomedical engineering, how to educate outstanding chemical engineers and biomedical engineers has become an important element in the development of science and technology. Because of the paucities in engineering education it is nearly impossible to fulfill education requirements, for example strengthening the coverage of fundamental principles, demonstrating about more industrial related design and operations, offering better instructions to improve students oral and written skills and reducing curriculum time without reducing the content, etc., if the same education approaches that have been practiced for 50 years are continued [1, 2]. It is necessary to find an alternative teaching strategy in engineering courses, particularly for conveying scientific principles to real situations. To assess innovative methods for solving the problems and limitations of the traditional teaching model in chemical engineering and biomedical engineering, a half interactive hands-on learning experiment, half lecture-teaching model is being explored. In this process, having the aim of a better understanding and absorption of key principles and difficult concepts in fluid mechanics and neuronal membrane physiology, we are combining multimedia technology with whiteboard and hands-on tabletop units.

A Fluid Mechanics and Heat Transfer course is a compulsory professional course for students in chemical engineering. Because of difficulty in understanding continuity and pressure drop concepts and associated calculations, most students are confused about how to apply these concepts. Similarly, when bioengineering students study neuronal membrane potential concepts related to trans-membrane ion transport in neurons are usually very abstract and difficult to understand. For instance, concepts related to the workings of ion channels, action potential, selectivity and applications of the Goldman-Hodgkin-Katz (GHK) equation, etc. are quite challenging to comprehend. The most common method to get a better understanding about the action potential is an animation demonstration. However, animations can only deliver an idea of how neurons work. It would be really helpful if students could actually observe or operate a system which mimics the neuronal membrane.

To address these conceptual difficulties we are developing desktop learning modules (DLMs) that demonstrate many chemical and bio-engineering concepts allowing students to use hands-on classroom activities and help them understand the concepts through what they experience. In this paper we highlight a simple classroom DLM unit to demonstrate pressure losses in chemical engineering classes. In this system, flow begins in one reservoir and is transferred to another at lower elevation. One group section had hands-on learning while the other had lecture on the same topics in a controlled study. For evaluating their performance we designed assessments using pre-test and post-test questions with the same questions about continuity and pressure drop, with the pre-test being taken at the beginning of the semester and the post-test just before the semester's end. After the implementation we did in the chemical engineering class, we designed a new system to mimic neuronal membranes, planned for demonstration in a bioengineering class. This system involves fluid flow from a reservoir through tubing past a dual ionophore Ion Selective Electrode (di-ISE) / reference electrode system with flow returning to a reservoir. We

report on both on system implementation, about design features, the pre-t/post-test results and expectations.

Chemical engineering implementation

In the chemical engineering classes we divided students into two sections. One section had only a lecture on continuity and pressure drop topics based on material from textbooks [3, 4] while the other section had hands-on learning on the same topics. The hands-on learning groups were asked to stay close around their DLM so they could work on the worksheet together and have interactive discussions.

To tackle the difficulty of understanding these principles, we designed a simple classroom unit to demonstrate continuity and pressure drop concepts. In our reservoir system, fluid moves under gravity from the bottom of a reservoir to another reservoir via tubing. In Figure 1, one end of some tubing connects with a WSU Desktop Learning Module Tank via a snap-on fitting and the other end connects with a 90° standard elbow that allows fluid flow in the vertical direction to another reservoir. The most common misunderstanding about flow from a higher level reservoir to a lower one is that velocity increases due to gravity or velocity slows as a result of friction. After the students in the hands-on section saw how the system works for 5 seconds they immediately came to realize the velocity does not change in a constant diameter tube.



Figure 1, photo of reservoir system for studying continuity.

From the assessment of take home quizzes, worksheets, a pre-test and post-test and an end of semester survey, hands-on learning units were deemed to help improve students' understanding about continuity and pressure drop concepts [5].

Bioengineering implementation

The success of DLM use in chemical engineering classes is inspiring us to develop more DLMs on other subjects. For example, we are designing a new set of hands-on learning class implementations based on neuronal membrane concepts which will be utilized in a bioengineering class.

