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Lessons Learned From Hybrid Face-to-Face and Virtual Teaching of Various Industrial Engineering Courses During the COVID-19 Pandemic

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1. Introduction

1.1. Impact of COVID-19 pandemic on higher education

The coronavirus disease 2019 (COVID-19) pandemic had an unprecedented socioeconomical impact worldwide. Global economic losses incurred by COVID-19 are estimated at 21 trillion dollars in 2020 alone, which is nearly equal to the annual U.S. GDP in 2019 [1]. The COVID-19 pandemic also impacted social aspects of daily lives including educational, political, and religious activities [2]. Specifically, in university classrooms, the COVID-19 pandemic restricted traditional face-to-face delivery of educational content. Such restrictions have enforced higher education institutions (e.g., colleges and universities) to seek alternative ways to deliver the course contents while maintaining their quality. Many institutions in the U.S. opted for offering virtual classes using internet-based platforms.

However, such rapid transformation into virtual education precipitated by the pandemic has yet to be examined in terms of its efficiency and effectiveness, particularly compared to the traditional face-to-face mode. In 2020, several studies investigated the online delivery of university classes with a focus on how efficient and effective it can be despite unexpected challenges for both instructors and students. While undergraduate students' performance in virtual classrooms was found to be similar to or even better than in the face-to-face classroom environment [3], the sudden transition to virtual education generated new and unusual challenges (e.g., [4]–[6]). Both instructors and students experienced difficulties in adapting to the virtual classrooms, especially because they had to become accustomed to new technologies and remain concentrated despite various distractions, restrictions to working space, increased burden on mental health, and privacy issues [7], [8].

1.2. The hybrid model of teaching

A large public university in Texas offered over 50% of Fall 2020 classes on a hybrid model. In this hybrid model, instructors provided face-to-face lectures to students who chose to be physically present in their classrooms while live-streaming and video-recording their lectures for both the synchronous and asynchronous delivery to the rest of the students. To accommodate different needs of learners and motivate students, instructors had to employ a mixture of instructional methods and adopt them rapidly and flexibly.

1.3. Objectives

This paper shares multiple instructors' hands-on experiences of teaching industrial engineering (IE) courses in a hybrid model under COVID-19 pandemic conditions, including challenges encountered and lessons learned from such adaptations. Learning from such adaptations may contribute to resilient responses to future disruptions to traditional teaching modes.

2. Method

2.1. Recruitment

Semi-structured interviews were conducted with faculty members in an Industrial and Systems Engineering Department in a large public university in Texas. Faculty members who taught in the hybrid model (both in class and virtual synchronously) in the Fall 2020 semester were identified from the course catalog. Invitation to participate was sent through email. Of the 19 faculty members who were qualified, 11 agreed to participate. The interviews took 15 to 30 minutes.

2.2. Procedure

A semi-structured interview protocol was designed by the research team to understand challenges encountered and adaptations made while teaching under the hybrid model. The interviews were conducted by two of the authors (XW and FS) who are doctoral level (postdoctoral fellow and faculty) researchers trained in interview techniques. All interviews were conducted via Zoom [9] and were recorded. The audio recordings were then transcribed using Otter.ai [10], an automated transcription software program, and refined manually. The study was approved by the university's Institutional Review Board.

2.3. Analysis

Two of the authors (XW and JM), including a postdoctoral fellow and a doctoral student (recently defended; degree conferral forthcoming), and one undergraduate student (GF) trained in qualitative methods conducted a thematic analysis [11] on the interview transcripts. The three coders finished coding independently based on the interview protocol. Then they met to discuss the codes and build a consensus among the coders.

3. Results

3.1. Demographic characteristics of participants

Table I summarizes the years of experience in teaching, type of the course taught in Fall 2020, number of times the course was taught before, and number of students registered in the course.

