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Examples of Virtual Teaching Implementations in Chemical Process Control during the COVID-19 Lockdown

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Examples of Virtual Teaching Implementations in Chemical Process Control during the COVID-19 Lockdown

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Abstract

COVID-19 has caused more than 2.6 million deaths and infected more than 117 million people in the world by March 7, 2021. The high infection rate of this deadly virus had imposed the lockdown of many schools in the US in Spring 2020. This virus has resulted in the switch of the traditional in-person teaching to totally virtual format. This brought significant challenges for teaching engineering courses like Chemical Process Control, in which difficult math operations require high interaction between the instructor and students. In addition, real-life experiments like Proportional-Integral-Derivative (PID) controller design that offers students practical control experience are not able to implement due to the campus lockdown. In this work, we present the approaches implemented in the course Chemical Process Control in Spring 2020 at Villanova University and share the feedback from the students on the virtual teaching format. In particular, every lecture was recorded and annotated note was provided on Blackboard for students. Video-based trainings were given so that students were able to implement the mathematical operations they learned from classes in MATLAB. In addition, MATLAB models were developed by students to simulate typical biochemical processes such as chemical reactors and cell growth in bioreactors. These simulation models offer students a chance to obtain deeper understanding of the processes. In order to offer lifelike experience on data-driven modeling and PID controller tuning, MATLAB models were used as *in-silico* objects for students to practice PID controller tuning. Homework assignments and exams were used to evaluate the students' technical performance. In particular, the same final exam problems as 2019 were used to compare students' performance between the in-person and on-line formats. Two sample t-test indicates that Class 2020 students had better final exam performance than Class 2019 (P-value 0.0059). Two sample t-test was also implemented on the teaching evaluation data for 2019 and 2020 (including evaluation of the teaching effectiveness as it contributed to students' learning, and students' own work in the course). The t-test turns out that the online format got better evaluation in both teaching effectiveness (P-value 3.43-04) and students' engagement (P-value 0.0046). Potential explanations for online format getting better evaluation results are: 1) the recorded videos, provided notes, and Zoom office hours offered students flexibility in the pandemic lockdown; 2) the modeling and simulation assignments provided certain compensation for their practical experience in designing controllers; and 3) additional resources were provided to help students master the skills.

Introduction

Since its outbreak, COVID-19 has caused more than 2.6 million deaths and infected more than 117 million people in the world by March 8, 2021. Due to COVID-19, schools in 150 countries were closed by March 25, 2020, and more school were closed afterwards [1]. Most schools switched to pure on-line format in Spring 2020. Since this switch took place during the spring semester, without any early warning signs, the instructors were required to adapt the new online teaching format. This was very challenging to certain courses that demanded high interaction between students and the instructor. Chemical Process Control is one of such courses. Chemical Process Control, which is within the chemical engineering curriculum at Villanova University, provides an experience in which students must apply their modeling skills to quantify the transient dynamics of chemical processes and thus design controllers with optimal performance. A typical project for students to solve is to design controllers for a chemical reactor to obtain desired quality product in a timely and safety manner. This involves integrating many process steps for heating, pressure change, reaction, and mixing. The most challenging topics in Chemical Process Control include the math-intensive Laplace Transform and the rationale for PID controller tuning. All these require high interaction between the students and the instructor. These make it challenging to switch Chemical Process Control completely to the on-line format.

Program platforms like MATLAB/Simulink and R were found to attract students' interest in math-related topics and equip students with confidence in handling math-related problems [2-5]. Video-based instructions on implementing Chemical Process Control concepts, such as Laplace Transform, transfer function, lead-lag processes and stability of closed loops, may be helpful for students to strengthen their understanding of the concepts. In addition, the Simulink-based models offer students' a friendly interface for students to tune the setting of PID controllers. This may be a good substitute for the onsite PID controller tunning experiment. This work presents the approaches implemented in Chemical Process Control at Villanova University in Spring 2020 after the course was totally moved to the online format. The teaching evaluations were compared between Spring 2019 (onsite format) and Spring 2020 (online format).

