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Cover Page Footnote

The author is thankful for support received from the IT office on the UW-Sout campus particularly Peggy Kralewski and her team. They set-up the remote control of the lab computers for the 2020 PLE-360 class and provided immediate trouble shooting service to the students during the labs. The author also would like to thank the two student lab assistants, Olivia Hile, and Emily Schattner, who worked diligently to help the students in the 2020 PLE-360 class.

Design and Implementation of a Fully Online and Remote Lab Course Under the Covid-19 Pandemic

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ABSTRACT

This case study focuses on developing a fully online material testing course while keeping the experiential learning component for the students. The course of interest is a junior level plastics engineering course, PLE-360 (Testing and Analysis of Plastics), during which students are required to utilize various equipment to characterize polymers. Along with online lectures, remote labs are designed and implemented. During these labs, students remotely log into the computers, design the experimental program, conduct the tests, collect and analyze the data. The effectiveness of this practice is assessed through examining students' lab grades and overall course grades. It is found that such remote lab course not only delivers the same learning content as the in-person class but also provides the "hands-on" experience to the students with much reduced risk of infection.

Keywords: Online, Hands-on, Remote Labs, Covid-19, Pandemic

INTRODUCTION

Covid-19 has greatly influenced the course delivery of higher education in the U.S. including the University of Wisconsin-Stout (UW-Stout), Wisconsin's Polytechnic University. According to the dashboard of College Crisis Initiative (C2i) [1] out of Davison College, in spring 2020, out of 1441 institutions reported, 1388 universities/colleges across the 50 states cancelled the in-person instruction and switched to online delivery; in fall 2020, 530 four-year institutions kept the fully or primarily online delivery, 494 with fully or primarily in-person instruction, leaving 381 with a hybrid model. Similar scenarios occurred in the State of Wisconsin (U.S.) and at UW-Stout. In late March 2020, when the virus started to surge in the country,

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Wisconsin governor signed a “safer at home” executive order, requiring all citizens to stay home except to conduct essential activities for a month period. UW-Stout also immediately shifted all of the instruction to alternative delivery methods primarily online instruction for the rest of the spring semester and the summer classes.
For fall 2020, when the situation was stabilized slightly, UW-Stout planned and implemented 50/50 fully online/in-person courses to accommodate the need of students and to slow down the spread of the virus. On average, 50% courses were taught fully online whereas the other 50% contained a certain degree of in-person activities for which students needed to be on campus.

Such implementation, in fact, was challenging to a polytechnic campus where many lab concentrated courses were offered especially those taught by the Department of Engineering and Technology. These courses, in addition to the lectures, typically had labs where students were required to utilize various laboratory equipment and materials to acquire the hands-on learning. For this, some courses chose to video record each lab activity, ask students to watch the video(s), and take the lab questions online afterwards. Some decided to split the class in half and rotate them to conduct the labs on campus, with mask covering, 6-feet social distance, and other safety precautions. One course that the author taught in the fall had a heavy lab component. However, the limited physical space of the lab area did not allow even half of the class (19 students and 2 lab assistants total) to practice social distance. In order to maintain the same learning experience, the author designed and implemented a fully online and hands-on lab course for the students for the first time on the campus. Such labs are known as remote labs [2-8], and positive findings have been found on student’s engagement and learning outcomes [4].

The course is "Testing and Analysis of Plastics" (PLE-360). This is a required junior level course for students enrolled in the Plastics Engineering Program, which is typically offered once per year. The course focuses on teaching students the physical, thermal, mechanical, and rheological properties of plastics, the testing protocols, and the structure-processing-properties relations. It generally consists of 13 2-hour lectures and 6 4-hour labs on utilizing a variety of instruments including differential scanning calorimetry, Fourier-transform infrared spectroscopy, thermogravimetric analyser, a rotational rheometer, a MTS mechanical testing system, and a dynamic mechanical analyzer. Fortunately, each equipment has a dedicated computer and is operated through an installed software. Through setting up remote control of these computers, students can access and operate the machines anywhere to conduct the labs. This is the basic working principle to materialize the remote lab course under the pandemic.

