Chemical Engineering Teaching in COVID-19 Times: Successfully Adapting a Capstone Design Course to a Remote Format

Nadia G. Khouri,^{*,†} Michelli Fontana,[†] Igor L. R. Dias,[†] Maria R. W. Maciel, Rubens Maciel Filho, and Adriano P. Mariano

Cite This: <https://doi.org/10.1021/acs.jchemed.1c00445>

Read Online

ACCESS |

Metrics & More

Article Recommendations

ABSTRACT: The coronavirus COVID-19 pandemic required educational institutions to adapt face-to-face to remote teaching. This study reports the experience in the first semester of 2020 for a Chemical Engineering Capstone Design Course at the University of Campinas in Brazil. In this course, senior year students develop a group project, in which they simulate a chemical plant and evaluate its technoeconomic feasibility. In 2020, the groups were proposed to design a process to replace diesel fuel from the bus fleet in Campinas city with renewable fuel DME. Because of the pandemic, several adaptations were needed: the theoretical classes became asynchronous, group meetings were online, a commercial simulator was replaced by an open access one, and the schedule was extended by 2 weeks. Despite that, the students had a great performance, comparable to face-to-face. To assess student satisfaction, a questionnaire was used. The course met the expectations of most of the students who also recommended keeping it in the remote format or merging it with face-to-face teaching. Therefore, these changes made it possible to apply new teaching dynamics and tools that could be used in the future to improve the course quality.

KEYWORDS: Upper-Division Undergraduate, Chemical Engineering, Computer-Based Learning, Distance Learning/Self Instruction, Internet/Web-Based Learning, Problem Solving/Decision Making, Industrial Chemistry

INTRODUCTION

COVID-19 affected more than 1.5 billion students over the world and almost 53 million students in Brazil.^{1,2} One of the main obstacles that instructors and students faced was the need for a fast adaptation to remote classes using digital tools.^{3,4} Beyond the concerns about the new teaching format, they were also worried about health and financial problems.^{5,6} Moreover, limited internet access can be an issue in some regions or even in countries.⁷

Several studies in different areas reported teaching approaches during COVID-19 lockdowns, such as remote classrooms, virtual laboratories, and new strategies for assessments.^{8–20} This reveals the importance of describing teaching experiences and approaches in a pandemic. Such studies contribute to the improvement of education not only during emergency times but also in a postpandemic situation.

Considering this scenario, the University of Campinas (UNICAMP) supported instructors and students in adapting face-to-face classes to remote education. For instructors, the university made available training on remote teaching tools and digital content and conducted virtual meetings to discuss teaching ideas and approaches. For students, UNICAMP

negotiated discounts on contract fees for mobile internet plans and lent computers according to their socioeconomic needs.²¹ The institution also adopted special actions for class withdrawals, leaves of absence, and grading policies. In addition, instructors and students were given access to free psychological assistance.

The entire UNICAMP academic community placed a great effort on quickly adapting the teaching format. At the School of Chemical Engineering (FEQ), the 34 courses offered in the first semester of 2020, including four laboratory courses, were maintained despite the pandemic. One of them was the Capstone Design Course, which is taught to undergraduates in the senior year (5th) of the Chemical Engineering course. It is offered annually in the first academic semester (March–July) for two classes: one in the morning (class A) and another in the

Received: April 17, 2021

Revised: September 19, 2021

Mass and Energy Balances

Figure 1. Schematic diagram of the design activities developed in the 2020 edition of the Capstone Design Course.

evening (class B). In this course, students are asked to design a chemical plant and evaluate its technoeconomic feasibility. In the 2020 edition, the project was the substitution of the diesel fuel used on the Campinas city bus fleet by renewable-based dimethyl ether (DME). Although the general framework of the case study was provided, the students had to define the renewable feedstock and the technology to process the feedstock to the precursor to DME, methanol, considering environmental and logistical concerns.

Before the COVID-19 pandemic, the course was taught face-to-face at FEQ computer laboratories equipped with a commercial process simulator. Then, because of the restrictions imposed by the pandemic, the course was forced to adopt a remote format. This transition was challenging because it required major changes in an academic semester that had already started in a conventional face-to-face format. Thus, this study reports the experience in the transition from face-to-face to remote education in a Capstone Design Course.

In this study, we cover

- The emergency remote teaching experience in a chemical engineering course at a public university in Brazil;
- Course adaptations to an open-source process simulator and changes in the class dynamics;
- Students' performance and engagement;
- Students' feedback regarding the change to remote teaching;
- Instructors' and teaching assistants' (TAs) critical view.

