An Interdisciplinary Glimpse into the Best Practices for Effective Student Engagement in the Virtual Laboratory

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An Interdisciplinary Glimpse into the Best Practices for Effective Student Engagement in the Virtual Laboratory

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Abstract

In a virtual higher education environment, the laboratory experience has become one of the most difficult, if not impossible, experiences to replace. A good starting effort is to begin with courses that have a high degree of difficulty transitioning into a virtual domain. The concepts of Materials Science and Organic Chemistry often intersect with each other especially at the atomic level. Here, we focus on these two courses populated by Engineering majors. Various different approaches to implementing virtual laboratory experiences spanning these STEM disciplines are discussed and analyzed for their effectiveness. This effectiveness is based on student feedback from end-semester surveys, student evaluations of teaching as well as one-on-one student engagement during the semester. Specific questions students are asked relate to the use of audio/video conferencing software, pre-recorded videos, simulation/data-analysis software, group versus individual assignments/discussion, and synchronous versus asynchronous content delivery.

Introduction

The declaration of COVID-19 as a worldwide pandemic by the World Health Organization in March 2020 had an unprecedented impact on the daily lives of citizens across the globe [1]. With social distancing a major recommendation of health officials to combat the spread of the virus, all levels of educational institutions abruptly shifted towards online learning and remote delivery of subject content [2]. Both faculty and students rapidly faced the daunting task of transitioning into a virtual space that many were not familiar with or could not readily access. The demand for online course offerings has steadily increased over the past 20 years especially with advancements in technology and the changing demographics of today's college students who need more schedule flexibility to complete their degree [3]. Nevertheless, up to this point, most online courses have acted as a substitute for face-to-face instruction. However, the pandemic has forced many college educators to take a second look at what the virtual classroom has to offer [4,5]. While there are many fields of study that might lend themselves well to an online modality, Science, Technology, Engineering, and Mathematics (STEM) faculty in particular have faced the challenge of demonstrating the physical principles of science and engineering virtually [6-8]. The sudden replacement of experimentation in a physical laboratory with a virtual experience has caused many faculty members to rethink their pedagogical approaches to laboratory technique, data analysis, and instrumentation procedures. This has required modification to the traditional, "hands-on" teaching many laboratory instructors implement with their students, to a more self-guided approach to learning [9,10]. Thoughtful course development and appropriate use of e-learning tools is essential in order to successfully accomplish these goals and increase student engagement [11]. However, with the massive amount of technology resources available, it can be very overwhelming to select the appropriate tools and implement the right engagement strategies to enable students to be successful. This article illustrates a variety of different student engagement strategies and e-learning tools applied to STEM courses in Materials Science and Organic Chemistry.

Methodology

Students from Materials Science and Organic Chemistry, two commonly required courses for Engineering majors, were surveyed to gauge their virtual laboratory experience. Selection of these particular courses was due to the very “hands on” nature of the laboratory activities and the subsequent challenges to translate the learning objectives into a virtual environment. The Materials Science course encompassed three lab sections each containing less than 24 students. One of two instructors facilitated the weekly sessions where students participated in the lab activity. The Organic Chemistry course had a similar format where two instructors were responsible for teaching one of the six weekly lab sections of 24 students. In both cases, the instructor “teams” met regularly to maintain consistency of the course delivery in each of the lab sections.

Another important consideration to make in an online course is the mode of delivery: fully asynchronous, fully synchronous, or a blend of the two. While there are arguments in favor and in opposition to all these options [12-13], the decision of implementing a blended model allowed the ability to assess each student’s level of engagement with both options. All synchronous lab activities were hosted through Zoom [14]. Asynchronous lab demonstration videos were made using Camtasia [15] and Kaltura [16] and hosted on the University Learning Management System, Blackboard Learn [17]. Another component of content delivery held consistent between these two courses was the use of Zoom breakout rooms. Each lab section had random pre-assigned groups (assigned to the same Zoom breakout room), kept constant for the duration of the semester. During the course of the semester, all instructors received feedback regarding these choices. Alternatives included self-selecting groups, changing groups weekly, submitting individual versus group reports and changing the method of submission.

Different engagement strategies utilized by all instructors included use of pre-recorded lab demonstration videos, synchronous audio/video pre-lab discussions, synchronous lab facilitation, working in groups during both scheduled and non-scheduled lab time, pre-lab reading/instructions, lab quizzes and using poll questions. Parallel engagement of software simulation and data analysis was assessed throughout the semester by completion of lab reports.

During the final week of the Fall 2020 semester, an 18-question survey was sent out to each student of every lab section. In total, 152 students participated in answering questions from three categories: individual demographics, course organization/delivery and student engagement strategies. The various questions asked for demographics can be seen in Figure 1.

