UPV SOTECH Experience: Remote Delivery of Chemical Engineering Laboratory Course during COVID-19 Pandemic

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Highlights

- Remote delivery of Chemical Engineering laboratory course at UPV SOTECH
- Assessment of student performance
- Assessment of the remote delivery of the course

Abstract

The COVID-19 pandemic has drastically changed the way universities deliver their services including teaching undergraduate students. The conduct of laboratory work is an integral part of engineering education which has been challenged by the shift to distance learning or remote delivery during the pandemic. This paper discusses the remote delivery implementation in the Second Semester of AY 2021-2022 of ChE 136: Chemical Engineering Laboratory II course of the BS Chemical Engineering program offered by the School of Technology, UP Visayas (UPV). In this paper, the adjustments made by the faculty members in the remote delivery of the laboratory course is described including the assessment of student performance and assessment of the course from the point of view of the students.

Key Words: Chemical engineering; laboratory; COVID-19 pandemic; UP Visayas

1. Introduction

Chemical engineering is a domain of engineering that uses physical sciences, life sciences, mathematics, and economics in the conversion of materials, energy, and chemicals (Garnier, 2014). Undergraduate students are expected to study a wide range of courses including heat, mass, and momentum transfer, unit operations, process control, thermodynamics, and chemical reaction engineering among others. Undergraduate students are exposed to a wide range of teaching and learning materials and activities in order to fully prepare them to become professional Chemical Engineers. Experiential learning conducted in many forms including laboratory work is a widely accepted integral part of education (Bhute et al., 2021).

With the onset of the COVID-19 pandemic in the early 2020, many sectors of society had to adjust in order to continue to deliver services while at the same time ensuring adherence to national protocols in preventing the spread of the virus. One of the most affected sectors is the education sector. Universities had to adjust their mode of delivery of services and faculty members had to quickly adapt to a changing environment in order to continue doing teaching, public service, and research. In various parts of the world, students were not allowed on campus and remote learning was adopted wherein learning is facilitated for students in the confines and safety of their homes. However, even if the COVID-19 pandemic affected most universities here and abroad, developing countries struggled mainly due to the lack of ICT infrastructures, internet access, lack of gadgets or computers for students etc. (Tadesse and Muluye, 2020). Remote delivery of courses was facilitated by the use of learning management systems (LMS) and other alternative media such as Facebook groups where faculty members can post lectures, notes, quizzes and provide feedback or correct exams. Lectures can be condensed into powerpoints and summarized notes. However, one of the key challenges during the period was the delivery of laboratory courses. In the interest of the safety of the students, faculty, and staff, universities had to suspend the face-to-face implementation of laboratory courses. Faculty members were directed to implement laboratory courses in a remote setting as well.

This paper discusses the remote delivery of the course ChE 136: Chemical Engineering Laboratory II, a laboratory course in the BS Chemical Engineering program of the School of Technology, UP Visayas. The paper discusses as well the adjustments made by the faculty in delivering the course, the mode of assessing student learning in the course, and feedback of the students who have undergone the remote learning delivery of the course.

2. Methods

In the Second Semester of AY 2021-2022, the ChE 136: Chemical Engineering Laboratory II course was delivered remotely through video experiments (4 experiments), home experiments (2 experiments) and a virtual experiment (1 experiment). The course delivery can be divided into three parts: (1) preparation of course materials; (2) delivery of laboratory experiments; and (3) student assessment.

2.1 Preparation of course materials

Before the start of the semester, the faculty members in-charge prepared a course pack including the detailed course syllabus and learning resources such as brief review notes, pre-laboratory manuals, and video experiments where applicable.

