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Virtual vs face-to-face synchronous laboratory instruction for programming matlab for biomedical engineers

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Virtual vs Face-to-Face Synchronous Laboratory Instruction for Programming MATLAB for Biomedical Engineers

Introduction

Studies of the educational efficacy of remote, distance, and virtual learning environments span a range of implementations, evolving as technology changes and student access to resources improves. Especially because of countermeasures employed to address the COVID-19 pandemic, remote, distance, and virtual learning environment utilization has expanded significantly in the past 3 years. With this shift comes concomitant consideration of retaining some or all of these features in instruction even as the need for these countermeasures recedes. While the COVID-19 pandemic created a far more challenging educational environment, but also created an opportunity for scrutiny of virtual instruction practices. The terms “remote”, “distance”, and “virtual” carry a variety of interpretations [1]; here we use the term “virtual” and “remote” interchangeably to refer to student interactions with an online learning management system (LMS) and other web-based tools and we use the term “synchronous” to refer to interactions that occur with faculty and students in real-time. “Face-to-face” (F2F) and “asynchronous” refer to in-person activity and prerecorded or static material accessed at a time of the students choosing, respectively.

Prior to the COVID-19 pandemic, virtual laboratory instruction practices were already receiving significant attention, owing to advantages of flexibility and reproducibility. Their implementation in a variety of disciplines has been reviewed [2], with the conclusion that educational efficacy depends strongly on proper implementation of a pedagogical framework and a supportive learning environment. From a discipline-specific perspective, programming or coding, as a practice, seems 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. However, 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 [3]. In addition, the virtual (synchronous or asynchronous) setting, can disproportionately impact students from underrepresented minority (URM) groups [4] and students struggling with financial, physical, and mental health challenges. Students in these groups benefit significantly from additional training in digital skills training [5], indicating that familiarity with the digital, online environment improves the likelihood of student success.

Virtual learning environments can be further subdivided in to “synchronous” and “asynchronous” modes [1]. The primary mode implemented in this study is “synchronous,” though subjects varied in their chosen mix of synchronous and asynchronous instruction. Asynchronous instruction can be particularly challenging; while flexibility is often cited as an advantage of the virtual environment [2], it can also present a challenge to students with poor time-management skills [6]. Programming can be particularly challenging, and students tend to prefer a synchronous and/or F2F component to augment a virtual programming laboratory experience [7]. Asynchronous instruction tends to lead to lower student engagement [8].

During the COVID-19 pandemic, 2020-2021 academic year, the majority of courses at our institution were offered in virtual modes (87%), while 13% of courses identified as essential were implemented in-person with an approved safety plan. Students were not compelled to attend face-to-face courses and were given the option to pursue virtual alternatives. In this case, we were able to offer identical material and synchronous instruction during the laboratory activity to virtual students. This combination of factors presented us with a unique opportunity to simultaneously study the impact of face-to-face and virtual synchronous instruction modes.

Background

The structure of the Biomedical Engineering program at Cal Poly, San Luis Obispo mirrors that of many peer institutions, with background coursework in chemistry, biology, math, and physics offered by other departments being taken before students engage in core BME courses at the junior level. The first junior-level BME course is BMED 310: Biomedical Engineering Measurement and Analysis, after which they go on to complete core coursework and technical area electives. One of the primary learning outcomes emphasized in the program is the ability to synthesize and apply knowledge from a variety of fields to the design of biomedical systems that improve human health. In support of this, BMED 310 emphasizes general system analysis techniques applicable across subdisciplines.

The overall goals of the course are to (i) apply and extend knowledge gained in prerequisite coursework and (ii) integrate potentially disparate topics with applications in biomedical engineering. The primary learning outcomes for the course reflect our desire to bring together information and analysis techniques from disparate fields and synthesize them in application to biomedical problems:

1. Apply compartmental analysis to model mass, momentum, charge, and energy in transport biomedical systems
2. Use fundamental time- and frequency-domain circuit analysis techniques to understand the behavior of biomedical systems
3. Analyze biomedical signals using time- and frequency-domain methods
4. Use principles of computer programming to model and analyze biomedical signals and systems

These objectives also reflect our emphasis on building a computational toolset for numerical analysis using MATLAB. Functional programming is one of the skills often highlighted as desirable by members of our Industrial Advisory Board. While MATLAB may not be the most rigorous programming tool, it provides versatile analytical capability, does not require adherence to rigid syntax, and coincides with content from prerequisite courses.

