Comparative Study of Online and Classroom Teaching of an Engineering Course Using Active Learning Pedagogy

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Abstract
During the COVID-19 pandemic, online teaching and learning became an indispensable choice for instructors and students to continue their teaching and learning without interruption. After the COVID-19 pandemic, most students are very happy to resuming face to face teaching and learning in classroom, but some students still request to offer an online option to meet their various learning needs, which has triggered the author's further thinking about effectiveness and efficiency of these two course delivery modes to instructors' teaching and students' learning. In this paper, the author will use assessment data collected under these two course-delivery environments respectively for teaching Vibration Theory in mechanical engineering program at Saint Martin's University as a case to carry out a comparative study of online and classroom teaching using actively learning pedagogy. Based on the data collected, advantages and disadvantages of each delivery mode to effectiveness and efficiency of teaching and learning using actively learning pedagogy have been discussed from the learners' point of view as well as instructor's point of view. The comparative study and data analysis will help engineering educators to have a direct insight of pros and cons of online and classroom teaching when active learning pedagogy is used. Based on the results of this comparative study, a new hybrid course delivery mode has been proposed. The new mode combines the advantages and avoids the disadvantages of both online and classroom teaching to better support active learning pedagogy for delivery of engineering courses.

Keywords: Online Teaching, Face to Face Teaching, Active Learning, COVID-19, Vibrations

Introduction

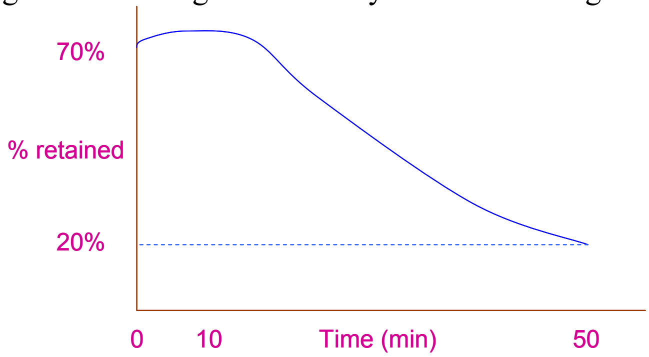
Active learning, which simply say is learning by doing, has been demonstrated as an effective teaching approach to engage students in learning process and accommodate their needs of various learning styles (Cho et al., 2021; Hernández-de-Menéndez et al., 2019). It is not only a process through which students must actively be involved in reading, writing, discussion, and problem-solving activities, but also a student-centered teaching approach (Felder & Felder, 2003). The approach involves students in all aspects of the learning process (Johnson & Johnson, 2008), and easily accommodates the students' own needs, abilities, learning styles, existing skills, and experiences (Bean & Melzer, 2021; Prince, 2004).

Before the COVID-19, the author had been using active learning pedagogy to develop lecture contents and design learning activities for delivering ME410 Vibration Theory to senior students in mechanical engineering program at Saint Martin's University (SMU). During the COVID-19 pandemic, online teaching and learning became an indispensable choice. Therefore, the author flipped the same lecture contents and learning activities of ME410 from face-to-face in-class room delivery into online delivery. Next, what will be discussed are ME 410 course information, comparative study of both face-to-face and online delivery modes, and a proposed new hybrid delivery mode.

Design of Active Learning Activities (ALA) for the Course ME 410

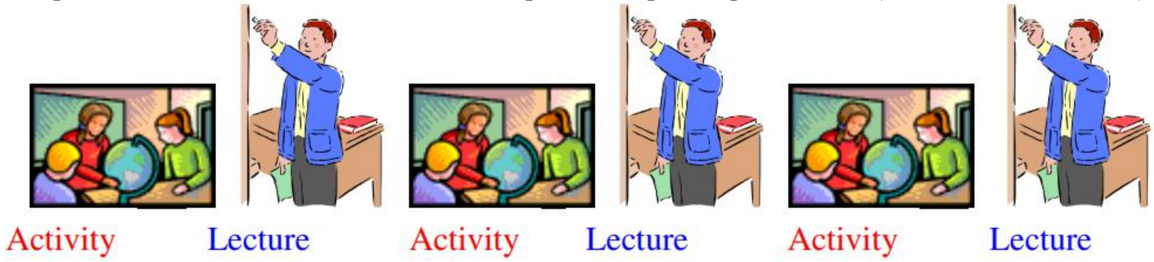
ME 410 Vibration Theory is a three-credit elective course offered to junior and senior students in the mechanical engineering program at SMU. It is a spin-off subject of dynamics and requires that students have a solid background in dynamics, differential equation theory, linear algebra, advanced engineering math such as Fourier series expansion and convolution integrals. From these prerequisites, it is obvious that ME 410 has a strong theoretical taste and requires intensive mathematical derivation. The instructor could not find an effective work around to these theoretical derivations because vibration concepts and methods are embedded into the derivation procedure. students may easily lose their learning interests at such extremely math-orientated derivation during traditional passive class lectures and further have difficulties to understand concepts and methods integrated in the derivation. On the other hand, the study (McKeachie, 2002) has shown that once a traditional fifty-minute lecture is finished and the students take a test on lecture contents immediately afterwards, their retention of the knowledge from the lecture can be illustrated by the curve shown in Figure 1. The figure indicates that retention of about 70% has been retained during the first fifteen minutes of the class lecture. The percentage of knowledge retention decreases after that and reduces to 20% level at end of the lecture To resolve learning interest issues and enhance learning effectiveness, active learning pedagogy has been integrated in teaching ME 410. The retention curve can be raised significantly after the first fifteen minutes of the lecture if active learning pedagogy is used (Duan & Ries, 2007).

