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Teaching First-year Engineering in an Online Learning Environment

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Abstract

Teaching models in face-to-face classes have evolved over time with goals to maximize student learning and use techniques such as problem and project based, experiential, active and discovery learning to name a few. Mastery of these techniques requires an instructor to be knowledgeable and proficient with different media (e.g. whiteboard, projector, demonstration equipment, feedback tools, communication tools, and learning management systems) while teaching and assessing students. In addition, instructors must also be experts in their own disciplines. When using different types of delivery methods (face-to-face, blended, or fully online) it is important to ensure that alternatives exist in all methods to accommodate and enhance learning. The recent Pandemic has caused a rapid transition to online teaching without time to adjust teaching methodologies. This paper compares the use of face-to-face and online teaching methodologies in some first-year engineering classes. Conclusions are then made on opportunities to improve teaching and learning in an online environment.

Introduction

There are many theories of learning which include: behaviorism, cognitivism, constructivism, and connectivism theories. Reviews and discussions of these theories have summarized behaviorism as learning as a change in behaviour from external processes [1] while cognitivism focuses on learning through internal processes [2]. Constructivism is seen to focus on learning as the construction of knowledge [1,2] unique to an individual while connectivism is a newer theory which sees learning as development of networks and connections [2]. Modern practices in teaching often involve stages of learning which involve incorporating a variety of the above theories to optimize learning [1]. Current teaching practices in engineering have used a variety of teaching strategies including: problem based [3,4], project based [5,6], experiential [7,8], and flipped [9-11] learning to name a few.

The recent Pandemic has caused a rapid transition to online teaching without time to adjust teaching and learning methodologies. This resulted in changes for both the teaching environment and the learning community which had to be immediately addressed. Traditionally, engineering has embraced the face-to-face modality but is challenged now with teaching in an online environment whether it be truly online or in a blended learning format. There have been previous studies on the use of online/blended learning in engineering courses (see for example [12-16]). Arguments for the use of online learning include potential to increase accessibility in terms of time and location [17] and inclusion [15]. Arguments against online learning include: issue of existing internet accessibility [13,14], digital competencies [14,16,18], academic integrity [13,16], limited sense of community [12,14,16,18], limited access to hardware [18], communication issues [12,16,18], pacing [12,18], and effects on at-risk students [16,19]. There has been a lack of agreement in the literature with respect to the results of the use of blended learning in terms of both student attitudes and performance (see [20]).

The goals of this research are to take an inventory of concepts and techniques used to teach first-year engineering, to reflect on recent online teaching experiences, and to discuss opportunities for improvements.

Teaching Modality – Face-to-Face

For the first-year engineering curriculum, students take a mix of math, physics, chemistry, english, and engineering courses. The current study is restricted to the engineering courses which include engineering mechanics I (statics), mechanics II (dynamics), programming, and design. Each course requires a certain number of hours of lectures, labs, and seminars per week as shown in Table 1.

Table 1. Comparison of courses with associated hours

Course	Lecture	Lab	Seminar
Mechanics I: Statics	3	2	0
Mechanics II: Dynamics	3	1.5	1
Engineering Programming	3	3	0
Engineering Design	1	0	2

In a face-to-face modality, each course is typically taught using a teaching methodology as shown in Table 2. Here, the instructors teach all lecture components, for all courses, in a mixed method. This involves part of the lecture being dedicated to the instructor teaching material in a lecture format and then part of the lecture being problem solving / practice based where students then work on problems involving newly learned material. The students then reinforce their learning through the problem-solving exercises in labs (statics, programming) and seminars (dynamics). For the design course, students reinforce their learning through a project. For most courses, students submit handwritten problem-solving exercises in a time limited environment. Students were encouraged to communicate with other students yet solve problems individually. Student engagement is at the forefront of all activities assigned to measure competency.

Table 2. Comparison of courses learning components for face-to-face modality

Course	Lecture	Lab	Seminar
Mechanics: Statics	Mixed: lecture / problem solving	Problem solving	--
Mechanics: Dynamics	Mixed: lecture / problem solving	Problem solving	Problem solving
Engineering Programming	Mixed: lecture / problem solving	Problem solving	--
Engineering Design	Mixed: lecture / problem solving	--	Project based

Next, Table 3 provides the conditions in which face-to-face modality occurs for the different parts of the course. For lectures, through teaching face-to-face in a mixed lecture/problem solving format students learn in a dedicated classroom within a controlled environment. This takes into account indoor environmental quality factors such as thermal, visual, and acoustical comfort as well as air quality [21]. Classrooms include teaching tools such as whiteboards, projectors, room for demonstrations, as well as providing opportunity for group breakout and asking questions. These conditions are similar for both the Lab and Seminar settings.

