Remote Teaching of Unit labs for Chemical Engineering Undergraduates during COVID-19

Rupak Dua
Hampton University, Hampton, VA, USA

Abstract

The unit labs in chemical engineering offer a unique learning experience to seniors through laboratory scaled industrial equipment. With the arrival of coronavirus disease 2019 (COVID-19), the whole education system was disrupted. It was challenging to teach unit labs in a virtual environment with the same sort of student engagement as done in face to face classes. However, the instructor provided a learning environment and hands-on like experience virtually to the students while conducting three virtual unit process experiments during the semester through interactive simulations. Further, educational videos related to their experiment and assignments were also supplemented to help students comprehend the material more effectively. Students had an experiential learning experience with interactive simulations and other materials provided. In conclusion, the availability and the use of modern technology and educational tools can be a key to teach effectively and make learning possible virtually even during unprecedented time.

Keywords

COVID-19, remote teaching, simulations, educational videos

Introduction

The Unit Operations Laboratory (Lab) courses in Chemical Engineering have many purposes. They offer a unique learning experience to seniors majoring in Chemical Engineering to get exposed to real-world chemical processes. They get hands-on activities on laboratory scaled industrial equipment, thus reinforcing the theoretical coursework through the medium of experimentation that they learned in their sophomore and upper-level chemical engineering lecture-based classes [1, 2]. In these labs, the students learn to define problems, plan and design experiments that will generate data on various aspects of chemical engineering theory, collect and analyze data and present their technical reports in professional form through written and oral reports. The Unit operations laboratory courses also provide students with examples of the agreement or disagreement between mathematical models of chemical engineering processes and the results of the operations themselves. The experiments conducted in this course are usually carried out in groups of two to four students; thus, this unit lab also teaches students to work together safely and cooperatively [3].

However, with the arrival of the coronavirus pandemic (COVID-19), the whole education system and its settings were abruptly disrupted. The instruction mode for Hampton University moved online to maintain a healthy and safe campus environment and minimize the spread of

COVID-19. It was challenging to teach unit operation laboratory courses in a virtual environment and sustain an adequate level of student engagement.

This paper provides an overview of how the instructor provided a learning environment and hands-on like experience virtually to the students while conducting three virtual unit process experiments during the semester.

Methods:

Class Delivery Mode

The teaching of Unit labs for Chemical Engineering Undergraduates during COVID-19 was completely done online, with Blackboard being the delivery vehicle for instructions. We made use of both synchronous and asynchronous learning methods. The course involved completing both independent (e.g. reading material, viewing online content, reflecting on information) asynchronously and dependent (e.g. online interactions with peers and instructor) through Blackboard Collaborate Ultra synchronously.

Experiments Conducted

The simulations employed for the chemical engineering processes in this course were through the Ministry of Human Resource Development (MHRD), Govt. of India, initiative and were open accessed. We conducted three virtual experiments over the course of the semester.

a) Fluid Circuit Lab: The purpose of the experiment was to clarify the idea of viscous flow in pipes. This experiment's objective was to determine and compare the friction losses across the pipe of different cross-sectional areas under laminar and turbulent flow situations. We conducted this experiment virtually through a link (http://uorepc-nitk.vlabs.ac.in/exp1/index.html#)

b) Fluidization: The purpose of this experiment was to investigate the effect of particle size on the minimum fluidization velocity of a packed bed flowing through water experimentally and theoretically. We conducted this experiment virtually through an open-access link (http://uorepc-nitk.vlabs.ac.in/exp6/index.html#)

c) Tray drying: The purpose of the tray drying unit operation laboratory was to investigate the drying rate of a 100 gms of solid at different operating conditions of the tray dryer. We collected the data through a simulation of a tray dryer remotely that was open accessed (http://vmt-iitg.vlabs.ac.in/Forced_draft_tray_dryer(theory).html).

Implementation:

Lectures

Course lectures are an essential part of the unit operation laboratory [3] and were given synchronously approximately for 1 hour prior to starting any virtual chemical engineering laboratory. The instructor covers the fundamentals of principles involved with mathematical relations, experimental design, statistical testing concepts, safety, and other material relevant to

the proposed experiment in these lectures using a video platform, Collaborate Ultra in Blackboard. Students are provided with the framework of how mathematical relations can be connected with their design, implementation, and analysis of their experiments.

Educational Videos

It has been found that documentation via video helps retain the information, and instructional videos' provision increases student performance in the class [4, 5]. To further enable a better understanding of the theoretical concepts and experimental designs covered in the lecture, educational videos through the Journal of Visualized Experiment (JOVE) and youtube related to the experiment were incorporated and watched during the synchronous lecture. The video was less than15 minutes in length. Still, it provided enough information to explain the purpose, theory, and protocols for operating the instrument, the context of the data obtained, and the methods used to process this collected data into presentable results. The video also included a discussion on the critical steps within the protocols, modification, and troubleshooting of the methods, limitations, and finally, the importance and potential applications of the method in the specified chemical engineering process. The videos' links were also uploaded on the blackboard too for students to watch them later if they wished.

