Paper ID #23104

Pilot Study on Experience of Engineering Students in Multimedia-enhanced Introductory Physics Labs

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Dr. Popovic has expertise in design and development of multimodal medical imaging systems for surgical guidance and diagnostics. He enjoys working with undergraduate students on independent research projects, and has supervised students' work on topics ranging from materials selection for x-ray imaging system characterization phantoms, to development of algorithms for lung tumor nodule classification. Dr. Popovic takes great delight in guiding students to improve their technical communication and hands-on skills through introductory physics labs. Dr. Popovic is a member of ASEE and SPIE, and is a reviewer for the Physics in Medicine and Biology journal.

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Introduction

Both literature [1] [2] and anecdotal evidence suggest that students, on average, do not critically read textbooks before coming to class. This lack of student preparedness is detrimental to creating an active and engaging learning environment. The increase in students' reliance on mobile phones and computers over books, further exacerbates this issue. While previous studies have shown that students learn better from reading print texts over digital texts [3], the students exhibit clear preference for digital medium; in addition to that, forcing students to read texts before coming to class can be challenging. This study does not aim to explore this premise, as the multimedia learning modules (MLMs) employed in this study contain much more than pure text. To build on that, tailoring the content delivery mechanisms to be more accessible to students via computers and mobile devices is one way to mediate the lack of student preparedness. This added resource may enable students to become more familiar with the material before coming to class, and several prior studies have used other institutions' or commercial MLMs to this end [4] [5]. In addition, higher frequency of interaction with different means of representing the same content correlated well with higher learning gains in another study [6]. Finally, higher level of student preparedness could then result in more class time being used to discuss and explore higher learning activities [7]. For example, instead of spending the lab time to comprehend what steps they need to take to acquire the data or grasp the theory and/or vocabulary, the students could scrutinize their data acquisition methods, and attempt to minimize any systematic or random errors in their setup or measurement techniques.

Previous work on related topic, comparing efficacy of multimedia modules with traditional textbooks in introductory Physics lectures and labs, found significant gains in student learning and performance (particularly in representational fluency and conceptual understanding). In studies utilizing multimedia learning modules [4] [8] [9], students' learning gains were measured using institutional Representative Fluency Survey (RFS) and Concept Survey of Electricity and Magnetism (CSEM). However, other work exploring effectiveness of multimedia learning modules used in introductory Physics courses for engineers [10] found mixed results when comparing students' learning gains using Force Concept Inventory (FCI) and CSEM scores. These examples present a conundrum that the conclusions from gains made from multimedia enhanced courses in these cases are still not understood adequately well, and imply a need to complement the knowledge with further research. Furthermore, most of these studies focus on effects of MLMs on lecture-based courses. In this pilot study, we attempt to supplement this line of knowledge by exploring the effects of MLMs in lab courses only. We explore the experiences of two groups of students, one taking a hybrid, multimedia-enhanced introductory Physics lab course, and the other taking a standard introductory Physics lab course over the course of one academic year.

Setting

At our institution, Physics introductory sequence courses are broken up into Physics lectures and Physics labs, taken concurrently each term. Due to scheduling constraints, students commonly take the lecture with one instructor, and the lab course with a different instructor. For each Physics introductory sequence course taken over one academic term, the lab course consists of 4 lab exercises done every two weeks, which a student completes in a group with a partner. The class sizes range from about 10 up to 30 students, depending on the section, and each lab is scheduled for 160 minutes. Each term, between 10-15 sections of lectures and labs (each) are offered.

Given four lab exercises each term, each student is responsible for writing at least two of the reports, while the other partner at a minimum helps with the experimental setup and data acquisition during the lab meeting. The students usually have one week to write-up their final report. The student who is not responsible for the writing of a specific lab is often of limited help during post-lab analysis of data, and is often not prepared for the material prior to coming to the lab (i.e. has not read the lab manual relevant to the lab exercise at all). This further limits an average student's deeper interaction with all material covered in these labs, restricting their learning.

