Assessment of Influence of Teaching Modality on Student Learning Outcomes and Perception of Instructors in Laboratory Classes

Simon Ghanat, Stephanie Laughton, and William J. Davis
The Citadel

Abstract

This paper analyzes data from summers 2019 and 2020 of the Materials Laboratory course to provide a direct assessment of the influence of teaching modality on student learning outcomes. The modality change, from in person to online, was dictated as a part of the college COVID-19 pandemic response. Direct assessment consists of student performance on a material properties quiz. Statistical analyses were performed using the collected data. The results showed no significant differences in student performance across the two delivery formats. However, students in the online section gave the instructor slightly higher ratings than they did in the face-to-face section. Additionally, the pedagogical approaches employed in face-to-face and online versions are discussed.

Keywords
Labs, COVID-19

Background

The COVID-19 pandemic necessitated a rapid transition of content delivery within higher education beginning in Spring 2020. The full effects of such a transition have yet to be measured pending a return to "normal" operations. However, preliminary data, such as this study, are starting to quantify the effect of this shift. Such analysis can inform the future online transformation of engineering education. The breadth and depth required by an engineering curriculum mandates that each class function to its highest ability to maximize the time available in the schedule, thus online transitions must maintain the quality of in person classes to prevent curriculum disruption.

In late spring and summer 2020, most colleges and universities, including The Citadel, operated in a fully remote fashion. Lecture and laboratory classes alike were disseminated online. While there is a host of prior research, largely due to the MOOC movement,[1–3] regarding the impact of fully online classes, online laboratories represent a different host of challenges from a lecture.[4–6] Laboratory classes are designed to provide students a hands-on experience with equipment and measurements that would supplement their understanding of chemical/physical properties of a tested material as well as their understanding of how practicing engineers may employ such tests.[7,8] The experimental aspect of the class is generally held to be important. The idea of students facing uncertainty regarding the result of an experiment can help students understand the importance of scientific inquiry and experimental design.

Heradio et al.'s 2016 review of virtual and remote lab studies posits that there are four main types of lab experimental environments: (1) local access- real resource, (2) local access- simulated resource, (3) remote access- real resource, and (4) remote access- simulated resource.[9]

While the COVID pandemic precluded either "local access" option because buildings were closed, the remote options- where students access a real or computer-simulated test instrument and collect data- were possible. During the emergency transition to online learning, another category identified by Faulconer and Gruss expanded its application: home lab kits.[4,6] This is where the school sent a package of (or required students to purchase on their own) test materials.[4] Another alternative that many schools had to resort to could be called "remote access- demonstrated resource".[6] With this method, a video recording of a test was shared with students, so they can see how operation occurs. However, students made no experimental decisions regarding testing parameters.

No great effect has been found between physical presence to task performance. In fact, under certain situations, a sense of presence may be sufficient to achieve the same goal.[10] Thus, being physically absent from a lab room is not anticipated to inherently have a negative effect on student learning outcomes. It has been argued that with sufficient spatial presence, involvement, and "realness" virtual environments may be able to replace real ones.[11] While a demonstration video in place of a lab may be sufficient for "emergency remote teaching", many agree that that is not a long term aspirational model of online learning.[12,13] This study takes place after the emergency teaching transition took place and thus was able to employ a more intentional laboratory format.

As compared to video demonstration, remote access to instrumentation is a better solution to accomplish student learning objectives by ensuring involvement and "realness", though there are some concerns regarding students' negative perceptions of online lab implementation. Kinney et al. indicates that students perceive they would be less willing to speak up and/or communicate with others during an online class.[14] Additionally, they measured that faculty and students alike question remote laboratories' effectiveness when asked hypothetically. Even with these doubts, several studies have found that remote labs (remote control of real instrumentation) or virtual labs (control of virtual instrumentation) actually had positive effects on student performance.[15–20] This spans a variety of science and engineering fields. Student perceptions of remote or virtual labs after completion of a lab/course have also tended to be positive.[20]

