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# Labs that should be hands-on are, in fact, not hands-on at all - What is this the state of our engineering laboratories today?

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# Labs that should be hands-on are, in fact, not hands-on at all. What is the state of our engineering laboratories today?

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## Abstract

The COVID-19 pandemic forced educators for engineering courses to transition hands-on laboratories to online settings. These settings were often pre-recorded or live-streamed real-time demonstration style experimental labs. In the wake of the pandemic, scholars are now armed with vital learning experiences from both laboratory settings (in-person and remote), which has fostered renewed interest in reexamining the advantages and disadvantages of remote and in-person laboratory environments and technologies. The purpose of this paper is to examine and compare the laboratory settings of two educational labs (Convection and Airfoil) that took place in a mechanical and aerospace engineering lab course pre- and post-COVID. This pilot study seeks to answer one research question. *How are in-person and remote online engineering laboratories experienced by 21st century students?* A qualitative Participant Observation Research Approach was used to observe and analyze the laboratory design, instruction, room and equipment layout, and student interactions (with each other, instructor, and equipment) during two labs. Qualitative data from research memos, notes, and informal student conversation were subjected to the first cycle of thematical coding analysis using a combined descriptive and exploratory coding techniques. Three themes emerged from this pilot study. First, students place higher value on hands-on versus demonstration style experimental labs. Second, arrangement of equipment and student access and visibility of equipment is vital for both online virtual and demonstration style labs. Third, the instructor's style of engagement and way of connecting the experiment to real world applications influences how students perceive and value the learning experience. Connecting learning outcomes and student curricular roadmap to the mechanisms of laboratory delivery should be further studied to identify strategies for affirming students' course knowledge and expanding their abilities to engage with equipment and independently design engineering experiments.

**Key words:** Engineering Labs, virtual labs, student perceptions on virtual labs, pilot scale study

## Introduction

Students' laboratory experiences are the most powerful and consistent influences in student learning and engagement in engineering higher education *[1, 2]* because they readily connect classroom theory to laboratory experimental design and technical equipment. The growing cost and complexity of experimental labs along with the burgeoning need for the enhancement of student knowledge have caused the interest and development of online and virtual laboratories to increase over the last decade *[3]*. Conversely, the viability and quality of online laboratories have been questioned by experts who postulate that the inability of students to actively participate in online laboratory experiments is detrimental to their learning. Therefore, these experts have surmised that virtual learning environments are less effective in student learning than traditional hands-on laboratory environments *[4]*. Nevertheless, the nationwide mandatory college shutdowns due to the COVID-19 pandemic forced institutions of higher education to make sweeping changes to the method of course and laboratory delivery of traditional hands-on laboratories from in-person to remote virtual experiences. In the wake of the pandemic, many scholars are revisiting the subject of engineering in-person educational labs, where interest had previously subsided over the last several decades. Instead, more emphasis has been placed on the development and study of virtual and simulation-based laboratory environments *[5, 6]*. Post-COVID, scholars are armed with vital learning data and experiences from both in-person and remote educational laboratory environments, which can be leveraged to reimagine how educational labs are conducted and experienced by 21st century engineering students.

During the COVID pandemic, many of virtual laboratories were either pre-recorded demonstration *[7]* or live streaming laboratory activities *[8]*. In these environments, multiple cameras were used to record or live-stream instructors carrying out the hands-on laboratory as students observed them along with the equipment. Students also often interacted with each other and the lab instructor via chat and orally through a virtual conference communication system such as WebEx or Zoom. Some scholars have highlighted the perceptions of students (during the COVID era) as they engaged in virtual labs highlighting the robustness of the laboratory design and instructor preparation (as evidenced by student course evaluations), along with several shortcomings of the virtual learning environment *[9]*. Some shortcomings noted by these researchers included: the lack of interaction between the teaching assistant and students and student-to-student interactions and teamwork, intense concentration needed to remotely observe technical demonstrations cognitively overloaded many students, home distractions, and lack of tactile learning typically gleaned in hands on laboratory experiences.

