

UC Davis

UC Davis Previously Published Works

Title

Board 10: Work in Progress: A Themed Problem-Learning Redesign of Bioinstrumentation Lectures

Permalink

<https://escholarship.org/uc/item/0zm0b9jj>

Authors

Wang, Xianglong

Lin, David

Publication Date

2023-06-25

DOI

10.18260/1-2--42377

Copyright Information

This work is made available under the terms of a Creative Commons Attribution-NonCommercial-NoDerivatives License, available at

<https://creativecommons.org/licenses/by-nc-nd/4.0/>

Peer reviewed

Board 10: Work in Progress: A Themed Problem-Learning Redesign of Bioinstrumentation Lectures

Dr. Xianglong Wang, University of California, Davis

Xianglong Wang is an Assistant Professor of Teaching at University of California, Davis. He is interested in problem-based learning in bioinstrumentation courses, gender equity in teaching of machine learning, and student experience and retention in BME students. He won the Teaching Excellence award in Biomedical Engineering at UC Davis in 2023. Prior to joining UC Davis, Xianglong was an Assistant Professor (Teaching) at Washington State University during 2020-2022, winning the Reid Miller Teaching Excellence Award in 2022.

David Lin, Washington State University

David Lin is an Associate Professor with a joint appointment in the Voiland School of Chemical Engineering and Bioengineering and Department of Integrative Physiology and Neuroscience at Washington State University, Pullman, WA. His teaching interests are in Bioinstrumentation, Biomechanics, Control Systems, and Physiology. His research interests are in the Biomechanics of the musculoskeletal systems and multi-scale physiology of muscle contraction.

Work in Progress: A Themed Problem-Learning Redesign of Bioinstrumentation Lectures

Introduction

The COVID-19 pandemic has severely disrupted higher education. The 2019–20 National Postsecondary Student Aid Study indicated that 84% of all undergraduates have experienced some of their classes moved online in Spring 2020. [1] Compared to in-person delivery, students have reported lower satisfaction level [2], lower motivation, [3], and lower engagement [4] with distance delivery. Many institutions transitioned back to in-person delivery since Fall 2021, however, attendance and student engagement fell in our affiliated universities compared to pre-pandemic levels. Revision to the curriculum, especially core courses with heavy lecture content, became necessary for retaining students. Problem-based learning (PBL) is a student-centered approach that is thought to benefit student learning [5] and motivation [6] when implemented correctly. PBL courses are organized around problems and the instructor acts as a facilitator in PBL sessions. The PBL approach will also create flexibility to integrate course content with engineering design. [7]

We chose the bioinstrumentation course for PBL redesign since this course was the first course taught by the authors immediately after attendance and engagement issues were observed. Bioinstrumentation is required by more than 90% of bioengineering or biomedical engineering (BME) undergraduate programs. [8] The structure and content of bioinstrumentation vary by the program, but often contains a lab module to build electronics circuits and/or prototypes of simple medical devices. [9] At Washington State University (WSU), the bioinstrumentation course contained students' first circuits-related lab. The lab protocols are based on Digilent Analog Discovery 2/Analog Devices ADALM2000, two low-cost portable oscilloscope/function generators. The contents of the labs contain basic circuits and sensing. At UC Davis (UCD), the existing labs are based on LabVIEW and National Instrument (NI) academic-grade systems (NI ELVIS), and the bioinstrumentation course is the third circuits-related lab experience for the students. We designed the new bioinstrumentation lectures with maximum translatability in mind that should flexibly fit into various ranges of existing lab protocol and student background.

This work-in-progress paper presents our PBL redesign of the lecture portion of the core undergraduate bioinstrumentation courses at WSU and UC Davis, and some preliminary results on students' performance and satisfaction.

Methods

Our learning objectives for both sites are the same before and after PBL, which is to teach students about electronics measurement systems so that they could be better prepared for

instrumentation-related design projects (next semester for WSU; concurrent quarter for UCD). The current version of the lecture used in UCD is a slight rearrangement (due to lab equipment) and addition (due to allocation of academic units) of the version currently used in WSU.