However, under emergency conditions, like the COVID pandemic, schools may not be able to quickly develop or adopt fully virtual labs or remote-controlled labs. In the case of materials laboratories, the scale of the equipment precludes creating test kits to mail to students. These labs involve testing of material compressibility, tension, and torsion, especially of metals, requiring instrumentation often weighing hundreds of pounds. Other universities have spent years developing and implementing online control systems for their material properties instruments and have observed student learning success and acceptance of such methods.[21] In this study, a "remote controlled" lab was approximated by a staff member in the physical laboratory who acted as the "hands" of the students to control the instruments. Student were able to read the gages over streaming video then discuss and analyze data accordingly. This instrument access method did mandate synchronous lab sessions, precluding any of the known benefits to student scores or perceptions by implementation of asynchronous tools.[22–25] Additionally, methods such as discussion boards and chat sessions were implemented, which have been shown to promote engagement, to further supplement the potential lack of student "involvement" in the lab sessions.[26]

In this study, student performance and perceptions of a Materials Laboratory course are compared. While the learning objectives are the same for both cohorts, the summer 2019 class was in person in the laboratory while the summer 2020 class was taught online due to the COVID pandemic. The modality of the experiments was adapted due to the restrictions on campus access; however, the test procedures and general course content did not change between the semesters. Course content was simply adapted to better fit the online environment. This work aims to determine the effect of modality change on (1) student academic performance and (2) student perception of the class.

Materials Lab Course at The Citadel

At The Citadel, Mechanical and Civil Engineering majors are required to take the Materials laboratory course in the second semester of sophomore year and first semester of junior year, respectively. This one-credit course meets once per week for two hours. The course is offered in the fall, spring and summer semesters. The course is essential to students studying mechanical, civil and construction engineering. The course operates as a foundation for more advanced future classes. It introduces students to the practice of testing machines and equipment, as well as to help them learn about the properties of engineering materials, as determined by results of tests in compression, tension, bending, torsion and more. For this study, data from sections of the course that were taught during 2019-2020 by the same instructor have been used. The course content, the laboratory material, experiments, and reports have stayed the same over the period of study.

Face-To-Face Laboratory

To improve the learning environment in the laboratory courses, a wide variety of teaching and learning tools were employed by the instructor. The learning activities were directly linked to the course learning objectives. Web-based pre-class and pre-lab reading responses were employed to motivate students to prepare for laboratory regularly and to inform in-class activities targeting their learning gap. [27] Students were required to respond to one open-ended question on the course website addressing the learning objectives of a specific experiment. A “One-Minute” paper was used to monitor student learning, which required students to answer a big picture question from the material that was presented in the laboratory in 60 seconds. [28] A “real world” laboratory assignment was developed which promoted student learning of concepts and the development of critical thinking skills. Think-Pair-Share active learning activities and a number of other teaching and learning techniques were used in laboratory.

Online Laboratory

Instead of pre-recording the lab experience, or attempting to hold hypothetical experiments, the instructor decided to hold Materials lab synchronously via Zoom, with one technician working alone in the lab, performing the interactive experiments live for the students (Figure 1). The unique idea first came to the course instructor during the emergency spring semester transition to online learning. In the Spring 2020, the instructor did demonstrations and provided data for the students to analyze, but he noticed something was missing. Students were not able to engage with each other, with a lab tech, or the instructor which led him to the idea to work with the lab tech to perform experiments remotely in the summer course.

The following is an example of a lab experiment. The lab tech conducted the tensile testing of an aluminum bar, while student #1 observed and reported the strain gage readings. Student #2 observed and reported the force readings. Student #3 observed and reported the ultimate strength of the Aluminum bar. Student #4 observed and reported the fracture stress of the bar. The rest of the students recorded incremental values of force and strain while having the opportunity to also keep an eye on the instrument gages over Zoom (Figure 2). By doing the labs in this format, students were able to share data and photos, and analyze data remotely — which was not possible in the demonstration-only format. It was the kind of first-hand experience and learning that could not be replicated without live demonstrations.

Other active learning pedagogies employed in online setting were group analysis of data in Zoom breakout rooms, brainstorming a question and submitting answers via Zoom chat box, class polling at the beginning and the end of lab, discussion boards requiring teamwork and active participation, and immediate feedback through email, chat box, and texting.

