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WIP: Virtual Vs. Face-to-Face Synchronous Laboratory Instruction for Programming MATLAB for Biomedical Engineers

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My professional interests focus on the development and use of microsystems (biosensors, microcontrollers, etc) to matters of human health. Primarily this is focused on microfluidics, but also ranges from wearable devices to laboratory equipment. Applications range from cell measurements to ecological questions. Educationally, I am focused on developing courses and content that connects theory to technology in practice, with an emphasis on rigorous understanding of both.

Work in Progress: Virtual vs Face-to-Face Synchronous Laboratory Instruction for Programming MATLAB for Biomedical Engineers

Introduction

In this work we leverage the virtual instructional environment resulting from the COVID-19 pandemic to compare student responses to face-to-face/virtual and synchronous/asynchronous instructional modes for programming focused laboratory activities in Biomedical Engineering. Across California Polytechnic University, San Luis Obispo (Cal Poly), courses were offered primarily in virtual mode (87%), but 13% of courses identified as essential were implemented in-person provided they obtained an approved safety plan. Students were not compelled to attend face-to-face courses and were given the option to pursue virtual alternatives. This combination of factors presented us with a unique opportunity to study the impact of face-to-face and virtual synchronous instruction modes.

A critical part of the biomedical engineering curriculum at [the institution], [this course] covers core engineering analytical and computational techniques, with a laboratory portion consisting of a sequence of MATLAB-based programming activities for undergraduates in biomedical engineering [1]. Typically offered in a face-to-face (F2F) modality, the most recent Fall 2020 term presented these activities to students in either virtual synchronous, virtual asynchronous, or face-to-face environments, providing a unique opportunity for comparison of student success. In this case, we were able to offer identical material and synchronous instruction during the laboratory activity to face-to-face (F2F) and virtual students. After completing the course, students were surveyed about their use of each modality, their success in the course, and which factors they attributed their success. Student responses (response rate 41%) strongly supported synchronous (96%) and F2F (83%) course components as essential to learning and success in the course.

Background

Programming or coding, as a practice, is primed for adaptation to a virtual environment. By its very nature, it requires no unique infrastructure, no difficult to maintain or handle materials, and no required “hands-on” components. There is a growing body of literature documenting the effectiveness of blended instruction in introductory programming courses, generally concluding that F2F and/or synchronous components significantly improve outcomes [2]. In addition, the virtual (synchronous or asynchronous) setting, can disproportionately impact students from underrepresented minority (URM) groups [3] and students struggling with financial, physical, and mental health challenges. Students in the early stages of learning programming struggle to separate technical issues from coding issues, such as how MATLAB organizes and references files versus coding syntax or execution errors.

Laboratory Activities

Originally developed for F2F courses and minimally modified for hybrid presentation, laboratory sessions begin with a description of the concepts to be implemented, both from a programming perspective and an application perspective. Initial laboratory activities focus on developing and implementing core programming concepts such as loops, array building/indexing, and functions. Subsequent lab activities introduce additional programming concepts and data types while also applying them to conceptually more challenging problems (**Table** 1). Many of these concepts are built and applied to a model for glucose-insulin response following the Bergman model [4]. Each laboratory activity is broken into three or four coding objectives which are submitted and checked using MATLAB’s Grader software.

Table 1: Laboratory activities focus on teaching and improving programming skill along with problem-solving applications relevant to Biomedical Engineering

	Title	Concepts	Application
1	Signal Properties	Arrays, Indexing, Loops	ECG Analysis, Descriptive Statistics
2	Systems of Equations	Arrays, Curve Fitting	Air Transport in Lungs (Windkessel Model)
3	Time and Frequency Domain	Loops, FFT	ECG Analysis, Pulse and Respiratory Rate Detection
4	Signal Processing	Filtering	ECG Analysis, Filtering
5	Edge Detection	Arrays, Loops, Convolution	Image Analysis
6	Ordinary Differential Equations	ODE Solver (ode45)	Linearized Glucose Insulin Model
7	System Response	ODE Solver (Euler)	Nonlinear Glucose Insulin Model
8	PID Control	PID Control, ODE (Euler)	PID Controlled Insulin Pump for Glucose Control

Intervention

The lab is typically taught in a F2F mode and one of the hallmarks of most lab sessions is frequent questions and troubleshooting interactions with students. We therefore developed an approach to support both the large number of students who would be engaging F2F as well as the students who elected to complete the course in an entirely virtual setting. Lab space was limited to ~16-18 students per room, with two rooms available to the two sections of the lab. While the majority of students enrolled in the F2F section of the class, various restrictions and quarantine events for students living on campus meant that a sizeable portion of students might be participating virtually during a given week. To accommodate the varying needs of all these students, the introductory and expository portions of the course were streamed live and recorded via the Zoom web conferencing platform. The instructor would deliver a prelab lecture and discuss material in one room with the content streamed live and projected in the second laboratory room. Students working remotely could follow along synchronously and all students had access to the recorded lecture portion of the course at any time. During class, students could receive immediate, one-on-one help either via in-person interactions, screen-sharing via Zoom session, or asynchronously via email, chat, or message board (all were available to students).