Our themed PBL redesign of the bioinstrumentation lectures focuses on general bioelectrical sensors and measurement, while considering integration into various styles of existing lab instructions. The new bioinstrumentation lectures begin with a themed project created by the first author during their undergraduate period, an electromyography (EMG)-based bedside controller. The EMG-based bedside controller, used as the theme of the redesigned lectures, captured EMG signals from flexes of the left and right arms. Each flex was coded into a bit (left: 0, right: 1). A hardware mode took two flexes and used a decoder to convert the flexes to one of four possible LED-based alarms, while a LabVIEW-based software mode converted eight flexes into a display message or a control command on a computer. Students aiming to design and recreate all functions of the device need to be trained in measurement principles, sensor principles, signal conditioning (amplification and filtering), conversion between analog and digital signals (sampling and quantization), signal processing, and logic circuits. Table 1 in Appendix A shows the outlines of the course in both sites with redesigned lectures and existing lab structures.

The “spiral-learning” method, where the subject is revisited after students gain additional expertise [10], is implemented in the new lectures to facilitate PBL. Two levels of PBL-based spiral-learning existed in the new lectures. First, the instructor decided to forgo a cumulative final exam and asked the students to complete a paper design for the signal acquisition and conditioning portions of the EMG controller at the end of the course. Second, instead of stopping at assigning, grading, and reflecting on homework assignments at the end of each module, students are additionally tasked with developing elementary design solutions for the portions of the EMG controller corresponding to the module. The PBL exercises are conducted as ungraded exercises. For simpler problems, for example, selecting the sampling frequency for digitization of EMG signals, a small group-discussion was held, and the instructor invited several groups to share their solutions with the class. For more complex problems such as the paper design of the EMG controller, a group worksheet (see Appendix B) was provided for designing subsystems of the circuit. After the groups completed their paper design, the instructor built one group’s paper design with their electronics kit and demonstrated live EMG collection in lecture.

Preliminary data on course evaluations and student performance were collected in WSU and analyzed with Python. The WSU IRB has designated the study to be Not Human Subject Research (NHSR). We are currently in the progress of obtaining appropriate IRB approval in UCD for a more comprehensive study.

Results and Discussion

The redesign of the bioinstrumentation lectures was implemented in 2022 in WSU ($n = 17$, 3rd year, 47% female) and UCD ($n = 85$, 4th year, 61% female, 19% campus-designated underrepresented minority). To compare the student performance in WSU, we will first define the

improvement metric d as shown in Equation (1).

$$d = [\text{Course grade in bioinstrumentation}] - [\text{Course grade in biotransport}]. \quad (1)$$

Since the same instructor instructed the bioinstrumentation and biotransport in both 2021 and 2022, the improvement metric d controls year-to-year student variation, instructor effects, and differences in instruction in online/in-person learning. A paired t -test ($p = 0.002$) on d indicated that students performed significantly better in the redesigned bioinstrumentation course, with $d = 6.02$ in 2022 and $d = 0.12$ in 2021. This evidence shows that students may have been performing better in instrumentation with controlled students and instructor, but a larger-sample and a better reference point are needed for understanding whether the redesigned bioinstrumentation lectures truly increase the student performance.

The attendance level never fell below 78% for WSU or UCD despite an attendance as low as 20% when students first returned to in-person instruction. In both sites, students were asked the question to evaluate the overall effectiveness of the instructor (I) and the value of the course (C) on a 1–5 Likert scale, with 1 being strongly disagree and 5 being strongly agree. Compared to a drop in Biotransport in WSU from 2021 (97% responded, 4.5I, 4.2C) to 2022 (97%, 4.1I, 3.9C), Bioinstrumentation obtained a much better rating (88%, 4.9I, 4.9C) than the 2021 version by the same instructor (83%, 4.3I, 3.9C), while faring better than the pre-pandemic version by a different instructor (2017–19 average 4.5I, 4.3C). Students reported that the class “modeled and encouraged problem-solving strategies” more in 2022 (4.9) than in 2021 (4.0). Better student satisfaction was shared by UCD (89%, 4.8I, 4.8C) versus the evaluation results from pre-pandemic instructors (2009-19 average 3.7I, 3.8C). Our results complement recent research on PBL-related improvement on self-reported learning [11], confidence [11], and perceived value [12] in biomedical engineering education.

