2021 ASEE ANNUAL CONFERENCE
Virtual Meeting | July 26–29, 2021 | Pacific Daylight Time
Paper ID #32711

Mechanical Engineering Activity-Based Freshman Course Online During a Pandemic

Prof. Dani Fadda P.E., University of Texas at Dallas

Dr. Fadda is Associate Professor of Practice in Mechanical Engineering. His background includes two decades of engineering practice in the energy industry where he has held numerous positions. Dr. Fadda has worked in product research and developed patented products for chemical, petrochemical, and nuclear applications. He is an ASME Fellow and a Professional Engineer.

Dr. Oziel Rios, University of Texas at Dallas

Dr. Oziel Rios earned his Ph.D. in mechanical engineering from the University of Texas at Austin in 2008 where his research focused on design of robotic systems with an emphasis on kinematic and dynamic modeling for analysis and control. Dr. Rios teaches the first-year and CAD courses in the Mechanical Engineering Department at the University of Texas at Dallas. Dr. Rios has also taught kinematics and dynamics of machines and graduate-level CAD courses. Dr. Rios' research and teaching interests include: robotics, design, kinematics and dynamics of machines and engineering education.

Mechanical Engineering Activity-Based Freshman Course Online During a Pandemic

Abstract

In this evidence-based paper, the practice of converting a first-year mechanical engineering course, consisting of weekly lectures and hands-on lab activities, to a fully asynchronous online format is presented. The course content and the course format, in the learning management system, are described along with some of the virtual activities created for the online course format. Assessment of student learning and student evaluations are presented to provide a comparison between the in-person and the online formats of the freshman course. In the future, online lectures with corresponding weekly quizzes are likely to continue in this class. The simulation work can be offered in the lab or online. However, the return to the lab for offering the physical activities is desired as soon as it is safe.

1. Introduction

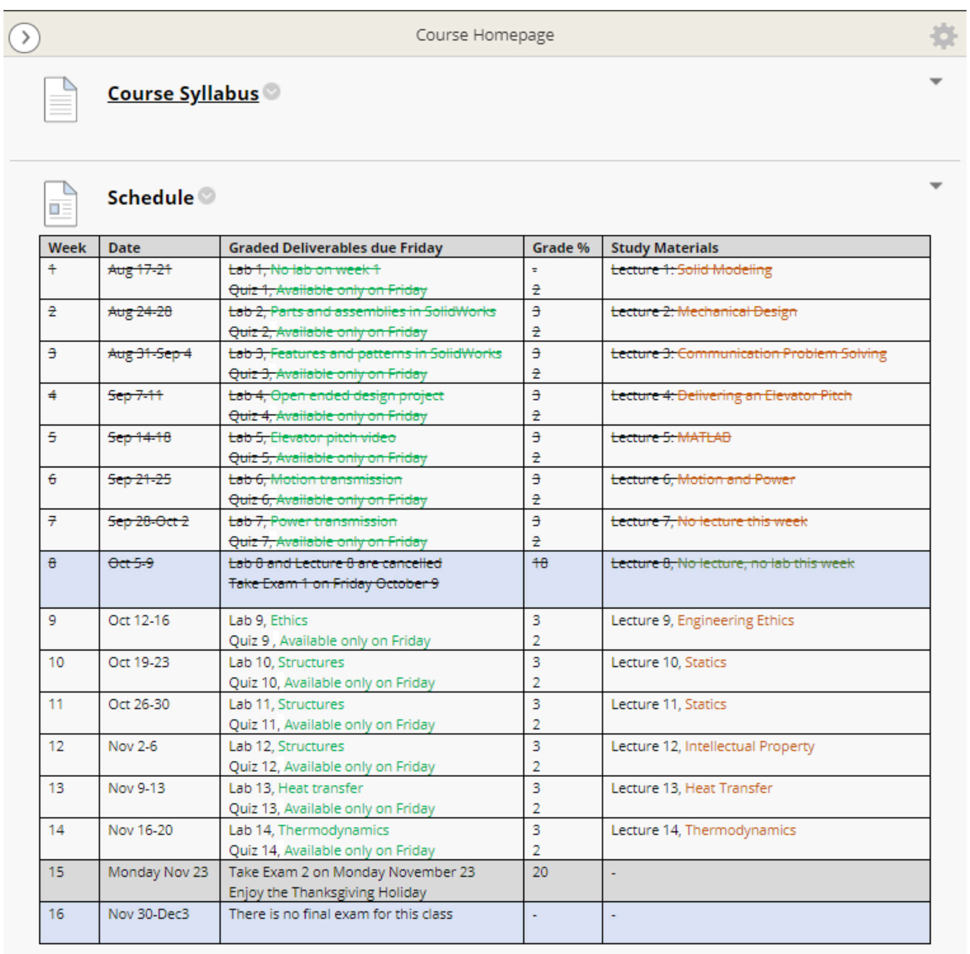
During the global pandemic of 2020 and its corresponding shutdowns, activity-based courses with large enrollment, requiring face-to-face interaction, are not considered safe. Many classes are transitioned to a virtual environment in an emergency situation, posing a complex challenge for instructors to ensure their students meet the course learning outcomes. An important aspect of an activity-based course is hands-on work with guidance from faculty, teaching assistants, and others.