Simulation

Previous studies have found that simulations help students learning outcomes [6, 7]. The simulations employed for the chemical engineering processes in this course were through the Ministry of Human Resource Development (MHRD), Govt. of India, initiative. These simulations were incorporated in the virtual laboratories that can be accessed easily through a website. Each student was given a unique set of experimental conditions for which they used to run the simulation. These simulations provided the raw data values that students would generally collect in real life from the instruments in the laboratory settings.

Assessment:

Laboratory Report

Three laboratory reports needed to be completed during the semester, and each laboratory report accounts for 15% of the grade. Group members have to work collaboratively with each other and present their results in the form of a group report. Each student works individually on a simulation for a particular experiment with a set of unique experimental conditions provided by the instructor. As a group, the students in their respective groups analyze their own results and fit them as a whole and discuss any trend that can be found with the changing variables in their experiment. Each of the laboratory reports is expected to have sections including Cover Page, Summary, Purpose/Aims, Background/Introduction, Theory, Apparatus, Safety precautions, Methodology/Standard Operating Procedures (SOP), Results (Calculations, Tables), Discussion and Conclusions, Sources of Error and References.

Assignments

To foster critical thinking, a short 3-5 question questionnaire related to the specific experiments students conducted was prepared and provided to students after the instructor's lecture. These

assessments were individual assignments worth 15% of their total grade that students completed independently and submitted the assignment on blackboard for grading within one week. The assignment was given for the first time in Fall 2020 semester to help students critically think about the processes and how these concepts can be used outside the laboratory settings without having access to the real equipment.

Oral and Poster Presentation

Each group presented their result within 15 minutes through a video platform in the form of an oral presentation and also through the development of a poster. Both these activities helped them develop skills like working together and improving their verbal and presenting skills. These assignments carry a total of 30% of their total grade. Each group member was equally responsible for the preparation of both oral and poster presentations.

Class Participation

The unit operation labs are very engaging, and without the active participation of students in the experimentation, these laboratory courses would not be successful. How well the students are prepared for each laboratory class and how much they participated in the class discussion was assessed by the instructor each week during laboratory class. Since the class size was small so it was easy for the instructor to have an account for each student. The grade for the laboratory participation forms 10% of a student's final grade.

Discussion and conclusions

We found that the students were engaged in completing their laboratory coursework throughout the semester during the COVID-19 pandemic. Each student ran the simulation individually and computed the results independently for their own set of readings. Then, as a group, they came together to compile a group laboratory report, thus developing skills of working in collaboration and analyzing results, and providing a comprehensive discussion. Further, the interactive simulations for the chemical engineering processes stimulated real experimentation, and data was collected virtually from those stimulations, which provided the experiential learning experience. The analysis, writing, and presentation of the report were done as a group assignment in the same way as the students have done in their face to face classes. Each group gave an oral presentation through Blackboard Collaborate Ultra and shared their presentation, and the delivery of the presentation was done in the same manner as they would have done in normal circumstances in the face to face class. The poster was also developed the same way, however, it was a little challenging to give a poster presentation on the computer screen. Besides, educational videos related to their experiment from the Journal of Visualized Experiments and assignments that were supplemented helped students comprehend the material more effectively. These outcomes were also reflected in the Likert-style survey we took in the class with targeted questions. Though the response rate for the survey was 40%, we got mixed feedback. 50% of the students who responded were intensely satisfied with the online experience in this course. 50 % of the students who took the survey strongly agreed that the education videos presented during the class helped improve their learning outcomes, and doing individual assignment fostered their critical thinking. Though this course was the first time taught in a virtual environment at Hampton University, we were able to provide a conducive learning environment.

However, one of the simulations employed in this course (Tray Drying) ran only for the windows-based operating system, so it was inconvenient for students who do not have windows-based operating systems. With the approach we took to teach unit operation laboratory course, the students had experiential learning with interactive simulations that provided them with hands-on like experience for unit processes and other activities and supplement material.

In conclusion, the availability and the use of modern technology and educational tools can be a key to teach effectively and make learning possible in unit operation laboratories courses virtually, even during such an unprecedented time.

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Rupak Dua, Ph.D.

Dr. Rupak Dua is an Assistant Professor in the Department of Chemical Engineering within the School of Engineering & Technology at Hampton University. Dr. Dua's research focuses on improving or finding solutions for the musculoskeletal system disorders that still exist clinically through biomimetics, chemical, and tissue engineering approaches. Dr. Dua graduated from Satyabama Institute of Science and Technology, India, with Bachelor's in Biomedical Engineering and received his MS and Ph.D. in Biomedical Engineering from Florida International University. Dr. Dua teaches sophomores, junior and senior-level chemical engineering courses to majors. Dr. Dua's research has been funded by several organizations, including the National Science Foundation (NSF).