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Responsive Educational Transformations During Emergency Situations: Collaborative Autoethnography Applied to the Engineering Classroom*

LISA B. BOSMAN[1], EBISA WOLLEGA[2] and USMAN NAEEM[3]
[1] Purdue University, 610 Purdue Mall, West Lafayette, IN, 47907, USA.
[2] Colorado State University Pueblo, 2200 Bonforte Blvd, Pueblo, CO, 81001, USA.
[3] School of Electronic Engineering and Computer Science, Queen Mary University of London, Mile End Road, London, E1 4NS, UK.
E-mail: lbosman@purdue.edu, ebisa.wollega@csupueblo.edu, u.naeem@qmul.ac.uk

In general, higher education has been slow to innovate in comparison to industry and many for-profit organizations. This is primarily because non-profit higher education institutions are highly regulated, extremely bureaucratic, and do not always act strategically concerning finances (given the non-profit status). However, COVID-19 has forced engineering educators to innovate and transform the learning experience within a short time period; yet, because COVID-19 is a recent phenomenon, there is limited literature highlighting best teaching practices for a variety of teaching formats such as HyFlex Learning, Virtual Synchronous Learning, and Blended Learning. The purpose of this study is to offer readers a collaborative autoethnographic approach summarizing the researchers' experience teaching engineering coursework in each of these learning environments. Autoethnography employs self-reflection to recognize, explore, and appreciate personal experiences and anecdotal evidence and allow for a deeper understanding across individual perspectives to contribute to a wider explanation of a phenomenon. The data was collected from three different professors at three different universities: (1) Public R1 University (Predominately White) in the Midwest United States (HyFlex Learning); (2) Hispanic Serving Institution in the Southwest United States – (Virtual Synchronous Learning); and (3) a Russell Group University in the United Kingdom – (Blended Learning). The data collection applied a structured approach, where each professor reflected upon and documented their experiences teaching during COVID-19 while considering: (1) background and context, (2) teaching and learning changes implemented, and (3) lessons learned. The study concludes with a table of best teaching practices and recommendations for engineering educators.

Keywords: autoethnography; pandemic; engineering; COVID-19; higher education; undergraduate

1. Introduction

Higher education institutions have been slow to innovate in comparison to industry and many for-profit organizations. This is primarily because non-profit higher education institutions are highly regulated, extremely bureaucratic, and do not always act strategically with respect to finances (given the non-profit status). However, it is important to note that educational innovations do exist, primarily with added government support. For example, the United States Department of Education prides itself in supporting alternative approaches to traditional education through funding projects and supporting initiatives including charter schools, open textbooks, pilot projects, online high schools, and competency-based education, to name a few. Moreover, educational innovations are happening throughout the world as can be seen through the solar-powered floating schools used in Bangladesh, pastoral nomad communities and mobile schools used with the Afar people in Ethiopia, and building schools in war zones. Although much has been done, many gaps exist. First, many of the sustainable and successful projects are taking place in the K-12 space with the primary focus to promote basic literacy and in some cases to promote advancements in science, technology, engineering, and math (STEM) education if money and resources allow. Yet, limited sustainable innovation is taking place in the higher education space and/or leveraging smart learning technology beyond email and the learning management system. Second, little focus and deployment have been placed on society-wide scaling. Instead, the projects typically target a small sample size and are context-specific.

Fast forward to the year 2020, the COVID-19 pandemic has forced educators and administrators to expedite the implementation of innovative and transformative pedagogical practices to meet the needs of students (and a society) aimed to fight the pandemic via social distancing. Thus, COVID-19 has required engineering educators to re-think their definition of a classroom and approach to learning design and management within the online environment. Yet, because COVID-19 is a recent phenomenon, there is limited literature highlighting best practices in conducting HyFlex Learning, Virtual

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Synchronous Learning, or Blended Learning in the engineering classroom.

The purpose of this study is to offer readers a collaborative autoethnographic approach summarizing the researchers' experience teaching engineering coursework in each of these learning environments. Autoethnography uses self-reflection and writing to understand and explore anecdotal and personal experiences which allow for a deeper connection across individual educator stories as well as contribute to a wider understanding of perspectives. Using a collaborative autoethnographic approach allows educators to discuss their experiences, coming together to make sense of their situation, context, and experiences. The study concludes by highlighting best practices and lessons learned for applying each of these teaching and learning formats, providing compelling justification for continued use of all or parts of these teaching and learning formats as a good practice (regardless of a pandemic). Examples are provided for these engineering courses: Leadership Strategies for Quality and Productivity; Stochastic Systems Engineering; and Capstone Projects. Leadership Strategies for Quality and Productivity course is an elective for Industrial Engineering Technology majors and has a pre-requisite of IET316 (Statistical Quality Control). Stochastic Systems Engineering is a required course for Industrial Engineering and Mechatronics Engineering majors, which mainly covers probability and statistics. The Capstone Projects course is for Electronic Engineering and Computer Science students.