To assess the impact of these measures and the patchwork of participation modes, we structured a questionnaire to gather information on the following:

- What fraction of time was spent in each mode of instruction (synchronous F2F, synchronous virtual, and asynchronous virtual)?
- How successful were students at meeting the learning objectives of the lab (Likert)?
- How did synchronous versus asynchronous interactions affect learning (Likert)?
- How did F2F versus virtual interactions affect learning (Likert)?
- What were the student's preferences for in-person versus virtual learning environments?
- What was the student's level of experience in programming/coding?
- What was the student's level of academic performance?

Students were asked to indicate rate their reactions to a number of statements (from "strongly disagree" to "strongly agree") addressing the above, along with quality control statements (to check for "straight-lining").

Results of Hybrid Adaptation

The Biomedical Engineering program at [institution] is made up of 411 total students: 45.3% women, 18% underrepresented minorities, and 95.4% enrolled full-time. The student population is 52.3% white, 18.0% Asian-American, 15.8% Hispanic/Latinx, 0.2% African-American, 0.2% Native American, and 13.5% multi-racial or other/unknown. 12.7% of BMED students receive Pell Grants. The population of students surveyed for this study were 54 students enrolled in [course], 64% women. Out of the 54 students surveyed, 25 responded. Most students (80%) reported having only 1 term of previous experience programming with MATLAB with the rest having more experience or experience with another programming language. Survey result data were analyzed using JMP 15 Pro. Likert scale results with abbreviated statements are shown in Figure 1.

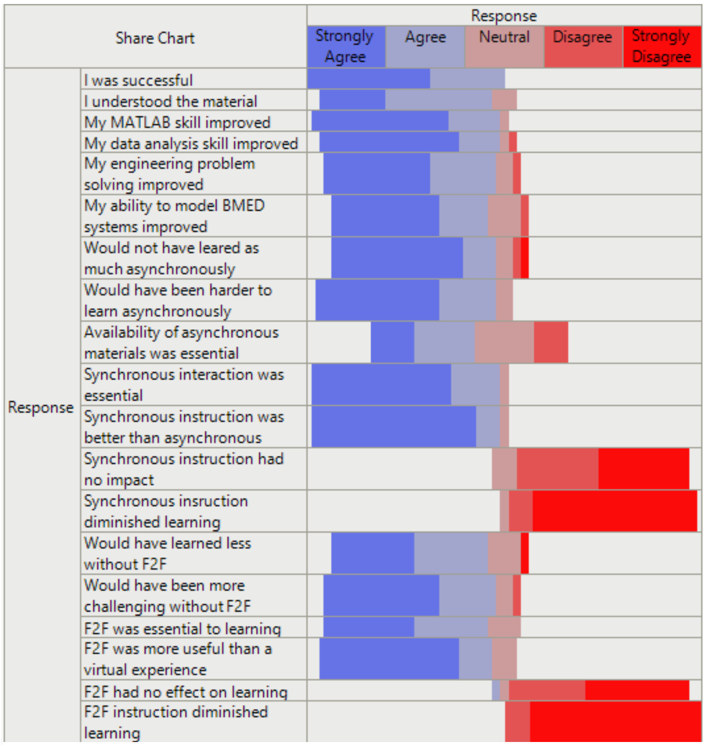

Figure 1: Results of Likert scale responses to survey questions, including quality control questions. A strong correlation was found between quality control questions, indicating participants were engage with the survey questions.

Throughout the term, the population of F2F students fluctuated. 64% of respondents indicated they participated F2F between 75% and 100% of the time, 16% between 25% and 75% of the time, and 8% less than 25%. A large majority of students indicated that F2F was both essential (83.3% SA/A) and preferable (87.5% SA/A) to virtual instruction. Similarly, a large majority indicated that synchronous delivery was essential (95.8% SA/A) and preferable (95.8% SA/A). Student self-assessment of learning in the course also indicated that the majority of respondents were successful (Q1 – Q6, Figure 1). A predictor screening analysis was performed to assess the possible effects of previous coding experience, academic performance, or synchronous participation on survey responses. None were found to be strong predictors of self-reported success in the course, except for "Grade in course" which strongly predicted responses to "I was successful" (Q1, 55% contribution). Participation in F2F activity was the only likely predictor of survey responses, primarily associated with indicating "synchronous interaction was essential" (Q10, 53% contribution) and "F2F was essential to learning (Q16, 43% contribution).

Conclusions

Overall, survey respondents strongly indicated a preference for F2F and synchronous modalities, independent of their prior coding experience and course performance. The results here are consistent with other work indicating the need for F2F or synchronous components to programming coursework [2]. This study is limited by participation bias and a limited ability to compare student responses to performance in the course. Improvement in the latter would enable valuable, quantitative assessment of the effectiveness of this teaching strategy in both virtual and F2F modalities. This will be addressed in future work by collecting student demographic information and paired course academic data as part of the analysis.

References

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