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Work-in-Progress: Implementation of a Biomedical Hands-On Learning Tool in Chemical Engineering Courses and Effects on Student Motivational and Conceptual Gains

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Work-in-Progress: Implementation of a Biomedical Hands-On Learning Tool in Chemical Engineering Courses and Effects on Student Motivational and Conceptual Gains*

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Chemical engineers frequently contribute to the advancement of the medical field; however, such applications are often not covered in the undergraduate curriculum until third- or fourth-year electives. We propose implementing a hands-on learning tool in an elective third- and fourth-year course and core third-year separations class to help undergraduate students apply chemical engineering concepts to biomedical applications. The hands-on learning tool of interest is used to introduce students to blood separation principles through a microbead settling device. See-through columns are filled with fluid and microbeads at various ratios to model the effect of hematocrit, or red blood cell fraction, on cell settling velocities and separation efficiencies. We hypothesize that the use of a biomedical hands-on learning tool will result in motivational and conceptual gains in comparison to traditional lecture and have significant effects on underrepresented minority groups in the class. Pre- and posttests will be used to assess conceptual understanding of separations principles with respect to biomedical applications across hands-on and lecture groups. Additionally, motivational surveys will be used to gauge levels of interactivity between the two groups, relating to the ICAP hypothesis. We plan to conclude the paper submission and presentation with theoretical and practical implications of our findings from Spring 2022 implementations.

*Title and abstract modified due to implementation in different courses than originally outlined in submission

1.0 Introduction

From drug delivery to tissue engineering, an incredible number of medical applications and processes require a chemical engineer's expertise. These applications, however, exist beyond the scope of topics traditionally emphasized in core chemical engineering courses. Having recently lived through COVID-19, it is critical now more than ever for chemical engineering students to understand how their skills can contribute to the ever-evolving medical field.

Researchers at Washington State University (WSU) have leveraged the use of hands-on learning devices in undergraduate chemical and mechanical engineering courses to enhance the learning environment and promote conceptual and motivational gains [1-3]. The hands-on learning tools originally developed are miniaturized versions of equipment seen in industry, such as double-pipe heat exchangers or venturi meters, that are low-cost, safe, and easy to use on a tablet-arm desk in a classroom setting.

In this paper we propose a similar solution for a device that portrays blood cell settling concepts to reduce the cognitive load of learning new separations principles while simultaneously applying them to biomedical applications. It is hypothesized that, similarly to the original hands-on learning tools, the cell settling device will result in higher conceptual and motivational gains for students who use the device in comparison to those in traditional lecture and have a significant impact on women and underrepresented minority groups in the classroom. Herein we will provide educational and conceptual theoretical underpinnings of the research, a brief description of the module manufacturing process, classroom implementation methods, and discussion of findings from hands-on versus lecture results.

2.0 Theory

2.1 Women in Engineering

The hands-on learning device of interest fosters a group learning environment while depicting direct applications to the medical field, i.e., impacts on human health and well-being, which are critical components of engaging women in STEM. In 2011, Brawner et al. created focus groups for junior- and senior-level women-identifying undergraduate students and conducted in-person interviews to better understand why women choose chemical engineering as a major [4]. From their early work, flexibility in career options was highlighted as a key factor in choosing chemical engineering for all 10 students interviewed. Additionally, 5 out of the 10 women noted they were considering medical school, and chemical engineering provides strong preparation but also is a good degree in case medical school does not work out for them. Then in 2015, Brawner et al. extended their work to answer the question, "Why do women choose and remain in chemical engineering?" by interviewing 16 junior- and senior-year women participants at both predominantly white institutions (PWI) and historically black colleges and universities (HBCUs) [5]. Their findings show that although institution and department reputation play a major role in choosing a chemical engineering program, fostering a sense of community and the use of real-world examples in class is impactful on their desire to stay in the program and helps them better understand course material. The outcomes from the aforementioned studies further support our hypothesis stated in the introduction, in which we predict women who use the cell settling device will have significantly higher conceptual and motivational gains in comparison to men in the experimental group.

2.2 Separations Principles

Key concepts portrayed in the cell settling device revolve around the effect of hematocrit, i.e., red to white blood cell population density, on settling velocities and final settling states. Outlined below are topics we intend to address with the hands-on learning tool and complementary worksheet for classroom activities:

- The dependence of settling velocity on particle diameter (d_p) and understanding the relationship between particle diameter, surface drag area, and volume.
- Effective porosity resulting from viscous effects due to the likelihood of cell interactions in variably dense scenarios, e.g., dense particle regimes resulting in greater hindered settling of larger particles and less frequent interactions of smaller particles allowing them to slip through interparticle spaces.
- The effect of cell population on suspension density in relation to fluid density.
- Continuity effects that reduce settling velocity due to upward flow of fluid resulting in its displacement as particles settle to the bottom of a container.
- Amplified effects through centrifugation versus gravitational force.