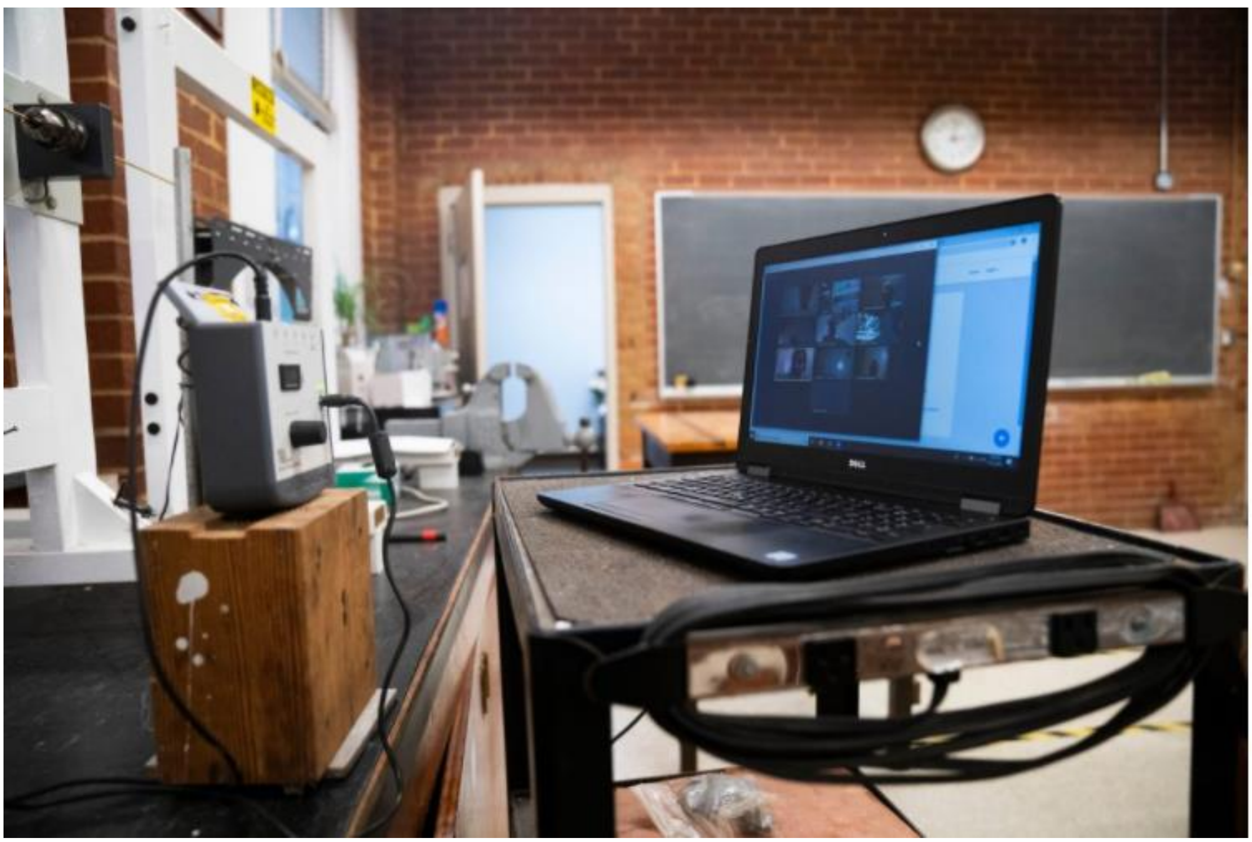

Figure 1. Material lab virtual lab setup

Study Methods:

The following describes the guiding research question for this study: Do students' performance and perceptions in online laboratory setting differ from those in face-to-face setting? The learning outcome has been directly assessed with a material properties quiz. The student perception has been evaluated by using the institutional procedure for course evaluations.

Direct Assessment Measure

Direct assessment data consist of student performance on a quiz on material properties from information presented in both sections. The material properties quiz (see Table 1 and Figure 2) was administered in both face-to-face and online sections.

Table 1. The material properties quiz

Q1	Which material is the most ductile in Figure below?
Q2	Which material is the most brittle in Figure below?
Q3	Which material has the largest modulus of elasticity in Figure below?
Q4	Estimate the yield stress for 1060 CR Steel in Figure below using an acceptable approach.

