Work in Progress: Modeling the Effect of Hematocrit on Blood Cell Separations Using a Hands-on Learning Device and Microbead Blood Simulant

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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 ˜37 years and for the past 23 years has focused on innovative pedagogy research and technical research in biotechnology. His 2007-2008 Fulbright exchange to Nigeria set the stage for him to receive the Marian Smith Award given annually to the most innovative teacher at WSU. He was also the recipient of the inaugural 2016 Innovation in Teaching Award given to one WSU faculty member per year.

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[blind submission]

ABSTRACT

Chemical engineering students learn valuable fundamentals that can be used to enhance the medical field, yet the lack of emphasis on such applications can misguide undergraduate students as they choose their major. To address this misconception, we propose the use of a hands-on, interactive learning tool to expose freshman-level chemical engineering undergraduate students to applications that go beyond the traditional oil refining and catalysis emphases typically discussed in the introductory "Applications in Chemical Engineering" course. We developed a low-cost, modified fidget spinner that introduces students to blood separation principles. On each arm of the spinner, there exists a see-through chamber filled with fluid and microbeads at various ratios, which simulates the effect of hematocrit, or red blood cell fraction, on settling velocities and terminal position—phenomena that are utilized to enhance blood separation efficiencies. Due to COVID-19, we plan to implement this device by mailing fidget spinner kits with a complementary worksheet to the students to conduct observational experiments at home in the spring 2021 semester. We hypothesize that introducing biomedical applications early in the undergraduate experience will help students understand that chemical engineering knowledge can easily be transferred to biological systems and will have a significant impact on motivation and retention of women in the cohort. Motivational surveys will be used to assess pre- and post-implementation attitudes toward chemical engineering as a major and will be compared to control data collected in fall 2020. In the paper and presentation, we will also share the mathematical modeling behind creating the microbead blood simulant. We plan to conclude the paper and presentation with theoretical and practical implications of our findings.

INTRODUCTION

Chemical engineers have a breadth of opportunity to utilize their skills in projects involving the life sciences and medical field, yet the misconception that this is not the case is prevalent amongst lower-division undergraduates. It is often seen that potential chemical engineering students who are interested in careers in medicine take a pre-medical route or switch to bioengineering as a major. Core classes such as transport phenomena and separations in the chemical engineering curriculum, though, teach students a number of invaluable concepts and fundamentals that can be applied to projects involving the life sciences.

To address the misconceptions of chemical engineering as a major and its importance in the medical field, we propose to use a hands-on, interactive learning tool to expose first-year chemical engineering undergraduate students to chemical engineering applications that go beyond the traditional oil refining and catalysis emphases. Our group's previous and ongoing projects utilize Low-Cost Desktop Learning Modules (LCDLMs) to increase comprehension and retention of theoretical concepts in upper-level chemical engineering courses. Studies performed with the traditional LCDLMs have proven to increase situational interest, resulting in students committing more emotional and attentional resources to learning engineering concepts [1,2]. We intend to leverage the usefulness of LCDLMs to increase interest and understanding of biomedical engineering (BME) applications within chemical engineering in lower-level classes before students certify into a major.

THEORY & DESIGN

The original idea was to introduce students to blood separation principles through the use of an entertaining and simple fidget-spinner-inspired centrifuge design. In more realistic applications, researchers had shown that fidget spinners, inexpensive and popular toys, can be used to separate blood [3]. Similarly, we intended to design a fidget spinner equipped with chambers in each arm to retain a suspension of beads in water. This device was meant to simulate the effect of blood cell density and size on settling speed and terminal position in a centrifuge, phenomena that are utilized to enhance blood separation efficiencies. Figure 1 displays the fidget spinner BME LCDLM, where three layers of the fidget spinner module were laser-cut and joint by injection molding.