The topics outlined are then translated into tangible student learning objectives, listed below, and relate to common misconceptions of sedimentation and separations principles, which we expect to mitigate through the hands-on, visual aid and group activities.

1. Understand the effect of particle diameter on drag force as particles settle through fluid.
2. Calculate effective porosity and relate to particle collisions in a dense suspension and how they hinder particle sedimentation.
3. Understand how particle concentration alters the density of the suspension and particle settling velocity.
4. Describe the different sedimentation scenarios and parameters that dominate particle settling.
5. Understand how gravitational force versus centrifugal force affects sedimentation.
6. Relate objectives 1 through 5 to blood cell separations and biomedical applications.

3.0 Methods & Materials

3.1 Cell Settling Device

The cell settling device is comprised of see-through columns and two kinds of polyethylene microspheres representing blood cells in a fluid suspension. Each device has three columns made of acrylic tubing that measures 305 mm in length per column with an inner diameter of 7 mm and are secured by silicone end caps. Each column in the device holds a 50% ethanol-water mixture as the suspending fluid and the same number of white beads but differs in number of red beads to obtain three different settling regimes: a dilute suspension where the larger white beads settle fastest, a very high population density where the smaller red beads settle fastest, and an intermediate population density where the balance of forces and effective interparticle collisions leads to an azeotrope-like condition where larger and smaller beads are in an azeotrope-like condition where both have the same settling rate. The white beads are larger in diameter but less dense than the red beads, which mimics the ratio in size and density of red and white blood cells. Exact values of the microbeads in comparison to blood cells are displayed in Table 1.

Figure 1. Cell settling device prototype that demonstrations hindered settling as bead population density increases

Table 1. Microbead and Blood Cell Diameters and Densities [6]

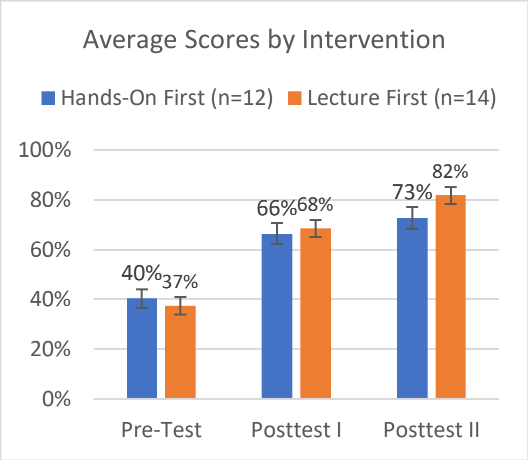
	Diameter [µm]	Density [g/cc]
Red blood cell	7 – 9	1.11
White blood cell	14 – 16	1.08
Red microbead	250 – 300	1.08
White microbead	500 – 600	1.00

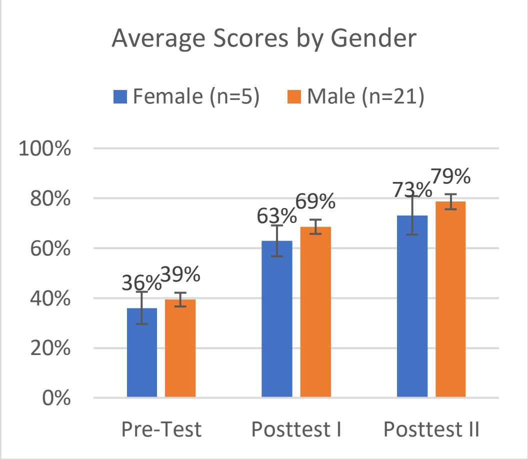
Each device costs $85 to build, including labor, and takes approximately an hour to assemble—making this hands-on learning tool reasonable for classroom adoption. Figure 1 shows an early prototype of the device.

3.2 Classroom Implementation

The cell settling device was implemented in a third-year core Chemical Engineering Separations course 75% through the end of the Spring 2022 semester. Students were divided into two larger groups consisting of four teams of four for each group, with teams self-selected earlier in the semester: a lecture group (control) and hands-on group (experimental). Six weeks prior to the implementation, all students took a pre-test to determine their initial understanding of concepts; the pre-test was planned for six weeks before the implementation to mitigate testing effects for when the students take the two posttests.

Over a 50-minute class period, students in the hands-on group worked in teams of four to make predictions on the final settling states for each column, conduct a short experiment with the cell settling device, write their observations and how they compare to their predictions, and further discuss the learning objectives outlined in the worksheet. Students in the lecture group experienced a traditional lecture with the instructor as conducted normally throughout the semester. After completing either lecture or the hands-on experiment, all students took the first posttest (posttest I) to assess conceptual gains. To ensure equal and fair learning opportunities, students in the lecture group conducted the hands-on learning experiment the next class period and vice-versa for the initial hands-on group. At the end of the week, all students took another posttest (posttest II) along with a motivational survey to determine growth after additional intervention and to assess levels of interest and interactivity when using the hands-on experiment.

