Work-in-Progress: Hands-On Learning Devices for Exposure to Biomedical Applications Within Chemical Engineering

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ABSTRACT (pre-COVID-19; [indicates edits])
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 noted to be prevalent at the undergraduate level. This perception can misguide [lower-division] students as they choose between chemical engineering and bioengineering as a major. We propose the use of two hands-on, interactive learning tools to expose [first-year] chemical engineering undergraduate students to applications that go beyond the traditional oil refining and catalysis foci.

The first device simulates fluid flow phenomena that occur in blood vessels that widen due to an aneurysm. We added features such as transparent tubing with a rounded, expanded midsection and standpipes to allow students to easily observe pressure trends. The second device may be used introduces students to blood separation principles through the use of an entertaining and simple fidget-spinner-inspired centrifuge design. On each arm of the spinner, there exists a clear chamber filled with fluid and microbeads at various ratios, which simulates the effect of blood cell density and size on settling speed and terminal position—phenomena that are utilized to enhance blood separation efficiencies.

Both devices will be implemented in the Spring 2020 Introduction to Chemical Engineering (ChE 110) course along with motivational surveys to assess pre- and post-implementation attitudes toward chemical engineering. We hypothesize that focusing on biomedical applications early in student undergraduate experience will help them understand that traditional chemical engineering knowledge can be easily transferred to biological systems, with the potential of increasing retention of women, who as a population tend to gravitate more toward public service-oriented careers.

INTRODUCTION
In the years 2006 to 2008, the National Academy of Engineering (NAE) conducted an 18-month social study to better understand the public view of engineering, leading to the publication of *Changing the Conversation*. In this report, it is cited that a common perception amongst girls in the K-12 interview group was those who are drawn to professions that more directly involve people and their lives, such as those in the healthcare and medical fields—a group the young girls closely identified with—are less likely to become engineers [1]. Engineers, however, 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 still 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 make a switch to bioengineering. Chemical engineering as a major, though, teaches students a number of invaluable concepts and fundamentals that can be applied to projects involving the life sciences and medical field.

The lack of understanding of the opportunities for chemical engineers may be a reason for the low retention rates as a major, especially for female undergraduates, as they are not exposed to the opportunities that interest them, such as biomedical applications, early enough in their undergraduate careers. Specifically, at Washington State University women represented only 15.7% of the total engineering graduating class in 2016-2017, down 0.5% from 2009-2010 [2]. Based on departmental retention data collected for the 2013-2015 freshman classes, greater than 50% of freshmen women leave the chemical engineering program by their sophomore year, and over 60% leave by their junior year.

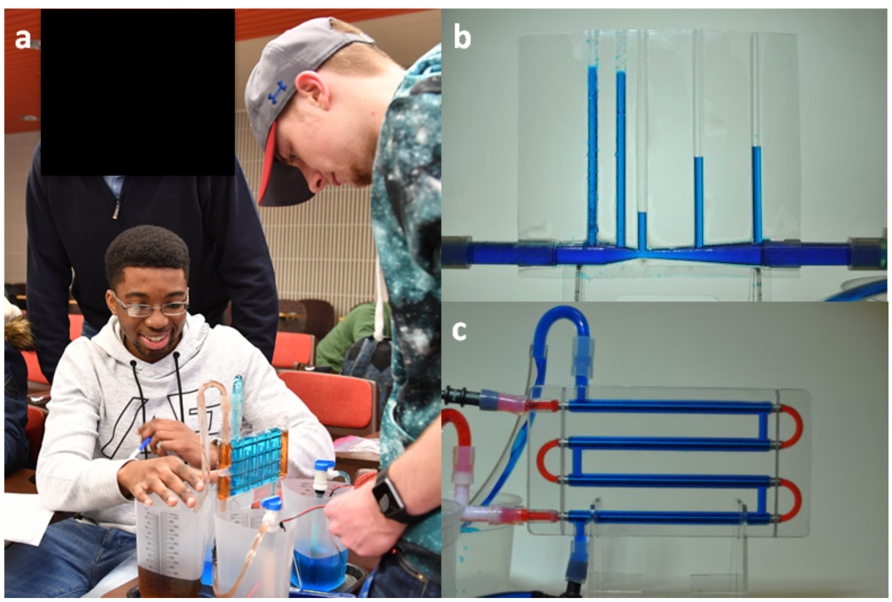
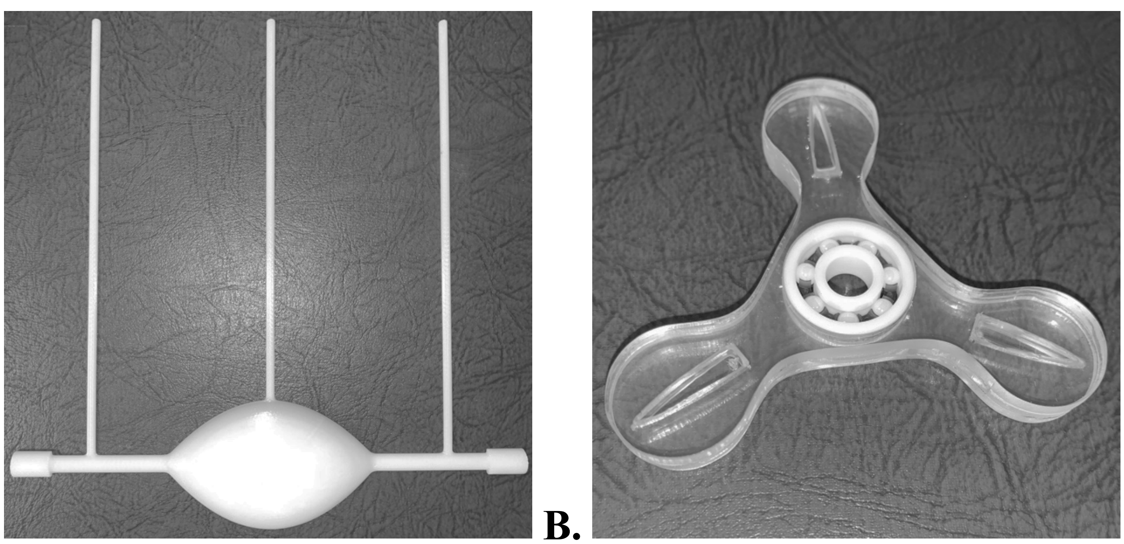