2. Background

2.1 Teaching Formats

This section provides a brief overview of the three teaching formats highlighted in this paper including HyFlex Learning, Virtual Synchronous Learning, and Blended Learning. A visual summary of the three methods is provided in Fig. 1.

HyFlex Learning is described as a mixture of online and face-to-face learning components whereby students can choose to complete any part of the course face-to-face, online synchronous, or online asynchronous [1]. From an instructional perspective, the course design typically is offered as a face-to-face class meeting combined with a video-conferencing system (whereby the class meeting is recorded); this provides students the option to attend in person, participate online, or engage with the recorded content outside the class meeting [2]. This type of course design allows students the most flexibility as it relates to time and learning mode, which is ideal for students who need to optimize work-life balance (e.g., work responsibilities, family obligations, etc. . . .) within the course schedule [2] or have social interaction preferences [3]. However, challenges do exist from both the student and instructor perspectives. One study highlighted the online students' frustration due to lack of instruction interaction, inability to chat with peers to clear up questions, and difficulty in paying attention online versus in-person [4]. Another study noted the high quantity of planning and preparation required of faculty teaching in a HyFlex mode for the learning to be effective [5]; since faculty cannot predict how many students will participate in each format for each class session, they may need to make changes on the fly to accommodate group work, for example.

Virtual Synchronous Learning is characterized by a learning environment in which the instructor and students all meet online at the same time; in contrast, virtual asynchronous allows students to access content on their own time and at their own pace [6]. One of the biggest motivations for virtual

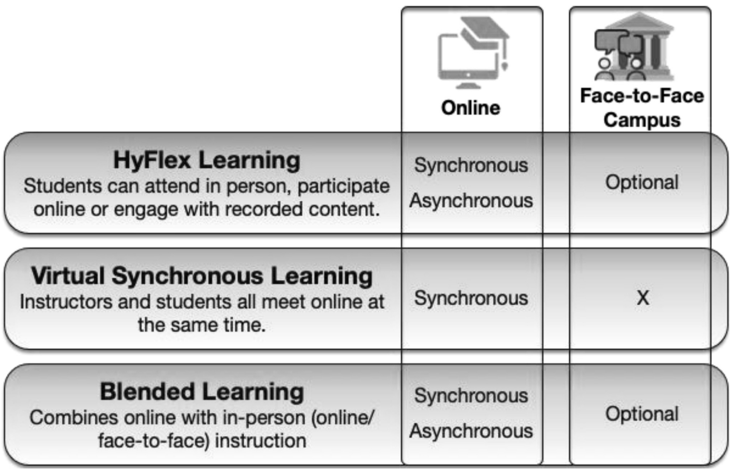

Fig. 1. Summary of teaching formats used in study.

learning (for both synchronous and asynchronous) is the increased accessibility to educational content whereby students can learn using a variety of devices and can learn from almost anywhere [7]. Nevertheless, challenges still exist. In one study, the researchers noted that fostering a sense of community and collaboration was more difficult [for the instructor] in a virtual environment versus a face-to-face environment; as a consequence, instructors need to be more intentional about using the technology and tools supported by the online setting to promote relationship building in a more explicit manner [8]. Moreover, another study highlighted the difficulty in communication within the virtual synchronous environment in that students needed to figure out new ways of communication and expressing their ideas primarily through typing and text (sans the integration of facial expressions which can provide greater meaning) [9]. In general, students tend to perceive virtual learning (synchronous or asynchronous, alike) as a lesser equivalent, with respect to perceived learning and satisfaction, in contrast to the face-to-face environment [10].

Blended Learning, commonly referred to as hybrid course design, combines online instruction with in-person instruction ultimately reducing the amount of seat time within the classroom; the proportion of in-person in comparison to online content can vary depending upon the learning goals and resource availability [11]. Hybrid course design is offered for many instructional reasons. First, it can be used to promote a flipped classroom environment where certain content (lectures, reading, quizzes, etc.) can be completed online outside the classroom with the intention to dedicate in-person class time to conduct authentic learning and complete open-ended problems [12]. Second, the web-based portion of the coursework promotes student flexibility to complete the assignments at a time ideal for them and allows students to work at their own pace [13]. Third, instructors can get to know the students better by interaction in both an online and in-person environment [11]. Fourth, for large classes, hybrid course design can assist in downsizing the quantity of students attending in-person (e.g., 20 students attending on Tuesday, 20 students attending on Thursday vs. 40 students attending on both Tuesday and Thursday) which allows instructors to get to know the students better [14]. Yet, challenges do exist. When students complete work online, there is limited interaction which may result in lower quantities of knowledge transfer in comparison to a face-to-face lecture and discussion [15]. Moreover, some students view the online portion as a way for instructors to lessen their teaching load and spend less time giving students course-related attention [16].