Table 3: Comparison of different variables for face-to-face modality

Component	Environmental	Tools	Connectivity
Classroom	Dedicated Classroom Controlled Environment	White board Computer Demonstrations	Instructor Other students
Lab			
Seminar			

Teaching Modality – Transition to Online Learning

The Pandemic in 2020 caused an abrupt switch in teaching modality for all courses. Table 4 provides a summary of the changes in modality of the courses under consideration (from face-to-face) for Fall 2020/Winter 2021. The beginning of the switch started midway through Winter 2020. As a result, approximately half of the term was based on the traditional model, and midterm assessments were still invigilated in-person exams. This sudden transition, however necessitated adapting in-person assessments to online ones in less than a week. The modality for the lectures was chosen to be online – synchronous as to allow students the opportunity to still ask questions in the live lectures. Students did still have the opportunity to view the lectures asynchronously as all lectures were recorded and put online for later viewing. A blended modality was chosen for the certain labs and seminars to satisfy the limits of the reduced room capacities due to Covid restrictions while still providing students learning opportunities in a controlled face-to-face environment.

Table 4. Comparison of courses modality for online learning environment

Course	Lecture	Lab	Seminar
Mechanics: Statics	Online - synchronous	Blended	--
Mechanics: Dynamics	Online - synchronous	Online - asynchronous	Online - synchronous
Engineering Programming	Online - synchronous	Blended	--
Engineering Design	Online - synchronous	--	Blended

The transition online also resulted in a need for software and hardware tools for both students and instructors. For students it was required that they have a digital device (ie. computer, tablet, phone) which had internet access, a speaker, and a microphone. The ideal device is one which has a large display with a strong graphics card, a webcam, noise canceling headset with microphone, and the ability to write with a stylus. In addition, access to a printer and scanner is helpful. For the instructor, a computer with a webcam, headset with microphone with a reliable internet connection and powerful graphics card is essential. For marking, a separate tablet with stylus was recommended for marking.

In terms of software, students had access to the learning management system BlackBoard for course materials. For course lecture delivery students had access to the web conferencing tool Blackboard Collaborate Ultra. For assignments and exams, the grading platform Crowdmark was used. For group work and student communication, Google Workspace was recommended to the students (including Google: Drive, Jamboard, Chat, and Meet). In terms of instruction, various tools were available to use as a digital white board, including Microsoft OneNote, and Xournal.

Software used for various courses is shown in Table 5. First, in terms of assessments, most students used traditional means (engineering paper and pencil) to solve problems. They were then taught how to use GNU Image Manipulation Program (GIMP) to enhance scanned images in terms of contrast as well as modify file size to ensure their assessments could be view by the markers. In terms of demonstrations, GeoGebra was used to show different mathematical concepts. To aid problem solving,

Table 5. Software Tools for Courses

Course	Tools
Mechanics: Statics	GeoGebra, GIMP
Mechanics: Dynamics	Maple
Engineering Programming	Octave, Dia
Engineering Design	AutoDesk Inventor, Dia, GanntProject, Cura

students were encouraged to use Maple to graphically visualize the problems they were solving as well as an extra check for their solutions. For programming, students used Octave with an ASCII editor. For drawing flowcharts students were encouraged to used Dia. Engineering Design required significantly more software to be used. For understanding project management, GanntProject was used. For various design stages, Dia was used for mind-mapping as well as developing function-mean trees. Finally, for the student projects, AutoDesk Inventor was recommended to develop their models while Cura was used to 3D print their design. In terms of course materials, course books were still available for the students but instructors also provided links to digital options from the publishers for students.

Discussion

Effects from the transition from face-to-face to online learning can be described in terms of environmental conditions, tool requirements, learning content, and inter-connectivity. In terms of the teaching environment, the shift online was simplified by a previous move to an online learning management system (Blackboard) in the past decade. Conferencing tools and white board apps made it possible to teach similarly to a face-to-face environment. Recordings made lectures more accessible to students. Issues existed, however, in terms of equal access to digital hardware which were lessened as compared with a face-to-face environment where students could learn without it. In addition, verification of a controlled indoor environment quality was not possible online and it is expected that some students may not have equal access to environments conductive to learning.