CONTEXTUALIZATION

Capstone Design Course

The duration of the Chemical Engineering undergraduate course at FEQ/UNICAMP is five years, and the Capstone Design Course (30 h), EQ922, is offered in the last year when the students are also completing a mandatory internship and the bachelor dissertation. In EQ922, students are asked to design a

chemical plant considering technoeconomic and environmental aspects. Thus, students must apply fundamental concepts learned throughout the undergraduate degree, such as mass and energy balances, equipment design, and economic analysis. The prerequisites to take EQ922 are EQ791 Techno-Economic Analysis, EQ812 Chemical Reactors, EQ817 Process Control, EQ852 Unit Operations III, and EQ861 Environmental Preservation.

The 2020 project was focused on improving the sustainability of the bus fleet at Campinas, SP, by replacing fossil diesel fuel with renewable DME. A total of 108 students were organized into groups (5 to 6 people) that represented fictional consulting companies. The course was under the responsibility of three instructors (FEQ faculty members) and three TAs. Conventionally, there are two TAs in EQ922 because of the large number of students (~100). The third was voluntary; therefore, it was circumstantial. The number of instructors and students was not different from previous face-to-face course editions.

Project Specification

The project was organized into two main steps (Figure 1). The first step was the design of a renewable methanol production plant, and the second step was the design of a plant that converts the renewable methanol into DME. Each of the steps had its schedule planned based on the time expected to complete early stage (black-box calculations) and preliminary equipment design activities.

The first step, the design of the methanol plant, consisted of an early stage technoeconomic evaluation, classified as FEL-1 in the front-end loading methodology. Each group had to define a renewable feedstock and search for a suitable process based on the literature suggested by the instructors, i.e., research papers on the technoeconomics of potential feedstock-process candidates. This choice should be based on different aspects, such as raw material availability in the region, technology maturity, and environmental impacts. Then, the groups had to

Figure 2. Capstone Design Course at FEQ/Unicamp: student profile, characteristics, and consequences due to the emergency remote teaching format.

estimate the production scale of methanol and DME and the demand for raw material needed to replace all diesel oil consumed by the Campinas bus fleet. Mass and energy balances were conducted in Microsoft Excel spreadsheets using yield, conversion, and utility consumption factors (black-box approach) based on literature data. Also based on a reference study, the groups calculated costs and revenues and used cash flow analysis to calculate the minimum methanol selling price (i.e., the price for which the net present value (NPV) of the cash flow equals zero assuming a discount rate of 10% after taxes). This first step was conceived to train students to conduct FEL-1

activities based on large-block analysis, which is generally used for early stage screening of investment options.

In the second step, students were requested to develop the basic engineering (FEL-2) of a DME plant using a process simulator and to assess its economic feasibility. This activity included the assessment of two options for the catalytic conversion of methanol into DME: option Cat 1 considered a high-temperature gas-phase reaction using a heterogeneous catalyst ($\gamma\text{-Al}_2\text{O}_3$), and option Cat 2 was a low-temperature liquid-phase reaction on an ion-exchange resin (Amberlyst 35).²² This competition between catalysts was the subject of the

Figure 3. Schedule adaptations in the Capstone Design Course in 2020.

American Institute of Chemical Engineers (AIChE) 2018 Design Competition, which was one of the main sources of information for the students. While students were also provided with a technoeconomic study of a DME plant reported by Diemer and Luyben,²³ in which they considered Cat 1 and simulated the plant using Aspen Plus, no reference regarding the process design of a DME plant using Cat 2 was provided for the students.

COURSE ADAPTATIONS

The academic semester started in March 2020, and the first lecture of EQ922 was introductory and held face-to-face on March 9th. However, on March 13th, UNICAMP was the first public university in Brazil²⁵ to suspend all face-to-face academic activities due to the pandemic.²⁴ In the following week, the university adopted an emergency remote teaching format to continue the academic semester, forcing the instructors of EQ922 to adapt the Capstone Design Course for an online format with a new dynamic (Figure 2). Overall, the unexpected events affected some of the tasks' duration, and the schedule had to be changed (Figure 3), but this was mitigated by the two-week extension.