The redesigned lectures are planned to be continually implemented in both sites. More track-record in time and the high enrollment (typically > 80 in UCD) will help us with finding the significance in student performance while understanding whether the improvement in student satisfaction is permanent or temporary. The diverse student population especially in UCD enables us to perform equity-focused studies in the future. With the students taking the bioinstrumentation as their third circuit-related course in UCD, a better reference point can be established for comparing student performance. Comparing the student performance of bioinstrumentation to Circuits I or II may be a fairer comparison than comparing to unrelated courses such as biotransport, even with a different instructor. We also plan to distribute pre-/post-surveys to understand whether the students’ interest and motivation in studying bioinstrumentation have increased due to the implementation of the redesigned lectures.

Conclusion

The redesigned bioinstrumentation lectures, featuring a theme of designing the acquisition and conditioning portions of an EMG-based controller, increase the satisfaction level of students. More studies are needed to understand the effect of these new lectures on student performance and motivation.

Appendix A: Outline for the Bioinstrumentation Course in Both Sites

Here is an outline for the bioinstrumentation course implemented in the two sites.

WSU: Second circuit/electronics course, first circuit/electronics lab, 3 (2 lecture + 1 lab) semester credits			
Module	Lecture	Lab	PBL exercise
1	Introduction to measurement and electronics labs	PSpice-based simulation; test equipment; RC circuits; sensors	Characterizing measurement with Binary Outcomes
2	Ideal and non-ideal amplifiers, interfacing circuits	Operational amplifiers and instrumentation amplifiers; building interfacing circuits for LED arrays	Amplifying biopotential
3	Filtering circuits	Passive and active filters	Filtering biopotential
4	Diodes and rectifying circuits	Rectifiers with LED	LED-based alarms
5	Sampling and quantization	Aliasing in analog to digital converters	Determining sampling rate
UCD: Third circuit experience with lab, 6 (4 lecture + 2 lab) quarter units			
Module	Lecture	Lab	PBL exercise
1	Introduction to measurement; review passive circuits	NI ELVIS Boards, Programming Virtual instrument (VI) in LabVIEW	None
2	Sampling and quantization	Sampling and aliasing with VIs	Determining sampling rate
3	Ideal and non-ideal amplifiers	Operational amplifiers and instrumentation amplifiers	Amplifying EMG
4	Filtering circuits	Passive and active filters; capturing electrocardiogram with LabVIEW	Filtering EMG
5	Interfacing circuits	Building a blood pressure monitor	Full EMG circuit
6	Sensors and digital signal processing	Building a pulse oximeter	LED-based alarms, electrode survey, biopotential signal processing

Table 1: Modular outline of the bioinstrumentation course as implemented in WSU and UCD. 1 semester credit is equivalent to 1.5 quarter units in instruction time. UCD additionally requires signals and systems as prerequisites of the bioinstrumentation course.

Here is a detailed list of labs used in WSU (15 weeks, 12 labs):

1. Reader study and experimenter bias: analysis of experiments with binary outcomes
2. Simulating circuits with Multisim Live
3. Oscilloscopes and function generators
4. RC circuits: natural and step responses
5. Temperature and acceleration sensing
6. Inverting and Non-inverting amplifiers
7. Calibration and conditioning with differential amplifiers (two-week lab)
8. Instrumentation amplifiers
9. Passive and active filters
10. Wheatstone bridges
11. Full-wave and half-wave rectifiers
12. Sampling and quantization

Here is a detailed list of labs used in UCD (10 weeks, 7 labs):

1. Introduction to LabVIEW
2. RC circuits in time domain; sampling and quantization
3. Amplifying signals with Op-Amps
4. Designing active filters
5. Designing an ECG measurement device
6. Blood pressure measurement (two-week lab)
7. Pulse oximeter (three-week lab)

Appendix B: PBL Worksheet for PBL Paper Design of EMG Controller

Interfacing Circuit

1. What is the output from the previous stage? (Essentially, what is the approximate range of EMG signals, and how many outputs do we have?)
2. What is the desired input, or transfer function for the desired input, for the next stage? (How large do you want the final EMG signal to be?)
3. What is the transfer function that helps us relate the output from the previous stage with the desired input?
4. What is the type of circuit that implements this transfer function?
5. What are the restrictions/requirements when we are selecting our circuit components?