Activities, traditionally used throughout our first-year mechanical engineering class at The University of Texas at Dallas, are physical, conceptual, or based on simulations [1-5]. They are performed in a lab where students form groups and work together on each activity. These activities are delivered temporarily in an online format using asynchronous video instruction, engineering software, and a discussion board in the learning management system. The synchronous format is not considered for this class because synchronous interaction between students, faculty, and teaching assistants can be very difficult due to a large number of students at different locations with varying Internet bandwidths. All activities are updated to eliminate physical contact, keeping them conceptual or based on simulations. They are also modified so they can be performed individually and remotely while some teamwork is retained. Converting the lab activities to an online format offered difficult challenges since this class traditionally includes hands-on work in a lab with computer simulation [2, 3] and physical builds [5] which could not be done in the online environment. However, the conversion was successful. A design activity and a heat transfer activity are described, as they give a good indication of other activities that are part of the online class.

The online course structure is described in this paper. The performance of the students during the Fall of 2020 (F’20) are compared to those of the Fall of 2019 (F’19) when the lecture/lab course was offered in-person. The course evaluations are also compared. Results of the comparison are used as evidence of the effectiveness of the online delivery during the pandemic.

2. Online Course Organization

The online version of the introduction to mechanical engineering class is offered through the eLearning Black Board learning management system similarly to a previously designed online computer-aided design course [6]. The top of the course's homepage, shown in Fig. 1, includes a link to the course syllabus. Immediately below that link is a schedule for the entire semester as also shown in Fig. 1. The schedule is pasted directly on the homepage and "strikethrough" is used for the contents of the past weeks as a quick reference for students. The screen print, shown in Fig. 1, indicates that it was taken during Week 9 because all entries in the schedule, up to Week 9 have the "strikethrough" formatting. The shown graded deliverables in the schedule for Week 9 are Lab 9, which is worth 3 points, and Quiz 9, which is worth 2 points. The study materials for Week 9 are Lecture 9 on the subject of Ethics. Several students provided feedback about this schedule and appreciated its simplicity, availability, and efficacy.