2.2 Delivery of laboratory experiments

At the start of the semester, a course orientation was conducted to the students to orient them of the course objectives, to discuss the course outline including the experiments and their respective timeline, and to explain the course policies, requirements, and delivery. During the orientation, the respective classes were also randomly divided into groups of three (3) which served as their permanent grouping for the whole semester. A week before each experiment, the learning resources necessary for the experiments were uploaded in the UPV Learning Management System (UPV LMS). After studying the resources, students were required to take a pre-laboratory test, a timed quiz in the UPV LMS, to gauge their understanding of the necessary concepts and preparedness for the actual laboratory experiment. For video experiments, a previously prepared video of the actual experiment was uploaded in the UPV LMS. The video showed the materials and equipment used in the experiment and the step-by-step process in conducting the experiment. The students were tasked to tour the video and gather relevant data and observation. After data collection, the students were to process these data, make pertinent interpretations, and draw conclusions from the results obtained.

2.3 Assessment of student performance

Students were assessed by requiring them to submit a written post-laboratory report one (1) week after the conduct of each experiment. Further, they were required to present an oral report of an assigned experiment at the middle and the end of the semester. In effect, each group submitted a total of seven (7) laboratory reports and presented two (2) oral reports.

2.4 Assessment of the course

The course delivery and the teaching performance of faculty members in-charge were evaluated by the students using the Online Student Evaluation of Teachers (OSET) regularly administered at the end of the semester. Three weeks before the end of the semester, students were to accomplish the OSET online through the UPV Computerized Registration System (CRS) platform.

3. Results and discussion

3.1 ChE 136: Chemical Engineering Laboratory II

There are two ChE laboratory courses in the study plan of the BS ChE program which are the ChE 135: Chemical Engineering Laboratory I which deals mainly with Fluid Mechanics and ChE 136: Chemical Engineering Laboratory II which deals mainly with other Unit Operations.

The following are the course objectives (CO) of ChE 136: Chemical Engineering Laboratory II. At the end of the course, the students should be able to:

CO1: design, perform, and evaluate experimental procedures for different unit operations and processes;
CO2: analyze results and draw conclusions using concepts of unit operations and processes;
CO3: formulate and present laboratory reports using effective written and oral communication; and
CO4: work within a team or collaborate with other teams to implement experiments and projects.

During the Second Semester of the Academic Year 2021-2022, the course was offered remotely due to the COVID-19 pandemic. The faculty members in-charge of the course had to recalibrate the content and delivery of the subject to adjust to the needs of the UPV ChE students. The faculty members used the UPV LMS, an online management system by UPV, with the primary purpose of communicating remotely with the students. In the UPV LMS, faculty members can post lectures, videos, quizzes, exams, announcements regarding the course and also interact with the students through messaging. Faculty members can also track the progress of students in the course and can grade submitted requirements. Table 1 shows the list of experiments included in the Second Semester AY 2021-2022 offering of ChE 136 recalibrated for remote delivery of the course. The table includes the corresponding experiment objectives and the CO satisfied by the experiments.

Table 1. List of experiments included in the remote delivery of the ChE 136 course.

	Experiment	**Remarks**	**Experiment Objectives**	**CO**
1	Size reduction and Screening	with video experiment	a. Determine the Kick’s, Rittinger’s, and Work index of solids b. Determine the particle size properties of the size-reduced solids	CO2 CO3
2	Bernoulli Theorem	with video experiment	a. Determine the static and kinetic head at different sections of the Venturi meter b. Determine the actual and theoretical total head of the sections	CO2 CO3

3	First and Second Order Systems	with video experiment	a. Plot the response of the system to reach equilibrium through time with respect to a step change b. Determine the effect of input step change to the system response	CO2 CO3
4	Gas absorption	with video experiment	a. Experimentally determine at which gas flowrates flooding occur for different liquid flowrates b. Plot the influence of the air and water flow rates variation on the pressure inside the column c. Identify the different sections of each curve of the plot	CO2 CO3
5	Batch Sedimentation	Home experiment	a. Perform batch sedimentation at different solid concentrations b. Plot a curve of interface height vs time for different solid concentrations c. Determine and compare the critical settling height, final settling height, and settling velocities for different solid concentrations d. Perform a scale up batch sedimentation and predict the settling data using the scale up equation	CO1 CO2 CO3 CO4
6	Settling of Individual Particles	Home experiment	a. Determine the drag coefficient of the particles of different shapes b. Determine the settling velocity of spherical particles based on the experiment and compare with predicted or theoretical settling velocity	CO1 CO2 CO3 CO4
7	Reaction Kinetic Studies in Batch Reactor	Virtual Laboratory	a. Perform a simulation experiment for the saponification process in a batch reactor at varying temperatures b. Determine the rate constant and effect of temperature on the rate constant c. Determine the frequency factor and activation energy	CO2 CO3 CO4