The course labs are carried out online through virtual meetings and remote control of the lab computers, operating various equipment. During these labs, students remotely log into the computers, design the experimental program, conduct their tests, collect and analyze the data. The whole process is operated virtually over the Microsoft Teams platform, where students can also discuss the experiments, share results, and ask questions. Ninety percent of the lab experience is exactly the same as that of in-person labs. The only difference is that the samples are loaded by the instructor or the lab assistant, but the loading process is live streamed to the students and discussed with them, especially when the experiment goes wrong. Along with the online lectures, the fully online course not only delivers the learning content but also provides the “hands-on” experience to the students with much reduced risk of infection.

The objective of this study is to design and implement the fully online/remote labs to the PLE-360 course under the pandemic. Students' performance will be compared to that of the same course taught in-person in spring 2019. Additionally, students' grades in another course, ETECH-251 (Fundamental of Plastics Materials and Processing), will be analysed in the similar fashion. This course was taught in person in spring 2019 but utilized video recorded labs in spring 2021. It is of interest to see how the remote labs compares to the video recorded labs in terms of student's learning. Detailed course delivery and assessment are described below. The results are presented, and the implications are discussed as well.

1 METHODOLOGY

1. 1 Online and hands-on labs (remote labs)

To conduct such online labs in the fall 2020 PLE-360 course, the class were divided into four groups, and individual meeting invites were sent out to each group with remote login information. The student who was to remotely log into the lab computer was predetermined and named as the group leader, and such role is rotated throughout the semester. The group leader was the main person operating the lab computer. Additionally, each group was assigned a lab assistant and/or the instructor. During the lab, the group members all joined the meeting; the group leader remotely logged into the specific lab computer and shared the screen with the rest of the group. The students discussed with each other on the lab details, the testing parameters, and designed the testing program. Then, either the lab assistant or the instructor loaded the sample, and the process was live streamed to the group. When everything was ready, the group started the test, collected the data, and analyzed them during the lab period. The whole meeting was recorded, serving references for future learning. The lab contents were the same as those in-person ones used prior to Covid-19. Afterwards, the students completed their lab report, and their learning was assessed.

1. 2 Video recorded labs

Video recorded labs were assigned to ETECH-251 in the spring 2021 class. During such class, the labs were pre-recorded with the instructor running the labs step by step. The experiment process and the generated raw data were shared with the students from the video. Then, upon assigning each specific lab, the class was asked to watch the associated video(s) and answer lab questions online. Also, students worked on the lab individually instead of working in groups as in the past semester of spring 2019. Such approach provided students with self-paced learning opportunities, but it did lack the discussion and interaction among the students and with the instructor/lab assistants.

1. 3 Assessment

To assess the effectiveness of both types of labs on the students' learning, the lab grades and the overall course letter grade student obtained in the online PLE-360 and ETECH-251 courses were compared to those of the same course taught in person in spring 2019. Details of these courses were summarized in *Table 1*. Students' feedbacks and their evaluation on the instructor were also used.

Table 1. Four courses studied in this work

Course	Semester	Lecture Delivery	Lab Delivery
PLE-360	Spring 2019	In-person	In-person

PLE-360	Fall 2020	Online	Online/hands-on (remote)
ETECH-251	Spring 2019	In-person	In-person
ETECH-251	Spring 2021	Online	Online with recorded videos