As can be seen in Figure 1 (a) and (b), all of the students are undergraduates with 82% of the students falling into the upper-division category and nearly all the students are taking the course due to major degree requirement. Another interesting point is revealed in Figure 1 (c) where over 72% of the students had taken less than two online courses prior to the virtual Fall 2020 semester. From a student expectation standpoint, this is indicative that the bar for quality instruction would not have been set prior to the virtual Fall semester. In addition, this data shows a very steep learning curve for students to navigate an extremely different mode of instruction and maintain the same level of engagement as in a face-to-face course. Some of the problems encountered included, lack of internet access, inadequate technology, personal/home environment, financial obligations and health concerns.

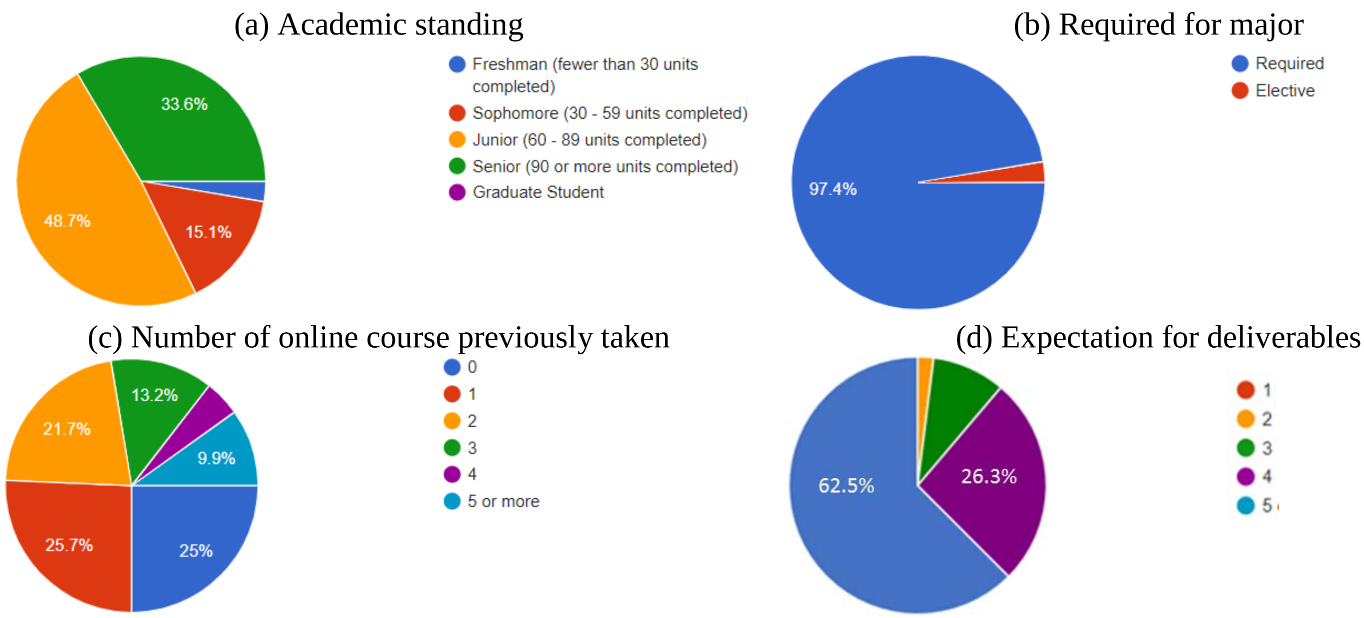

Figure 1: Demographics of student taking the survey.

Figure 1(d) shows the number (percentage) of students that felt comfortable with course expectations. Expectations addressed included the generation/completion of laboratory reports, the usage of software for simulation and data-analysis and working in a group environment where all members are expected to contribute. The 1 to 5 rating can be considered a Likert-type scale [18] with 5 being “thorough expectations given” and 1 being “no expectations given”. Nearly 89% of the students responded with a 5, which excludes a lack of understanding regarding the requirements as reason for poor engagement with the course material. Statements made in the University-sanctioned Student Evaluation of Teaching (SET) forms also confirmed this statistic. Comments included: *“explained what was expected of us for every assignment very clearly”*, *“explains things in a clear and concise way”*, *“explains things without confusing students”* and *“explained everything that would have done in an in-person lab very well.”*

Results

In terms of the course organization and delivery methods, the survey data revealed that students overwhelmingly favored (~92%) synchronous facilitation of the laboratory including a live pre-laboratory lecture and pre-recorded laboratory technique videos as summarized in Figure 2 (a, b, c). Also, Figure 2 (d, e, f) seems to demonstrate the students’ perspective for an effective course to have a structured meeting time with prepared materials for discussion. Students also responded favorably (~90%) to the use of pre-laboratory readings and quizzes as a means of effective engagement with laboratory concepts and experimental procedures (Figure 2 (f, g)). The use of embedded poll questions during the pre-laboratory lecture also received positive marks with ~86% of the students (Figure 2 (h)) indicating that they felt this technique contributed to their overall engagement. A takeaway as a whole: enabling the students to have an opportunity to engage