As presented in Table 1, all the experiments contribute to the fulfillment of the CO's. It can be observed that CO2 and CO3 are satisfied by all the experiments. CO1 is fulfilled only by Experiments no. 5 and 6 because these are the only experiments students can perform physically in the confines of their homes. These experiments do not require costly materials and equipment. CO4 is satisfied by Experiments 5, 6, and 7 because students work together to conduct and perform these experiments.

3.2 Experiments 1 to 4: With video experiments

The first four of the experiments included an "experiment package" posted in the UPV LMS prior to the class period. The experiment package included the following:

a. **Brief review notes -** The review notes contain the general concept of the topic of experiment. It includes a brief discussion on the theory, important relationships, and key equations.
b. **Prelaboratory notes -** The prelaboratory notes contain the objectives of the experiment, a brief methodology, and the expected analysis or results that the teams should include or discuss in the laboratory report.
c. **Video experiment -** The faculty members in-charge performed a complete run of the experiment in the SOTECH laboratory and a copy of the video was provided to the students. The video was recorded from the perspective of the student with the faculty in the video guiding the student in the step-by-step process of the experiment including weighing of the samples, manipulating knobs, adjusting gas

pressure and the likes. Figure 1 shows screen captured images from the recorded videos of experiments in Bernoulli theorem and Gas absorption.

(a) (b)

Figure 1. Screenshot taken from (a) Bernoulli theorem video experiment: water levels in the columns; and (b) Gas absorption video experiment: packed tower columns.

These experiments require some costly equipment or materials that might not be available in the students' homes. Hence, the need for alternative methods for students to understand the concept of the experiment which in this case is delivered via assisted tutorial video recorded by the faculty.

Once the experiment package is posted in the UPV LMS, the students, working as a team, are expected to tour the video and collect raw data based on the video. The students are then expected to perform the necessary calculations and discuss the result in their laboratory report to be submitted to the faculty in-charge.

3.3 Experiments 5 to 6: Home experiments

The second set focused on experiments that may be done at the respective homes of the students without needing sophisticated equipment and procurement of costly materials. Albeit the simplicity of the experimental set-up, these experiments were designed to be in line with the objectives of the course. Like Experiments 1 to 4, an experiment package, containing brief review notes and pre-laboratory manual, was also provided through the UPV LMS. Figure 2 shows a screen captured image of sample steps included in the home experiments for Batch Sedimentation.