2.2 Autoethnography

Autoethnography is "a research method that uses personal experience ("auto") to describe and interpret ("graphy") cultural texts, experiences, beliefs, and practices ("ethno")" [17]. Autoethnography is not new to engineering and engineering education. One recent study explored the perspectives of engineering education graduate students to better understand identities and experiences associated with Canadian engineering education scholarship [18]. The study concludes with a recommendation for developing and deploying communities of practice to support engineering education research efforts of graduate students. Another recent research article, completed by three female engineering faculty, used autoethnography to investigate the role of perceived gender bias and its implications for the academic engineering learning environment [19]. The article concludes with recommendations for research and support of female faculty who are faced with gender biases within the classroom. Another manuscript showcased the use of collaborative autoethnography to examine social justice engineering curriculum taking into consideration the perspectives of junior female faculty and women of color faculty [20]. The manuscript concludes that stereotypes, norms, and microaggressions have an innate ability to undermine efforts for social and systematic changes supported by institutional administrators. Another autoethnography research investigation, done in collaboration between an environment engineering instructor and arts instructor, aimed to explore opportunities for incorporating STEAM (science, technology, engineering, arts, math) enrichment experiences into the engineering classroom [21]. The investigation concludes by providing educational opportunities for instructors and students to explore connections between the natural environment, design, materials, and society. Finally, another study highlighted the use of autoethnography as a teaching tool within the computer science classroom where students worked on a human-computer interaction design project to prototype a personal MP3 player [22]. In an attempt to teach students ethnography skills, a professor required students to first consider their experience with music by drafting a "personal ethnography" and then reviewing a friend's materials to use ethnographic observation for drafting a summary of how and when the friend engages in listening to music. Critical thinking skills were gained as students were able to compare and contrast one's own perspectives versus the perspectives of another individual.

The purpose of this study is to offer readers a collaborative autoethnographic approach summarizing the researchers' experience teaching engineering coursework in each of these learning environments: HyFlex Learning, Virtual Synchronous Learning, and Blended Learning.

3. Methods

3.1 Study Design and Data Analysis

Given the research goals, a collaborative autoethnographic approach [23] was applied. Autoethnography employs self-reflection to recognize, explore, and appreciate personal experiences and anecdotal evidence to allow for a deeper understanding and connection across individual perspectives to contribute to a wider awareness and explanation of a phenomenon [24]. The data collection applied a structured approach, where each researcher/educator (participant) reflected upon and documented their experiences teaching during COVID-19. The Results section provides a summary of the experience taking into consideration responses to the following questions:

- What was the background and context of your COVID-19 teaching experience?
- What teaching and learning changes were implemented during the COVID-19 teaching experience?
- What were the lessons learned from your COVID-19 teaching experience?

The Discussion section provides a summary of the themes related to best practices for teaching during emergency situations. This part of the study followed a qualitative approach using thematic analysis. According to Braun and Clark [25], a thematic analysis is a foundational qualitative method for discovering patterns within the data. It should be conducted using a step-by-step process. All three authors participated in the data analysis. The authors first read through the reflections several times to become familiar with the data. Themes were generated using NVivo. All three authors compared and contrasted the information to come to a consensus and agreement upon the themes generated. Then, the report was drafted. The qualitative approach to the research was a result of the goal aimed to explore perspectives (versus explain perspectives like what is done with quantitative research) and potential themes within the data.

3.2 Participants

The data was collected from three different researchers/educators at three different universities deploying three different approaches to learning:

- HyFlex Learning: Public R1 University (Predominately White) in the Midwest United States – Leadership Strategies for Quality and Productivity.
- Virtual Synchronous Learning: Hispanic Serving Institution in the Southwest United States – Stochastic Systems Engineering.
- Blended Learning: Russell Group University in the United Kingdom – Capstone Projects for Electronic Engineering and Computer Science.