TABLE I
SAMPLE CHARACTERISTICS

Participant No.	Years of Experience	Course Type	Number of Times the Same Course Taught Before	Number of Students
1	<1	Undergraduate	0	52
2	21	Undergraduate	3 in person	13
3	34	Undergraduate	2 in person	52
4	4	Graduate	3 in person	9
5	7	Undergraduate	6 in person, 1 online	55
6	1	Undergraduate	3 in person	54

7	<1	Undergraduate	1 in person, 1 online	40
8	25	Graduate	5 in person	32
9	22	Undergraduate	~20 in person, 1 online	81
10	9	Graduate	4 in person	26
11	<1	Undergraduate	0	90

3.2. Findings from interviews

3.2.1. Overall experience

All of the participants (11/11) indicated that teaching in the hybrid model was more difficult compared to in person. For the four participants who had experience teaching online-only courses, two indicated that the hybrid model was more difficult compared to online-only, and two indicated that it was similar to online-only. When asked whether they liked anything about the hybrid model, most participants (10/11) indicated that they did not perceive anything positive for instructors. Only one participant recycled the videos recorded for a previous online session and used class time to solve example problems, and so experienced less workload preparing the lectures. When probed on potential advantages of teaching under this hybrid model, five participants mentioned that an advantage of the hybrid model for students was the flexibility to attend in person, attend online, or watch the video asynchronously.

> *The only thing is that it really does provide choice for the students to attend or not attend under the pandemic. But otherwise, it was more challenging to me. – P1*

3.2.2. Unique challenges

A vast majority of participants (9/11) reported lack of feedback from learners as a common difficulty under the virtual platform. With most students joining the lectures virtually (e.g., via Zoom), instructors found it hard to "gauge how much students were engaged and [if they] were able to grasp all the concepts," and two participants specifically mentioned that it was hard to make a connection with students compared to the traditional face-to-face method.

A majority of participants (7/11) pointed out attention allocation as another unique difficulty experienced. Participants indicated that there was increased workload to "coordinate so many things at the same time." Instructors received questions from students in the classroom, students speaking over Zoom, or questions sent through Zoom chat box at the same time. Instructors also needed to juggle between two sides – repeating questions asked in the classroom to students on Zoom, or read questions that were brought up through the chat box. It was also distractive to monitor and ensure that the delivery of both synchronous and asynchronous lectures was working properly.

> *I had the Zoom recording, I had the slides, my own writing on the board…I have to listen to the questions from Zoom, and from the students who were in the classroom. Sometimes people ask questions through the chat box, which was very hard for me to follow. – P8*

Several other difficulties were also identified from our interviews. Two participants had technical difficulties using functions or features of Zoom or projecting to the classroom and Zoom at the same time. One participant stated that accommodating students who were infected with COVID-19 or under self-quarantine was challenging.

3.2.3. Attendance

All of the participants indicated that a majority of students chose to attend the course online, and that the overall attendance decreased throughout the semester. Majority of participants (6/11) mentioned that the number of students in the classroom dropped quickly within a few weeks into the semester.

> *The first week I was having close to 20 people come to class. And then after two weeks, it was down to around six on average. – P7*

3.2.4. Online participation

A majority of participants (8/11) indicated that there was less participation, e.g., asking questions, responding to questions, and participating in class activities, from online attendees compared to in-person attendees of the same class. Four participants mentioned that they noticed a few students being active, but the majority of students were very passive.

> *So normally, in my in-person courses, they are more discussion based where I ask questions…compared to in-person, both online and hybrid were disappointing compared to previous times I taught it. – P5*

> *But overall participation was kind of dominated by, I would say, maybe two, three, maximum four students, they would be the ones always asking questions, whether in class, during the Zoom session, or even outside of the classroom. The rest of them were kind of passive. – P2*

3.2.5. Adaptations made for in-class activities

Adaptations were made for class activities such as in-class exercises and group discussions. Four participants stated that they initially had Q&A time for in-class exercises, but these activities were discontinued because of the lack of feedback or inconvenience of communicating to both virtual and in-person students. For similar reasons, two participants canceled group discussion sessions for their courses.

Two participants tried using the Zoom breakout room function for group discussion. Two other participants mentioned using polls to help engage students. Also, two other participants mentioned using more help from teaching assistants to moderate virtual discussions.

3.2.6. Adaptations made for exams

Exams were held online for the hybrid classes and typically proctored on Zoom. A vast majority of participants (9/11) indicated that there were more integrity concerns and difficulty in proctoring with online exams. To address the issue, five participants chose to make the exam open book; three participants mentioned designing longer and more challenging exams to reduce the odds of collaboration; two participants prepared different versions of the exam papers to avoid cheating; and one participant switched to take-home exam. Only four participants indicated that they had enough support in proctoring exams.