The lecture portion of BMED 310 focuses on developing conceptual and analytical tools while the laboratory portion focuses on the computational application of these same processes. Because they have approached their prerequisite coursework in different fields from different departments across campus, students often store this prerequisite knowledge in separate "silos" [9]. For application in multidisciplinary fields like Biomedical Engineering, we must find ways to bridge these "silos" and connect content across fields so that students bring a comprehensive knowledge base to any problem. The framework for the development of analytical skills within the course is also broken down in terms of the approach to an engineering problem. The problem-solving framework is to (i) from an abstract problem, develop a conceptual description applying background knowledge and governing equations, (ii) translate the conceptual problem into a mathematical form, (iii) perform analysis of the system based on its mathematical representation, and, if necessary, (iv) determine a quantitative response given a system input. At each step along this process, students will develop and implement a variety of analytical tools. This concept map is arranged graphically in Figure 1.

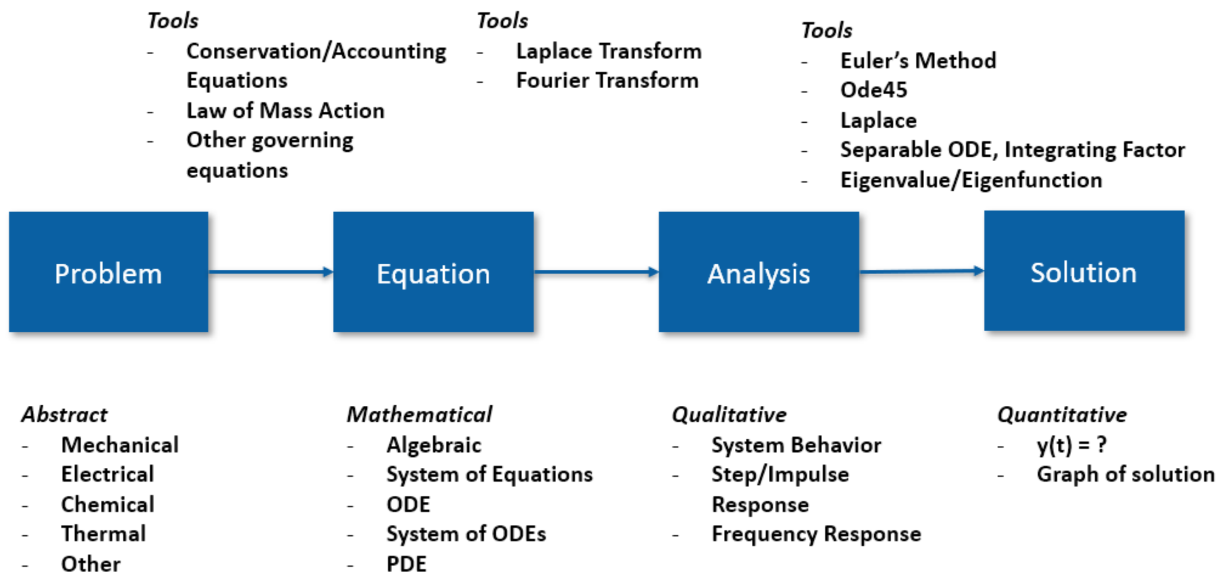

Figure 1: Graphical map of concepts taught in BMED 310 in the framework of a problem-solving process.

Developing these skills independently is possible but does not achieve the goal of connecting the separate "tools" across disciplines. Therefore, these topics are integrated in to programming lab exercises where data from real-world sources and models is used to teach programming skills and analytical tools simultaneously [10].

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 prefer synchronous (96%) and F2F (83%) course components as essential to learning and success in the course.

In this work we leverage the virtual instructional environment resulting from the COVID-19 pandemic during the Fall 2020 term to compare student responses to face-to-face/virtual and synchronous/asynchronous instructional modes for programming focused laboratory activities in Biomedical Engineering. Across 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.