4. Results and Discussion

4.1 Instructor 1 Reflection: HyFlex – Leadership Strategies for Quality and Productivity

4.1.1 Background and Context

I am an assistant professor at a research-intensive university located in the Midwest United States (about 40,000 students), where I have been employed since August 2018. During the summer of 2020, university administration worked with individual faculty to determine the optimal teaching format taking into consideration the size of the class, the size of the room, and faculty health concerns (as requested). For the Fall 2020 semester, I was assigned to teach a [new to me] course titled, "Leadership Strategies for Quality and Productivity." This course is an elective for Industrial Engineering Technology majors and has a pre-requisite of IET316 (Statistical Quality Control). The course was scheduled for Mondays and Wednesdays at 8:30 am. The class size was 13 students, and it was determined the room could safely accommodate all students (sitting six feet apart). The class was taught via the HyFlex course design. Thus, if one day a student wakes up, is feeling health-related symptoms, and doesn't want to risk infecting others, then the student simply shows up online during the posted class session or does the work on their own in an asynchronous manner. Then, once the student feels better, the student simply shows up in person (or continues in one of the other options).

4.1.2 Examples of Teaching and Learning Changes Implemented

- *"In-Class" Assignments and Accountability*: These types of assignments were used to promote participation and active learning during the class period. The "in-class" assignments were also intended to incentivize synchronous class participation (either through in-person or virtual). For students who attended class synchronously during the designated class period, they got to work in groups and had no problem finishing the required assignment during the class period. For those that chose not to participate during the class, they did not receive the assistance of a group and would have to do the assignment on their own which likely took them longer than the class period to finish the assignment. To accommodate students who chose to participate asynchronously, the assignment deadline was 11:59 pm.

- *"In-Class" Assignments and Google Docs*: On Mondays, the "in-class" assignments utilized Google Docs. Before class, I created the assignment template in Google Docs. During the class period, once I knew which students were in attendance, I would randomly place students in teams and email them the link to the Google Doc to start working. I intentionally assigned in-person students to their own groups, and online students to their own groups; this promoted fairness for the in-person students who clearly have a preference for in-person versus online. For students in the class, I walk around and see if they have questions. For students online, I pop in the breakout room to see if they have questions. For both groups of students, I go to their Google Docs to oversee their work to ensure they are on the right track. At the end of the class, I do a debrief highlighting one good example from each group.
- *Video Conference System*: During the first few weeks of the semester, I used WebEx (as it is the institution's default video conferencing tool). However, I quickly realized the difficulty for students to complete group work online without disrupting each other. In week 3, I switched to Zoom as it allowed for breakout rooms. During the class period, after assigning the teams to conduct collaborative group work using Google Docs, I would assign the online teams to breakout rooms and then pop in as needed to see if they had any questions and/or provide feedback based on the work completed in the Google Docs.

4.1.3 Lessons Learned

The Fall 2020 semester required thinking outside the box and trying new things. HyFlex teaching requires a lot of preparation, and even then, things don't always go as planned. Moving forward, I plan to institute a "reservation" system whereby students need to decide within two hours of class if they plan to participate in-person, online synchronous, or online asynchronous. This will allow additional time for planning group work (if allowed based on the numbers) and other assignments that are people-dependent. Also, in the event the class size is less than 10, knowing what I know now, I would work with the administration to request the course be completely face-to-face, completely virtually synchronous, or complete virtually asynchronous as the HyFlex model works much better with bigger class sizes.

4.2 Instructor 2 Reflection: Virtual Synchronous – Stochastic Systems Engineering

4.2.1 Background and Context

I am an assistant professor of engineering at a United States public university. The university is designated by the federal government as a Hispanic Serving Institution (HSI) with a population of Hispanic students exceeding 25% from about 5000 students enrolled per year. This university is a comprehensive regional university that offers a limited number of graduate programs and a broad array of baccalaureate degree programs with a strong professional focus and a firm grounding in the liberal arts and sciences. I have been employed by the university since August 2015. In the Fall 2020 semester, I taught Stochastic Systems Engineering. Before COVID-19, I taught all my courses face-to-face in physical classrooms, and I did not have any prior online course teaching experience. I generally utilized PowerPoint-slide-based lecture presentations and physical classroom whiteboards to teach the course materials in class. School emails were heavily used to communicate with students outside of the classroom and during office hours. I also implemented an open-door policy so that students could walk in to ask questions any time they saw my office door open. Course materials were made accessible through the official course site that is being used by our university – the Blackboard.