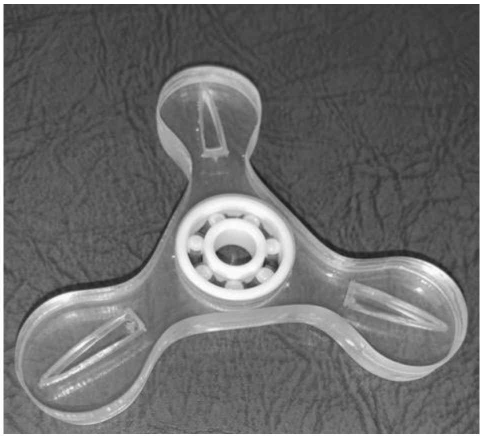

Figure 1. *BME LCDLM module design for a fidget-spinner-inspired centrifugation device to show effects of cell suspension density and hematocrit on blood separations–multi-colored, multi-sized 100-300 micrometer plastic beads in water were used as a blood simulant for this design.*

A series of microbead ratios were tested in a makeshift version of the fidget spinner BME LCDLM to display the three potential separation outcomes based on varying hematocrit: a case where the white beads representing white blood cells settle faster, a case where the red beads representing red blood cells settle faster, and a case where the beads form an azeotrope and appear to be mixed. The model used to predict microbead settling in the fidget spinner was that of Barnea and Mizrahi [4] shown in Equation 1 to take into account the effect of varied microbead sizes on void space and suspension densities. Settling of the microbeads relative to the container were also incorporated into the final settling velocity.

$$V_i = S_i \omega^2 r_c \left(\frac{\rho_i - \bar{\rho}_{susp}}{\rho_i - \rho_f}\right) \frac{\exp\left(\frac{-5(1-\epsilon_i)}{3\epsilon_i}\right)}{1+(1-\epsilon_i)^{1/3}} \qquad \text{(Equation 1)}$$

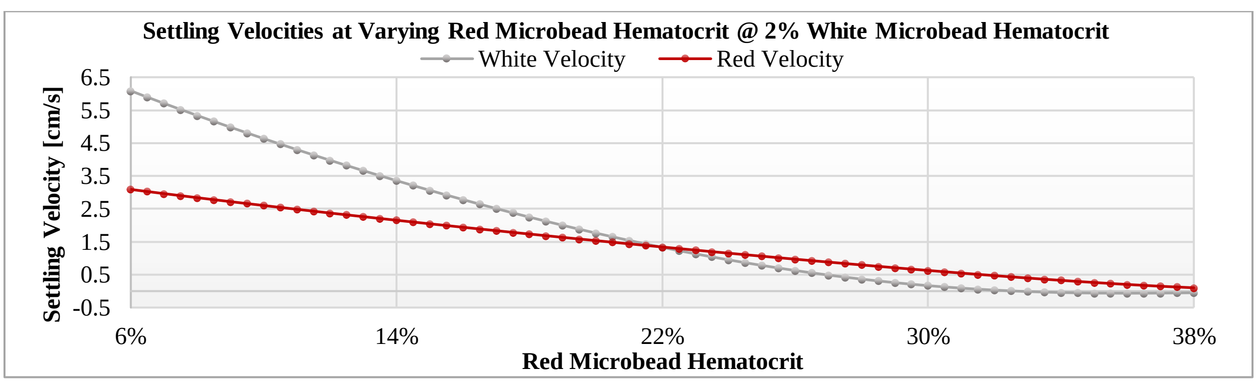

Figure 2. *Settling velocities of red and white microbeads with diameter ranges of 425-500 microns and 850-1000 microns, respectively, in water at 20°C spinning at 300 RPM in a 4-cm-radius fidget spinner.*

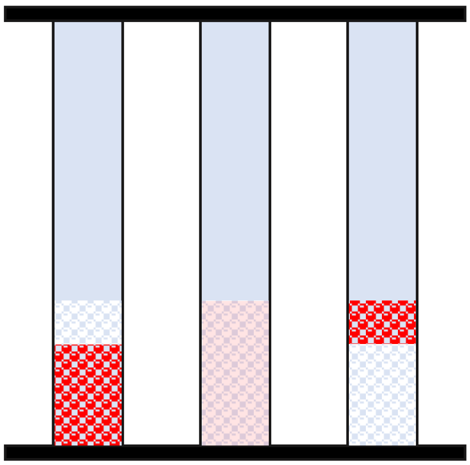

Figure 3. *A rendering of the BME LCDLM displaying three microbead separation outcomes in acrylic tubing by varying the hematocrit. From left to right: the case where the red microbead settles faster, the case where the beads form an azeotrope, and the case where the white microbead settles faster.*