Classroom setup

We will divide bioengineering classes into two sections: a lecture section and a hands-on learning section. For the lecture section students will receive lectures on the topic of the neuronal membranes, ion channels, and the Goldman-Hodgkin-Katz (GHK) model equation. The hands-on learning section will have group learning using hands-on operations using a newly designed DLM di-ISE system on the same topic. The hands-on learning section will have subgroups with 3 to 5 students each. We will assure a mix within each subgroup of GPA's, gender, nationality and race. Research shows that under this atmosphere most students, especially those who like to work alone, will be more likely to cooperate with group mates and participate in the work assignment [6, 7].

The DLM system is designed to be held in a semi-lab classroom which will allow students, instructor and TAs to gather around DLMs for viewing and instruction and, because the room is equipped with a document camera system, students can also listen to mini-lectures interjected between short activities. Every group member should stay close to the DLM to participate in hands-on experiments and discuss about the worksheet together [8] [9]. We find this process works best when the instructor and TAs should circulate to help individual groups in case they have questions during the discussions and experiments [10].

Experimental design

This system in Figure 2 is designed to demonstrate to students about how di-ISEs work to mimic ion channels. Fluid flows from the WSU DLM system tank A through a tube (supply A), and passes a di-ISE and reference electrode, both connected to a potentiometer interfaced with a computer, and then flows back to tank A (return A). Then 1 M KCl solution is added into tank A and stirred to reach a final concentration of 0.1 M. When the K^+ ionophore side of the membrane is unblocked, the di-ISE will start to transport K^+ ions, simulating what happens when a neuronal ion channel transports K^+ ions. Student can immediately see the voltage change on the computer screen. When the K^+ ionophore side of membrane is blocked by tightening the screw, the K^+ ion is prevented from going through the electrode membrane, as when a K^+ ion channel closes. However, the Na^+ ionophore side of membrane is unblocked, which is similar to when a Na^+ ion channel remains open to let Na^+ ions through. Due to continuing Na^+ ion flow across the membrane, a measurable voltage will always be shown on the display screen.

The di-ISE concept is inspired by living neuronal physiology. Fig 3 shows a schematic diagram of the di-ISE concept. The di-ISE consists of two membrane portions, both electrically connected to the same fluid reservoirs on the top and bottom, but with one membrane portion containing a highly K^+ selective ionophore and the other a Na^+ ionophore with 10 times lower selectivity to K^+ ions than Na^+ ionophores. The two membranes are exposed to the same 0.1 M NaCl solution on the inside of the electrode. In Fig 3A, valinomycin (A.G. Scientific. INC) as K^+ ionophore is on the left side, and sodium ionophore X (NaX, Fluka) is on the right side of the membrane. The Na^+ gradient is in one direction from the inside of the electrode to the outside and the K^+ gradient is in the opposite direction. After 10 min of calibration the di-ISE system will reach the Na^+ and K^+ ion concentration/electrical equilibrium resting potential as is for a living neuron before stimulation [11].

Fig. 3 B shows how the sensor will react when the K^+ ionophore side is blocked by a screw-actuated flexible cover. Blockade of the K^+ flux allows fewer K^+ ions to flow through the membrane than Na^+ ions, i.e., only those carried by the low K^+ selective NaX will cross on the NaX side. Hence, the voltage will change and move towards the Na^+ equilibrium potential. The presence of the NaX ionophore gives the membrane a certain baseline ion carrying capacity. So even though there is little or no K^+ ionophore participation, there will still be a measurable voltage.