4.2.2 Overview of Teaching and Learning Changes Implemented

- *Video Conference System*: I used the Zoom video communications platform that was adopted as the official virtual instructional technology tool by our university. I created one Zoom ID and access code per course valid for the entire semester for any virtual interaction pertaining to the course including the class lectures and holding office hours. Any meetings outside of the class time were run via Zoom using the same access information used for lectures to avoid confusion, as students tend to have multiple Zoom meetings a day with different meeting IDs for their other classes as well. The Zoom access information was available only to the students taking the course. For student convenience, the Zoom meeting link for each course was integrated into the Blackboard course site. The access information was also included in the course syllabus. Office hours were held remotely for this course.
- *Zoom "Whiteboard"*: When teaching in a physical classroom, I would typically use the whiteboard to write notes on during lectures; in the Zoom environment, I used a Wacom tablet and touch screen laptop with a stylus pen, which was

more convenient for me and the students. I utilized the "screen sharing" feature of Zoom to present the course material lectures from my Wacom and personal computers, while students could follow along from their personal electronic devices.

- *Course Assignments – Publisher Resources:* For the homework assignments, my initial thought was to use Blackboard to post the homework assignment questions and receive submissions through the course site as well. However, I did some research for probability and statistics textbooks that have e-book versions and online homework assignments. Luckily, the WileyPLUS version of the *Applied Statistics and Probability for Engineers (7th edition)* textbook has that capability, and I decided to adopt it as the textbook for the course. The homework assignments were auto-graded through the WileyPLUS. The publisher provides sufficient explanations for the homework solutions. For each homework assignment, I randomly selected problems and solved them to verify the accuracy of the solutions. I also encouraged the students to communicate to me any homework problem solutions that did not make sense to them, and I resolved the problems to make sure that they understood the solutions correctly.

4.2.3 Lessons Learned

Once the COVID-19 pandemic is behind us, leveraging virtual synchronous instructional technology will be vital for educational efficacy especially during school closures due to factors such as snowstorms. Moving forward, there are several things I will keep or do differently. First, students asked fewer questions during the synchronous lectures compared to face-to-face lectures. When I inquired about this, a few mentioned to me that they did not want to interrupt me, while others thought it would sound rude to interrupt me to ask questions in the middle of the class lectures. In the future, I will be more explicit to allow time for students to ask questions at regular intervals throughout the class period. Second, I plan to offer virtual synchronous office hours. Before COVID, I used to meet students in the computer labs and assist them one-on-one. Now, using the virtual "screen sharing" capability, I can serve my students while sitting in my physical office or working from home. Third, the integration of Wiley's auto-grading system improved my teaching efficiency immensely. Students would instantly receive a solution to the problem they incorrectly answered. As a result, I was able to avoid the grading redundancy for my teaching assistants. Finally, the switch to online homework assignment submissions is good for the environment and saves students printing money; however, the university has to increase its server storage capacity proportional to the storage demand. Thus, a request has been made to the administration.

4.3 Instructor 3 Reflection: Blended – Capstone Design

4.3.1 Background and Context

I am a lecturer (assistant professor) within the School of Electronic Engineering and Computer Science at Queen Mary University of London. COVID-19 provided us with an opportunity to think outside the box when it came to re-designing our delivery model for the fall semester in 2020. Given the COVID-19 restrictions, course instructors could deliver their sessions online or on-campus (with a restricted number of students, which was facilitated via an online booking system). For the Fall 2020 semester, I was the instructor for the Undergraduate Final Year Project (aka, Capstone Projects), which included 323 students in their final year of undergraduate study. This is the most crucial element of the degree program within our discipline, as it allows students to work on an extensive piece of work within the areas of Electronic Engineering and Computer Science. The project also allows students to demonstrate their problem-solving abilities by being able to apply a range of skills that they have acquired throughout their degree program.

4.3.2 Overview of Teaching and Learning Changes Implemented

- *Preparation (Outside of Class) – Interactive Videos*: As the coordinator for undergraduate projects, I am always looking for ways to measure and improve student engagement. This is important because the project is an important element of a degree program and is also a significant piece of independent work that students undertake over two semesters. Hence, it is important to ensure that students are engaged and motivated. This became even more significant given the pandemic and the asynchronous/synchronous way of teaching that we were planning to deploy during the fall semester in 2020. To address this challenge, for the first step (preparation) of the blended learning approach, I developed an online e-series, which was made up of small interactive videos (5–10 minutes) that students needed to watch before the live session. These interactive videos were developed using H5P – HTML5 Package (a framework that allows users to create interactive content), which allowed me to track student engagement in terms of if they had watched the video and answered the embedded interactive questions that appeared during the video. One of the reasons for using this mechanism is that it can be difficult to see if a large class (300+ students) is engaging with the content being delivered during the course. Hence asking students to watch the pre-recorded short videos before the live session provided me with an indication of the students who were not engaging. Hence, I was able to contact the supervisors of the students who were not engaging to find out the reason for low engagement, as this could be down to many factors. Hence being aware of these issues, can enable the institution to provide students the necessary support to re-engage with their studies.