Methods

For this study, we have provided some sections of students with additional materials (pre-lab videos) and activities (pre-lab quizzes) aligning with the lab exercises. The students in the test sections were expected to interact with these before coming to lab, via the learning management system Moodle. Moodle is also available to instructors in control sections, but most do not utilize it in their lab sections. We recorded short (8 – 10 minutes long) multimedia learning modules (pre-lab videos), relevant to each particular lab, by means of the multimedia management system, Panopto. In those (hybrid) lab sections, instructor integrated the pre-lab videos into Moodle course pages, and required students to view each lab video online before coming to lab; the students were also asked to take a brief 5-question low-stakes pre-lab quiz. The quiz questions were usually multiple-choice questions, taken directly from the relevant lab exercise in the lab manual or the pre-lab video, both of which are an allowed resource during quiz taking. The students were able to re-take a quiz multiple times, and only the highest grade was recorded; that is, the focus was on the fact that the student is interacting with the material before coming to the lab, rather than looking to rigorously assess their deep understanding of the material at this point.

Data collection

A questionnaire (survey) was administered to both groups once towards the end of the academic term (test group in the hybrid course had access to and was interacting with the pre-lab videos and quizzes, and the control group did not). The survey was aimed to gauge students' general lab preparation habits and attitudes towards additional pre-lab work, among other things (Appendix A). The survey format and content was approved by the IRB (IR# RHS0300). The control group only completed a part of the survey related to general lab practices (questions 1-6), leaving the rest of the survey blank. The data was collected via paper evaluation forms for the conservation of linear momentum lab in PH111L (during Fall term), the capacitance lab in PH112L (during Winter term) and the lenses lab in PH113L (during Spring term).

It is important to note here a potential limitation of the study brought on by variations in instructors' teaching styles and class sizes. Due to students having differing instructors, there might be effects on their learning gains due to differences in instructors' teaching styles. Considering the variance in lab sections with small vs large student enrollment as well, a student in a latter environment would have, on average, less opportunity to interact with the instructor in the course of a lab meeting, potentially limiting their learning. In this study, the authors attempt to mediate these issues as related to the control group by collecting the survey data from multiple instructors' sections each term. The test group was however, only comprised of students from first author's lab sections for this study; in order to minimize the effects of the above factors, more instructors would need to adapt the hybrid lab section approach in their courses.

The answers to questions regarding pre-lab preparation habits and self-assessment of lab preparedness of students taking a multimedia-enhanced lab courses were compared to a cohort of students not enrolled in the hybrid sections (polar and Likert type questions for questions 1-5). Additionally, a soft metric using written student feedback is presented (from question 6 in Appendix A). This feedback relates to students' conceptual understanding of lab goals and objectives, as this is an important step in students' learning (albeit students' self-reported opinion may not match the resulting data, as we often see in other studies [3]). We will also present additional data from the test group only (from page 2 of the survey) to illustrate students' impressions of the multimedia-enhanced setting they were exposed to. Note that the survey was voluntary both for the test and control groups as outlined by the IRB (see appendix A). Hence, not all students chose to participate in the survey, and out of those who did participate, not all students answered all questions in the survey. For illustration, the total number of responses in the tables and graphs below may vary for different questions (e.g. in table 1, N_1=97 for Q1 for the test group, but N_2=95 for Q2 for the same cohort, while $N_{enrolled}$ was 107 in the same group).

Data from Moodle and Panopto (video delivery subsystem) were mined to observe frequency and duration of students' interaction with materials. Note that the Moodle data was available only for a small subset of the control group – 24 out of 205 students (as mentioned before, not all instructors use the Moodle platform for lab courses).

Results and Discussion

The survey results will be explored first and the Moodle/Panopto data will be presented towards the end. The raw data for questions 1 and 2 is located in table 1 below.