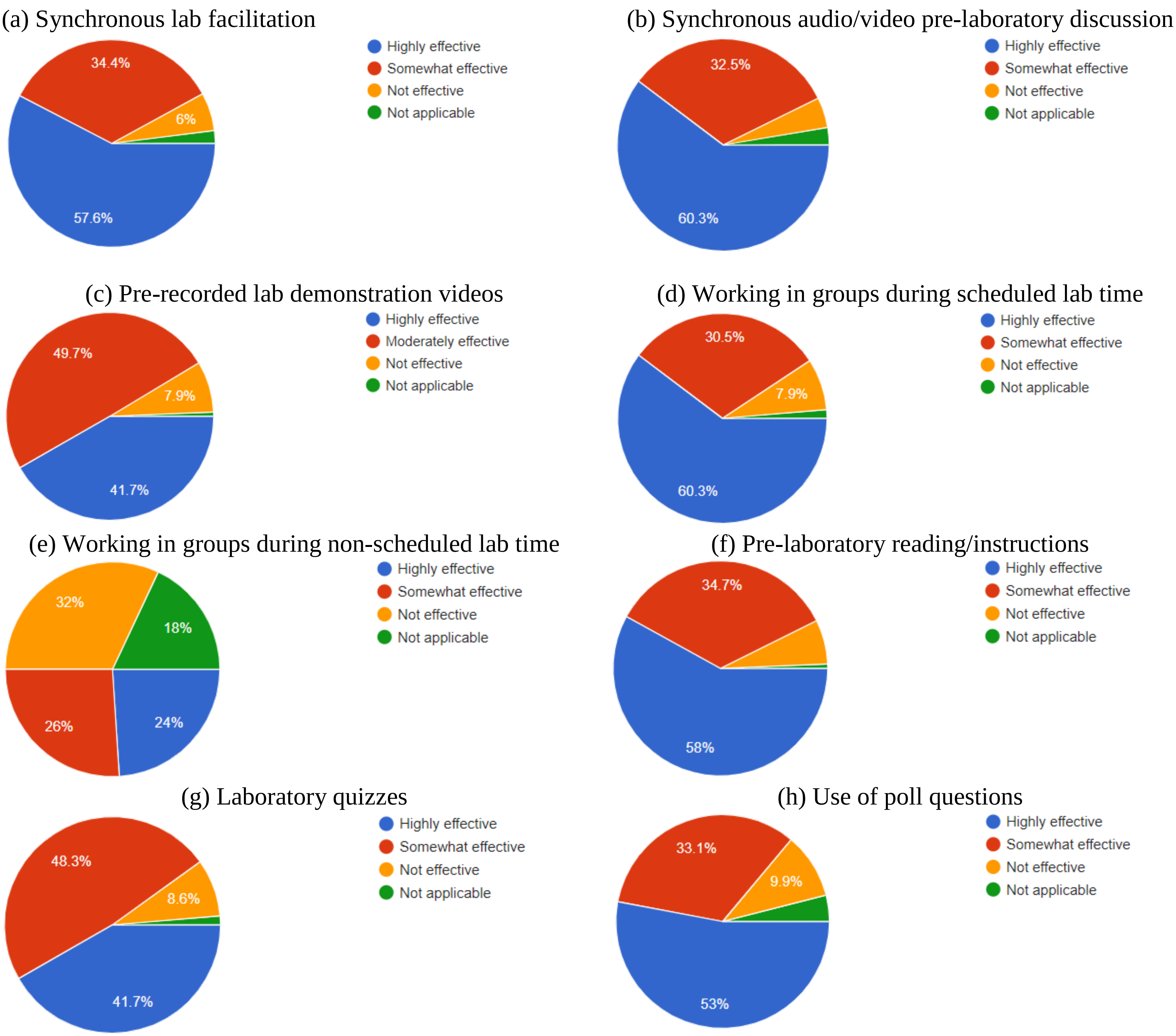

Figure 2: Engagement strategies.

with the laboratory concepts in a variety of different ways and in real time seems to have an important impact on student outlooks. Data from the SET forms also supports the idea that students appreciate the opportunity to interact with the instructor and their peers even in an online format with comments including: *"The class is very interactive. Even though it is* *completely online the instructor keeps us involved with the class", "The instructor comes into our breakout rooms to check on us for questions" and "Breakout groups and polls in the Zoom call have encouraged students to participate."*

Figure 3 summarizes the survey data collected regarding the effective use of group work in the virtual laboratory. In a face-to-face model, groups typically form organically whether by lab space constrains or cohorts from previous courses.