- *Live Session (During Class) – Interactive Polls*: During the live session, I would elaborate on the content covered in the e-series and initiate a series of interactive polls using *Mentimeter* to interact with the large group of students. I also found it extremely useful to have a moderator who filtered the questions through to me, so that I could concentrate on delivering the live session. I would then answer the questions during the final segment of the live session. I did not make use of Microsoft teams for the live sessions, as this was a large class (300+), hence I used Blackboard Collaborate, which also had chat and breakout facilities.
- *Post (Outside of Class) – Application*: The post-session activities required the students to apply the principles they learned during the e-series and live sessions to their project deliverables, such as literature review, interim report, presentation slides, project showcase video, and final report.

4.3.3 Lessons Learned

During the fall semester of 2020, I have come across a few challenges, however, I have also discovered many good practices that I will adopt going forward into a post-COVID world. One of the biggest challenges I have faced is during the live sessions for the larger class, which is being able to see if students are actually engaged. As there have been many instances where I would have 250+ students present in the class, however whenever I would conduct a poll only 100+ students would respond. Now there can be many reasons for this, one being that students may have a poor internet connection, or they are possibly watching the live sessions on a small screen (e.g., smartphone) as opposed to a laptop. Nevertheless, this will always be a challenge, as if students do not turn on their cameras or respond to polls then how will you know if they are actually watching your live session? In terms of good practices, I will continue to use many collaborative tools such as Microsoft Teams channels to facilitate group projects. In addition to this, I felt that the e-series of interactive videos was an excellent way to capture engagement stats of students engaging or struggling with the content before the live session, which was very insightful.

4.4 Summary of Themes

In summary, the previous three subsections responded to the collaborative autoethnographic approach of the researchers' experience teaching engineering coursework in each of these learning environments: HyFlex Learning, Virtual Synchronous Learning, and Blended Learning. A summary of best practices related to educational planning and classroom management are shown in Table 1 and Table 2, respectively.

In general, three themes were expressed and recognized across the three different experiences. First, all three instructors attempted to maximize student learning gains while being cognizant of the time and energy invested in the course. Informal follow-up conversations with the instructors highlighted their intention to maintain a work-life balance during the pandemic. Second, all three instructors took lessons learned from the initial switch to online in March-May 2020 (the latter part of the Spring 2020 semester when COVID-19 required going online with limited notice) to create a better, more thoughtful, and intentional approach to student learning in the Fall 2020 semester. Third, a silver lining associated with the transition to online allowed instructors to experiment and validate new pedagogical approaches (especially using technology). Fourth, all three instructors were intentional to spend time over the summer (between Spring 2020 and Fall 2020) to be better prepared for the second round; here, the instructors invested a decent amount of time in research best practices online and through informal conversations with peers.

5. Discussion

Since the COVID-19 pandemic started, some other publications have come out to document best practices and lessons learned within the engineering classroom [26–30]. Piyatamrong, Derrick, and Nyamapfene [28] conducted semi-structured interviews with eleven post-grad engineering students from three universities in the United Kingdom. Findings from the study suggest students were disappointed with the limited ability to build social connections, steep degradation of expectations and accountability, and lack of opportunities to practice hands-on skills. Liu, Vijay, Tommasini, and Wiznia [26] published a case study document-

Table 1. Summary of Educational Planning Best Practices

Best Practice	Benefit	Resources (Time/Cost) Required
Publisher Resources and Learning Management System (LMS): Quiz Test Bank and Automatic Grading	Allows for real-time student feedback and automatic grading allows for instructor time savings.	Time: This took about 4 hours preparation at beginning of semester to download test bank from publisher site, upload to LMS, and create individual quizzes. Cost: The book (with associated publisher resources) costs the students about 150 USD.
Microsoft Power BI Tutorials ("Lab" Day)	Allows for students to learn software using a workbook as a guide (which works well for students to go at their own pace).	Time: Microsoft Power BI currently doesn't work on Mac OS, as such the IT department needed to download the software to a computer lab whereby Mac users could access the software remotely. This required minimal time for the instructor but the IT department took about 3 weeks to complete. Cost: The tutorial workbook cost the students about 10 USD. Software: This course used Microsoft Power BI desktop (free to download in U.S.).
"In-Class" Group Assignments	Incentivizes students to show up for class (either in-person or virtually) as they receive the benefit of working on assignments in a group (versus having to do it individually).	Time: Preparing the mini-lecture and class assignment required about 1–2 hours each week, but they are now ready to be used for following semesters.
Creation of Interactive Videos Using H5P	These short videos were embedded with interactive exercises. Students were expected to watch these before the live synchronous sessions. These videos can allow instructors to capture engagement stats of students engaging or struggling with the content before the live session, which can be very insightful.	Time: The creation of these videos involves the following steps: (1) Record a video using a screen recording tool (PowerPoint or Keynote can also be used for this). The duration of this step is dependent on the content that the instructor will be presenting. (2) Upload the recorded video and embed the H5P interactive exercises. A typical video with 2–3 questions can take around 30–45 minutes to create. Cost: H5P is a free and open-source framework that can be installed in the Learning Management System as a plugin.
Open-Source Statistical Analysis Software	The open-source statistical analysis software, R, was used as it is freely accessible both on and off university campus.	Cost: Open-source software is free.