Figure 1: Percentage of Knowledge Retained by Students During a Traditional Lecture



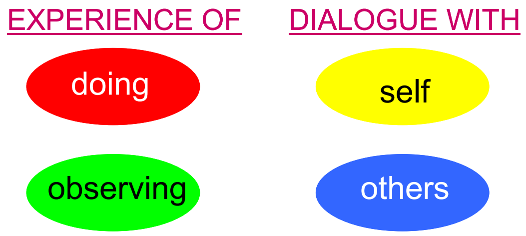
Thus, various active learning activities were designed in ME 410, such as in-class-teams, think-pair-share, in-class-writing-assignments, course projects with problem-based learning, etc., to facilitate learning needs of the students. Specifically, at the beginning of class, a two-minute learning activity was arranged for students to reflect on what they had learned from the previous class session and engage themselves in learning the current lecture contents. After warming up, the instructor lectured for about fifteen minutes. Another three-minute activity was given for students to work on the lecture contents. Then another two lectures were given about fifteen minutes and ten minutes respectively with a five-minute activity arranged between them. The students were required to participate in these activities and class discussions. The process is illustrated in Figure 2. In practice, the arrangement of lectures and activities were dynamic rather than identical for each class period.

Figure 2: Illustration of Active Learning Planning Design Process (Duan & Ries., 2007)



To integrate the course with activities that are woven around a well-established process and allow students to experience vibrations analysis themselves rather than just completely passively listen to how it is supposed to work, a basic model was used as illustrated in Figure 3 for design of the activities. The following are a few samples to show how active learning strategies were explored to carry out this integration.

Figure 3: A Model for Guiding Design of Active Learning Activities (Duan & Ries, 2007)



Students Actively Involved in Mathematical Derivation in a Group Setting

Rather than passively listening to the instructor delivering the entire mathematical derivations, students were involved in the derivations actively in group. Take the derivation of formulations for the steady-state response of the equation of motion for forced vibration of an undamped system under harmonic force as a simple example. After the equations of motion $m\ddot{x} + kx = F_0 \cos\omega t$ (*m*: mass of an object, *k*: stiffness of spring, *x:* state variables, F_0: magnitude of excitation force, and ω: frequency of the excitation force) was set up, the following activities were carried out:

Instructor: Assuming the particular-solution is $x_p(t) = X\cos\omega t$. Three students work in a group and substitute $x_p(t)$ into the equation of motion. Then obtain equation for X. You have about three minutes to work on it.

Students*:* Work in group to obtain the equation for X

Instructor*:* Check the results with a few groups and ask two groups to give their results to Class

Activities of Think-Pair Share

During the activities, the instructor gave requirements. Students thought of answers individually, formed pairs to produce joint answers, and then shared answers with class. Take introduction to vibrations as a simple example. A think-pair share activity was arranged as follow:

Instructor: Please think about two examples each of the bad and good effects of vibrations individually first, then find a partner to exchange your results, and share your joint answers with class.

Students: Pair-think share and present answers to class.

Course Project Integrated With Problem-Based Learning Techniques

Two or three students formed a project team and worked together throughout the entire semester. Each team was asked to write a proposal and problem statement. They had to create hypotheses to initiate the modeling process, and derive and solve equations of motion to apply what they learned in class. The topic of the project was selected by each project team. The topic would be senior design project, national competition, or a real-world problem of interest to all team members to model, simulate, and analyze. Figure 4 shows some samples of selected team projects. The project was divided into three phases. Basic requirements of each phase are listed in Table 1 below.