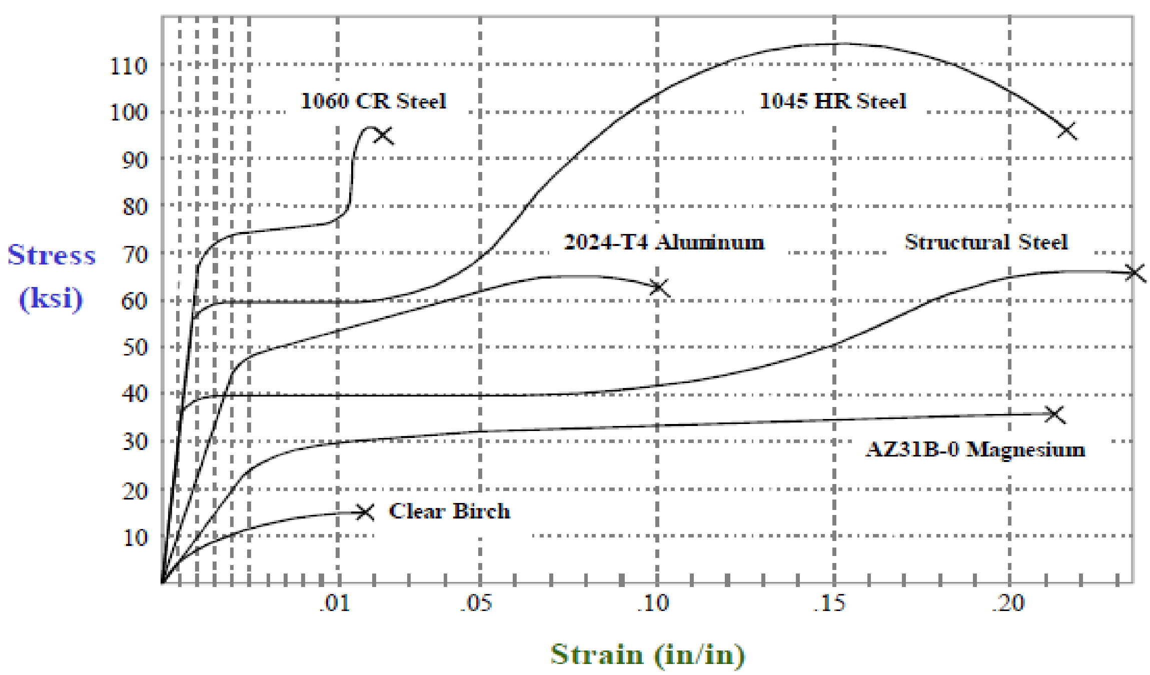

Figure 2. Stress-strain plots of several materials utilized for the direct assessment

Figure 3 illustrates the average student scores and analyzes students' performance on each question on the material property quiz. In the 2019 face-to-face section, the mean for questions 1 through 4 were 71, 75, 79, 80, respectively. In the 2020 online section, the mean of questions 1 through 4 were 80, 80, 84, 85, respectively. Students in the online section (n =23) outperformed students in the in-person section (n =37) on every question and overall. The results clearly indicate that student performance was increased at least 5% on all four questions of the material property quiz in the online section. While the online modality may have helped, this does not preclude the influence of the smaller class size on the improved performance.

A two-sample t-test statistical analysis at five percent level of significance (α =0.05) was conducted to see if there is a significant difference between the means of the in-person section (Mean = 76.3) and online section (Mean = 82.2). The results showed that the difference between the online and face-to-face versions of lab was not statistically significant.