ing lessons learned from converting a traditional hands-on and team-based engineering design course to a remote learning environment. Similar to our study, Liu and colleagues propose the use of increased instructor-student interaction through discussion sessions (e.g., tutorials) to offer greater support. In addition, similar to our study, the authors propose a greater dependence upon technology; in their case, using simulation, computer-aided design (CAD), and finite element analysis (FEA) software to replace large scale physical prototypes. Different from our study, Liu and colleagues acknowledged the need for larger course budgets to pay for shipping out small-scale prototype materials. Asgari, Trajkovic, Rahmani, Zhang, Lo, and Sciortino [27] conducted a study including 110 faculty members and 627 students from six engineering departments which required participants to respond to a survey with both quantitative and qualitative questions. The purpose of the survey was to gauge challenges experienced as a result of switching to online teaching and learning. Similar to our study, the paper recommends the use of Zoom break-out rooms for small group problem-solving activities. Different from our study, the lessons learned went beyond instructor lessons learned to highlight interventions and strategies which can be implemented at the student, instructor, and university/administration levels. For example, Asgari and colleagues recommend having a syllabus template for teaching online, developing a university-wide repository for sharing resources, and encouraging students to use free smartphone scanning apps to share their work.

6. Conclusions

6.1 Practical Implications

In conclusion, the purpose of this study was to offer readers a collaborative autoethnographic approach summarizing the researchers' experience teaching engineering coursework including industrial engineering/technology courses during the COVID-19 pandemic. Three different teaching formats were addressed: HyFlex, Virtual Synchronous, and Hybrid. In addition, three different types of engineering courses were considered: Leadership Strategies for Quality and Productivity; Stochastic

Table 2. Summary of Classroom Management Best Practices

Best Practice	Benefit	Resources Required
Instructor Shared Google Docs	Allows for social distanced group work, students could start working right away, and instructor and check on student work in real time (and correct students if not on track).	Time: This took about 5–10 minutes to upload document to Google Drive (prior to class) and 1–2 minutes to share with students during class.
Zoom Breakout Rooms and/ or Channels on Microsoft Teams	Allows for social distanced groups to talk without interrupting peers, and instructor can check in with individual groups to answer questions.	Time: This took about <1 minute during class.
Weekly Reminder Emails	Allows for instructor to communicate with students to keep them on track and inform students of upcoming deadlines.	Time: This took about 5–10 minutes to draft and send email through learning management system.
Crap Happens Clause	Allows students grace for submitting up to three assignments with a 3-day extension (no justification required).	Time: This took less than 5 minutes per week to keep track of deadline extensions.
Calendly.com for Virtual Office Hours	Allows students to choose a meeting time based on about 10 thirty-minute timeslots offered at various times/days each week.	Time: This took less than 5 minutes per week to update availability.
Virtual Lab Booking System using Microsoft Forms	Allows students to request 1-to-1 TA support during practical lab sessions. Once students complete the form, they have access to a read-only dynamic spreadsheet which shows their position within the queue.	Time: This took about 5–10 minutes to setup a form for each lab group.
Interactive polls using Microsoft Forms and Mentimeter	Allows students to reinforce their understanding of the content covered in the live synchronous session, by asking students to participate in the polls.	Time: This took about 10–15 minutes to set up the poll questions before the live session.
Including a Discussion Moderator During Live Synchronous Sessions	During the live session, the instructor delivers the course content and the moderator answers student questions in real time. After the live session (and during Q&A breaks), the instructor can answer remaining questions.	Time: A moderator (i.e., TA) is required for duration of the live session.
Posting Classroom Access Information in Multiple Online Locations	Allows students to have flexibility of joining the classroom via a link found in various course related electronic resources (e.g., LMS, syllabus, and/or calendar.	Time: This takes less than 10 minutes setup time per semester.
Inspace.chat Instructional Technology	Provides students with the ability to virtually move around, talk, collaborate just like the physical classroom.	Cost: This product is a commercial software (prices are negotiated per institution).