The composition of students within the BME program at Cal Poly is shown by gender and ethnicity in Table 1, below. As commonly noted in Biomedical Engineering programs, women are strongly represented relative to other engineering programs. This is consistent at Cal Poly.

Table 1: Demographic data for cohorts potentially participating in study

Year	% African American	% Asian American	% Hispanic/Latino	% Multi-Racial	% Native American	% Non-Resident/Alien	% Pacific Islander/Hawaiian	% Unknown/Other	% White	% Men	% Non-Binary	% Women	Total
2017	1.1	18.9	14.4	8.9	0.0	1.1	0.0	4.4	51.1	33.3	0.0	66.7	90
2018	0.0	21.1	7.8	12.2	0.0	1.1	0.0	2.2	55.6	44.4	0.0	55.6	90
2019	0.0	15.2	12.1	7.6	1.5	3.0	0.0	1.5	59.1	37.9	0.0	62.1	66

In addition, 12.7% of BMED students receive Pell Grants. The population of students surveyed for this study were 54 students enrolled in BMED 310, 64% women.

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 2). Many of these concepts are built and applied to a model for glucose-insulin response following the Bergman model [11]. Each laboratory activity is broken into three or four coding objectives which are submitted and checked using MATLAB's Grader software.

Table 2: 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?

The full text of the questionnaire is provided in Appendix I. Students were asked to indicate rate their reactions to several statements (from "strongly disagree" to "strongly agree") addressing the above, along with quality control statements (to check for "straight-lining").

Figure 2: Results of Likert scale responses to survey questions, including quality control questions. A strong correlation was found between quality control questions, supporting a measure of internal validation.

Results of Hybrid Adaptation

Out of the 54 students surveyed, 25 responded. Survey result data were analyzed using JMP 16 Pro. Likert scale results with abbreviated statements are shown in Figure 2. Categorical responses were quantified by assigning values of 1 through 5 for "Strongly Disagree" through "Strongly Agree," respectively. No outliers were found in the data, using Q =1 (outliers are outside Q times the interquartile range). Three analyses were performed: response screening, effects analysis, and predictor screening. In each analysis, the response variables are student

Predictor	Successful			Understanding		
	Contribution	Portion	Rank	Contribution	Portion	Rank
% Face-to-Face Act.	1.45203	0.2783	3	2.87144	0.3509	2
% Sync Virtual Act.	2.30637	0.4420	1	3.85514	0.4711	1
% Asynch Virtual Act.	1.45913	0.2797	2	1.45654	0.1780	3

Figure 3: Predictor screening for success ("I was successful") and understanding ("I understood the material"), based on the fraction of time spent in F2F vs virtual and synchronous vs asynchronous instruction.

responses to self-assessment questions rating the statements in question 6 of the questionnaire on a Likert scale (Appendix I).

Response Screening

A response screening analysis was performed to identify key linearly related factors and responses. Two factors were strongly correlated in this analysis: "% Face-to-Face" instruction was strongly correlated with student's improvement in "Processing data in MATLAB" ($p = 0.0034$) and "Grade in course" was strongly correlated with student's improved ability to "Solve engineering problems" ($p = 0.00288$). Response screening was also used to see which perspectives on virtual vs F2F and synchronous vs asynchronous modalities. These results (**Table** 3) indicated that students who valued F2F and synchronous instruction modes also indicated significant improvement in MATLAB skill and engineering problem solving skills.

Table 3: Response screening results for correlated student responses. Only correlations with $p < 0.01$ are reported. Response statements are statements from Question 6 in the questionnaire. "Factor" statements are in Questions 7 and 8.

Response	Factor	p-Value
BMED Modeling Imp.	No F2F would have hurt learning	0.0068
MATLAB Skill Imp.	Async materials essential	0.00594
MATLAB Skill Imp.	Sync. had NO impact	0.00905
MATLAB Data Imp.	Sync. hurt learning	0.00627
MATLAB Data Imp.	No F2F would have hurt learning	0.00875
Eng. Prob. Solv. Imp.	No F2F would have hurt learning	0.0084

Predictor Screening

Throughout the term, the population of F2F students fluctuated. As conditions due to the pandemic shifted, some were required to quarantine, and others chose to isolate out of concern for their health. Based on survey responses, 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%. Predictor screening analysis of this factor is shown in Figure 3. The results show that the self-reported fraction of time spent in F2F vs virtual or synchronous vs asynchronous was not a strong predictor of success or understanding, with the strongest alignment found between synchronous virtual engagement and measured outcomes.