Materials and Teaching Methodology

The teaching materials

Detailed online handouts were provided to students before every lecture. All the homework assignments were provided online. All lectures were recorded and provided to students to re-watch if they felt necessary. In addition to these regular teaching materials, the following online materials were provided to facilitate students' on-line learning.

1) Introduction of MATLAB and Simulink, including the basic commands, introduction of MATLAB-installation, user interface, help and plot functions; Data format, operation, import and export; data display-multiple curves, error bars, 3D plotting; data iterative processing - function, looping and logic operation. The detail of the handouts, along with recorded videos can be found in [6, 7].
2) MATLAB Simulink examples for solving ODE models, including the liquid level in a tank with an outlet valve, the enzymatic reaction, the cell population in a fed-batch bioreactor, and the temperature in a CSTR reactor (refer to [7] for more detail of the ODE models). Each example came with a detailed description of the ODE model, along with a video showing step-by-step on how to implement the ODE model in MATLAB Simulink.
3) MATLAB commands and examples to perform Laplace transform and inverse Laplace transform, solve a linear ODE model using the Laplace transform approach, generate complex input signals for a control system, study the behavior of second order systems

with different denominator roots and understand oscillatory dynamics, evaluate the impact of the time constants on lead-lag systems, implement examples for inverse response, and simplify the transfer functions for sequential processes. Recorded videos with 15-25 minute durations were given for these examples. The handouts and videos can be found in [2] and the webpage [8], respectively.

4) Simulink-based platform to evaluate the impact of K_P, K_I and K_D on the performance of PID controllers and to tune PID controllers for controlling the outlet mass fraction of a species in a blending tank. The recorded video and the handout can be found on the webpage [8].

The teaching approaches

Once the course was switched to online format, all the lectures were given on Zoom, with the following approaches:

- A tablet (e.g., a Surface Pro laptop) was used as a virtual projector for annotating notes.
- The breakout rooms were created in Zoom during the lectures to encourage group discussion.
- All lectures were recorded and provided to students.
- Online office hours were provided in Zoom.
- All handouts, homework announcement, homework grading, and recorded lecture links were posted on Blackboard.
- The exams were given online, with monitoring cameras on and after students signed an Academic Integrity Form, which mainly included the following statement "By signing my name in the box below, I pledge that I have taken this exam under all instructions/rules, policies, and guidelines that have been given by my instructor(s), as well as those that also are outlined by the Dept of Chemical and Biological Engineering, College of Engineering, and the University as a whole. In other words, I have not committed a violation of the Academic Integrity code while taking this exam, either to my benefit, or to the benefit of another student"

The evaluation of the online approaches

The performance of the students in homework and exams were evaluated by the instructor. An anonymous teaching evaluation is organized by the university at the end of each semester for each course. Table 1 shows some items listed in the teaching evaluation form. The teaching evaluation results for 2019 (onsite) and 2020 (mostly online) were compared to evaluate the online teaching approaches. The two-sample t-test was performed to compare the teaching evaluation results to identify the items with statistical significance. In addition, the 2019 final exam, which was kept confidential, was given to the 2020 students to quantitively compare students' performance. Although the students in 2019 and 2020 did not have exactly the same academic background, the comparison may still provide certain indication on how the switch to the online format influences students' learning.