Course Format Planned before the Pandemic Outbreak

The Capstone Design Course would be conducted in a computer lab at FEQ equipped with the commercial process simulator Aspen Plus. Since remote access to the simulator is not allowed by the department's policy, students would have to develop their project mandatorily at the computer lab. Attendance to weekly 2 h class sessions would be mandatory with a minimum frequency of 75%. While most of the sessions would be for practical activities, two sessions were planned to be lectures to present the case study and to review the concepts of technoeconomic analysis. A schedule was proposed for students to keep the development of the project at a constant pace (Figure 3). During the sessions, the groups were expected to ask questions of instructors and TAs and show their progress. Historically, instructors/TAs were generally consulted individually. The course would have 15 weeks and end by late July 2020. At the end of each of the two project steps (Figure 1), students were asked to deliver a written report and a face-to-face presentation.

Course Format During the Pandemic

Lecture classes were adapted to asynchronous remote format. Students could access those video lessons by the Google

Table 1. Major Differences in the Performance of COCO Simulator in Comparison to Aspen Plus in This Project

Equipment	COCO Limitations
Plug flow reactor	It has a limitation in its settings: it is only possible to simulate with the heterogeneous catalyst located in the shell and the heat exchange fluid in the tubes. This specification is a major flaw because the opposite is observed in real life and in Aspen Plus.
Distillation columns	The separation processes are done in a separate program (Chemsep) that has a free access version (Chemsep LITE) and a full version that is commercialized (ChemSep Consortium). The full module can simulate nonequilibrium columns and has a design mode that calculates the tray sizing and the column height. The free access version is more limited compared to the full version and Aspen Plus.

REPORT CORRECTION

Activities evaluated
At each step, we evaluated the following activities:

Step 1		Step 2			
Black Box System		Simulation	Cat. 1	Cat. 2	
Diesel demand	☐	Thermodynamic model	☐	☐	
DME demand	☐	Kinetic model	☐	☐	
Methanol demand	☐	Feed specifications	☐	☐	
Mass balance	☐	Mixers and pumps	☐	☐	
Energy balance	☐	Heat exchangers	☐	☐	
		Reactors	☐	☐	
		Output specifications	☐	☐	
Economic analysis		Economic analysis			
CAPEX	☐	CAPEX	☐	☐	
OPEX	☐	OPEX	☐	☐	
Revenue	☐	Revenue	☐	☐	
Cash Flow	☐	Cash Flow	☐	☐	
Sensitivity analysis	☐	Sensitivity analysis	☐	☐	

Performance of Activities evaluated
We filled the spaces above with colors according to the following criteria:

● Not performed
 ● Many mistakes
 ● Few mistakes
 ● Correct

GRADES

R: Grade of reports (0-10)
Average grade of reports from Step 1 and 2.

OP: Oral presentation grade (0-10)
We evaluated the reasoning, originality, and quality.

PF: Participation Factor (0-1)
Students assessed the participation and engagement of team members.

$$\text{Final Grade (FG)} = \frac{2 \times R + OP}{3} \times PF$$

Figure 4. Criteria to assess the results accuracy and final grade equation used in 2020.

Classroom platform. Beyond that, Google Classroom was used to share content and important information about the course.

Due to lockdown, students did not have access to the computer lab and, consequently, to Aspen Plus. Thus, we had to change the process simulator to open-source software that could be used in this course and that

- Has a databank of all the compounds used (methanol, water, and dimethyl ether);
- Simulates all the unit-operations needed (mixer, pump, heat exchanger, plug flow reactor, and distillation columns);
- Has a variety of thermodynamic models;
- Allows the user to specify any kind of reaction kinetics.

Then, COCO (Cape-Open to Cape-Open) was selected because it fulfilled those requirements, and it is also able to do sensitivity analysis. In addition, the COCO site has several sample flowsheets, including the dehydration of methanol to produce dimethyl ether, that could help the students to develop the simulation.²⁶ In general, the COCO simulator was capable of substituting Aspen Plus. However, it presented some limitations (Table 1) that did not hinder the project.

The regular meetings with instructors and TAs were online during class time using Google Meet and were not mandatory. These meetings were scheduled by the TAs on Google Calendar

according to the group's requests. The meeting invitations were sent to the students' email. Each group had an average of 15 min to clarify any questions about the project progress. All member of the pedagogical team participated in this meeting; therefore, all of them could see the groups' progress. This represents a change in the dynamic of the class, establishing a better interaction between students and instructors. Usually, the regular meetings were not enough to resolve all issues of some groups. For this reason, those groups requested extra class meetings with the TAs. These extra meetings were focused on issues about calculations and technical difficulties related to the COCO simulator. In addition, instructors and TAs were available to answer questions via email.