Figure 1. *(a) Students collecting data and smiling with a shell and tube heat exchanger LCDLM in the classroom, and detailed views of a (b) venturi meter and (c) double pipe heat exchanger LC-DLMs with colored water to help students visualize pressure trends and fluid movement.*

To address the misconceptions of chemical engineering as a major and low retention rates, we propose to use hands-on, interactive learning tools to expose first-year chemical engineering undergraduate students to chemical engineering applications that go beyond the traditional oil refining and catalysis emphases. We are particularly interested in demonstrating biomedical engineering (BME) applications because of their direct, easily-grasped impact on people's lives. 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 [3,4]. We intend to leverage the usefulness of LCDLMs to increase interest and understanding of biomedical applications in chemical engineering in lower-level classes before students choose a major. Figure 1 shows examples of the current LCDLMs as well as a student group collecting temperature data in the classroom.

DESIGN & MANUFACTURING

The first BME LC-DLM simulates the fluid flow phenomena that occurs in blood vessels that have widened in the case of an aneurysm. Briefly, to fabricate the aneurysm LCDLM, half of the module was designed in SolidWorks and 3D printed using acrylonitrile butadiene styrene (ABS). Then, using a vacuum forming machine and two of the 3D printed molds, each half of the aneurysm is formed with a polyethylene terephthalate glycol-modified (PETG) thermoplastic sheet. To fasten the two halves together, we will place one half in a wooden jig to hold it in place, provide a bead of epoxy glue along the perimeter of that half, position the face of the other half onto the bead align by rods passing through holes in the two halves and clamp together for drying. It is anticipated that later versions will be injection molded and a glue dispenser and jigs used for adhesion and alignment. We added standpipes as design features, which, because they are transparent, allow students to easily observe liquid pressure head trends, while transparent tubing and aneurism allows visualization of flow of colored liquid as well as insertion of bubbles and beads for flow characterization.



A. B.

Figure 2. *BME LC-DLM module designs: (a) Expanded mid-section with pressure head standpipes to show pressure phenomena in blood vessel aneurisms, and (b) fidget-spinner-inspired centrifugation device to show effects of cell suspension density or hematocrit on blood separations–multi-colored, multi-sized 100-300 micrometer plastic beads in water will be used as a blood simulant.*

The second module will introduce students to blood separation principles through use of an entertaining and simple fidget-spinner-inspired centrifuge design. Researchers have recently shown that fidget spinners, inexpensive and popular toys, can be used to separate blood [5]. Similarly, we leverage this design to create a simple centrifuge equipped with chambers that will retain a suspension of beads in water. This system may be used to simulate the effect of blood cell density and size on settling speed and terminal position, phenomena that are utilized to enhance blood separation efficiencies. Three layers of the fidget spinner module are laser-cut and joint by injection molding.