Responses related subject skill with MATLAB and data analysis were similarly inconclusive, as shown in Figure 4. The strongest alignment was found between asynchronous participation and MATLAB and data analysis skills. Most students (80%) reported having only 1 term of previous experience programming with MATLAB with the rest having more experience or experience

	MATLAB Skill Imp.			MATLAB Data Imp.		
Predictor	Contribution	Portion	Rank	Contribution	Portion	Rank
% Face-to-Face Act.	1.94324	0.2976	3	1.09316	0.1118	3
% Sync Virtual Act.	1.95533	0.2995	2	3.65212	0.3736	2
% Asynch Virtual Act.	2.63070	0.4029	1	5.03142	0.5146	1

Figure 4: Predictor screening for MATLAB Skill ("My MATLAB skill improved") and data analysis ("My data analysis skill improved"), based on the fraction of time spent in F2F vs virtual and synchronous vs asynchronous instruction.

with another programming language. This result is somewhat surprising, given the strong preference shown for F2F modality, shown later, but could potentially reflect the low number of participants utilizing this modality. Finally, engineering problem solving and modeling biomedical systems were analyzed for predictive value, and again the results were limited, as shown in Figure 5. The strongest alignment was found between F2F and synchronous instruction and outcome measures.

	Eng. Prob. Solv. Imp.			BMED Modeling Imp.		
Predictor	Contribution	Portion	Rank	Contribution	Portion	Rank
% Face-to-Face Act.	3.14440	0.3972	2	1.82598	0.5441	1
% Sync Virtual Act.	3.49232	0.4412	1	0.90355	0.2692	2
% Asynch Virtual Act.	1.27888	0.1616	3	0.62649	0.1867	3

Figure 5: Predictor screening for engineering problem solving ("My engineering problem solving improved") and biomedical modeling ("My ability to model biomedical systems improved"), based on the fraction of time spent in F2F vs virtual and synchronous vs asynchronous instruction.

Looking at other potential predictive measures, previous academic performance and training in programming were examined. The strongest predictor of self-reported success and ability to model biomedical systems was the students' grade in BMED 310, Figure 6.

	Successful			BMED Modeling Imp.		
Predictor	Contribution	Portion	Rank	Contribution	Portion	Rank
Grade in Course	4.32884	0.8095	1	2.14334	0.7487	1
Typical Technical GPA	0.56961	0.1065	2	0.27794	0.0971	3
Previous programming	0.44921	0.0840	3	0.44158	0.1542	2

Figure 6: Predictor screening for success ("I was successful") and engineering problem solving ("My engineering problem solving improved"), based on the grade in BMED 310, typical (previous) technical GPA, and previous programming experience.

In considering student preferences, 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). 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), as shown in Figure 7 and Figure 8.

Predictor	Synchronous interaction was essential: Contribution	Portion	Rank	Synchronous instruction had no impact: Contribution	Portion	Rank
% Face-to-Face Act.	4.81018	0.5734	1	3.59842	0.5104	1
Typical Technical GPA	1.51724	0.1809	3	1.20181	0.1705	3
Grade in Course	0.19873	0.0237	4	0.86336	0.1225	4
Previous programming	1.86261	0.2220	2	1.38629	0.1966	2

Figure 7: Predictor screening for survey response, with amount of time spent in F2F instruction ("% Face-to-Face Act") being a strong predictor of responses to "Synchronous interaction was essential" and "Synchronous instruction had no impact". Strong alignment here is an example of an internal validation question included in the questionnaire.

Predictor	Would have been more challenging without F2F: Contribution	Portion	Rank	F2F was essential to learning: Contribution	Portion	Rank
% Face-to-Face Act.	5.66372	0.5828	1	5.14775	0.5705	1
Typical Technical GPA	2.72764	0.2807	2	2.42541	0.2688	2
Grade in Course	0.80304	0.0826	3	1.02279	0.1134	3
Previous programming	0.52424	0.0539	4	0.42705	0.0473	4

Figure 8: Predictor screening for survey response, with amount of time spent in F2F instruction ("% Face-to-Face Act") being a strong predictor of responses to "Would have been more challenging without F2F" and "F2F was essential to learning". Strong alignment here is an example of an internal validation question included in the questionnaire.