> *So, one thing I did make this time for the exams is fully open book. Because of the academic integrity issues, I was not sure how much I can actually ensure that the students would not collaborate or cheat even with the zoom video on. So, what I instead did was to make all the exams open book, but also at the same time made the questions more challenging. – P4*

3.2.7. Efficiency and effectiveness of delivering knowledge

Participants were asked if they felt more or less efficient in delivering lectures or knowledge using the hybrid model. Eight participants indicated that they felt less efficient, and three participants indicated that they felt similar; thus, none felt more efficient with the hybrid method. Of the eight participants who felt less efficient, six mentioned lack of feedback, three mentioned attention allocation, and two mentioned technical issues as the reasons.

> *This is definitely less efficient. I mean, there's no doubt about it. So, because of this split set of students, you have to kind of make sure that all of them are following along to the best possible extent. When we have it in class, it's much easier. And you can see facial expressions and all that, and I can easily adjust the speed of the course based on visible cues, which is lacking in this particular format. – P2*

> *Definitely less efficient, again, this attending to both online and in class, I think slowed me down. And it was much harder for me to make sure I'm attending to both visually, but also attending to chat and raised hands and repeating questions. So, it really added time and effort. – P10*

3.2.8 Changes in student performance

Five participants mentioned that the overall academic performance of students dropped compared to previous semesters before the COVID-19 pandemic started. Three participants indicated that some students had very low grades. Participants mentioned that students who struggled on the course found it harder to recover from challenges during the pandemic.

> *And that is from student assessment that they're saying that during a normal semester, they probably would have tried more after that failure. But with everything that is going on, it was a lot easier just to give up…So that I do think that the situation in the last year has definitely played a role based on their statements. – P5*

One participant mentioned that students were experiencing more stress during the transition.

> *I think it was very difficult for students as well, because they were going through lots of stress, and it was difficult for them to transition. They have four or five courses and for every course instructors are trying different things. So as a student, it becomes difficult for you to keep up with everything because every instructor has slightly different rules for their course and the lecture delivery is slightly different. The demand of the course is slightly different. So, I think that might have contributed to the drop in the performance of the students. – P6*

3.2.9. Resources

When asked whether faculty were provided with enough human and technical resources to effectively implement the hybrid model, only four participants indicated that they had all the resources they needed. Five participants mentioned experiencing technical issues, or needing additional technical resources, such as a second monitor in the classroom to monitor the online students. Similarly, one participant mentioned needing additional human resources (e.g., teaching assistant and grader) to help monitor online students.

> *It would be better if…there were two screens in the classroom. I can probably ask students [to] turn on the cameras. So, I can kind of see their reactions. And I am familiar with Zoom, but I know that some professors do not know Zoom pretty well. – P1*

> *…while I'm lecturing, I can't be reading the chat…But having somebody monitor the chat, and monitor if you have the ability to have people turn on their videos so that you can monitor their facial responses to things, then I think having some of that go on could be very valuable for an online class…to have more human support on the instructor side, to keep people engaged and to keep the pace the way it should be. – P3*

3.2.10. Lessons learned

Participants were asked to describe overall lessons learned from teaching using the hybrid model and plans for addressing the issues if they needed to teach under the same settings again. Five participants said they would require online students to turn on cameras to collect feedback and improve engagement. Five participants stated they would use more monitors or seek help from teaching assistants to keep track of online students' questions and feedback. Five participants mentioned that they would attempt to experiment on methods for interactive activities to engage students taking online classes. Four participants called for better solutions for group discussions. Two participants planned to set up rules for asking questions on Zoom to reduce distractions and interruptions. Two participants planned to require attendance or proof of watching lecture videos to improve students' learning outcome.

I think if I have to teach again in future, one thing definitely I would like to do is make the online teaching more interactive, make students switch on their webcam, make it compulsory that they cannot turn their webcams off, make it look more like a face to face class…would like to have more groups, group discussion sessions, at regular intervals, let's say up every month, I can devote like 15 minutes for discussion and question-answer session so that each student can participate. So, participation is the key thing which was lacking in online mode. And that's where I would like to focus more…I can say that was the learning part that in online teaching method, student participation is very difficult to have. So, one should focus on that and I would focus on that if I'm doing this next time. – P6

3.2.11. Challenges Specific to IE

While challenges summarized above may apply to most engineering courses, several participants mentioned challenges that are more specific to IE courses. IE covers a wide spectrum of topics including programming, simulation, and mathematical modeling/theory, each of which were affected by the hybrid model of teaching.

Two participants mentioned the technical difficulties of teaching courses with mathematical modeling contents (e.g., operations research), which typically involve handwriting (e.g., solving problems on a white/blackboard) in addition to making sure the content is projected to both in the class and virtual students.