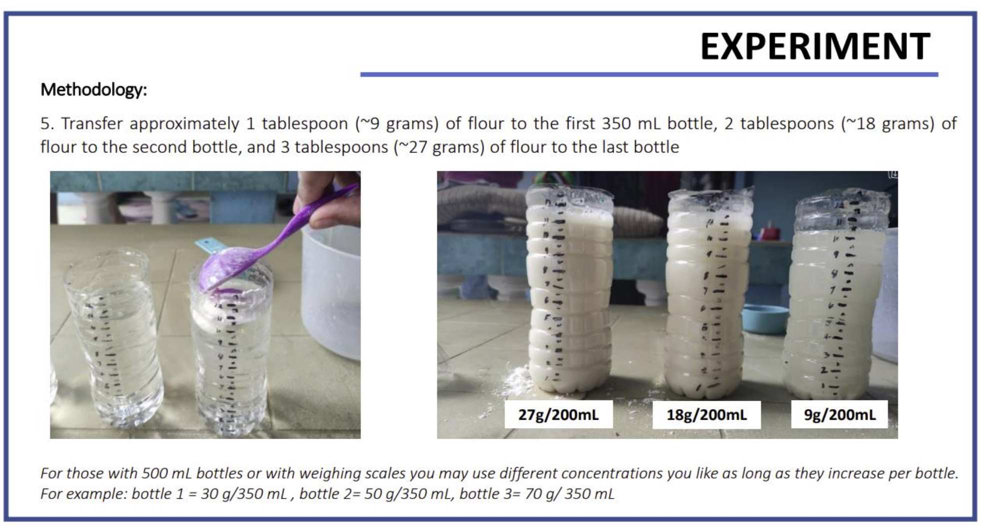

Figure 2. Screenshot taken from Batch sedimentation home experiment's pre-laboratory manual.

The brief review notes and the pre-laboratory manual were posted ahead of time prior to the scheduled date of experiment so that the students have sufficient time to review the concepts and prepare the materials necessary for the experiment. During the experiment proper, the students individually conducted their own experiments but presented their results and findings as a group for their laboratory report. With these home experiments, the faculty members-in-charge aimed to minimize the restrictions of a remote learning environment on the students' skills development by allowing students to be able to fully achieve one of the most important learning outcomes for the course which is to design, perform, and evaluate experimental procedures for different unit operations and processes.

3.4 Experiment 7: Virtual Laboratory

Virtual laboratories are platforms used to augment or support student learning in blended education settings (Diwakar et al., 2016). These are beneficial in a remote learning environment as this eliminates the equipment, reagents, and a laboratory space needed for traditional laboratory activities and experiments. For ChE 136, a virtual laboratory exercise was utilized for an experiment on reaction kinetics studies in a batch reactor. The Virtual Labs interface contains relevant concepts and theories, equations, and the simulator. Inside the simulator, a virtual reactor is set-up where different parameters such as reactor volume, initial reactant concentration, and reaction temperature may be adjusted. For the experiment, the students were free to choose the parameters that they wanted to set or adjust depending on the objectives that they wanted to achieve.

3.5 Assessment of student performance

Students in the course were assessed based on the criteria as agreed by the faculty members in-charge as listed in Table 2.

Table 2. List of assessment criteria with their corresponding percentage points.

Assessment Criteria	**Percentage (%)**
Quizzes	15
Post-laboratory reports	60
Oral reports	20
Peer evaluation/Recitation	5
Total	**100**

Figure 3 shows the final ratings received by the students enrolled in the course. In the grading system implemented by UPV, 1.0 is the highest and 5.0 is equivalent to failure. It is also classified descriptively from "Pass" to "Excellent". Based on the results, all the 20 enrolled students passed the course with 55% rated as "Very Good".

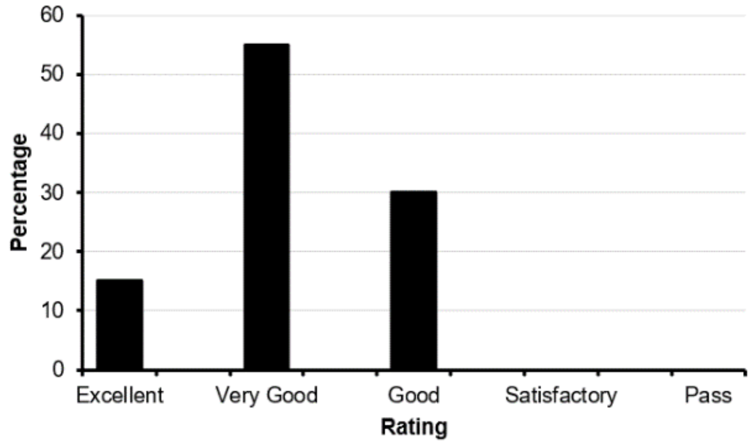

Figure 3. Final rating of students enrolled in ChE 136 last Second Semester Academic Year 2021-2022.