	Test group			Control group		
	Yes	no	% yes	yes	no	% yes
Q1: Have you fully read this Lab's exercise write-up in your Lab Manual?	61	36	62.9	118	85	57.6
Q2: Are you the person responsible (PI) for the lab write-up this week?	55	40	N/A	126	76	N/A
Q2a (derived from data): If the student is the PI, did they read the lab manual?	37	18	67.3	72	54	57.2

Table 1: Data from the first two questions on the student survey.

A test of proportions was ran on Question 1, which asked students if they read the lab manual before coming to lab. The test indicated that the difference in the percent of individuals from the control and test group who read the lab exercise write-up in the lab manual was not statistically different at the significance level of 5%. A test of proportions was ran on Question 2a, with similar conclusions (no statistical difference).

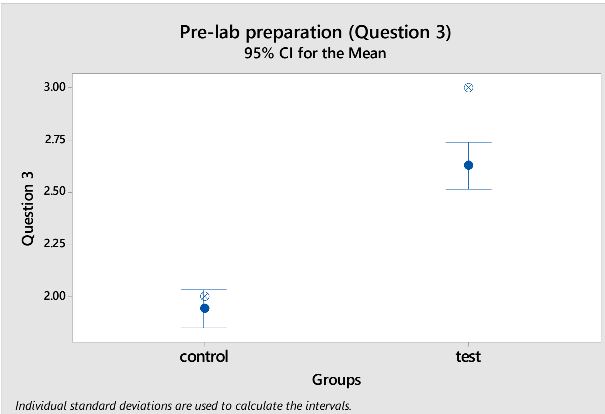

Figure 1: Interval plot of Question 3 data - “On average, how much time per lab week do you spend on pre-lab work and lab notebook prep?”. Note that the scale here goes from 1-4 representing ranges as follows: “1=”None”, 2=”<1 hours”, 3=”1-2 hours”, 4=”3+ hours”.

Full dot and error bars represent mean and the 95% CI for the mean, and the cross dots represents the median of each set of data.

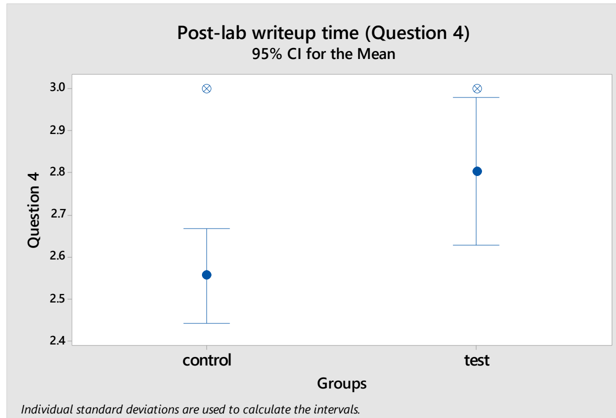

Figure 2: Interval plot of Question 4 data - “On average, how much time do you spend writing up each of your Physics lab reports after lab?”. Note that the scale here goes from 1-4 representing ranges as follows: “1=”0-2 hours”, 2=”3-4 hours”, 3=”5-6 hours”, 4=”7+ hours”.

Full dot and error bars represent mean and the 95% CI for the mean, and the cross dots represents the median of each set of data.

Mann-Whitney test was run to compare the median answers on Questions 3 and 4. Both tests resulted in statistically significant difference in the median response between the control and test groups. For Question 3, the median response was 2 for the control group (<1 hour of pre-lab work), and 3 for the test group (1-2 hours of pre-lab work). P-value (adjusted for ties) was approximately 0, suggesting that the difference in responses is statistically significant at significance level of 5%. For question 4, the median response was 3 for both groups (5-6 hours of post-lab write-up time). P-value (adjusted for ties) was 0.017, suggesting that the difference in responses is statistically significant at significance level of 5%. This data might not directly relate to pre-lab student preparedness, but it is interesting to see that the students’ time spent on both pre-lab and post-lab work on the lab follow a similar trend.

	str agree	agree	neutral	disagree	str disagree	% of agree/str agree
Control group	5	74	98	24	4	38.5
Test group	4	48	35	8	2	53.6

Table 2. Data from Question 5 on the survey: How do you agree with this statement? “I feel well prepared for this lab” (N=205 for control group, N=97 for test group).