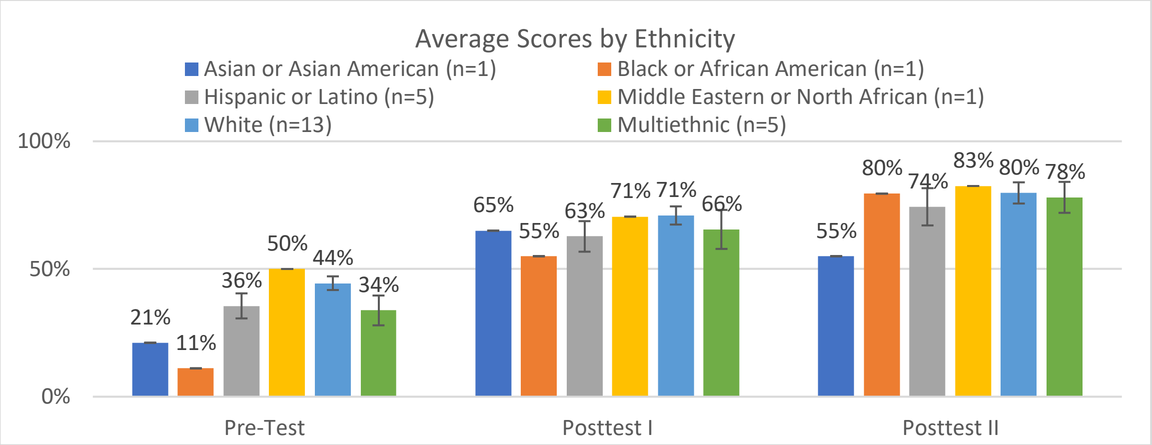




4.0 Results & Discussion

SPSS one-way ANCOVA analyses across group, gender, or ethnicity revealed no statistical significance from pre-test (covariate) to posttest I or pre-test and posttest I (covariates) to posttest II. The lack of statistical significance may be due to small sample sizes, with 26 students in the analysis total. Although statistically backed conclusions cannot be made on the average test scores with respect to group, gender, or ethnicity, all students increased from pre-test through the posttests after the interventions.

There are a couple of factors to bring to the readers' attention that may have skewed the data: instructor experience and teaching approaches. The hands-on group met with a Ph.D. candidate who has little teaching experience, while the lecture group met with the professor of the class who has nearly 40 years of teaching experience—the experience gap between the instructors may have been the cause of the higher conceptual gain for the lecture group in comparison to the hands-on group. Additionally, it was intended for the lecture group to be taught in a traditional lecture setting where the students take notes without interacting with classmates; however, the instructor for that section conducted think-pair-share activities, which is a form of active learning.



Aside from conceptual aspects of the implementation, students gave positive feedback on their experiences with the biomedical learning tools. The words used most frequently by students to describe the hands-on learning tool were “helped/helpful”, “learning”, “understanding”, and “visual”, in order of prevalence. Although these terms are expected outcomes of hands-on learning tools, it is valuable feedback for the development of this module, as core principles of blood cell separations such as effective viscosity and void envelope thickness are difficult concepts to visualize. Students also found the worksheet to be a critical component of the implementation, with one student mentioning, “The worksheet was amazing. The device was good, but following what we observed with a beautiful worksheet, made it perfect.” and another saying, “The worksheet was amazing and I wish my class used them. Guided learning is incredibly underrated in engineering classes.”

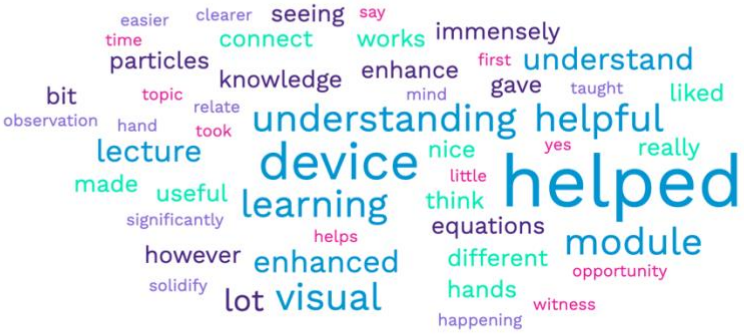


Figure 2. A word cloud of statements made by students on the motivational survey after both groups used the hands-on learning tool.

Future work will assess regrading of the pre- and posttests by all-or-nothing versus partial-credit scores and a breakdown of the motivational survey responses by gender and ethnicity.

5.0 Acknowledgements

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6.0 References

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