Course Homepage

Course Syllabus

Schedule

Week	Date	Graded Deliverables due Friday	Grade %	Study Materials
~~1~~	~~Aug 17-21~~	~~Lab 1, No lab on week 1~~ ~~Quiz 1, Available only on Friday~~	~~-~~ ~~2~~	~~Lecture 1: Solid Modeling~~
~~2~~	~~Aug 24-28~~	~~Lab 2, Parts and assemblies in SolidWorks~~ ~~Quiz 2, Available only on Friday~~	~~3~~ ~~2~~	~~Lecture 2: Mechanical Design~~
~~3~~	~~Aug 31-Sep 4~~	~~Lab 3, Features and patterns in SolidWorks~~ ~~Quiz 3, Available only on Friday~~	~~3~~ ~~2~~	~~Lecture 3: Communication Problem Solving~~
~~4~~	~~Sep 7-11~~	~~Lab 4, Open ended design project~~ ~~Quiz 4, Available only on Friday~~	~~3~~ ~~2~~	~~Lecture 4: Delivering an Elevator Pitch~~
~~5~~	~~Sep 14-18~~	~~Lab 5, Elevator pitch video~~ ~~Quiz 5, Available only on Friday~~	~~3~~ ~~2~~	~~Lecture 5: MATLAB~~
~~6~~	~~Sep 21-25~~	~~Lab 6, Motion transmission~~ ~~Quiz 6, Available only on Friday~~	~~3~~ ~~2~~	~~Lecture 6, Motion and Power~~
~~7~~	~~Sep 28-Oct 2~~	~~Lab 7, Power transmission~~ ~~Quiz 7, Available only on Friday~~	~~3~~ ~~2~~	~~Lecture 7, No lecture this week~~
~~8~~	~~Oct 5-9~~	~~Lab 8 and Lecture 8 are cancelled~~ ~~Take Exam 1 on Friday October 9~~	~~18~~	~~Lecture 8, No lecture, no lab this week~~
9	Oct 12-16	Lab 9, Ethics Quiz 9 , Available only on Friday	3 2	Lecture 9, Engineering Ethics
10	Oct 19-23	Lab 10, Structures Quiz 10, Available only on Friday	3 2	Lecture 10, Statics
11	Oct 26-30	Lab 11, Structures Quiz 11, Available only on Friday	3 2	Lecture 11, Statics
12	Nov 2-6	Lab 12, Structures Quiz 12, Available only on Friday	3 2	Lecture 12, Intellectual Property
13	Nov 9-13	Lab 13, Heat transfer Quiz 13, Available only on Friday	3 2	Lecture 13, Heat Transfer
14	Nov 16-20	Lab 14, Thermodynamics Quiz 14, Available only on Friday	3 2	Lecture 14, Thermodynamics
15	Monday Nov 23	Take Exam 2 on Monday November 23 Enjoy the Thanksgiving Holiday	20	-
16	Nov 30-Dec3	There is no final exam for this class	-	-

Fig. 1, Top of the Course's Homepage

A link is provided, below the schedule, to a discussion board where all technical questions are asked and resolved. As presented in a previous paper [6], discussion boards initialized a sense of community and helps students interact with the professor, teaching assistants, and one another. Ray and Tabas [7] deployed a survey in their online class. Their survey indicates that 8% and 54% of the students strongly agree or agree that the discussion boards provided the biggest impact on community. In this introductory class, most students used the discussion board with no hesitation while email, phone calls, and video conferences were used for discussing grades and other personal issues.

Overall there were a total of 141 different threads in the discussion board over the duration of the F’20 semester. Each thread is initiated with a question and includes a response from another student, teaching assistants, or professor. Often, the response leads to more questions by the same or a different student offering further discussions and many special teaching moments related to the course material for that particular week. The discussion board includes an optional “subscribe” feature where emails are generated automatically to alert about new posts. The discussion board buzzed with activity throughout the semester. Helpful separators, shown in Fig. 2 for the start of Week 9, were used to separate the discussions among the weeks. Similar separators were included for each week.