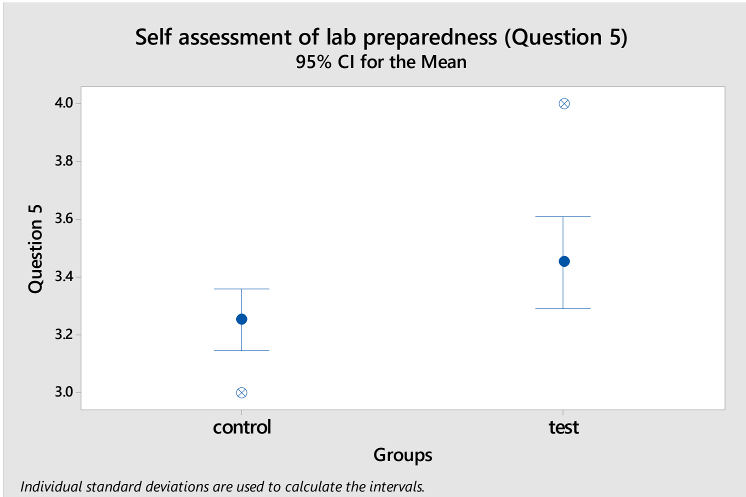

Figure 3: Interval plot of Question 5 data. Full dot and error bars represent mean and the 95% CI for the mean, and the cross dots represents the median of each set of data.

Mann-Whitney test was run to compare the median answers on Question 5. The test resulted in statistically significant difference in the median response between the control and test groups. For Question 5, the median response was 3 for the control group (neutral), and 4 for the test group (agree). P-value (adjusted for ties) was 0.02, suggesting that the difference in responses is statistically significant at significance level of 5%.

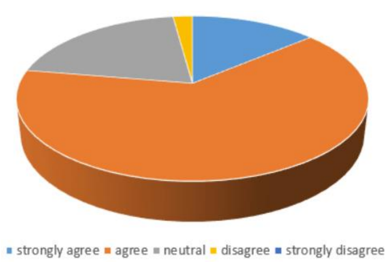

Figure 4: Data from Question 8 on the survey: “The pre-lab videos are helpful in understanding topics covered and learning the course material”; N=94, 77% agree/strongly agree (test cohort during one academic year).

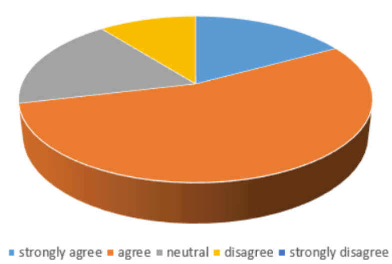

Figure 5: Data from Question 9 on the survey: “The pre-lab quizzes are helpful in understanding the topics covered and preparing me for the lab”; N=94, 71% agree/strongly agree (test cohort during one academic year).

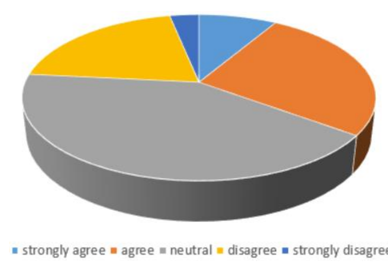

Figure 6: Data from Question 10 on the survey: “I prefer web-enhanced courses to traditional courses”; N=94, 35% agree/strongly agree, but 23.5% disagree/strongly disagree (test cohort during one academic year).