Microbead pairings of larger diameters in the 300-to-1000-micron range were tested due to clumping and unreasonably slow settling of beads below 300 microns, regardless of adding a Tween 80 surfactant. Despite calculations showing that we could obtain the three separation outcomes by varying the red microbead percentage (Figure 2), we were unable to visually obtain them with the small fidget spinner chambers.

As of the Spring 2021 semester, we have shifted our focus to designing a further simplified module with more column length for the beads to settle that will display the same concepts. The module has three see-through, acrylic tubes that will contain the microbead suspension, rather than the fidget spinner vessel—a rendering of the new BME LCDLM is shown in Figure 3. We estimate costs to build the BME LCDLM will be approximately $50 each with majority of the cost coming from the microbeads, whereas our current, traditional LCDLMs cost $100-$200 each to manufacture [5]. Additionally, the BME LCDLM will be small enough to fit in a standard manila envelope, in the case of virtual classes, or on a standard tablet-arm desk for use in any classroom setting. The low cost and flexibility of the LCDLMs makes this mode of learning and exposure accessible and transferable to a large number of students, both cross-departmentally and cross-institutionally.

IMPLEMENTATION METHODS

Because the BME LCDLM will be implemented in lower-level chemical engineering courses, conceptual assessment data will not be collected, as it is not the primary outcome of interest in using these devices. We are, however, collecting pre- and post- motivational assessment data to assess whether or not exposure to biomedical applications changes students' perceptions of chemical engineering as a major. The motivational surveys were designed in collaboration with researchers from the [blind] Department of Educational Psychology.

The students we are surveying are first-year undergraduates in the CHE 110 course, who were enrolled in CHE 101 the previous semester. Due to limitations with COVID-19, we are currently collecting control data for the whole class and conducting Zoom interviews with a small focus group of students who volunteered to test the new BME LCDLMs. To collect control data for the Spring 2021 semester, we have implemented motivational surveys to assess student views on chemical engineering as a major—the pre-survey focuses on attitudes after CHE 101/before CHE 110 and the post-survey focuses on attitudes after CHE 110. Both surveys include a series of Likert-scale questions grouped into the following topics:

1. How the student's <u>lecture experience</u> in CHE 101/110 affected his/her/their perceptions of chemical engineering as a major and as a field

2. How group or learning activities in CHE 101/110 affected the student's understanding of chemical engineering as a major and as a field
3. How the student perceives his/her/their sense of belonging and projected success in the program after CHE 101/110

As for the focus group, about 10 students in the CHE 110 class will be mailed a BME LCDLM with instructions to conduct an experiment similar to the traditional in-class implementations. After completing the experiment, we will meet with the group on a Zoom call to gauge ease of use and how the hands-on learning kit withstood shipping transportation. From the focus group responses, we may reiterate on the BME LCDLM design, or proceed with in-person use in the Fall 2021 semester.

CONCLUSIONS & FUTURE WORK

It was originally planned to have enough BME LCDLM prototypes built for implementation in the Spring 2021 CHE 110 course, but due to the change in design from the fidget spinner vessel to acrylic tubing, we are now focused on collecting control data while interviewing focus groups. We are currently in the process of gathering volunteers to test the BME LCDLMs and have sent the motivational pre-survey to the class—the post-survey will be released at the end of the semester. We plan to have the focus group interviews completed before the second draft of the ASEE paper submission and the data analysis for the motivational pre- and post- surveys completed before the conference.

ACKNOWLEDGEMENTS

We acknowledge support from the [blind] Teaching and Learning Endowment grant and NSF DUE grants [blind] and [blind], The research team is grateful to senior-undergraduate [blind] for modeling the fidget spinner BME LCDLM in SolidWorks and assisting the graduate students in manufacturing the prototypes.

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