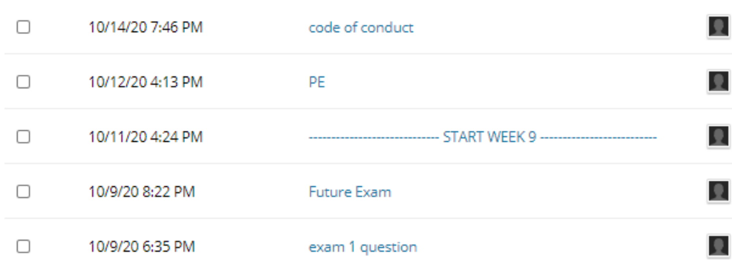
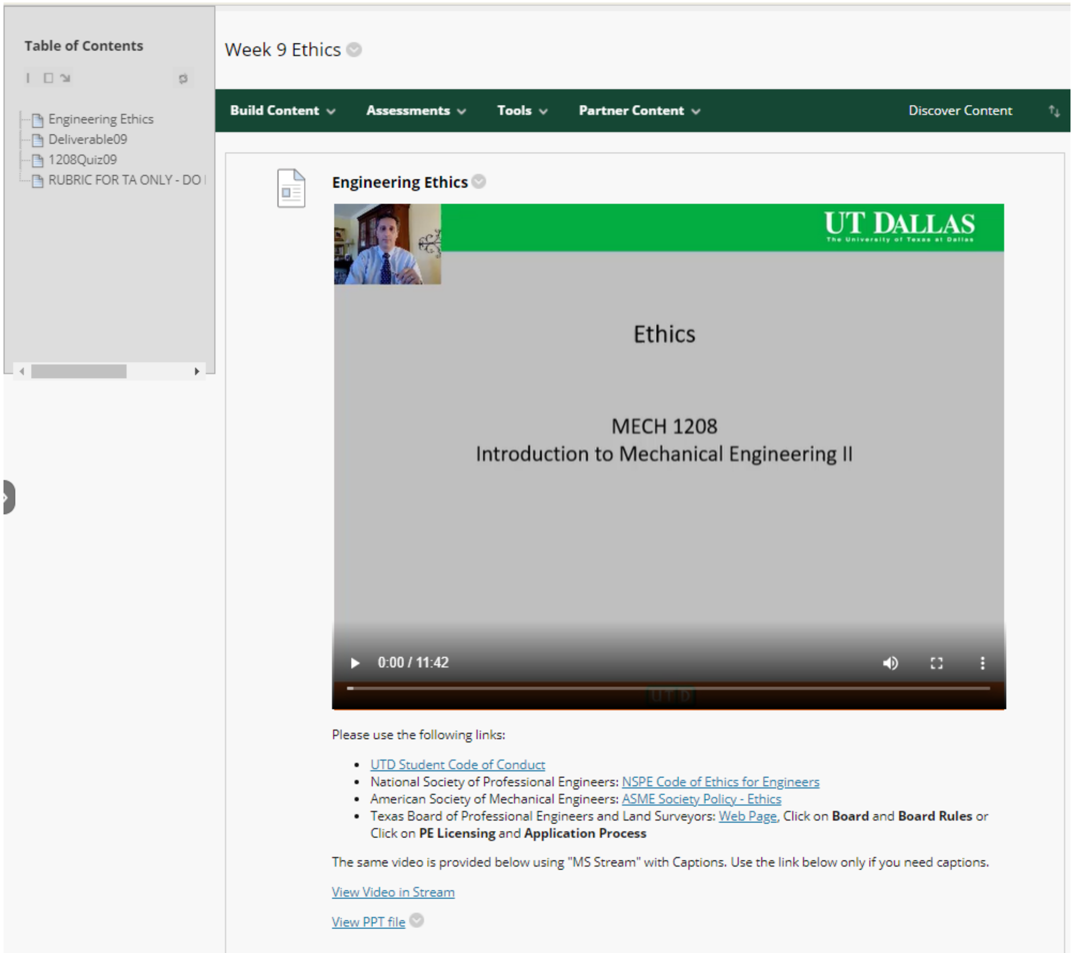


Fig. 2, Discussion Board

Since the schedule shown in Fig. 1 is for Week 9, below the discussion board is a link to the learning module of Week 9, which is shown in Fig. 3. This includes a short lecture on the subject of engineering ethics along with links to different codes of ethics. Modules used for other weeks can include a multitude of short lectures, each on a specific subject. Once visible, this learning module is always made available and the modules for previous weeks are moved to a “Previous Weeks” folder that is accessible from the homepage.

The lecture video recordings are streamed directly from the university’s cloud-based file storage system to play within eLearning. The same videos are also available in Microsoft Stream with subtitles using a link placed directly under the video (Fig. 3). This gives redundancy, as the same video is available from two different and independent file streaming systems. In both cases, there is nothing for the students to download and the students need only to come to eLearning for all the class content. The lecture slides for this week are also provided in PDF format as shown in Fig. 3.

When students complete watching the video, they find Deliverable09 in the module's Table of Contents (Fig. 3). This link, for each week, includes instructions along with a space to upload the deliverable (file response). The link is available throughout the week with an expiration date on Friday at midnight. The link to the quiz appears on Friday morning at 12 am and expires on the same Friday at 11:59 pm.



Fig, 3, Week 9

When the students go back to the homepage, they find additional links and instructions to download the student version of all software used in the class. Additionally, instructions to use the university's computers via "Remote Desktop Connection" are provided since most engineering software used in the class is available only for Windows computers while students use other types of computers.

A thank you note is added at the bottom of the homepage. It includes a statement of thanks to the students for taking the class and for all their hard work. It also includes the email of the professor and an encouraging statement.