When course were moved to online instruction, instructors chose a hybrid model with synchronous lectures and in-person problem-solving exercises. One challenge faced by some instructors was to convince students to participate in synchronous lectures when recordings of the lectures were available asynchronously. It is expected that this caused some students to not make effective use of their time. By the end of each term, some students fell behind in course content and were challenged to complete assessments on time. Many students expressed frustration about the volume of course content presented. Some instructors noted an increased volume of email communication. For some students, online lecture recordings were beneficial for optimizing schedules and for reinforcing new concepts. In terms of teaching, some in-class demonstrations were not possible, however, effort is being made to aid this through the development of augmented reality experiences. Students seemed more stressed (observed order of magnitude increase in email volume) with the imposed online teaching. Academic integrity was a concern for high-stakes exams without some form of proctoring. The use of low-stakes assessments eased some of the students concerns and anxiety, but increased workloads for both students and instructors.

In terms of teaching tools, some students found it difficult to navigate and use the software but seemed quick to pick up on it. Before the beginning of the term, students normally engage in a week-long "Boot Camp" to help them transition from high school to university. During this time more effort was placed on introducing students to these technologies and provide opportunities for them to practice them before the start of term. For instructors, the combination of a large format pen tablet, Blackboard collaborate web conferencing, and either Microsoft OneNote or Xournal software worked extremely well for delivery of synchronous lectures involving problem solving. In addition, the use of the grading software worked well in terms of assessment collection (and return), marking, and providing consistent feedback. Some difficulties still existed in terms of quality of the submitted work in terms of contrast and resolution. A benefit noted for online marking was the ability to zoom in on students' work in cases where the submission was too small.

In terms of content, the internet is populated with many online videos on various engineering topics. Some students found this beneficial. However, there is no standardization of notation and methodologies which can cause confusion in the delivery of more complex concepts. It is expected that, in combination with access to asynchronous lectures, this has lead to an increased use of these online resources. In addition, easy access to solutions to practice problems often enticed students to use these resources instead of developing their own problem-solving skills and obscured the fine line between proper use of resources and violations of academic integrity. Benefits were noted in terms of books, in terms of accessibility with more options for students to purchase the often cheaper online version. Some questions were raised by instructors in terms of whether students read the online content as opposed to searching it.

In terms of connectivity between students, peers, and instructors, it is expected that students had less opportunities to develop study groups in the online environment and this resulted in an increase in communication with instructors through email. In terms of peers, it was noted that students had well-developed skills in instant messaging platforms (such as Discord) prior to starting the university term but this did not seem to lead to formal study groups. Opportunities existed in second term, for students to interact through a group design project. Effort is being made to provide students with online ice-breaker opportunities during the program's next "Boot Camp" in 2021 as well as developing more in-class group work opportunities.

In terms of future improvements to online line learning, at the university level there are opportunities for institutions to ensure that supports exist for students such as online learning spaces or loan programs which would include low cost tools and alternatives for ensuring equity and inclusion in student learning. In addition, when scheduling courses more effort could be placed on optimizing student attention/ concentration during synchronous class by looking the effectiveness of shorter classes or ensuring longer breaks between classes. Universities could also provide supports for in-house servers and moderation of them to help students connect with one another. For instructors, there are opportunities for improving online learning through the re-assessment of course content focusing on learning in a digitized world in terms of the effectiveness of traditional assessment methods and time/content management. Furthermore, opportunities exist to improve upon developing standards for digital homework submissions, development of online material for demonstrations, development of opportunities for students to connect with one another as well as the promotion of peer help. Finally, students should be provided learning opportunities to develop their meta-cognition skills on learning in terms of the importance of synchronous lectures, a well-controlled learning environment, the importance of developing connections, and the benefits and pitfalls of the internet.

Conclusions

The combined delivery method (synchronous classes with recordings/in-person) was observationally effective and comparable to a face-to-face learning environment as it catered to all students learning needs. Both students and faculty preferred some form of in-person engagement especially for summative assessments. Efforts should be made to make hardware accessible for students learning online as well as providing access to controlled environments for learning. Some development opportunities were noted in terms of online teaching tools of demonstrations for kinesthetic learners, and standardization of online content. Research potential exists in terms of developing an understanding of the effects of the use of online textbooks on learning, developing an alternative to practice problems (when solutions exist online), and developing software to pre-check student submissions for quality. Finally, efforts will be made to improve communication between students and instructors as well as efforts to improve participation rates for all activities.

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