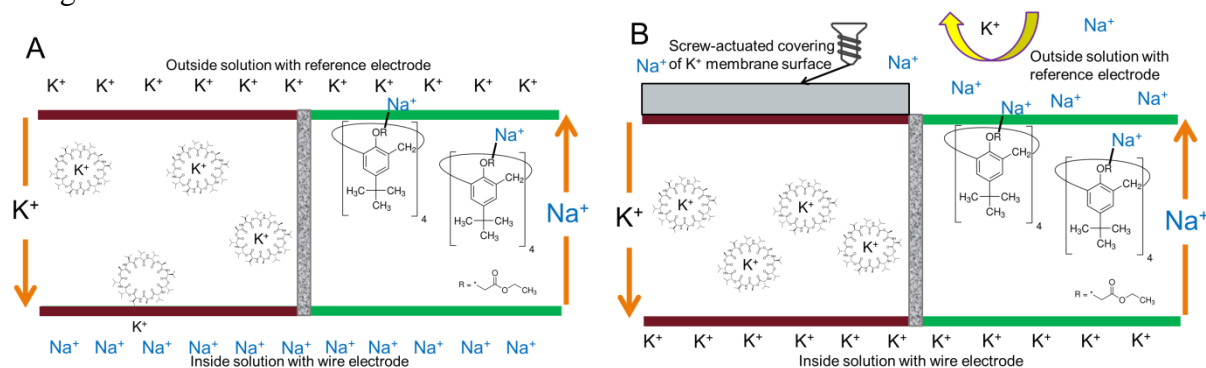


Figure 3: Sensing concept: A) A dual ionophore ion selective electrode (di-ISE) is designed to consist of two separate membrane segments with common top and bottom electrolyte solutions. One segment (LHS) contains K^+ ionophores while the other, (RHS) contains Na^+ ionophores. Opposing K^+ and Na^+ concentration gradients create a resting potential. B) Turning a screw actuates blockade of K^+ flux resulting in a measurable voltage shift.

Assessment

We will ask students to submit a take home quiz before they have the topic and expect from this students will have a basic understanding about the topic and be prepared for the interactive hands-on session. We will also design a worksheet to help students understand neuronal membrane concepts through hands-on experiments and observations. The content of the worksheet will be questions related to neuronal membrane concepts, ion channels, and the GHK model. They will discuss questions within the group, with the instructor or with the TA's help. Before students start the experiment, they will be asked to discuss responses to the following prompts: 1. Explain the formation of the action potential in neurons. 2. What will cause depolarization in a neuron? 3. In living cells, what ions are the main contributors to membrane potential? 4. How do you calculate the resting membrane potential (V_m)? After the discussion, they will begin running the experiment and take notes as indicated in instruction tables. After running the DLM and the observations, they will be asked to go back to the original set of questions to make corrections and explain their rationale within their groups.

We have already designed pre-test and post-test questions as shown in Table 1. The pre-test will be given to students before the class period on neuronal membranes, and the post-test on the same topics will be given at the beginning of the period after students learn about the topic. Results will be evaluated to assess improvements in performance.

Table 1: Pre-test and post-test questions related to membrane potential.

Concept	Question
Ion channels	1. Describe how ion channels work.
Action potential	<p>2. Please fill in the blanks to indicate the different phases of the neuronal action potential.</p> <p style="text-align: center;">Action Potential in a Neuron</p> <p style="text-align: center;">Time (milliseconds)</p>
Selectivity	3. What does ion selectivity mean in a neuronal membrane system?
GHK Equation	$V_m = \frac{RT}{zF} \log \frac{(p_{Na}/p_K)Na_o + (p_{Cl}/p_K)Cl_i}{(p_{Na}/p_K)Na_i + (p_{Cl}/p_K)Cl_o}$ <p>4. How will temperature affect the neuronal response?</p> <p>5. How does membrane permeability affect the neuronal response?</p> <p>6. (Post-test only) How does the hands-on class activity on the dual ionophore-ISE help demonstrate the concepts related to neuronal response when considering:</p> <ol style="list-style-type: none"> The response to a temperature change? The response to K⁺ ionophore blockade? The response to varying K⁺ concentration changes in the outside solution? The response to varying Na⁺ concentration changes in the outside solution? The response to varying Cl⁻ concentration changes in the outside solution?

This is a work in progress. The rubric used to rate student work will be the same as that used for the chemical engineering class and is being presented in another companion ASEE paper [12]. We will also design an end-of-semester survey which allows students to provide feedback helpful in evaluating DLM effectiveness in promoting the conceptual understanding. Questions will be asked to ascertain how we can improve the system performance and our teaching methods. We expect the implementation will help students to improve their understanding of concepts by not only receiving knowledge from books, lectures and homeworks, but in addition from their observations, operations and interactive discussions.

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