So, there were quite a few technical issues making sure that [when] I annotate, I do not have a PowerPoint slide. So, I actually do everything by hand. So, I was using my iPad and going through the derivations, formulas, and all of that. So, to project that screen, both in person I mean, in the class, as well as on the zoom. And having that also recorded at the same time. It was quite a bit of mess because some new trouble [happened] almost every day. – P4

So, some of our equipment for our particular building arrived too late. And like I said, the format isn't set up well for working on the board whatsoever, which is, it's much more necessary in like, mathematics-based concepts. I'm not saying it's not impossible to do otherwise. But PowerPoints are largely pointless prep for class like this and working on tablets was difficult because the control and writing even if you have a relatively sensitive screen. – P5

One participant mentioned the difficulty of teaching programming languages, since providing assistance on coding in real-time is more efficient in a face-to-face setting compared to providing feedback offline or remotely.

This class actually is a very hands-on class. So, the students that came to class, I actually had a much better time along with the TA. She would come to the class also, to help them I mean, sometimes the code doesn't work. So, we stand a few feet away and tell them, okay, go do this, go do that. And most of the time, the

> *errors could be identified and resolved. Whereas the same thing was much more challenging for the online students; they had to email the code, and we had to look at it and then respond back. – P2*

One participant reported technical issues in teaching a simulation course, specifically with providing simulation software remotely through virtual machine.

> *Of course, we have issues with these virtual machines…that has been nagging us; people that teach simulation; all the time, because Simio* [12] *and all these other software run extremely slowly on that and most of the time students have to buy their own copy…People have issues especially when they have to remotely log in some of the software products that we have. They are extreme resource hogs, and this virtual machine is not prepared very well to cater to such kind of software. – P2*

4. Discussion

This paper presented some of the challenges of COVID-19 associated with sudden transition to the hybrid model of teaching and adaptations made to deal with the challenges for a subset of courses taught in a large Industrial and Systems Engineering department. In particular, we found that instructors had difficulties with divided attention (i.e., attending to both in-class and online attendees) when delivering hybrid classes as well as with motivating the students to learn and engage. Such findings confirm the negative impacts of the pandemic on higher education such as reduced motivation and diminished academic performance [13]. While similar issues related to virtual education have been acknowledged in the literature [14], our study documented some of the unique challenges of a hybrid model of teaching where instructors need to attend to students attending the course via different modalities. Given the potential for extended restrictions and new variants, the hybrid instructional model may be used in the future; therefore, it is timely to identify challenges in delivering courses in such hybrid mode to alleviate the negative effects of the ongoing pandemic on higher education proactively.

While the overall experience of the participants in this study was generally negative, in line with the literature [e.g., 14], we found evidence of students' positive attitude towards such hybrid model of teaching mainly due to flexibility it offers. However, future research is needed to identify ways to satisfy the needs of both instructors and students of hybrid classes. While our study identified that instructors adapted their methods of class activities and exams to the hybrid model, it remains unclear whether such adaptations were actually effective in providing necessary knowledge to students and motivating them to learn and participate in classes more actively. In such regards, future research is warranted to elicit student feedback to understand the contributors to lower engagement or degraded performance associated with this hybrid teaching mode as well as to measure a wider range of learning and performance outcomes to inform the development of solutions that make hybrid classes beneficial for both instructors and learners.

Finally, we found that additional efforts are necessary to provide technical support to instructors for improved hybrid teaching. Particularly, some of the participants in our study reported difficulties utilizing features of online technologies (e.g., Zoom) for interactive Q&A sessions,

small group breakout sessions, and proctoring exams. To mitigate such difficulties in future hybrid classes, sufficient support should be provided to instructors such as specialized training on existing and emerging technical tools and programs for dual-mode class management, online proctoring, and student engagement.

Several limitations of the current study are noteworthy. First, this study involved feedback from a small subset of faculty and was limited to the Industrial and Systems Engineering courses. While we reached saturation even with this small sample size, more work is needed to evaluate the generalizability of these findings to a wider of range of engineering and non-engineering disciplines (e.g., with more emphasis on in-class discussions/activities). In addition, while some (4/11) of the participants in this study had experience teaching the same course in an online-only mode, most only had experience in an in-person only mode. More work is needed to compare our findings to other modes of delivery (e.g., virtual-only classes) in the same period to understand if these findings were indeed unique to the hybrid model of teaching. Finally, we only captured feedback from the instructors who taught hybrid classes during the current pandemic. A more holistic understanding of the challenges requires input from a wider range of stakeholders including students, administrators, teaching assistants and technical support personnel.