Due to the uncertainty of returning to face-to-face activities, the first presentation was canceled. In this way, for the first step of the project, students only had to submit the report. After the report correction, students had an online meeting and a feedback document pointing out the necessary corrections for step 2 of the project.

After concluding step 2, students submitted the final report and presented their projects in a collective video call with all groups. Unlike in step 1, students only received written feedback, but they could schedule a meeting to clarify the corrections. Because of all the changes over the period, the

course's end was extended to August (academic week 17). Thus, students could have more time to perform tasks.

STUDENTS' PERFORMANCE AND ENGAGEMENT

In general, all groups developed high-quality projects, as demonstrated by the final grades. The grades were given on the basis of the average grade of the reports from steps 1 and 2, the oral presentation grade, and the participation factor (Figure 4).

Moreover, there were no significant changes on the grades if compared to the face-to-face editions of the course; the average grades for each year were higher than 8.7 (Figure 5). The

Figure 5. Grades distribution along the last years (2018–2020).

standard deviation fluctuated (0.28–0.93); however, all the grades were superior to 7.7, being enough to pass the class (≥ 5.0). Thus, the remote format and the project's scope did not impact the students' performance. This was also observed in other studies.^{14,17} On the other hand, there are reports of greater dropouts by students,⁵ a fact not observed in this Capstone Design Course.

The level of student engagement was analyzed on the basis of their frequency of the regular and extra class meetings whose presence on both was not mandatory (Figure 6A,B). Beyond that, the high demand for extra meetings observed in this semester did not exist before the pandemic; this might be justified by the ease of scheduling online meetings. We observed that, on average, more groups participated in regular meetings in step 1 rather than in step 2 (Figure 6C). This is probably due to the need for the instructors' guidance regarding technological information, such as the types of renewable raw material and processes. In contrast, the number of extra meetings increased in step 2 (Figure 6D). In this stage, students had more questions about using the COCO simulator. Thus, they scheduled more extra meetings with the TAs to solve simulation problems. In addition, days referring to step 1 feedback (academic week 8) and the final presentation (academic week 17) were not counted in the weekly average meetings, but all groups participated in those activities.

At the end of the academic semester, we had the idea to invite a representative of the Campinas Transport Department for a web conference. In this meeting, some groups presented their projects, and important aspects were discussed. The representative appreciated the solutions proposed and offered a real-world perspective of the project's applications and its impacts. The remote format of this course facilitated this reunion because it is usually difficult to arrange face-to-face meetings with professionals from other environments. In the COVID-19 pandemic,

online meetings became usual in people's routines. Thus, this approach could be used in the future editions of the Capstone Design Course.

2020 COURSE EVALUATION

To verify student perceptions about the Capstone Design course remote format, they answered a Google forms questionnaire with the following questions:

- Q1: Did the course meet your expectations? The objective of the first question was to assess if the students enjoyed the course overall and if it managed to incorporate all the characteristics that were constructed along the Chemical Engineering degree.
- Q2: Which project's step did you like the most (step 1, methanol plant; step 2, DME plant)? This question was to observe the preference between an early stage evaluation (step 1) vs preliminary equipment design (step 2). Usually early stage activities are common in our students' internship. On the other hand, the Chemical Engineering course is focused on preliminary equipment design, so those are tasks well-known to the students.
- Q3: Would you recommend the use of a COCO simulator in future course editions? The third question was to recognize if the COCO simulator could satisfy the students' necessities.
- Q4: Would you recommend the Capstone Design Course to be offered remotely in future semesters, even with no pandemic? The last question was to evaluate if this new dynamic can be implemented in future semesters. In addition to the questions, students could also write their comments and suggestions.

Overall, 55 of the 108 students answered the course evaluation questionnaire (Figure 7). The questionnaire results were discussed on the basis of the students' opinions and comments.

Question 1

According to the results collected, the adapted course met most of the students' expectations (Figure 7, question 1). Several factors contributed to this acceptance. Many students were motivated by the project theme because it is a current issue. It is observed that current and relevant problems for society increase student engagement.^{27,28} Another reason that contributed to the course acceptance was the project scope. The students considered that the work was coherent with the fundamentals acquired throughout the Chemical Engineering course. Some of them also highlighted the importance of a schedule (Figure 3), as they were able to organize themselves to carry out the activities within the stipulated deadline. Besides that, the instability of the pandemic affected some students psychologically, which was a common problem observed in other studies.^{16,20} However, the ease of communication with TAs and instructors made students feel heard. Weekly sessions and extra class meetings were essential in this moment. Other studies also observed the importance of communication for successful remote lessons.^{14,17,29} All of these factors indicate that the adaptations were successful. Therefore, despite the adversities, the course objectives were fulfilled.