Figure 4: Selected Project Titles From ME 410

Minute Paper Activity

The instructor asked students to anonymously write down (1) the main point(s) of the lecture, and (2) the muddies point(s) of the lecture, then collect papers, look through the responses to check understanding, and begin the next lecture by addressing common questions from the minute papers.

Table 1: Three Phases for Selected Team Project

	Phase I	Phase II	Phase III
Requirements	1. Pick up a vibration device or system to model and analysis 2. Write project proposal 3. Form preliminary vibration system model and explain how to carry out analysis	1.Set up equations of motion 2. Solution of equation of motion 3. Explain your results modeling->equations of motion-> solution -> interpretation of results	1.Possible Matlab computer simulation & analysis 2. Per simulation data, revise the system parameters if necessary 3. Carry out simulation again 4. Interpretation of results
Presentations & evaluation	1.Proposal/presentation 2. Phase I grading	1. Progress report presentation 2. Phase II grading	1.Final report & presentation 2. Final project evaluation

Activities of In-Class Writing Assignment

The students were asked to write what they knew about a topic before the instructor delivered a lecture on it to help them subsequently connect new ideas to what they already knew. Sometimes the students were asked to generate a list of questions they had about the topic or a list of practical applications of new materials.

Flipping In-Classroom Lectures and Activities Above Online Virtually

During the COVID-19, the lectures and learning activities mentioned above were flipped for online delivery. Zoom and Moodle were two key platforms used for online delivery of ME410. Zoom was selected for synchronous live lectures and active learning activities and was key course flip platform. Moodle was used as course communication platform for assignment, assessment, and asynchronous delivery of pre-recorded lectures. Microsoft Note was chosen as lecture note writing blackboard. The online technical system is like that used in the previous application (Duan & Bassett, 2011).

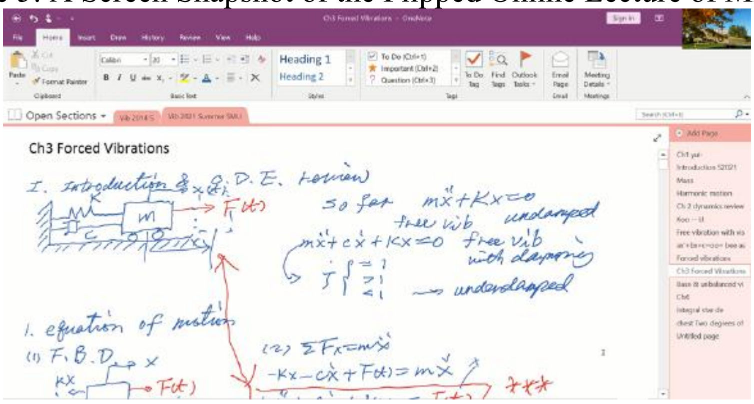
Several functions of Zoom were used, such as Breakout Room, Chat, Broadcast, Share, Audio & Video (A/V) etc., to flip the lectures and active learning activities in Zoom environment. In-classroom lectures could be supported by A/V and share of Zoom functions. Table 2 shows a correlation between ALA and Zoom functions for flip the learning activities.

Table 2: Correlation of ALA Supported by Zoom Functions

ALA	Math derivation	Think pair	Course project presentation	Minute paper	In-class writing
Zoom functions	Breakout room; broadcast; A/V; share; chat	Breakout room; broadcast; A/V; share, raise hand	A/V; share; chat; raise hand	Chat	Chat

For example, the activity of mathematical derivation in group was accommodated via breakout room for forming group, broadcast for instructor's announcement, A/V and share for each group to share their results, and chat for each group chatting with the instructor. Figure 5 shows a screen snapshot of the flipped Zoom lecture. After the course was delivered online virtually, the same assessment tool used in classroom teaching was utilized to gather learning experience feedback from the students. Based on data collected from both in-classroom and online teaching modes, discussion focus next will turn into comparative study and analysis of students' learning and the instructor's teaching experiences under these two environments.

Figure 5: A Screen Snapshot of the Flipped Online Lecture of ME 410



The Course Assessment and Comparative Study of Learning and Teaching Effectiveness

Homework problems, computing assignments, quizzes and exams were used to assess students' learning and the effectiveness of teaching ME 410 Vibrations Theory under two delivery modes using active learning pedagogy. In addition, an anonymous student survey was conducted to obtain evaluation for teaching and learning. Table 3 below shows the students' summative feedback on questions used to assess their learning experiences, and sample feedback of student engagement in the course is present in Table 4. For convenience, data of the hybrid delivery mode has been added into Table 3, which will be used for further discussion of the hybrid mode late on.