Table 1. The Questions in the Teaching Evaluation Evaluation

Item	Questions on the Teaching Approach		Questions on the Students' Learning	
1	Organizes and plans the course effectively.	① ② ③ ④ ⑤	Hard work is required to get good grades in this course.	① ② ③ ④ ⑤
2	Uses class time effectively.	① ② ③ ④ ⑤	I found the course intellectually stimulating.	① ② ③ ④ ⑤
3	Interacts effectively with the students.	① ② ③ ④ ⑤	I attended most class sessions.	① ② ③ ④ ⑤
4	Treats students in a respectful manner.	① ② ③ ④ ⑤	I kept up with the assigned work.	① ② ③ ④ ⑤
5	Is available for help outside of class.	① ② ③ ④ ⑤	I learned a great deal in this course.	① ② ③ ④ ⑤
6	Encourages students to ask questions and participate.	① ② ③ ④ ⑤	To my knowledge there was no cheating in this class.	① ② ③ ④ ⑤
7	Explains course material clearly.	① ② ③ ④ ⑤		
8	Responds effectively to student questions.	① ② ③ ④ ⑤		
9	Provides helpful feedback on student work.	① ② ③ ④ ⑤		
10	Quality of instruction in this course as it contributed to your learning.	① ② ③ ④ ⑤		

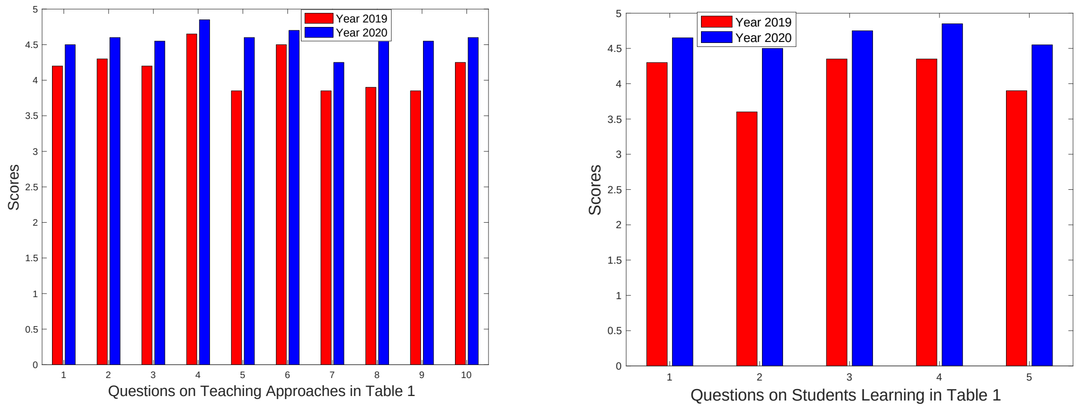
Note: the selection of 5 represents the highest agreement.

Results and Discussion

Evaluation of the online teaching on the basis of the teaching evaluation

Since only the average score for each item in Table 1 was available from the teaching evaluation, the comparison of the teaching evaluation between 2019 (onsite) and 2020 (online) was mainly based upon the average scores of the items shown in Table 1. The evaluation results for the 10 questions on the teaching approaches are shown in Figure 1A. A two-sample t-test was performed for the evaluation results for 2019 and 2020. The students' feedbacks from 2020 are generally better than those from 2019 (p-value 3.43 e-04). In particular, students' feedbacks on Questions 5, 8, and 9 are more positive in 2020 than in 2019. This indicates that the online help sections were more effective in helping students with their questions. Since the online help appointments offered students flexibility in their schedule, this may explain students in 2020 were more positive on those three questions.

While Figure 1A illustrates the evaluation results on the teaching approaches, Figure 1B shows the results for the questions on students' learning. Similarly, a two-sample t-test was performed on the evaluation results, and it turns out that students in 2020 generally had better learning experience than those in 2019 (p-value 0.0046). Compared with the results on teaching approaches, the evaluation results on students' learning experience were not that different between 2019 and 2020. The largest difference is seen in Question 2, in which the students in 2020 found the course intellectually stimulating. One potential reason for this is that lectures were recorded so that students in 2020 might watch the lectures and get inspired more by the control and modeling examples shown in the lectures.



(A) (B)

Figure 1, Evaluations from students in 2019 (onsite) and in 2020 (online) for questions on teaching approaches in Table 1 (A), and for questions on students' learning in Table 1 (B).