Question 2

There was a division among students' preferences (Figure 7, question 2). This may be related to the affinity for the different activities for each stage. As discussed before, step 1 is focused in

Figure 6. (A) Number of regular and extra class meetings requested by groups during the academic semester. (B) Weekly average of meetings at each project step. (C) Weekly average of regular meetings at each step. (D) Weekly average of extra class meetings at each step. Note: Weekly average of meetings of the step is the total number of meetings in this step divided by the academic weeks required in such step.

early stage activities, and its calculations were simpler, requiring only Microsoft Excel. On the other hand, step 2 is based on preliminary equipment design, needing a process simulator. Such abilities are developed throughout the Chemical Engineering course, which is an indication of why there is a slight preference.

On the other hand, this behavior may reflect the students' adaptability to the new process simulator. The hypothesis about the simulator adaptability is corroborated by the question 3 answers.

Question 3

Slightly more than half of the students recommended the COCO simulator for future course editions (Figure 7, question 3). Some students liked to learn a new simulator, as this knowledge helped to expand their software variety. Another advantage pointed out by them is that COCO is free and can be accessed from anywhere. Therefore, students did not have to meet in college.

However, others did not approve of COCO. One of the problems students observed was the unfamiliarity with this new software in comparison to Aspen Plus. This process simulator was the most used throughout the Chemical Engineering course. They pointed out the need for prior training for COCO since this was their first contact. Qiang et al.²⁰ also noted this difficulty for students in learning new software. According to the author, students unfamiliar with computational tools take longer to learn how to use them. Beyond that, some students would like to

have the flexibility to choose the simulator. They even suggested using the DWSIM simulator, which is also open access. In addition, students emphasized that open-source simulators should be encouraged during the undergraduate degree. Thus, they could already have been familiar with these tools.

Question 4

Most students recommend offering the course in a remote format for the next semesters, even under regular conditions (Figure 7, question 4). Samuelli et al.¹⁰ also observed that over a half of their undergraduate medical students in a diagnostic pathology course in Israel preferred the remote format.

As discussed in question 1, the instructors' and TAs' availability were essential to this acceptance. Students highlighted the importance of flexibility for extra class meetings and email attendance. Another point is that remote classes facilitate time management since students can participate from anywhere.¹⁰ Typically, students take this course along with an internship and bachelor dissertation. Thus, the remote format simplifies mobility, as it does not require commuting.

Despite the advantages of remote classes, 23.6% of the students prefer a face-to-face format. For them, it would be easier to solve issues in face-to-face classes, especially related to the simulator's technical problems. Alqurshi⁹ reported that his students had difficulty concentrating on virtual meetings and over half of them would like review lectures. Other studies have also pointed out that remote education provides a less interactive environment.^{9,14,15,17,20,29} Problems related to the

Figure 7. Answers to the Capstone Design Course evaluation questionnaire.

internet connection and home office were not reported in our Capstone Design Course. However, other studies have observed that these factors were common and hindered the performance of online courses.^{8,9,13,16}

Students also reported that the situation of physical distance made it difficult for the group to organize and communicate. Some pointed out that the lack of face-to-face meetings generated less engagement, resulting in a slower progress than expected. In contrast, other groups considered that in this format they performed better than in the face-to-face format. Therefore, the ease of group work organization in the remote format is personal. Thus, the students suggested mixing face-to-face and remote classes in the postpandemic editions of the course.

2021 PERSPECTIVE

The 2021 Capstone Design Course had a dynamic similar to that in 2020. We asked the same set of questions of the 2021 classes; 33 out of 91 students answered the questionnaire, and it was possible to compare the 2021 results with those of 2020:

- Q1: The course meets the expectations of 71.0% in 2021 vs 85.5% (2020). The majority of students enjoyed the course in both years.

- Q2: 54.8% in 2021 preferred step 2 vs 52.7% (2020). This corroborates the arguments discussed previously; preliminary equipment design is common to our students.
- Q3: 93.5% in 2021 recommend using COCO vs 52.5% (2020). The 2021 class had used this simulator in other classes, indicating that familiarity was essential.
- Q4: 93.5% in 2021 recommend the remote format vs 76.4% (2020). The 2021 class were used to this format because of their previous classes, showing that this new dynamic can be implemented in future editions.