3. Student Assessment

The assessment in the online class is based on two multiple-choice exams, weekly multiple-choice quizzes, and weekly deliverables. The exams and quizzes are provided according to the schedule that is shown in Fig. 1. The quizzes are formulated in a manner that makes them comparable to attendance and contribution in a traditional class. Specifically, the quiz questions cover certain things that were said or demonstrated in the lectures. Students can take these quizzes with unlimited attempts on Fridays and the highest grade is recorded in the gradebook but the correct answers are not revealed. The quizzes are available anywhere using any device with Internet capability.

Unlike quiz questions, exam questions are formulated to check for the student's gained knowledge of the concepts taught in the class. Some exam questions require remembering and solving engineering equations that are covered in the class. Others ask for the meaning of engineering terms or the governing phenomena over certain engineering concepts. Others ask about specifics of the analysis or design software used. Others include different aspects of the course fundamentals.

The design activity covers multiple aspects of engineering design. The students learn the basics of CAD and go through tutorials where they create three dimensional parts and assemblies in SolidWorks [8]. In parallel, they also learn the engineering design process and the components of an effective elevator pitch. An open-ended design activity follows, where the students are asked to design a tool that can be attractive to buyers who shop in a hardware store. The students are asked to define their concept, create a 3D CAD model, and deliver an elevator pitch [9]. When taking the class in person during the Fall of 2019 (F'19), the students worked in the freshman lab in teams of two. They learned together, brainstormed together, did the CAD work together, and delivered the pitch together. However, when doing the work in the virtual environment, students worked at their homes. They learned, did the CAD work, and delivered the pitch individually. However, teams of four were formed for brainstorming. Each student presented an idea to the team and received feedback on the idea from the teammates.

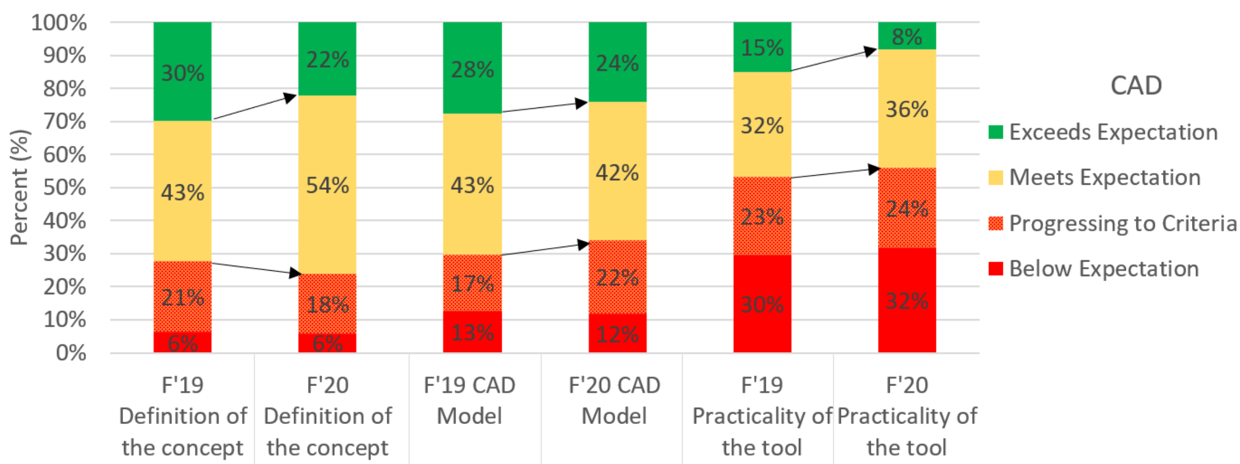
46 to 50 deliverables are selected from F'19 and F'20. They are evaluated according to the rubric shown in Table 1. This rubric is independent of the grading rubric and the actual grades that are confidential.