Evaluation of the online teaching on the basis of the final exam

The final exam with the same problems was implemented in both 2019 and 2020 to evaluate students' performance in solving controller design questions. The two-sample t-test indicates that the students in 2020 had better performance (p-value 0.0059). Certain potential reasons include:

- students took the final exam in classrooms in 2019, but students in 2020 did it online. Students were given 10 minutes more in the online format to scan and email their solutions. Students had slightly more time in 2020.
- while students had signed the Academic Integrity Agreement and kept their cameras on during the final exam in 2020, it was challenging for the instructor to make sure each of the 57 students was really working on the exam all by himself/herself.
- lectures were recorded and provided to students in 2020. This offered students another chance to check the lectures for the challenging concepts in chemical process control. This may be helpful for students to understand the course materials better.
- although the final exam problems in 2019 are kept confidential by the instructor, students in 2020 may find a way to obtain information on final exams of previous years.

Conclusion and Discussion

This work presents the teaching materials and approached implemented in Chemical Process Control during the COVID-19 pandemic in Spring 2020. The teaching evaluation results from 2019 (onsite) and 2020 (online) were compared using two sample t-test. The same final exam questions were also tested in 2019 and 2020, and the results were also compared. It is surprised to see that students from the online teaching format showed better teaching evaluation and testing scores. This may be due to the recorded lectures that were helpful for students to review some challenging concepts or calculation examples. In addition, the online help sections were preferred by the students, as this offered students with flexibility in their schedule. Recorded MATLAB videos and MATLAB assignments played an important role in enhancing students' practical experience in process control design. This compensates the lack of onsite PID design experiment. The conclusions of this work were based on the comparison of the teaching/testing evaluations between students from 2019 (onsite) and from 2020 (online). The conclusions have limitation, as students from 2019 and 2020 might have different academic background. Although students signed the academic integrity form, academic integrity is still a big issue in exams that are not conducted in person format. A potential approach to addressing these issues is to separate the students into two groups (i.e., onsite and online) and re-do the teaching evaluation.

References

[1] P. Sahu, "Closure of Universities Due to Coronavirus Disease 2019 (COVID-19): Impact on Education and Mental Health of Students and Academic Staff," (in English), *Cureus*, vol. 12, no. 4, Apr 4 2020.

[2] X. H. Li and Z. Y. Huang, "An inverted classroom approach to educate MATLAB in chemical process controlXianhua," (in English), *Education for Chemical Engineers*, vol. 19, pp. 1-12, Apr 2017.

[3] J. Geng, K. Chen, N. Wang, S. Ling, M. Guo, and Z. Huang, "Comparison of R and MATLAB Simulink in Educating High School Students with ODE Modeling Skills " *Chemical Engineering Education* vol. in press, 2018.

[4] C. Ekaputra and Z. Huang, "A Teaching Module for Educating High School Students in Process Control with a Simulink-Based Controller," presented at the ASEE-SE 2015, University of Florida, Gainesville, FL, 2015,

[5] P. Guo, K. Yuan, and Z. Huang, "Develop Web-based Modules to Educate High-School Students in Studying Microbial Fuel Cell Dynamics," presented at the 2017 ASEE Mid Atlantic Section Spring Conference, Baltimore, Maryland, 2017.

[6] S. Nersesov and Z. Huang, "Work in Progress: Development of MATLAB Instructional Modules for Engineering Students," in *2019 ASEE Annual Conference*, Tampa, FL, 2019.

[7] Z. Huang, *Doing Cool Research Projects in Simulating Biochemical Reactors on Computers by a Layperson: MATLAB and R Codes, and Instruction Videos*. Lafayette hill: IVY STEM Outreach Publishing, 2019.

[8] Z. Huang. (2021). Available: https://www1.villanova.edu/villanova/engineering/research/Faculty/biological-environmental-systems-engineering/educational-resources.html