IMPROVEMENT SUGGESTIONS

Students suggested improvements for the course in the remote format. Many considered that the 15 min time period for regular meetings was insufficient to solve all their questions. They suggested that a single instructor and TA were designated to specific groups; therefore, each group could have more time per meeting without depending on the presence of all instructors and TAs. However, this might limit the pedagogical team's global view of the groups' progression, and also the ability of students to learn with the contributions of all instructors.

Another solution is to use forums for students to share their questions.³⁰ In these forums, students can see the questions and answers already provided to other students. Google Classroom was used in this course and can be applied by students to post their questions and comment on previous answers, but this feature was not fully exploited. Thus, we encourage the use of posts and comments in Google Classroom for future semesters.

INSTRUCTORS' AND TEACHING ASSISTANTS' CRITICAL VIEW

We adapted the Capstone Design Course to the emergency remote format without difficulties and resistance from the students. This new format was enough to aid our students and enabled a great performance of the course, comparable to face-to-face. We highlight that this dynamic success is directly related to our students' profile, focused on internship activities. The use of an open-source simulator and online meetings gives flexibility for the students to develop the projects in any time and place, helping them to manage their internship and bachelor dissertation responsibilities. This approach saves time in commuting, because the presence at the university is no longer necessary in this course. We also had a better rapport of groups and instructors, because all of the pedagogical team could follow their progress, answer their questions, and correct their mistakes in an efficient way. Also, because of the limited time, the students already came with the questions previously prepared. Thus, they participated more actively in the discussions that were more focused.

This experience was a great opportunity for us to improve our teaching and software skills, despite the challenges caused by the pandemic. The process simulator COCO was new for everyone, and we had to dedicate some time to study and understand how the simulator works to help students. However, this simulator could be used in the course without adaptations of the project. We encourage instructors to use open access simulators, which could be an alternative to universities that cannot afford commercial simulators. Beyond that, the remote class also implied an enhancement of our knowledge in Google tools such as Classroom, Meets, Forms, and Calendar, which are really useful for managing online work. Therefore, we recommend applying this dynamic for similar courses even with no pandemic.

CONCLUSION

The COVID-19 pandemic required the adjustment of face-to-face classes to the remote format. This sudden change in an unstable scenario was challenging for instructors and students. Regardless, we managed to adapt the Capstone Design Course as a remote class without reducing the teaching quality. The students accepted the new format well and fulfilled the course's objectives. The constant presence of instructors and TAs was essential to ensure a great class performance and engagement. This new format provided the learning of new tools and techniques. These may be implemented in future editions of the course even after the pandemic, allowing an improvement and modernization.

AUTHOR INFORMATION

Corresponding Author

Nadia G. Khouri — Department of Process and Product Development, School of Chemical Engineering, University of Campinas, 13083-852 Campinas, São Paulo, Brazil;

orcid.org/0000-0002-2954-4947;
Email: khouri.g.nadia@gmail.com

Authors

Michelli Fontana — Department of Process and Product Development, School of Chemical Engineering, University of Campinas, 13083-852 Campinas, São Paulo, Brazil;

orcid.org/0000-0003-1855-3343

Igor L. R. Dias — Department of Process and Product Development, School of Chemical Engineering, University of Campinas, 13083-852 Campinas, São Paulo, Brazil

Maria R. W. Maciel — Department of Process and Product Development, School of Chemical Engineering, University of Campinas, 13083-852 Campinas, São Paulo, Brazil

Rubens Maciel Filho — Department of Process and Product Development, School of Chemical Engineering, University of Campinas, 13083-852 Campinas, São Paulo, Brazil

Adriano P. Mariano — Department of Process and Product Development, School of Chemical Engineering, University of Campinas, 13083-852 Campinas, São Paulo, Brazil;

orcid.org/0000-0003-2934-992X

Complete contact information is available at:
<https://pubs.acs.org/10.1021/acs.jchemed.1c00445>

Author Contributions

[†]N.G.K., M.F., I.L.R.D. contributed equally.

Notes

All opinions expressed here are personal and do not represent a position of the University of Campinas.
The authors declare no competing financial interest.