2 RESULTS

Before examining the remote labs conducted in the fall 2020 PLE-360 course, first, let's assess the effects of video recorded labs on student's performance in the ETECH-251 course. Both the spring 2019 and spring 2021 ETECH-251 courses have 4 identical labs although the delivery format differs. These 4 labs focus on material identification, tensile properties study, melt flow rate test, and moisture measurement. The averaged lab grade each student earned in the courses is plotted in Fig. 1. In the 2019 class, the 25 students were divided into 6 groups, and each student obtained the same lab grade as the rest group members. The grade ranges from 85.3% to 100%, which is quite normal for such hands-on course. The averaged lab grade of the class is 91.5% ± 4.1%. The 4.1% is the standard deviation based on the 25 students' grades. In 2021, the students took the labs individually by watching pre-recorded lab videos. The lab grade earned spans from 63.3% to 100%, with a class average of 88.0% ± 8.8%. The class average of the 2021 class is lowered by 3.5% with an almost double standard deviation. The data might indicate that the students are not that well performed with the videos recorded labs, although at the same time we cannot exclude the group effect in the performance. To warrant the observation, long term studies or comparisons between multiple sessions might be needed. Regardless, according to the course grading scale, a 3.5% difference would generally lower the class average by one letter grade. The lower performance is not surprising though, due to the lack of interaction and onsite learning opportunity on the machines.

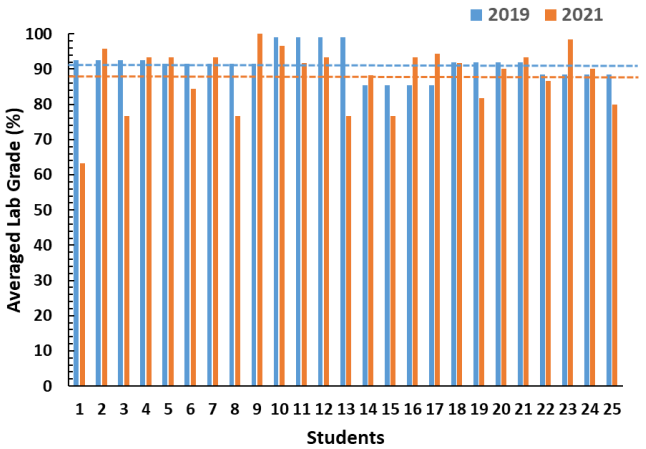

Fig.1: Each student's average lab grade of the 2019 ETECH-251 course with in-person labs and the 2021 course with recorded video labs. Dashed lines represent the class averages.

In addition to the lab grade, student's overall performance is analyzed through comparing the final letter grade student earned in these two ETECH-251 classes. In order to represent the data in clarity, the grades are clustered as A for students scored A and A^-, B for B^+, B, and B^-, C for C^+, C, and C^-, D for D^+, D, and D^-. The percentage of students scored each group of letter grade is shown in Fig. 2 for both the 2019 and 2021 classes. In 2019, 48%, 40%, 8%, and 4% of the class score a letter grade of A, B, C, and D, respectively. The majority class earning either an A or a B might benefit from their great lab performance especially since the labs take a large portion of their

final grade. In 2021, 16%, 64%, 16%, and 4% of the class score a letter grade of A, B, C, and D, respectively. Apparently, the 2021 class has more students score either a B or a C letter grade. Such down shift in the final grade might partially come from the lower performed labs, as shown earlier in Fig. 1.

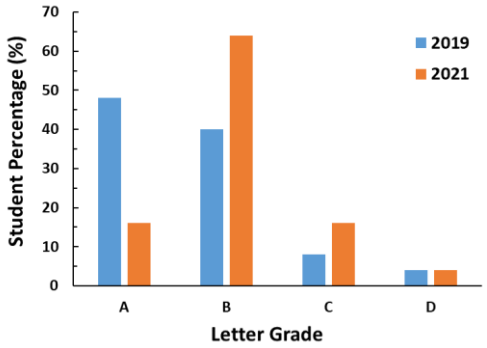

Fig.2: The percentage of students scored various letter grade in the 2019 ETECH 251 class with in-person delivery and in the 2021 class with online lectures and video recorded labs. Here A represents letter grades of A and A^-, B for B^+, B, and B^-, C for C^+, C, C^-, and D for D^+, D, and D^-.