Systems Engineering; and Capstone Projects. It is the researchers' intention that the act of sharing best practices can assist others in teaching efficiently and effectively, not only during a pandemic but also for teaching during normal circumstances. The overarching goal of this research is to ''move the needle'' with respect to improving the persistence and completion rates of engineering students worldwide through implementing best practices in teaching. Although our focus was on best practices within engineering, we are confident that other courses outside of engineering would also benefit from this information.

6.2 Future Research

This study has several limitations which should be mentioned. First, although the study was qualitative and intended to be exploratory in nature, it ultimately lacked explaining from a statistical perspective. Therefore, it is recommended that future research incorporates quantitative methods with the purpose to explain phenomena versus explore the phenomena. Second, this study only considered the insights from the researchers and failed to consider insights from the students and other stakeholders. As such, future research would benefit from triangulating data sources to include perspectives not only of the educator but also the learner. Third, the study only incorporated the perspectives of three individuals. Indeed, the individuals represent very different teaching and learning environments in engineering, represent very different demographic perspectives, and represent different regions throughout the world; yet future research would benefit from an even greater quantity of diverse perspectives. Fourth, the timeframe reflected upon by the researchers was limited to one semester (Fall 2020). Although there is a tremendous benefit to share best practices as soon as possible, future research would benefit from longitudinal data collection across multiple semesters.

Since the COVID-19 pandemic started, some other publications have come out to document best practices and lessons learned within the engineering classroom [26–30]. Yet, many longitudinal questions remain. Will pandemic-inspired best practices remain after the pandemic is over? Are pandemic inspired best practices sustainable? Should some pandemic-inspired best practices only be used for emergency situations? Is the student learning comparable for emergency situations versus the traditional learning environment?

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Lisa Bosman, PhD in Industrial Engineering, is an Assistant Professor within the Purdue Polytechnic Institute (formerly, the College of Technology) at Purdue University. Dr. Bosman's education research interests include the entrepreneurial

mindset, energy education, interdisciplinary education, and faculty professional development. In addition, her engineering research focuses on the development of decision support systems to enable the integration of grid optimization, solar energy performance modeling, and optimize decision making. Prior to joining higher education, Dr. Bosman spent several years working in industry as a manufacturing engineer with well-known companies including Harley-Davidson Motor Company, John Deere, and Oshkosh Truck. Dr. Bosman's desire to increase STEM (science, technology, engineering, mathematics) education accessibility and attainment has resulted in her founding of the Purdue University iAGREE Labs (www.iagree.org). Dr. Bosman has authored over 50 publications, and has recently co-authored the book, "Teaching the entrepreneurial mindset to engineers" (Springer-Verlag GmbH, 2018). In addition, she has obtained over $1M USD in research funding from agencies including the National Science Foundation (NSF), Environmental Protection Agency (EPA), and the National Aeronautics and Space Administration (NASA). She has been an invited speaker and workshop facilitator for over 20 engagements. She is active in the American Society for Engineering Education (ASEE) and currently serves as an officer for the Industrial Engineering Division. In addition, she is active in the Council for Undergraduate Research and currently serves as an Engineering Councilor.

Ebisa Wollega, PhD is an Associate professor in the Department of Engineering at Colorado State University Pueblo, USA. His research interest areas include large scale systems optimization, data analytics, artificial intelligence, and engineering education. Dr. Wollega serves as an officer in the American Society for Engineering Education Industrial Engineering Division. His profile can be found at https://www.csupueblo.edu/profile/ebisa-wollega/index.html.

Usman Naeem, PhD is a Senior Lecturer (Associate Professor) within the School of Electronic Engineering and Computer Science at Queen Mary University of London, UK. He was awarded his PhD in 2009 and 1st class BSc (Hons) in Information and Communication Technology in 2005, both from Queen Mary University of London, UK. His research interests are within the areas of ubiquitous computing where the focus is on assistive technologies to support independent living. His other research interests include context awareness, machine learning techniques, mobile sensing, educational technologies, gamification, and ambient intelligent environments. Dr. Naeem's education research interests include student engagement and measuring student experience and feedback using novel techniques. Dr. Naeem has published pedagogical work based on student engagement at conferences such as IEEE Global Engineering Education Conference (EDUCON) and IEEE International Conference on Engineering, Technology and Education (TALE). Dr Naeem is also a Senior Fellow of Higher Education Academy (SFHEA).