The result from figure 6 (answers to “I prefer web-enhanced courses to traditional courses”) reflects experience seen elsewhere [11], in that students prefer traditional instruction formats, even though they themselves recognize the benefits of additional learning resources, as shown in figures 4 and 5. Please note that the analysis up to this point includes quantitative data collected from the student surveys. The Moodle/Panopto data will be presented hereafter.

	Number of views (hits) from Moodle		Number of minutes of videos watched from Panopto logs	
	Total	Average per student	Total	Average per student
Control group	368	15.3	N/A	
Test group	2162	29.2	3102	41.9

Table 3: When examining the data from student Moodle and Panopto logs, we observe a significant increase in average student ‘hits’ in multimedia enhanced courses (N=74) as compared to the traditional course (N=24). Total data and number of students are from two academic terms, but the average per student metric is calculated per one academic term. Note that due to the timing of this manuscript, this data is from two academic terms only.

Table 3 shows the data collected from the online logs mined from Moodle learning management system after all labs from first two academic terms were completed. The main purpose of this data is to show that there is a significant increase in student interaction with lab-related materials before coming to the lab, which in turn, correlates with higher learning gains [6]. The number of views (hits) for the test group includes views from lab videos, quizzes, syllabi and grading rubric; for the control group, it includes views from lab handouts, grading and useful analysis tools (code for calculating standard error, linear least squares fit and elliptic integrals). The increase in activity in test group presented in table 3 stems from the fact that accessing the videos and quizzes is paramount for the students in test group as a portion of their lab grade is dependent on completion of pre-lab quizzes (the low stake grade seems to be a good motivator for increasing pre-lab preparation). Since the access to and successful completion of quizzes is inseparable of access to each lab’s specific pre-lab video, this implies that there is at least a basic exposure to lab-specific concepts prior to students coming to lab, across the board. The video view frequency data shown in figure 7 implies that the majority of students watched each video at least once, and that the majority came back to re-watch them later. The higher frequency of interaction with different means of representing the same content can be correlated with higher learning gains [6].

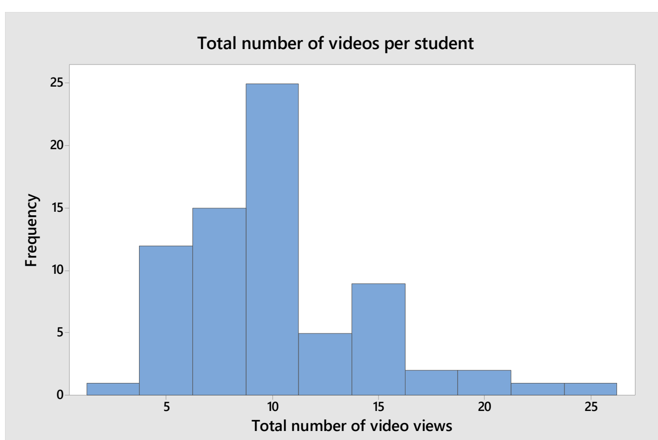

Figure 7: Panopto data on total number of views of videos by each student in four test sections across two academic terms (N=5 videos per term).

Furthermore, qualitative data from responses on Question 6 (“What is the main goal and/or objective in this lab?”) from the paper surveys from both test and control groups’ written responses is compared below. The surveys were distributed during the conservation of linear momentum lab in PH111L, the capacitance lab in PH112L and the lenses lab in PH113L. The forms were distributed to 136 students in the six PH111L sections, 133 students in the six PH112L sections, and to 87 students in the four PH113L sections at the beginning of the class hour prior to conducting their lab work. 116 students, or approximately 85% of the population, completed the lab evaluation for PH111L; 119 students, or approximately 89% of the population, completed the lab evaluation for PH112L and 68, or approximately 78% of the population completed the lab evaluation for PH113L.