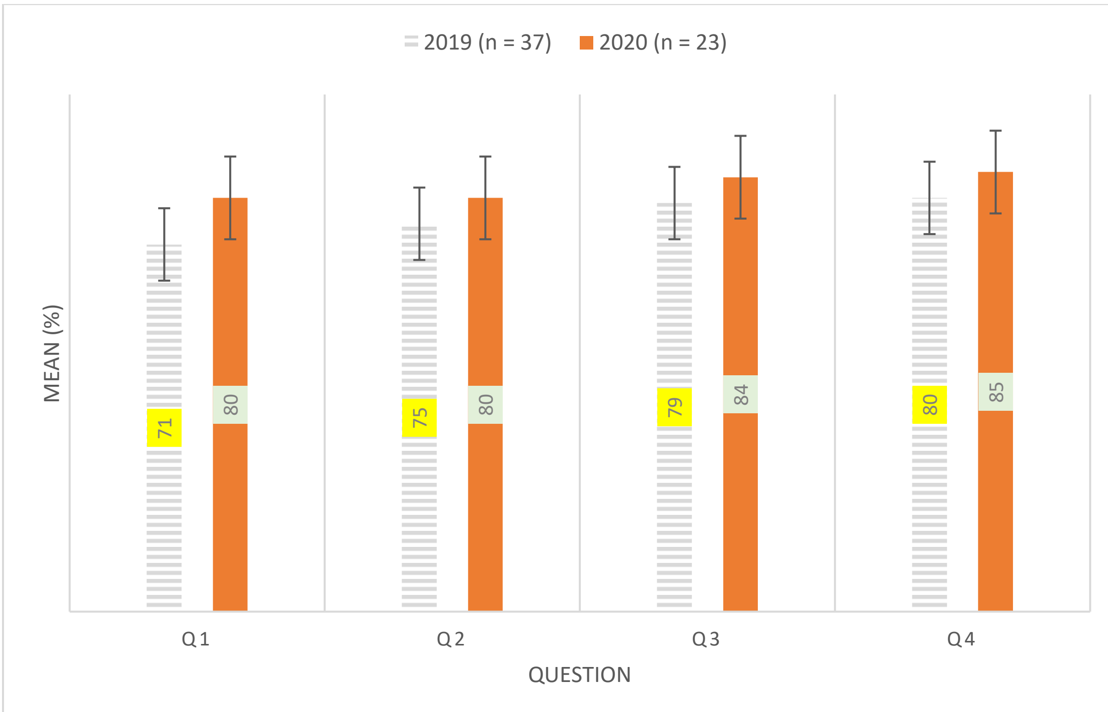

Figure 3. Comparison of mean and standard error for face-to-face and online sections

Indirect Assessment Measure

The student perception of learning and satisfaction with course was measured through an end-of-semester survey. The survey was conducted in electronic format only for both classes and students had access to the survey during the last week of summer session. Students were asked to respond to the statements shown in Table 2. The questions in the survey were specifically aimed at comprehending the students' perception of their own learning, their professor effectively challenging students to think, and the instructor's availability to assist students. Students responded to the questions on a five-point Likert scale (1-5), with '1' representing a strong disagreement with the survey statement and '5' representing a strong agreement with the survey statement. Students were asked to respond to the following statements in the survey:

Table 2. Institution’s online student perception survey.

Q1. My professor effectively challenged me to think Strongly Disagree= [1] Disagree = [2] Neutral = [3] Agree = [4] Strongly Agree = [5]
Q2. My professor is accessible to answer questions Strongly Disagree= [1] Disagree = [2] Neutral = [3] Agree = [4] Strongly Agree = [5]
Q3. My professor maintains an active presence in the course Strongly Disagree= [1] Disagree = [2] Neutral = [3] Agree = [4] Strongly Agree = [5]
Q4. My professor communicates enthusiasm when teaching Strongly Disagree= [1] Disagree = [2] Neutral = [3] Agree = [4] Strongly Agree = [5]
Q5. My professor makes a good use of examples and illustrations Strongly Disagree= [1] Disagree = [2] Neutral = [3] Agree = [4] Strongly Agree = [5]
Q6. I learned a lot in this course Strongly Disagree= [1] Disagree = [2] Neutral = [3] Agree = [4] Strongly Agree = [5]
Q7. I would enjoy taking another course from this professor Strongly Disagree= [1] Disagree = [2] Neutral = [3] Agree = [4] Strongly Agree = [5]

Evaluation of Survey Results

The student perception survey responses were converted to a percentage scale in the standard way, with a score of “5” being considered equivalent to 100. In this way, an equivalent mean percentage was obtained for the survey questions. As shown in Figure 4, 100% of online students strongly agreed with all seven statements. On the other hand, 92% of the face-to-face students strongly agreed with all seven statements. The results showed that students in the online section gave the instructor slightly higher ratings than they did in the face-to-face section.