**Research Purpose and Research Question**

Having returned back to in-person learning, many students and instructors have new impressions of virtual and in-person learning environments that are informed by both positive and negative experiences in virtual communication, networking platforms, and technological advances. As a community of educators and scholars in higher education – we are revisiting the *norms and expectations of educational engineering labs, given our newly formed knowledge of what can and cannot be done virtually*. Thus, the purpose of this pilot study was to examine and compare the laboratory settings of two educational labs (Convection and Airfoil) that took place in a mechanical and aerospace engineering lab course pre- and post-COVID. The project took place at a Research tier one institution located in the Northeastern Region of the United States. This pilot study seeks to answer one research question. *How are in-person and remote online engineering laboratories experienced by 21st century students?*

**Research Methodology and Data Collection**

A qualitative Participant Observation Research Approach *[10]* was used to observe and analyze the laboratory design, instruction, room and equipment layout, and student interactions (with each other, instructor, and equipment) during two labs. Qualitative data from research memos, notes, and informal student conversation were subjected to the first cycle of thematical coding analysis *[10]* using a combined descriptive and exploratory coding techniques *[11]*.
Six labs were observed during 2021 spring and summer sessions, where four of the six labs were demonstration labs. This pilot study discusses the findings from two labs of the six labs, the Airfoil and Convection Laboratories. These labs provide context for both demonstration and

hands-on/physical lab learning environments. In addition, all students are required to take fluid mechanics, engineering mechanics, dynamics, and heat transfer courses as part of their undergraduate curriculum, which cover lift, drag, air foil design, and forced and natural convection. Multiple sections of the same lab were observed.

This pilot study was exploratory in nature, where the investigators observed laboratory sessions seeking to identify themes in student experience and lab design. However, a list of initial observation variables was identified as points of observation for both labs. These variables included: 1) laboratory set up, 2) equipment used, 3) lab timing of events, e.g., duration of instructor lab description and demonstration, duration of student interaction with equipment, 4) student behavior, language used, and body disposition, and 5) opportunities for student-to-student, student-to-instructor, and student-to-equipment. Informal conversations with students about their experiences with the lab occurred prior to and after the labs were completed. Students were asked, "*How was the lab?"* Their responses were recorded along with the observation data. Data was recorded in the form of notes and memos. The selection of students to interview was ad hoc and based on student willingness to engage.

**Results and Discussion**

The Convection Lab focused on students monitoring temperature fluctuations of the gases surrounding an object that was heated using a joule heating process. After the object reached a set temperature, it is subjected to a steady stream of airflow, while the temperature changes in the area surrounding the object within the chamber were monitored using sensors. The input temperature of the chamber and increasing current input to the object are monitored, and the decreasing temperature of the gas surrounding the object was the output data that was displayed on computer screen for students to monitor from outside of the room.

This lab was set up in two parts. First, the instructor showed students the equipment (convection chamber) and computer monitoring system while verbally describing the purpose of the lab, variables to be observed and measured, along with the equipment to be used (10 - 15 minutes). During this part of the lab, students' questions are answered by the teaching assistant. In the second part of the lab, students were dismissed out of the laboratory room that contained the equipment (30 minutes). The students observed the lab as the teaching assistant conducted the "hands-on" experiment through a transparent observatory glass window. The number of students observing the demonstration labs varied from six to eight depending on the section. The TA would periodically leave the demonstration lab room to announce temperature changes within the chamber to the students in the hallway. At the completion of the lab, students were given a class dataset to analyze and report on in their laboratory report.

During the lab, students were most engaged during the first portion of the discussion and overview. Students who appeared to be the most interested in the lab positioned themselves close to the observation window so they could continue to visually monitor the system from the outside. Due to the size of the window, the number of students who could easily view the computer monitor was limited and those students who were shorter in stature struggled more than others to view the lab. These students interacted with the TA when he came outside the room to give the students updates on the lab. Conversely, many other students lost interest in the lab once they were escorted outside of the lab room. These students were either distracted with their mobile phones or engaged in social conversations with other students.

Following the lab several students answered the interviewer's question, "*How was the lab*?" Several of the students expressed interest and enthusiasm for the lab content and wanted to relate it back to their previous coursework. Others indicated that since there was no formal training on how the lab convection chamber, sensors, and monitoring system operated, it was difficult for them to fully appreciate what was going on even though the TA had described the input and output data. The majority of the students were disconnected by the end of the lab and explained that their lack of interest was not due to the lab engineering technical content, but the disappointment of not actively working with any equipment. Several students commented that they found no measurable difference between the in-person and online virtual lab experiences from years before, where they watched the lab and were then handed data in both scenarios.

The Airfoil Lab was carried out in an analogous way to the Convection Lab. In particular, the Airfoil Lab consisted of two parts: a lab overview by the TA and experimentation. However, the Airfoil Lab was not a demonstration laboratory. Instead, students (paired in twos) with the guidance of the TA secured airfoils within the wind tunnel chamber, used a force balance to weigh the airfoils, and operated air flow and sensor measurement controls. In this way, students were able to determine the lift and drag forces acting on different airfoils and compare them to published data. The TA also encouraged students to provide arguments for the choice of specific airfoils for specific applications.