In a similar fashion, we studied the student performance in the spring 2019 and fall 2020 PLE-360 classes. Note that in 2019 (before Covid-19), both the lectures and labs of the PLE-360 were taught in-person. In 2020, the lectures were delivered online and the labs were conducted online and remotely, as described in earlier sections. For both classes, students were divided into groups and conducted lab as a group. Student received the same grade as their group members. The averaged lab grade each student earned in both classes is plotted in Fig. 3. In the 2019 class, there are 14 students enrolled in the class. The average lab grade ranges from 93.2% to 98.8%, with a class average of 94.7% ± 2.5%. In the 2020 class, there are 19 students enrolled, the average lab grade ranges from 92.1% to 95.6% with a class average of 93.9 ± 1.3%. The class average is higher than those observed in the ETECH-251 courses. More importantly, the difference between these two PLE-360 classes is very minimum, 0.8%, and is much lower than that of the ETECH-251 classes, 3.5%. The results might indicate that the fully online and hands-on labs deliver similar learning experience to the students as the in-person ones. Additionally, such remote lab practice impacts students more positively than the video recording one.

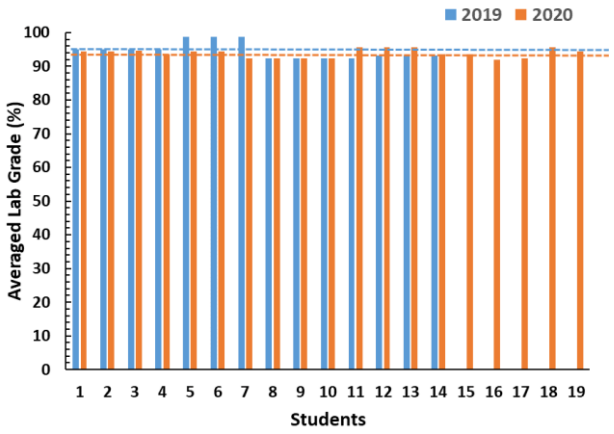

Fig.3: Each student's average lab grade of the 2019 PLE-360 course with in-person labs and the 2020 class with fully online and hands-on labs. Dashed lines represent the class averages.

Students' final letter grades of the PLE-360 classes are shown in Fig. 4. Similar to Fig. 2, here A represents students who actually earned either A or A^- for the class, B for B^+, B, and B^-, C for C^+, C, C^-. Overall, the distributions in both classes are similar. In 2019, 57% (8 students) and 43% (6 students) of the class score a letter grade of A and B, respectively. In 2020, 53% (10 students), 42% (8 students), and 5% (1 student) of the class score a letter grade of A, B, and C, respectively. Except the only one student who scores a C, the rest is similar to the spring 2019 class. The data is in a good agreement with the lab grades shown in Fig. 3. Overall, there is no significant difference in students' performance in both 2019 and 2020 classes. Switching to online lectures and fully online/remote labs seems to provide similar learning outcomes to the students, which is consistent with literature findings [4,7]. Considering the reduced risk of infection, implementing fully online lecture and labs under the pandemic might provide unique opportunities to maintain the hands-on learning in higher education.

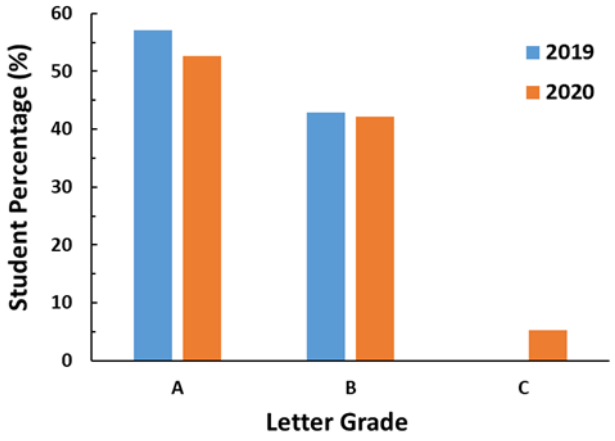

Fig.4: The percentage of students scored various letter grade in the 2019 PLE-360 class with in-person delivery and in the 2020 class with online lectures and online/hands-on labs. Here A represents letter grades of A and A^-, B for B^+, B, and B^-, and C for C^+, C, C^-.