Table 1, Design Activity Rubric

	Below Expectation	Progressing to Criteria	Meets Expectation	Exceeds Expectation
Definition of the concept	Concept not defined	Concept is not clear	Concept is clear	Concept is ambitious
CAD Model	Incomplete & include errors	Complete with some errors	Complete	Complete and functional
Practicality of the tool	Impractical	Can be used by some	Practical	Attractive to buyers

The results for F’19 and F’20 are shown in Fig. 4. When working virtually (F’20), more than half the class defined the concept in a manner that meets expectation. Specifically, the concept definition was clear for 54% of the reports in F’20. There were less reports with ambitious concepts or not-clear concepts when compared to the reports of F’19.
When comparing the CAD models of F’19 to those of F’20, a few more errors were detected when students worked alone (F’20). There were also less CAD models that exceed expectations. However, the difference between the percentages in F’19 and F’20 are not significant.

The practicality of the tools, designed in F’19, are also comparable to those of F’20. Less are considered attractive to buyers (exceed expectations) in F’20. About 30% of the designs in F’19 and F’20 are considered impractical. Examples include the use of exotic materials with attractive properties for simple hardware tools or incomplete assemblies of the desired tools. Additionally, 23% to 24% are progressing to criteria. Examples include the design of ergonomic tools that are missing key components or hand tools that may not fit a normal hand. Tools that meet expectation are ones that can be fabricated and sold at a hardware store. Those that exceed expectation are ones that would be very attractive to buyers should they be fabricated and sold at a hardware store. Examples include special tools designed with features that make them ideal for specific applications such as 3D printing or automotive applications. This performance is acceptable since this is a freshman level course, which is followed by a computer aided design course during the sophomore year [6].



Fig, 4, Student Assessment for the Design Activity

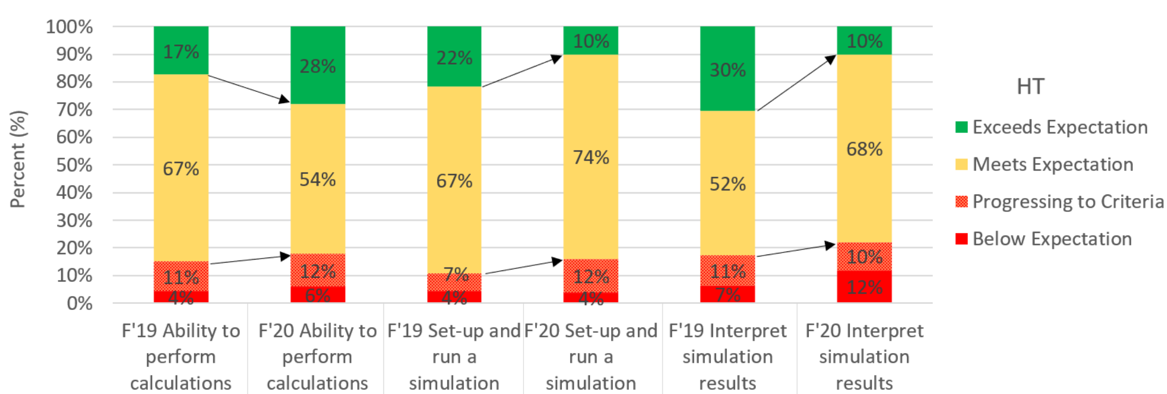
The heat transfer problem selected in F’19 is the cooling of a ball-bearing (sphere) with lump capacitance model. The students are given the analytical equation [10] and are asked to plot the temperature of the sphere over time. They are also asked to create a thermal model in SolidWorks [8] to generate the same plot and discuss any discrepancy in the results.

The problem selected in F’20 is a two-dimensional conduction problem where a buried pipe with a given surface temperature is losing heat by conduction through the earth to the atmosphere above. The students are also given the analytical solution [10] and they are asked to calculate the heat loss from the pipe. Since the SDK version of SolidWorks [8], which is available to the students on their personal computers, does not include a thermal package, the students are asked to download and use the Energy2D software [11] to create the equivalent geometry. The calculated heat loss from the pipe (using the analytical solution) is used as input and the temperature of the pipe is calculated and compared to the initially given surface temperature. The rubric, shown in Table 2, is used to evaluate the student's work in a manner applicable to both problems, independently of the grading in the class.