While various forms of hands-on learning approaches are becoming increasingly common in engineering education, the LCDLMs are unique due to their extremely low cost and flexible applications. The construction costs of our current fluid mechanics models range from $100-$200 each, the price of an average textbook [6]. Additionally, the BME LC-DLMs are built to fit on a standard tablet-arm desk, allowing their use in any classroom setting. The low cost and flexibility of 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 LCDLMs 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 will be, however, collecting motivational assessment data to assess whether or not exposure to biomedical applications changes students' perceptions of chemical engineering as a major. The motivational surveys will be designed in collaboration with Prof. Olusola Adesope of the Washington State University Department of Educational Psychology and his graduate student, Olufunso Oje.

Before class, students will take a pre-implementation attitudes survey with a series of Likert-scale questions assessing their current views on chemical engineering as a major. Then, for a 50-minute class period, the students will form groups where each student plays a different role [7] and they will perform a series of mini-experiments using the BME LCDLM devices. After class, the students will take a post-implementation attitudes survey with similar Likert-scale questions to the pre-assessment. Unlike our previous work, these motivational surveys can be done outside of class, as there is no concern for cheating since no conceptual questions will be asked.

We intend to address several research questions with the motivational surveys:

1) Initial perceptions of chemical engineering as a career and motivations for choosing the major amongst lower-division undergraduate students
2) Whether exposure to BME modules early in students' chemical engineering studies improves their self-assessed likelihood of remaining in the major

3) Whether the BME modules teach students about new applications and career options within chemical engineering
4) Whether BME modules increase the percentage of students who feel they can achieve their professional/personal career goals with a degree in chemical engineering
5) Whether BME modules increase the percentage of students who feel chemical engineers can directly impact peoples' lives with their work

We will also ask students to provide a short answer response about their attitude towards the implementation, how they feel the implementation could be improved, and whether they felt the implementation was valuable for their learning.

The results from the pre- and post- activity motivational surveys will be grouped by gender and analyzed to determine if the BME LCDLMs were largely beneficial for the five areas of student motivation listed above, and specifically, whether female students had a disproportionate change in motivation compared to male students.

CONCLUSIONS & FUTURE WORK

It was originally planned to have the BME LCDLM prototypes along with motivational surveys implemented in the first-year Introduction to Chemical Engineering (CHE 110) class for the spring 2020 semester. Due to the switch to virtual classes because of the COVID-19 national crisis, though, the in-person implementation is postponed to a similar course offered in fall 2020, Overview of Chemical Engineering (CHE 101). This presentation for the 2020 ASEE Conference & Exposition will still include modeling and manufacturing methods of the hands-on learning devices and design of motivational assessments.

Future plans include applying for additional funding and expanding the types of biomedical modules available, similar to what has been done with the traditional LCDLMs, and to develop pre- and posttests to assess conceptual gains in higher-level chemical engineering courses.

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REFERENCES

1. National Academy of Engineering 2008. *Changing the Conversation: Messages for Improving Public Understanding of Engineering*. Washington, DC: The National Academies Press. 57-59. https://doi.org/10.17226/12187.

2. The Chronicle List 2019, “Which Colleges Are Best and Worst at Enrolling and Graduating Women in Computer Science and Engineering?” (2019, February 24), Retrieved March 15, 2019, from https://www.chronicle.com/article/Which-Colleges-Are-Best-and/245758?cid=at&utm_source=at&utm_medium=en&elqTrackId=61c76ff393544f33916cdf7efa62f902&elq=1228defe891449bf8337f489863032f4&elqaid=22356&elqat=1&elqCampaignId=11012
3. Burgher, J.K., D. M. Finkel, B. J. Van Wie, and O. O. Adesope, "Implementing and Assessing Interactive Physical Models in the Fluid Mechanics Classroom," *International Journal of Engineering Education,* vol. 32, no. 6, pp. 2501–2516, 2016.
4. Hunsu, N.J., O. Adesope, and B.J. Van Wie, “Engendering situational interest through innovative instruction in an engineering classroom: what really mattered?” *Instructional Science*, vol. 45, pp. 789-804, 2017.
5. Liu C., C. Chen, S. Chen, T. Tsai, C. Chu, C. Chang, and C. Chen, “Blood Plasma Separation Using a Fidget-Spinner,” *Analytical Chemistry*, vol. 91, no. 2, pp. 1247-1253, 2019.
6. Njau S. W., B. J. Van Wie, J. K. Burgher, P. B. Golter, C. D. Richards, F. S. Meng, O. O. Adesope, N. Hunsu, N. Beheshti Pour, P. Dutta, D. B. Thiessen, A. D. Graviet, and A. Nazempour 2015, “Miniature Low-Cost Desktop Learning Modules for Multi-Disciplinary Engineering Process Applications”, *Am. Soc. for Eng. Ed. Annual Conf. & Exposition 2015, Seattle, Washington, 14-17 June.*
7. B. Oakley, R. Brent, R. Felder, and I. Elhajj, Turning student groups into effective teams, Journal of Student Centered Learning, 2(1), pp. 9-34, 2004.