Filtering

1. We will need hardware filtering for EMG. Based on the frequency components of EMG, determine the cutoff frequencies.
2. Distribute the gain among all stages that are capable of amplification.
3. Draw the EMG acquisition circuit diagram and label the parts that you intend to use.

[Followed by a list of Op-Amps, resistors, and capacitors in the authors' electronics kit for live demonstration]

References

- [1] M. Cameron, T. A. Lacy, P. Siegel, J. Wu, A. Wilson, R. Johnson, R. Burns, and J. Wine, “2019-20 national postsecondary student aid study (npsas: 20): First look at the impact of the coronavirus (covid-19) pandemic on undergraduate student enrollment, housing, and finances (preliminary data). nces 2021-456.” *National Center for Education Statistics*, 2021.
- [2] D. P. Banks and S. M. Vergez, “Online and in-person learning preferences during the covid-19 pandemic among students attending the city university of new york,” *Journal of Microbiology & Biology Education*, vol. 23, no. 1, pp. e00 012–22, 2022. [Online]. Available: <https://journals.asm.org/doi/abs/10.1128/jmbe.00012-22>
- [3] J. H. Corpus, K. A. Robinson, and Z. Liu, “Comparing college students’ motivation trajectories before and during covid-19: A self-determination theory approach,” *Frontiers in Education*, vol. 7, 2022. [Online]. Available: <https://www.frontiersin.org/articles/10.3389/feduc.2022.848643>
- [4] E. R. Wester, L. L. Walsh, S. Arango-Caro, and K. L. Callis-Duehl, “Student engagement declines in stem undergraduates during covid-19–driven remote learning,” *Journal of microbiology & biology education*, vol. 22, no. 1, pp. ev22i1–2385, 2021.
- [5] E. De Graaf and A. Kolmos, “Characteristics of problem-based learning,” *International journal of engineering education*, vol. 19, no. 5, pp. 657–662, 2003.
- [6] J. I. Rotgans and H. G. Schmidt, *Effects of Problem-Based Learning on Motivation, Interest, and Learning*. John Wiley & Sons, Ltd, 2019, ch. 7, pp. 157–179. [Online]. Available: <https://onlinelibrary.wiley.com/doi/abs/10.1002/9781119173243.ch7>
- [7] R. Raman, M. Mitchell, P. Perez-Pinera, R. Bashir, and L. DeStefano, “Design and integration of a problem-based biofabrication course into an undergraduate biomedical engineering curriculum,” *Journal of Biological Engineering*, vol. 10, pp. 1–8, 2016.
- [8] J. A. White, D. P. Gaver, R. J. Butera, B. Choi, M. J. Dunlop, K. J. Grande-Allen, A. Grosberg, R. W. Hitchcock, A. Y. Huang-Saad, M. Kotche *et al.*, “Core competencies for undergraduates in bioengineering and biomedical engineering: findings, consequences, and recommendations,” pp. 905–912, 2020.
- [9] J. G. Webster, “A course in bioinstrumentation,” in *Proceedings of the 19th Annual International Conference of the IEEE Engineering in Medicine and Biology Society. 'Magnificent Milestones and Emerging Opportunities in Medical Engineering' (Cat. No. 97CH36136)*, vol. 3. IEEE, 1997, pp. 1040–1043.
- [10] A. M. Kyle, D. C. Jangraw, M. B. Bouchard, and M. E. Downs, “Bioinstrumentation: A project-based engineering course,” *IEEE Transactions on Education*, vol. 59, no. 1, pp. 52–58, 2016.
- [11] J. Long, E. Dragich, and A. Saterbak, “Problem-based learning impacts students’ reported learning and confidence in an undergraduate biomedical engineering course,” *Biomedical Engineering Education*, vol. 2, no. 2, pp. 209–232, 2022.
- [12] G. Lam, N. Gill, and R. Ghaemi, “Semi-structured design and problem-based experiential learning in a first-year biomedical engineering laboratory course,” *Proceedings of the Canadian engineering education association (CEEAA)*, 2020.