The students were extremely attentive in the hands-on Airfoil Lab. They eagerly asked questions of the TA about the experiment (10 – 15 minutes depending on the section). Student pairs also discussed experimental steps and cross-checked methods with each other while doing the lab. The students engaged in the lab for 40 minutes. The majority of students were actively engaged in the lab through the duration of the lab time, but they were unable to test all available airfoils due to time limitations. When asked about their experiences with the lab, all students indicated that they felt that the experience was worthwhile and invaluable. They also indicated that this particular lab could not be experienced in the same manner in a virtual lab setting.

Several themes arise from this pilot study. First, students value hands-on versus demonstration style experimental labs for engagement and learning of equipment use. Labs that prevent visual and auditory engagement with the instructor can lead to student distraction or complete disconnection from the lab. In these instances, some students may have more communication in virtual learning environments where chat room discussions and multiple cameras may be used to provide continuous interaction with the instructor and virtually with the equipment. Second, experimental labs in the majority of engineering institutions are designed for visible observations. Hence, demonstration labs that preclude observation of the lab or make visibility difficult discourage student engagement, especially in 21$^{st}$ century classrooms where students have access to other means of entertainment, i.e., smart phones, etc. Third, the instructor's presentation style, degree and extent of engagement, and means of connecting lab to real-world data or industry influence how students value the educational lab experience. This latter theme was more important in virtual and demonstration labs than in hands-on active learning environments.

## Conclusions

This pilot study indicates that *how students perceive the value of laboratory experiences* is connected to delivery style, venue of experience, e.g., remote or in-person, and demonstration versus hands-on experience. Connecting learning outcomes and student curricular roadmap to the mechanisms of laboratory delivery should be further studied to identify strategies for affirming students' course knowledge and expanding their abilities to engage with equipment and independent design of engineering experiments.

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## References

[1] J. F. Volkwein, L. R. Lattuca, P. T. Terenzini, L. C. Strauss, and J. Sukhbaatar, "Engineering change: A study of the impact of EC2000," *International Journal of Engineering Education*, vol. 20, no. 3, pp. 318-328, 2004.

[2] L. R. Lattuca, P. T. Terenzini, J. F. Volkwein, and Ieee, "Panel session - Engineering change: Findings from a study of the impact of EC2000," in *36th Annual Frontiers in Education (FIE 2006)*, San Diego, CA, Oct 28-31 2006, in Frontiers in Education Conference, 2006, pp. 1206-+, [Online]. Available: <Go to ISI>://WOS:000245981400298

[3] M. M. Waldrop, "Education online: The virtual lab," *Nature*, vol. 499, no. 7458, pp. 268-270, 2013/07/01 2013.

[4] T. Mgutshini, "Online or not? A comparison of students' experiences of an online and an on-campus class," (in eng), *Curationis*, vol. 36, no. 1, pp. E1-7, Mar 18 2013.

[5] J. E. Corter, J. V. Nickerson, S. K. Esche, C. Chassapis, S. Im, and J. Ma, "Constructing reality: A study of remote, hands-on, and simulated laboratories," *ACM Trans. Comput.-Hum. Interact.*, vol. 14, no. 2, pp. 7–es, 2007.

[6] R. Estriegana, J. A. Medina-Merodio, and R. Barchino, "Student acceptance of virtual laboratory and practical work: An extension of the technology acceptance model," *Computers & Education*, vol. 135, pp. 1-14, Jul 2019.

[7] J. Campbell, A. Macey, W. Q. Chen, U. V. Shah, and C. Brechtelsbauer, "Creating a Confident and Curious Cohort: The Effect of Video-Led Instructions on Teaching First-Year Chemical Engineering Laboratories," *Journal of Chemical Education*, vol. 97, no. 11, pp. 4001-4007, Nov 2020.

[8] K. Woelk and P. D. Whitefield, "As Close as It Might Get to the Real Lab Experience Live-Streamed Laboratory Activities," *Journal of Chemical Education*, vol. 97, no. 9, pp. 2996-3001, Sep 2020.

[9] K. Cook-Chennault and A. Farooq, "Virtualizing Hands-On Mechanical Engineering Laboratories - A Paradox or Oxymoron," presented at the ASEE 2022 Annual Conference - Excellence Through Diversity, Minneapolis, Minnesota, 2022, 38443. [Online]. Available: https://peer.asee.org/virtualizing-hands-on-mechanical-engineering-laboratories-a-paradox-or-oxymoron.

[10] G. Terry, V. Braun, N. Hayfield, and V. Clarke, "Thematic Analysis," ed, 2017, pp. 17-37.

[11] J. Saldaña, *The coding manual for qualitative researchers*, [Third edition]. ed. London ;: SAGE, 2016.