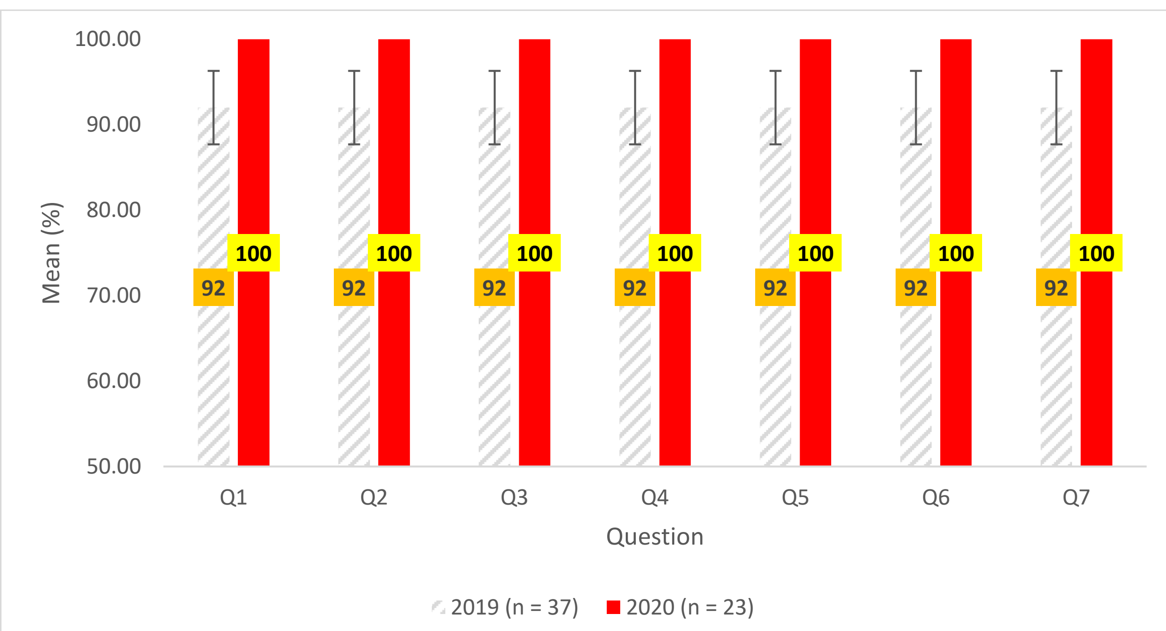

Figure 4. Means and standard errors for questions 1-7 of survey.

Conclusions

A study was conducted to analyze data from summers 2019 and 2020 of the Materials Laboratory course to provide a direct assessment of the influence of teaching modality on student learning outcomes. The modality change, from in person to online, was dictated as a part of the college COVID-19 pandemic response. The results showed no significant differences in student performance across the two delivery formats. However, students in the online section gave the instructor slightly higher ratings than they did in the face-to-face section. Nevertheless, it is difficult to move beyond observations into recommendations due to the small sample size. Further data collection and analysis is warranted over the next few offerings.

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Simon Ghanat, PhD, PE

Dr. Ghanat is an Associate Professor of Civil and Environmental Engineering at The Citadel. He received his Ph.D. in Civil Engineering from Arizona State University (ASU). Dr. Ghanat’s research interests are in Engineering Education and Geotechnical Earthquake Engineering. He previously taught at Bucknell University and ASU.

Stephanie Laughton, PhD

Dr. Laughton is an Assistant Professor of Civil and Environmental Engineering at The Citadel. She received her Ph.D. in Civil and Environmental Engineering from Carnegie Mellon University. Dr. Laughton’s research interests include environmental nanotechnology, sustainability, and engineering education.

William J. Davis, PhD, PE

Dr. Davis is Dept. Head of Civil and Construction Engineering at The Citadel. His research interests include: constructing spatial databases for better management of transportation infrastructure, improving transportation design, operation, safety and construction, understanding long-term effects of urban development patterns, and advancing active living within the built environment for improved public health. He has served in numerous leadership positions in ITE, ASCE and TRB.