ACKNOWLEDGMENTS

This work was executed with support from grants 2015/20630-4, 2019/24071-0, and 2019/03019-0, São Paulo Research Foundation (FAPESP); CNPq, National Council for Scientific and Technological Development, Brazil; and Coordenação de Aperfeiçoamento de Pessoal de Nível Superior—Brazil (CAPES), Finance Code 001. We acknowledge the University of Campinas and the School of Chemical Engineering, Campinas, SP, Brazil. We are also grateful for the students of the Capstone Design Course of the first semester of 2020 and 2021.

REFERENCES

- (1) UNESCO. Education: From disruption to recovery. <https://en.unesco.org/covid19/educationresponse> (accessed Sep 10, 2020).
- (2) UNESCO. Global Education Coalition. <https://en.unesco.org/covid19/educationresponse/globalcoalition> (accessed Sep 10, 2020).
- (3) Clark, T. M.; Callam, C. S.; Paul, N. M.; Stoltzfus, M. W.; Turner, D. Testing in the Time of COVID-19: A Sudden Transition to Unproctored Online Exams. *J. Chem. Educ.* **2020**, *97* (9), 3413–3417.
- (4) Davison, R. M. The Transformative Potential of Disruptions: A Viewpoint. *International Journal of Information Management*. **2020**, *55* (May), 102149.
- (5) Aucejo, E. M.; French, J.; Ugalde Araya, M. P.; Zafar, B. The Impact of COVID-19 on Student Experiences and Expectations: Evidence from a Survey. *Journal of Public Economics*. **2020**, *191*, 104271.
- (6) Krishnamurthy, S. The Future of Business Education: A Commentary in the Shadow of the Covid-19 Pandemic. *Journal of Business Research*. **2020**, *117* (May), 1–5.
- (7) UNESCO. UNESCO reaffirms need for Internet Universality, amid intensified threats. <https://en.unesco.org/news/unesco>

reaffirms-need-internet-universality-amid-intensified-threats (accessed Nov 2, 2021).

(8) Dietrich, N.; Kentheswaran, K.; Ahmadi, A.; Teychene, J.; Bessiere, Y.; Alfenore, S.; Laborie, S.; Bastoul, D.; Loubiere, K.; Guigui, C.; Sperandio, M.; Barna, L.; Paul, E.; Cabassud, C.; Line, A.; Hebrard, G. Attempts, Successes, and Failures of Distance Learning in the Time of Covid-19. *J. Chem. Educ.* **2020**, *97* (9), 2448–2457.

(9) Alqurshi, A. Investigating the Impact of COVID-19 Lockdown on Pharmaceutical Education in Saudi Arabia – A Call for a Remote Teaching Contingency Strategy. *Saudi Pharm. J.* **2020**, *28* (9), 1075–1083.

(10) Samueli, B.; Srer, N.; Jotkowitz, A.; Taragin, B. Remote Pathology Education during the COVID-19 Era: Crisis Converted to Opportunity. *Ann. Diagn. Pathol.* **2020**, *49*, 151612.

(11) Sansom, R. L. Pressure from the Pandemic: Pedagogical Dissatisfaction Reveals Faculty Beliefs. *J. Chem. Educ.* **2020**, *97* (9), 2378–2382.

(12) Stowe, R. L.; Esselman, B. J.; Ralph, V. R.; Ellison, A. J.; Martell, J. D.; Deglopper, K. S.; Schwarz, C. E. Impact of Maintaining Assessment Emphasis on Three-Dimensional Learning as Organic Chemistry Moved Online. *J. Chem. Educ.* **2020**, *97* (9), 2408–2420.

(13) Bhute, V. J.; Campbell, J.; Kogelbauer, A.; Shah, U. V.; Brechtelsbauer, C. Moving to Timed Remote Assessments: The Impact of COVID-19 on Year End Exams in Chemical Engineering at Imperial College London. *J. Chem. Educ.* **2020**, *97* (9), 2760–2767.

(14) Jamieson, M. V. Keeping a Learning Community and Academic Integrity Intact after a Mid-Term Shift to Online Learning in Chemical Engineering Design during the COVID-19 Pandemic. *J. Chem. Educ.* **2020**, *97* (9), 2768–2772.

(15) Li, C. H.; Rajamohan, A. G.; Acharya, P. T.; Liu, C. S. J.; Patel, V.; Go, J. L.; Kim, P. E.; Acharya, J. Virtual Read-Out: Radiology Education for the 21st Century During the COVID-19 Pandemic. *Academic Radiology*. **2020**, *27* (6), 872–881.