5. Conclusions

The COVID-19 pandemic has brought unforeseen challenges to higher education. This paper provided findings focused on several industrial and systems engineering instructors' account of difficulties experienced with the hybrid teaching and adaptations exercised to cope with the difficulties. As negative impacts of the current pandemic are expected on a prolonged basis, work is needed to identify technical and training support needs and expectations from various system-level stakeholders. Additional efforts are necessary to develop robust teaching methods in which both instructors and students can achieve their goals in a hybrid teaching model while minimizing risks and complying with safety and health guidelines.

Reference

[1] W. McKibbin and R. Fernando, "Economics in the Time of COVID-19," *VOX, CEPR Policy Portal*. https://voxeu.org/content/economics-time-covid-19 (accessed Mar. 05, 2021).

[2] M. Nicola *et al.*, "The socio-economic implications of the coronavirus pandemic (COVID-19): A review," *Int. J. Surg. Lond. Engl.*, vol. 78, pp. 185–193, Jun. 2020, doi: 10.1016/j.ijsu.2020.04.018.

[3] M. L. George, "Effective teaching and examination strategies for undergraduate learning During COVID-19 school restrictions," *J. Educ. Technol. Syst.*, vol. 49, no. 1, pp. 23–48, Sep. 2020, doi: 10.1177/0047239520934017.

[4] B. L. Moorhouse, "Adaptations to a face-to-face initial teacher education course 'forced' online due to the COVID-19 pandemic," *J. Educ. Teach.*, vol. 46, no. 4, pp. 609–611, Apr. 2020, doi: 10.1080/02607476.2020.1755205.

[5] T. Kanij and J. Grundy, "Adapting teaching of a software engineering service course due to COVID-19," in *2020 IEEE 32nd Conference on Software Engineering Education and Training (CSEE T)*, Nov. 2020, pp. 1–6. doi: 10.1109/CSEET49119.2020.9206204.

[6] Daniel C. Barton, “Impacts of the COVID-19 pandemic on field instruction and remote teaching alternatives: Results from a survey of instructors,” *Ecol. Evol.*, vol. 10, no. 22, pp. 12499–12507, Aug. 2020, doi: 10.1002/ece3.6628.
[7] L. Mishra, T. Gupta, and A. Shree, “Online teaching-learning in higher education during lockdown period of COVID-19 pandemic,” *Int. J. Educ. Res. Open*, vol. 1, p. 100012, Jan. 2020, doi: 10.1016/j.ijedro.2020.100012.
[8] R. Sunasee, “Challenges of teaching organic chemistry during COVID-19 pandemic at a primarily undergraduate institution,” *J. Chem. Educ.*, vol. 97, no. 9, pp. 3176–3181, Sep. 2020, doi: 10.1021/acs.jchemed.0c00542.
[9] Zoom Video Communications, “Zoom,” 2020. https://zoom.us/ (accessed Mar. 05, 2021).
[10] Otter.ai, “Otter Voice Meeting Notes,” *Otter Voice Meeting Notes*, 2020. https://otter.ai/ (accessed Mar. 05, 2021).
[11] V. Braun and V. Clarke, “Using thematic analysis in psychology,” *Qual. Res. Psychol.*, vol. 3, no. 2, pp. 77–101, 2006, doi: 10.1191/1478088706qp063oa.
[12] Simio LLC, “Simio,” 2020. https://www.simio.com/ (accessed May 23, 2021).
[13] M. Adnan and K. Anwar, “Online learning amid the COVID-19 pandemic: Students’ perspectives,” *J. Pedagog. Sociol. Psychol.*, vol. 2, no. 1, pp. 45–51, Jun. 2020, doi: 10.33902/JPSP. 2020261309.
[14] M. Kebritchi, A. Lipschuetz, and L. Santiague, “Issues and challenges for teaching successful online courses in higher education: A literature review,” *J. Educ. Technol. Syst.*, vol. 46, no. 1, pp. 4–29, Sep. 2017, doi: 10.1177/0047239516661713.
[15] S. Dhawan, “Online learning: A panacea in the time of COVID-19 crisis,” *J. Educ. Technol. Syst.*, vol. 49, no. 1, pp. 5–22, Sep. 2020, doi: 10.1177/0047239520934018.