Table 3: Percentage of Student Responses to Summative Questions Under 3 Delivery Modes

Summative questions	**Delivery mode**	Excellent (5)	Very good (4)	Good (3)	Fair (2)	Poor (1)	Very poor (0)	Ave.
The course as a whole was:	In-class	25%	38%	37%				3.9
	Zoom	20%	60%	20%				4.0
	Hybrid	60%	20%	20%				4.4
The course content was:	In-class	25%	38%	37%				3.9
	Zoom	20%	60%	20%				4.0
	Hybrid	20%	60%	20%				4.0

Survey Result Discussion

Table 3 shows that there is no significant difference between in-class and online delivery modes for summative evaluations in terms of "the course as a whole was" and "the course content was" according to learning experience feedback from the students. However, for student engagement in the course, Table 4 indicates that in term of "The amount of effort you put into the course was" the student put much more effort into the course in online delivery mode than in-class delivery mode. The author chatted with the students enrolled in the online course. They felt it took more time for them to do homework in term of format and submission process under online mode than in-class mode. Because in-class delivery mode, they just turned in the hand-writing homework in class while for online delivery mode, they had to type the homework using software such as Word etc. or convert hand-writing homework into an E-document file format for submission in Moodle platform. Among the students in online class, a few students mentioned that online mode saved commuting time, which may explain why difference of average scores between in-class and Zoom is subtle rather than significant in term of "Your involvement in course (attend class, homework…)". A few students mentioned they occasionally encountered some difficulties associated with internet connections, speed, and sound quality of their devices. Generally, the students' learning experiences were equivalent between in-class and online delivery modes for all other areas, but in term of "use of class time was" in-class delivery was slightly efficient than online delivery as shown in Table 4.

Table 4: Percentage of Student Responses to Engagement Questions Under 3 Delivery Modes

Engagement questions	**Delivery mode**	Much higher (7)	(6)	(5)	(4)	(3)	(2)	Much lower (1)	Ave.
The amount of effort you put into the course was:	In-class	38%	12%	38%	12%				5.8
	Zoom	60%	20%		20%				6.2
	Hybrid		60%	40%					5.6
Your involvement in course (attend class, homework…) was:	In-class	38%	25%	25%	12%				5.9
	Zoom	40%	20%	20%	20%				5.8
	Hybrid		60%	20%	20%				5.4
Use of class time was	In-class	43%	29%	14%	14%				6.01
	Zoom	20%	40%	40%					5.8
	Hybrid	20%	60%	20%					6

Instructor's Comments of Teaching Experiences of ME410 Between In-Class and Online Modes

From the instructor's point of view, online delivery provided convenience for the instructor to accommodate students' learning needs easier than in-class delivery. For example, a student was able to attend class virtually when he/she had to stay home or was not able to attend the class in person. Paper was not needed because all student works were graded on computers, which saves resources and is environment friendly. However, the online delivery was not favorable for the instructor to keep eye contact with the students during lecturing, which lost a chance for the instructor to immediately know the facial responses of the students to the lecture contents or questions. As comparison with in-class delivery, online delivery also increased workload of the instructor due to extra time added for setup each class session and grading E-version of homework and returning them to the students.

The Proposed Hybrid Course Delivery Mode

After the Covid-19, most students were very happy to attend the class in person and have face to face lectures and activities in classroom, but there were situations in which some students asked to attend the class online when the class was offered in classroom. To accommodate needs of the students, ME410 has been offered in a hybrid mode. Zoom, Microsoft note, and Moodle have been utilized together in the hybrid mode. The lectures and learning activities carried out mainly in classroom with Zoom access virtually. The lectures have been recorded in Zoom and posted in Moodle for the students to watch in case anyone misses a class session. The author has been trying to keep advantages and avoid disadvantages of both in-class and online delivery in the hybrid mode for students' learning. In term of "the course as a whole was" the average score is higher in the hybrid mode than both in-class and online modes as indicated in Table 3.

Conclusion

The comparative study presented in this paper highlights the strengths and weaknesses of both online and classroom-based teaching methods, particularly in the context of active learning pedagogy for engineering courses. By analyzing assessment data from Vibration Theory courses at the author's University, the study provides valuable insights into how these two modes of delivery impact both teaching effectiveness and learning outcomes. The proposed hybrid model, which combines the benefits of online and face-to-face teaching while minimizing their respective drawbacks, offers a promising solution for enhancing active learning in engineering education. This approach can serve as a useful framework for educators looking to optimize their course delivery methods and better meet the diverse needs of students.

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