(16) Nogales-Delgado, S.; Roman Suero, S. R.; Martín, J. M. E. COVID-19 Outbreak: Insights about Teaching Tasks in a Chemical Engineering Laboratory. *Education Sciences*. **2020**, *10* (9), 226.

(17) O'Carroll, I. P.; Buck, M. R.; Durkin, D. P.; Farrell, W. S. With Anchors Aweigh, Synchronous Instruction Preferred by Naval Academy Instructors in Small Undergraduate Chemistry Classes. *J. Chem. Educ.* **2020**, *97* (9), 2383–2388.

(18) Ong, M. T. Y.; Ling, S. K. K.; Wong, R. M. Y.; Ho, K. K. W.; Chow, S. K. H.; Cheung, L. W. H.; Yung, P. S. H. Impact of COVID-19 on Orthopaedic Clinical Service, Education and Research in a University Hospital. *Journal of Orthopaedic Translation*. **2020**, *25*, 125–127.

(19) Patel, P. M.; Tsui, C. L.; Varma, A.; Levitt, J. Remote Learning for Medical Student-Level Dermatology during the COVID-19 Pandemic. *J. Am. Acad. Dermatol.* **2020**, *83* (6), e469–e470.

(20) Qiang, Z.; Obando, A. G.; Chen, Y.; Ye, C. Revisiting Distance Learning Resources for Undergraduate Research and Lab Activities during COVID-19 Pandemic. *J. Chem. Educ.* **2020**, *97* (9), 3446–3449.

(21) UNICAMP. Unicamp students can hire special mobile internet plans (in Portuguese). <https://www.unicamp.br/unicamp/noticias/2020/04/17/alunos-da-unicamp-podem-contratar-planos-especiais-de-internet-movel> (accessed Dec 9, 2020).

(22) American Institute of Chemical Engineers. Production and Cost Analysis of Dimethyl Ether for Transportation. https://www.aiche.org/sites/default/files/node/aiche-student-design-competition/production_and_cost_analysis_of_dimethyl_ether_for_transportation.pdf (accessed Dec 9, 2020).

(23) Diemer, R. B.; Luyben, W. L. Design and Control of a Methyl Acetate Process Using Carbonylation of Dimethyl Ether. *Ind. Eng. Chem. Res.* **2010**, *49* (23), 12224–12241.

(24) UNICAMP. Resolution GR-024/2020. Attorney General of UNICAMP, 2020. https://www.pg.unicamp.br/mostra_norma.php?id_norma=17655 (accessed Dec 9, 2020).

(25) G1. Unicamp announces suspension of activities due to the coronavirus; it is the first public university in Brazil to take action, says MEC (in Portuguese). <https://g1.globo.com/sp/campinas-regiao/>

[noticia/2020/03/12/unicamp-anuncia-suspensao-das-atividades-por-conta-do-coronavirus.ghtml](https://g1.globo.com/sp/campinas-regiao/noticia/2020/03/12/unicamp-anuncia-suspensao-das-atividades-por-conta-do-coronavirus.ghtml) (accessed Dec 9, 2020).

(26) COCO Simulator. Sample flowsheets. https://www.cocosimulator.org/index_sample.html (accessed Apr 1, 2020).

(27) Talanquer, V.; Bucat, R.; Tasker, R.; Mahaffy, P. G. Lessons from a Pandemic: Educating for Complexity, Change, Uncertainty, Vulnerability, and Resilience. *J. Chem. Educ.* **2020**, *97* (9), 2696–2700.

(28) Youssef, M.; McKinstry, E. L.; Dunne, A.; Bitton, A.; Brady, A. G.; Jordan, T. Developing Engaging Remote Laboratory Activities for a Nonmajors Chemistry Course during Covid-19. *J. Chem. Educ.* **2020**, *97* (9), 3048–3054.

(29) Kollalpitiya, K. Y.; Partigianoni, C. M.; Adsmund, D. A. The Role of Communication in the Success/Failure of Remote Learning of Chemistry during Covid-19. *J. Chem. Educ.* **2020**, *97* (9), 3386–3390.

(30) Dwivedi, Y. K.; Hughes, D. L.; Coombs, C.; Constantiou, I.; Duan, Y.; Edwards, J. S.; Gupta, B.; Lal, B.; Misra, S.; Prashant, P.; Raman, R.; Rana, N. P.; Sharma, S. K.; Upadhyay, N. Impact of COVID-19 Pandemic on Information Management Research and Practice: Transforming Education, Work and Life. *International Journal of Information Management*. **2020**, *55* (July), 102211.