For the qualitative data analysis, peer review and debriefing was executed throughout the study as the validation strategy. Additionally, the data was checked for reliability by authors’ intercoder agreement. Coding was completed for student responses to the question regarding the objective of each of the labs. The codes included linear momentum for the PH111L lab, capacitance for the PH112L lab, and lenses for the PH113L lab. Approximately 72% of the 116 students included the code for the PH111L lab objective, 66% of the 119 students included the code for the PH112L lab objective, and 69% of the 68 students included the code for the PH113L lab objective. Specifically, approximately 77% of PH111L sections, 88% of PH112L sections, and 85% of PH113L sections for the test group included the codes for the lab objective. This compares to approximately 71% of PH111L sections, 56% of PH112L sections, and 58% of PH113L sections for the control group that included the codes for the lab objective.

In conclusion, data exploring experience of engineering students in multimedia-enhanced introductory Physics labs was collected during one academic year. The data was collected through Moodle, Panopto and via paper survey. The students in the multimedia-enhanced labs seemed to value the availability of the additional resources, even inclusive of the pre-lab quiz (figures 4 and 5), and they spent significantly more time in preparation for the lab compared to the control group (figure 1). Furthermore, the qualitative data regarding the conceptual understanding of the material, as well as clear understanding of the goals and/or objectives of the lab prior to starting the lab exercise, supports the observed quantitative trend, and is also in line with prior research [8]. Ultimately, the higher lab-preparedness might imply higher learning gains and higher opinion about learning, and our data (table 2 and figure 3) supports that hypothesis at the confidence level of 5% (p-value of 0.02).

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Appendix A: Survey used for data collection. The control group was only asked to fill out the first six questions of the survey, while the test group completed the full questionnaire.

<u>Pilot study on experience of students in introductory physics labs</u>

You are being invited to participate in a research study about experience of students in hybrid versus traditional introductory Physics labs. This study is being conducted by Dr. Popovic, from Physics and Optical Engineering Department at Rose-Hulman Institute of Technology. There are no known risks or costs if you decide to participate in this research study. The information you provide will be used to compare student habits and experiences across different labs. The information collected may not benefit you directly, but the information from this study could provide some information we (instructors) can use to make future introductory Physics labs courses better. This survey is anonymous. Should the data be published, no individual information will be disclosed. Your participation in this study is voluntary. By completing the survey, you are voluntarily agreeing to participate. You are free to skip any particular question you do not wish to answer for any reason. If you have any questions about the study, please contact Dr. Popovic at x8190 or popovic@rose-hulman.edu. If you have any questions about your rights as a research subject or if you feel you've been placed at risk, you may contact the Institutional Reviewer, [redacted] (IRB reviewer's name redacted for privacy)

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1. Have you fully read this Lab's exercise write-up in your Lab Manual? Yes No

2. Are you the person responsible (PI) for the lab write-up this week? Yes No

3. On average, how much time per lab week do you spend on pre-lab work and lab notebook prep (if applicable, including time spent on watching the video and taking the quiz)?

   None <1 hours 1-2 hours 3+ hours

4. On average, how much time do you spend writing up each of your Physics lab reports after lab?

   0-2 hours 3-4 hours 5-6 hours 7 hrs+

5. How do you agree with this statement?

   "I feel well prepared for this lab"

   Strongly Agree Agree Neutral Disagree Strongly Disagree

6. In a couple of sentences, what is the main goal and/or objective in this lab?

7. Have you watched the pre-lab video? Yes No

If yes, which part(s) did you find most useful?

What part(s) did you find the most confusing, and why?

What would you add to the videos?

8. The pre-lab videos are helpful in understanding topics covered and learning the course material.

Strongly Agree Agree Neutral Disagree Strongly Disagree

9. The pre-lab quiz is helpful in understanding the topics covered and preparing me for the lab.

Strongly Agree Agree Neutral Disagree Strongly Disagree

10. I prefer web-enhanced courses to traditional courses.

Strongly Agree Agree Neutral Disagree Strongly Disagree