Table 2, Heat Transfer Activity Rubric

	Below Expectation	Progressing to Criteria	Meets Expectation	Exceeds Expectation
Ability to perform calculations	Incomplete & include errors	Complete with some errors	Complete	Complete and professional
Set-up and run a simulation	Incomplete & include errors	Complete with some errors	Complete	Complete and professional
Interpret simulation results	Cannot interpret	Interpretation is lacking	Acceptable	Well-researched

The results are shown in Fig. 5 where the first two bars represent the student's ability to perform calculations. Only a few students provided incomplete calculations with errors, even though some provided calculations with errors. There were noticeably more reports that exceed expectations in F'20 where the students provided complete and professional work while working independently at home as opposed to working with a partner in the lab under time constraints. Setting up the simulation and interpreting the results include some more reports that are below or progressing to criteria in F'20, as compared to F'19. These include errors in setting up the simulation and a corresponding lacking interpretation of the results. This is in part due to working at home in F'20 instead of working with a helpful partner in F'19 in the presence of the professor and teaching assistants. Furthermore, there were significantly less reports that exceed expectations in setting up the simulation and interpreting the results. This is mainly due to the transient problem given in F'19, coupled with the capabilities of SolidWorks to refine the meshing and the time step to get accurate solutions. This was not available in the steady state problem of F'20, solved with Energy2D which does not have controls over meshing. In this regard, the reduction in the percentage of reports exceeding expectation in F'20 is not a concern but an indication of significant room for improvement.



Fig, 5, Student Assessment for the Heat Transfer Activity

4. Student Feedback

The class evaluations, completed by the students, are positive. The in-person (F'19) and online (F'20) sections included 110 and 99 students, respectively. 45 students and 31 students answered the course evaluation at the end of the semester for these two semesters. Each student responded to given statements on a 5 level Likert scale including Strongly Disagree (SD), Disagree (D), Neutral (N), Agree (A), and Strongly Agree (SA). Among the statements given, some notable ones are shown in Table 3 where numbers less than 5% are shown in gray.

Items 1 to 3 in this table indicate that the students agreed or strongly agreed that the course objectives were clearly defined, the course was well organized, and overall, the course was excellent. The use of a separate module to cover each week is very helpful to achieve this evaluation. There is an obvious drop from strongly agree (SA) to agree (A) in these categories. This drop is attributed to offering the class in a new format (online asynchronous) for the first time with a large number of students.

Table 3, Student Course Evaluation [12]

Item	Statement	Term	SD	D	N	A	SA
1	The course objectives were clearly defined.	F'19	0%	0%	0%	18%	82%
		F'20	0%	0%	3%	31%	66%
2	The course was well organized.	F'19	0%	0%	2%	13%	84%
		F'20	0%	0%	0%	28%	72%
3	Overall, the course was excellent.	F'19	0%	0%	2%	11%	87%
		F'20	0%	0%	0%	38%	63%
4	The instructor provided timely feedback.	F'19	0%	0%	2%	13%	84%
		F'20	0%	0%	0%	25%	75%
5	The instructor was accessible outside of class.	F'19	0%	0%	7%	11%	82%
		F'20	3%	0%	3%	19%	75%
6	I was free to ask questions and express my opinions and ideas.	F'19	0%	0%	2%	9%	89%
		F'20	0%	0%	3%	28%	69%
7	I discussed ideas from this course with others outside the classroom.	F'19	0%	0%	11%	13%	76%
		F'20	3%	3%	0%	44%	50%
8	This course has been (or will be) of value to me.	F'19	0%	0%	2%	11%	87%
		F'20	0%	0%	3%	29%	68%
9	This course inspired me to learn more.	F'19	0%	0%	4%	16%	80%
		F'20	0%	0%	3%	31%	66%

Gray font is used for numbers below 5%

The statements numbered as items 4 to 6 (in Table 3) indicate that most students agreed or strongly agreed that the instructor provided timely feedback, the instructor was accessible outside of class, and they were free to ask questions and express opinions and ideas. The F'19 class was in person and office hours were offered while the F'20 class required all communication using a discussion board in learning management system. Being present for the students virtually required long hours of answering questions in-writing promptly to achieve and maintain a high level of trust between the professor and the class.

Statement number 7 relates to the student's discussion of the course materials with others outside the classroom. Even though there was no physical classroom during the F'20 semester, there was an online classroom community and students discussed ideas from the class with others outside the classroom community. These discussions can help the students learn from others in addition to learning from the professor and the teaching assistant.

The final two statements (8 and 9) in Table 3 indicate that the students feel the course has been or will be of value to them and inspired them to do more. Again, there were no disagreements with these statements. However, the shift from SA to A is persistent but acceptable.