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 [3]. 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.

This work was conducted with Cal Poly, San Luis Obispo IRB approval (Project: #2021-009-CP).

References

[1] J. L. Moore, C. Dickson-Deane and K. Galyen, "e-Learning, online learning, and distance learning environments: Are they the same?," *The Internet and Higher Education,* vol. 14, no. 2, pp. 129-135, 2011.

[2] T. Alkhaldi, I. Pranata and R. I. Athauda, "A review of contemporary virtual and remote laboratory implementations: observations and findings," *Journal of Computers in Education,* vol. 3, pp. 329-351, 2016.

[3] A. Alammary, "Blended learning models for introductory programming courses: A systematic review," *PLoS ONE,* vol. 14, no. 4, p. e0221765, 2019.

[4] T. O. Howard, M.-A. Winkelmes and M. Shegog, "Transparency Teaching in the Virtual Classroom: Assessing the Opportunities and Challenges of Integrating Transparency

Teaching Methods with Online Learning," *Journal of Political Science Education ,* vol. 16, no. 2, pp. 198-211, 2019.

[5] M. L. Bernacki, L. K. Vosicka and J. C. Utz, "Can a brief, digital skill training intervention help undergraduates "learn to learn" and improve their STEM achievement?," *Journal of Educational Psychology,* vol. 112, no. 4, pp. 765-781, 2019.

[6] R. Baker, B. Evans, Q. Li and B. Cung, "Does inducing students to schedule lecture watching in online classes improve their academic performance? An experimental analysis of a time management intervention," *Research in Higher Education,* vol. 60, pp. 521-552, 2019.

[7] B. K. Triwijoyo and A. Anggrawan, "Research and Development of Asynchronous Online Learning Module for Computer Programming," *Turkish Journal of Computer and Mathematics Education,* vol. 12, no. 13, pp. 4408-4422, 2021.

[8] C. Alario-Hoyos, I. Estevez-Ayres, J. M. Gallego-Romero, C. D. Kloos, C. Fernandez-Panadero, R. M. Crespo-Garcia, F. Almanares, M. B. Ibanez, J. Villena-Roman and J. Ruiz-Magana, "A Study of Learning-by-Doing in MOOCs through the Integration of Third-Party External Tools: Comparison of Synchronous and Asynchronous Running Modes," *Journal of Universal Computer Science,* vol. 24, no. 8, pp. 1015-1033, 2018.

[9] M. Borrego and L. K. Newswander, "Definitions of Interdisciplinary Research: Toward Graduate-Level Interdisciplinary Learning Outcomes," *The Review of Higher Education,* pp. 61-84, 2010.

[10] B. G. Hawkins and J. Eason, "Laboratory Course Development for Biomedical Signals and Systems," in *ASEE Pacific Southwest Section Meeting*, Los Angeles, 2019.

[11] W. E. Schiesser, "Diabetes Glucose Tolerance Test," in *Differential Equation Analysis in Biomedical Science and Engineering: Ordinary Differential Equation Applications with R*, Hoboken, New Jersey, John Wiley & Sons, Inc., 2014, pp. 79-143.

Appendix I

Questionnaire text sent to students after completing BMED 310. Abbreviations are used to describe question type:

- [MC] for multiple choice, with options listed in parentheses, separated by a slash
- [MR] for multiple radio button, where each subquestion allows students to select one of the options listed in parentheses, separated by commas
- [LS] for Likert scale, with rating options in parentheses, separated by commas
- [SA] for short answer, where a text box is given to respond.