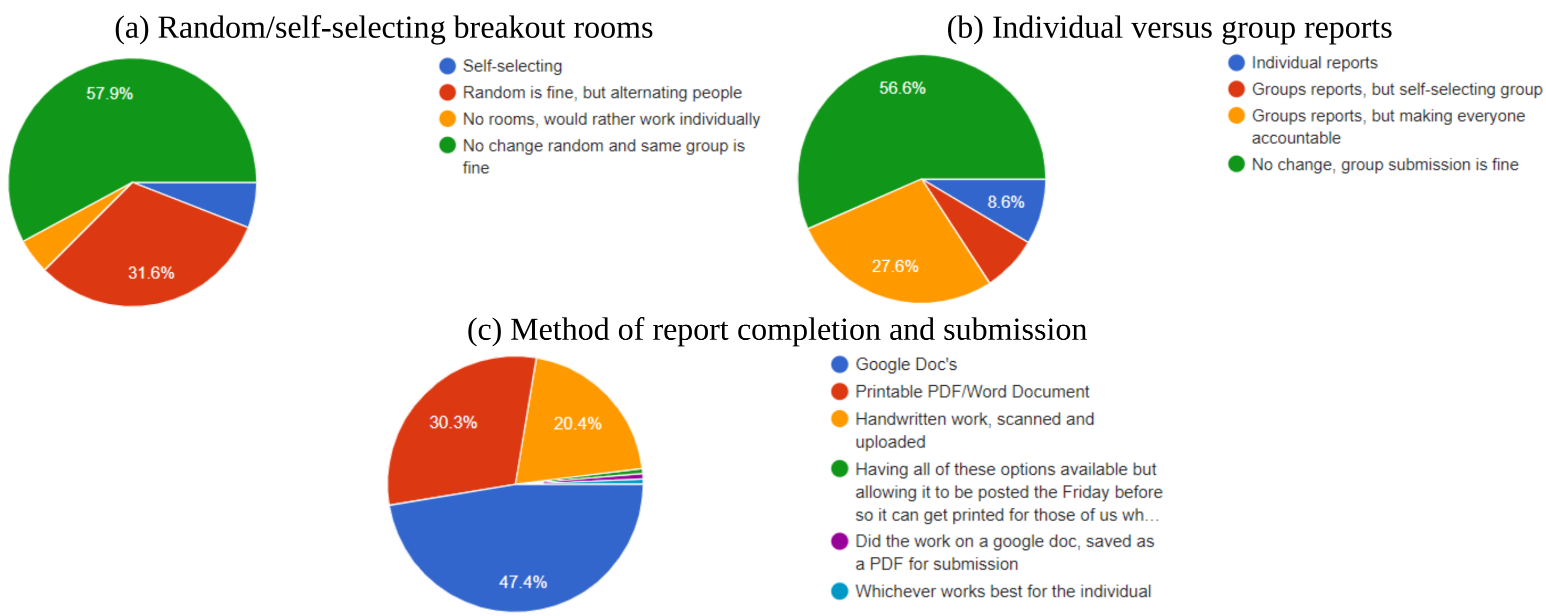

Figure 3: Use of group work

In the virtual classroom, it can be much harder to form groups that will effectively engage with the course material/assignments, the instructor, and each other. From the Figure 3 (a, b), the majority of students (~91%) responded that working in groups during the scheduled lab time was the most effective use of their time to complete the laboratory assignment as opposed to working offline with their group members reinforced by in Figure 2 (d, e). Another interesting point, is that most of the students agreed with the instructor's original choice of group implementation for both pre-assigned groups (rooms) and reports. Something that stands out in the group selection data is the nearly 32% of students would prefer alternating random assignments. Thus, with a little extra work an instructor may allow students to choose constant or alternating team members and increase the satisfaction of this category to around 90%.

With regards to report generation, the instructors of both courses allowed for the use of Google Doc's, printable PDF/Word or handwritten/scanned, representing over 99% of student's preference for submission options. Since neither option was a strong majority continuing to allow all three seems to maximize equitability and accountability. Making every student equally accountable was something not probed in this data and is a possible area of future research. This is something not limited to the virtual laboratory environment, but probably exacerbated by it, and short of simply requiring individual reports is a daunting gap to address (students are inherently reluctant, nor should be required, to "tattle" on their peers).

Conclusion and Future Work

Analysis of this study shows two primary conclusions with regards to improved engagement in an online laboratory environment. First, synchronous components for laboratory activities are very useful, and second, additional student feedback mechanisms, other than graded laboratory reports, such as quizzes and poll questions are also really helpful. While these statements may seem obvious, this work provides data that in support of them. Future work involves a performance analysis via earned grades and correlating this data with the survey results. The authors also plan to continue gathering data and incorporate additional engagement mechanisms into the online laboratory that students can assess in future surveys.

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