The course evaluation for the online class also includes three questions asking the students what aspects of this course should remain the same, what aspects should change, and offers a place to add additional comments. Answers to what should remain the same are quite flattering. One student wrote, "I like how well the class is organized. The expectations are clearly outlined. I like how the material is available for download, it makes it easier to view and re-view."

As for what needs improvements, the majority of the comments in the online class relate to the quizzes and exams. One student felt "the quizzes were not as focused as things discussed in the lecture as much as it is just regular facts and stuff we should know." Other students also asked for a review session to cover the contents of the exams. Due to these comments, more emphasis on the purpose of the quizzes is provided to students as we move forward. Specifically, the quizzes test for "attendance" and the questions asked are intended to provide a very good indication of the student's attention to the recorded lectures that are provided.

The additional free comments were also flattering in general. One student wrote, "Out of all my classes this was the best. It was well organized and easy to understand due to the videos for each topic. During this time of everything being remote, it has been extremely hard to keep up with assignments but this class for sure was the most organized and well prepared out of all of them." These comments from the students are well appreciated and make worthwhile all the course preparation and teaching efforts.

7. Summary

The online offering of the introduction to mechanical engineering during the coronavirus pandemic is considered successful, as the assessments show comparable results to previous offering in a traditional face-to-face format. The student's feedback, provided in their course evaluation, indicates appreciation for the online class. After the successful completion of this online class, some improvements in the materials and communication with the students will be implemented for at least one more online semester. However, the online lectures and their corresponding quizzes are likely to continue for this class because they are considered highly effective, as compared to live lectures with recorded attendance. Simulation work can continue virtually or in the lab and more work is needed for future publications on the tradeoffs between virtual and in-person versions of these simulations. However, the return to the lab is highly desired for the physical activities that could not be done at home.

References

[1] O. Rios and D. Fadda, 2017, "A Mechanical Engineering Freshman Course Implementing Four Design Activities," Proceedings of the ASME International Mechanical Engineering Congress & Exposition, IMECE17, November 5-8, Tampa, Florida, USA

[2] O. Rios and D. Fadda, 2019, "Using Computer Simulations in a Freshman Mechanical Engineering Course to Make Informed Design Decisions," 126th ASEE Annual Conference and Exposition, June 15 - 19, 2019, Tampa, Florida, USA

[3] D. Fadda and O. Rios, 2018, "Introduction to Heat Transfer in a First-Year Mechanical Engineering Course," ASEE Annual Conference and Exposition, June 24-27, 2018, Salt Lake City, UT, USA

[4] O. Rios and D. Fadda, 2018, "A Conceptual Design Activity for a First-Year Mechanical Engineering Course," ASEE Annual Conference and Exposition, June 24-27, 2018, Salt Lake City, UT, USA

[5] D. Fadda and O. Rios, 2017, "Designing a Scalable Statics Project for a First-Year Mechanical Engineering Course," ASEE First Year Engineering Experience (FYEE) Conference, August 6-8, Daytona Beach, Florida, USA

[6] D. Fadda and O. Rios, 2019, "Online Computer Aided Design Class," 126th ASEE Annual Conference and Exposition, June 15 - 19, 2019, Tampa, Florida, USA

[7] V. M. Ray and J. Tabas, "Developing Improved Methodology for Online Delivery of Coursework Providing a Framework for Quality Online Education," in Proceedings of the ASEE Annual Conference and Exposition, Salt Lake City, Utah, 2018.

[8] SolidWorks: www.solidworks.com

[9] The elevator pitch: advocating for your good ideas, University of New Haven, KERN Entrepreneurial Engineering Network (KEEN): www.newhaven.edu/engineering/kern-entrepreneurial-engineering-network/elearning-modules/

[10] T.L. Bergman, A.S. Lavine, F.P. Incropera, and D.P. Dewitt, "Fundamentals of Heat and Mass Transfer," 7th Edition, Wiley, 2011.

[11] Energy2D: Interactive Heat Transfer Simulations for Everyone, The Concord Consortium, NSF Funded Free Software: energy.concord.org/energy2d/

[12] Coursebook: https://coursebook.utdallas.edu/search/mech1208.001.20f and https://coursebook.utdallas.edu/search/mech1208.001.19f