Lastly, we would like to examine the students' feedbacks on the lab portion of the courses. In the instructor evaluation survey of each semester, one question directly asks students to rate the instructor's use of laboratory equipment and materials from 1 to 5. 1 represents the use is most valuable whereas 5 means the least valuable. The survey received for these four courses have response rates from 50% to 88%. The average class response is shown in Fig. 5. The rating is 1.64 and 2.25 for 2019 and 2021 ETECH 251 classes, 1.78 and 1.67 for the 2019 and 2020 PLE-360 classes. The 2.25 rating is slightly higher than those received in the three other classes. Such might give clue that the ETECH-251 students do not think video recording is a good way for the instructor to use the instrument/materials. On the contrast, the PLE-360 students do value the hands-on remote labs received under the pandemic, as further confirmed by the feedbacks shown below (copied verbatim from the 2020 PLE-360 class).

"Wei is still encouraging collaboration and group efforts. Even though the students are not physically with each other, they still have good communication and are working as teams as far as I can tell."---from a lab assistant

"I enjoy that we each have been able to take our turn with controlling the programs we are running. When it is not our turn, we are still able to view and discuss the program our groupmate is inputting."---from a student

"Good use of the equipment without having to be in person" ---from a student

"Very good at adapting online" ---from a student

"Course knowledge, caring her students" ---from a student

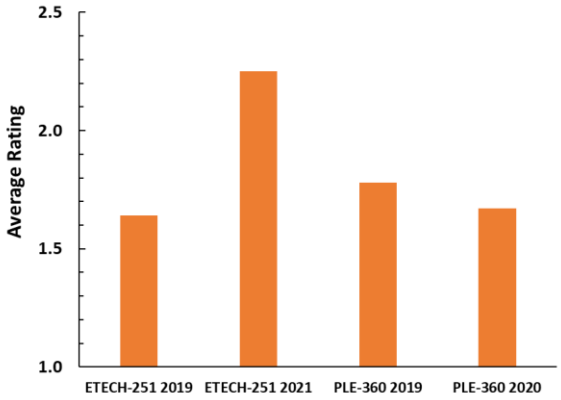

Fig.5: Student's rating on whether the instructor's use of laboratory equipment and materials is valuable in the 2019 and 2021 ETECH-251 classes, and the 2019 and 2020 PLE-360 classes.

3 SUMMARY AND ACKNOWLEDGMENTS

Fully online and remote labs are designed and implemented in a junior level plastics engineering course, PLE-360. The effectiveness of such remote labs is assessed through comparing the lab grade and the overall letter grade student earned in the same course taught online in fall 2020 and in-person in spring 2019. For comparison, such assessment was also conducted in another ETECH-251 courses where video recorded labs were performed. For the 2021 ETECH-251 course, the class average of the lab grade is lower by 3.5% than the same course taught in-person. Along with the lower lab grade, the student's final letter grade is also lower. For the PLE-360 course, in fact, students behaved relatively the same in both classes, indicating the effectiveness of the online remote labs, comparable to in-person delivery. Upon rating about instructor's use of laboratory equipment and materials, students of both 2019 and 2020 PLE-360 classes gave almost the same high rating regardless of the course delivery methods. However, the rating is worse from the 2021 ETECH-251 class where students had video recorded labs. The online and hands-on lab practice is also supported by the positive feedbacks received from the lab assistant and the students. Along with online lectures, the remote lab course seems to be able to deliver not only the same learning content but also provide the "hands-on" experience to the students with much reduced risk of infection. Such remote lab format is also being adopted in other teaching activities, and has the potential to be used for trainings and even research where learners are no longer required to be physically present in a lab setting environment. As being promoted in several campus and local news [9,10], such practice has the potential to provide much more flexibility and freedom to the polytechnic education. Long term studies on this practice will certainly benefit the learning community.

The author is thankful for support received from the IT office on the UW-Sout campus particularly Peggy Kralewski and her team. They set-up the remote control of the lab computers for the 2020 PLE-360 class and provided immediate trouble shooting service to the students during the labs. The author also would like to thank the two student lab assistants, Olivia Hile, and Emily Schattner, who worked diligently to help the students in the 2020 PLE-360 class.

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