1. [MC] Are you 18 years of age or older?
   (Yes/No)
2. [MC] During which quarter did you participate in BMED 310?
   (Fall 2020/Winter 2020/Other)
3. [MC] The lab supported several options for different participation modes. Synchronous (at the same time) face-to-face, synchronous virtual, and asynchronous virtual. In which mode did you plan on engaging in the course (you'll be asked to quantify different modes later, for now this is just what you planned)?
   (Synchronous Face-to-Face/Synchronous Virtual/Asynchronous Virtual)
4. [MR] Quantify the degree to which you used each mode of instruction (relative to total amount of time spent on the lab portion of the course). *(<25%, 25% to 50%, 50% to 75%, 75% to 100%)*
   a. Synchronous Face-to-Face
   b. Synchronous Virtual
   c. Asynchronous Virtual
5. [SA] Who was your primary instructor for the course?
6. [LS] Please indicate the degree to which you agree or disagree with the following statements about your learning in BMED 310. This section focuses on your overall learning in the lab. *(Strongly Disagree, Disagree, Neutral, Agree, Strongly Agree, N/A)*
   a. I was successful in the laboratory
   b. I understood all the material in the laboratory
   c. My MATLAB programming skill increased as a result of this lab
   d. My understanding of how to process data in MATLAB increased as a result of this lab.
   e. My understanding of how to solve engineering problems increased as a result of this lab.
   f. My understanding of how the model biomedical systems increased as a result of this lab.
7. [LS] Please indicate the degree to which you agree or disagree with the following statements about your learning in BMED 310. This section focuses on your experiences in synchronous vs asynchronous experiences. *(Strongly Disagree, Disagree, Neutral, Agree, Strongly Agree, N/A)*
   a. I would not have learned as much if the lab had been completely asynchronous.
   b. The lab would have been more challenging if it was completely asynchronous.
   c. Access to asynchronous materials (to review later) was essential to the lab.

    d. Access to instructors synchronously (face-to-face or virtual) was essential to the lab.
    e. Access to instructors synchronously (face-to-face or virtual) helped me learn more than a completely asynchronous experience.
    f. Synchronous instruction (face-to-face or virtual) did NOT affect my learning in the lab.
    g. Synchronous instruction (face-to-face or virtual) hurt, impeded, or otherwise impaired my ability to learn in the lab.

8. [LS] Please indicate the degree to which you agree or disagree with the following statements about your learning in BMED 310. This section focuses on your experiences in face-to-face vs virtual SYNCHRONOUS environments. (If you engaged in BMED 310 entirely asynchronously, mark "N/A" or skip this question.) *(Strongly Disagree, Disagree, Neutral, Agree, Strongly Agree, N/A)*
    a. I would not have learned as much if the lab had been completely virtual.
    b. The lab would have been more challenging if it was completely virtual.
    c. Face-to-face interaction with instructors synchronously was essential to the lab.
    d. Face-to-face interaction with instructors synchronously helped me learn more than a completely virtual experience.
    e. Face-to-face instruction did NOT affect my learning in the lab.
    f. Face-to-face instruction hurt, impeded, or otherwise impaired my ability to learn in the lab.

9. [MR] The COVID-19 pandemic and Cal Poly’s response likely played a significant role in your choice of how you participated in BMED 310. Based on your experiences in BMED 310, IF YOU WERE ABLE TO CHOOSE, DURING A NORMAL QUARTER, WITH NO PANDEMIC, to what degree would you like to engage with mode of instruction (relative to total amount of time spent on the lab portion of the course). *(<25%, 25% to 50%, 50% to 75%, 75% to 100%)*
    a. Synchronous Face-to-Face
    b. Synchronous Virtual
    c. Asynchronous Virtual

10. [MC] How would you characterize your typical academic performance in technical (science, math, physics, engineering) coursework?
    a. A (3.5 – 4.0)
    b. B (2.5 – 3.5)
    c. C (1.5 – 2.5)
    d. D (0.5 – 1.5)
    e. Prefer not to answer.

11. [MC] How would you characterize your performance in THIS LAB?
    a. A (3.5 – 4.0)
    b. B (2.5 – 3.5)
    c. C (1.5 – 2.5)
    d. D (0.5 – 1.5)
    e. Prefer not to answer.

12. [MC] How much previous experience did you have with programming/coding, prior to BMED 310?
    a. 1 quarter MATLAB programming

b. 1 quarter programming in another language
c. 1 or more quarters and additional experience using MATLAB roughly equivalent to 1 year
d. 1 or more quarters and additional experience using another language roughly equivalent to 1 year
e. More than 1 year equivalent experience using MATLAB
f. More than 1 year equivalent experience using another language
g. No previous experience with any programming language