3.6 Assessment of the course

The delivery of the course was assessed by the students at the end of the semester using the OSET before the Final Exam period. There were two sections of ChE 136. Table 3 shows the ratings and comments received by the faculty members handling the course last Second Semester AY 2021-2022. Ratings used in the OSET is from 1 to 5 with 5 as the highest. It can also be expressed descriptively from "*Very Low Teaching Effectiveness*" up to "*Very High Teaching Effectiveness*".

Based on Table 3, all faculty members received *"Very high teaching effectiveness"* score from the students who answered the survey. There were very few written comments from the students but one of them recommended increasing the one (1) week time for post laboratory report submission and improving the video experiments. This is understandable because the video experiments were recorded by amateur faculty members. It is suggested that should the course delivery continue to be remote, videos should be improved in terms of clarity and procedure.

Table 3. OSET results of the faculty members handling ChE 136.

Faculty	**Respondents**	**Description**	**Comments**
Faculty 1	9/10	Very high teaching effectiveness	*"Try to lengthen the time for submissions since one week is not enough and we also have other outputs in other subjects. Try to improve the video experiments since some errors are not addressed which affects our data collection."*
Faculty 2*	9/10	Very high teaching effectiveness	*"Very approachable and considerate in setting deadlines, provides feedback on outputs"*
Faculty 3*		Very high teaching effectiveness	*"Approachable"*

**team teaching*

The quality of the course is improved following the Plan-Do-Check-Act (PDCA) cycle as seen in Figure 4.

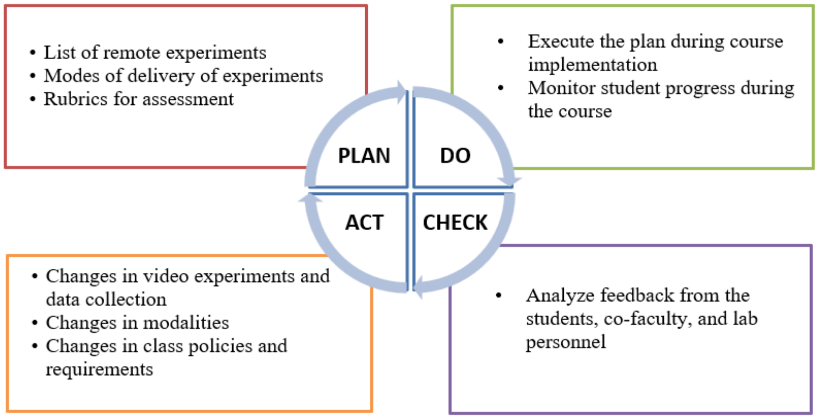

Figure 4. PDCA cycle for ChE 136.

The planning stage involves the listing of the experiments that can be included in the course based on its contribution to the CO's. The modes of delivery are also important, as well as the rubric by which the students are evaluated. Then the implementation of the plan as communicated in the syllabus is monitored throughout the semester. At the end of every semester, the course is assessed based on formal and informal feedback from the students, the faculty, and the lab personnel. Changes in the course is then initiated to address issues and concerns of the stakeholders. The cycle includes adjustments to the data collection procedure, recording of video experiments, class policies including submission timetables, and change in modalities due to ease of access in the laboratory.

4. Conclusions

Due to the COVID-19 pandemic, the course ChE 136: Chemical Engineering Laboratory II of the School of Technology, UP Visayas was delivered in a remote set-up last Second Semester AY 2021-2022. Because students were unable to attend in-person classes, faculty members resorted to video experiments, home experiments, and virtual lab in order to deliver the course. All the students passed the course. The faculty members received high ratings in terms of student feedback. In-person classes should be the ideal mode of delivery but should remote delivery or hybrid delivery be implemented, videos should be improved.

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