An Online Engineering Dynamics Class for College Sophomores: Design, Implementation, and Assessment

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1 Introduction

This paper presents design, development, and implementation of a new online Engineering Dynamics class for post-secondary sophomores. This online class was offered for the first time at Stony Brook University (SBU) in the summer of 2016 to 70 students who came from 11 different universities. For its development, the OSCQR (Open SUNY Course Quality Review) Rubric [1] was followed, which was created by the Open SUNY Center for Online Teaching Excellence (COTE). The OSCQR is an openly licensed rubric that addresses both the instructional design and accessibility of an online course.

Engineering Dynamics, which deals with the science of motion is generally a core, required class in Mechanical Engineering major at undergraduate level. The anecdotal and quantitative feedback from the students indicates that the class is of appreciable difficulty in content [2, 3] and presents a major roadblock to timely graduation rate [4]. Engineering Dynamics typically requires students to apply their newly acquired knowledge of vector-algebra, differential- and integral-calculus, and to some extent differential equations from their freshmen and sophomore year. In addition, they are also expected to use their pre-requisite knowledge and skills from Engineering Statics class, such as drawing Free Body Diagrams (FBD), performing static equilibrium analysis, and following a systematic approach to problem solving. Some universities combine Engineering Statics and Dynamics in one course or simply forego Statics class; however, at SBU, these two classes have been offered in sequence with Statics as a pre-requisite for the Dynamics class. Engineering Dynamics, by its very nature, is organic and connected – topics sequentially build upon previous concepts. This prevents a fragmented and discrete presentation of the course material, which in turn increases cognitive load on students.

It is widely believed among the students that Dynamics is best taken in-person, while the paucity of an online version of the class seems to indicate that the educators have not been convinced of the idea of an online class either. A few researchers have created limited online learning objects for enhancing learning of the material in Dynamics [5], and some have used flipped class material into an online class [6]; however, there have been meagre efforts in creating a completely online Dynamics class. This could be attributed to either the lack of effectiveness in delivering the course outcomes using an online *only* medium or simply the difficulties associated with creating such a class. However, these challenges also pose an opportunity to create a well-designed online Dynamics class, which can help students overcome some of their fears and difficulties, but also help departments meet their program-level and student-outcomes. An online version of the class consisting of topical videos of the lecture, on-line quizzes and homework, and assessments could 1) facilitate self-study and -pacing of the material on part of students, 2) enable problem solving and critical discussion between students and instructors using an online forum, and 3) scale-up the class to reach a large number of students.

By creating effective online modules consisting of short and self-contained video lectures, which demonstrate the concepts, techniques, procedures, and problem solving approach in a consistent fashion, students were first exposed to the learning material. Thereafter, they were given a series of formative and summative assessments. A total of 94 videos spanning more than 1500 minutes were created in Khan-academy style and are freely available for anyone to watch and learn from at the author's youtube playlist at https://www.youtube.com/PurwarSBU. The class utilized both synchronous and asynchronous modalities to facilitate students-to-students and students-to-instructor interaction. This paper will present details of class design, implementation, resources developed, and the assessment data on meeting the course learning objectives apart from discussing the best practices and technologies used.

The rest of the paper is organized as follows: in section 2, motivation, goals, and learning outcomes of the new online class are presented; in section 3, the design and implementation of the course is discussed; and finally, in section 4, data and assessment are presented.

2 Motivation, Goals, and Learning Outcomes

2.1 Motivation

Engineering Dynamics, offered in the Spring and the Summer sessions at the SBU, is a required undergraduate class in the Mechanical Engineering department. Students have to pass this class with a grade of C or better to advance further in the major. Engineering Statics with a grade of C or higher is a pre-requisite for this class. The class deals with the kinematics and kinetics of particles and rigid bodies and advocates and rigorously enforces a vector-based systematic approach to problem solving. This helps students learn that every problem does not require a different approach to solving problems. The class prepares students to take junior-level Kinematics of Machinery, Machine Design, and Senior Design classes, wherein a solid theoretical and analytical foundation in Engineering Dynamics is absolutely essential.

At SBU, this class has always been offered as a traditional face-to-face (F2F) class. Beginning in 2005, the first author Purwar taught the F2F class for five years every year in the Spring semester in a single section with an average enrollment of 175 students, which swung between 85 to 300+ students. From 2006 to 2015, the author also taught this class every summer in an F2F format with an average enrollment of 40 students. The F2F classes have been primarily taken by the students from our own university only with less than 20% students from other schools taking the class in the summer. In contrast, the Spring semester enrollment draws from our own university only. Unfortunately, it was observed that on average the quality of the students in the summer had been on the lower side owing to the fact that most of the students from our own university were taking this class after having failed it in the Spring. This was evident from 1) the lack of preparation indicated by the students' score on the introductory quizzes given to the students, which tested their pre-requisite knowledge and 2) inferior in-class discussions and problem solving skills displayed by the students during recitations. What exacerbated this problem further was that the summer F2F offering was compressed over a period of six weeks, while the Spring semester class is a 13 weeks long class with the same content and same number of assessment instruments, viz. homework, quizzes, and exams. The author found that the summer F2F class was mentally and physically demanding for both the students and him – he was lecturing for almost five hours twice a week and the students were expected to pay attention for an inordinate amount of time, but given very little time to absorb the material and practice problem solving. While there were clear learning obstacles to overcome in the class, it was even more challenging for part-time students who were either working to support themselves financially or doing an internship. Consider the following two anonymous comments from students of the Summer 2015 class, which are reflective of some of the difficulties faced by the students:

1. *Less homework. It's impossible to finish if you work and have other priorities in life.*
2. *The difficulty of the class. The home works were brutal and due every class if there was not a test that day.*

The author used several strategies to engage the students in the class by delivering an authentic chalk-and-board lecture, connecting principles with real-life examples, and asking students to come to the board to solve problems with the help from the instructor. Despite these efforts, the summer F2F classes were challenging to teach and even more so for the students to take.

2.2 Goals

In recent years, it has become obvious that online classes offer significant benefits to students who learn differently, need flexibility in learning the material through videos and notes at their own time and pace due to their work schedule or general preference, or have difficulty adjusting to a F2F class due to the language and social issues [7, 8]. The two flavors of online classes that have been popular are Flipped-Format (FF) and 100% Online (OL) ones. In the flipped format, students typically watch videos of course material and study assigned readings or notes outside the class and supposedly attend the class for group problem solving, engage in critical discussions, and interact with the instructor. On the other hand, in an online class, usually there is no face to face interaction with the instructor, and all learning takes place outside the "classroom", which has no physical space. In the OL format, students watch videos, study notes and text, do homework, take quizzes and exams all at their own time and pace, albeit with some restrictions on the due dates of some of the assessment instruments. All OL classes also incorporate an online interaction component for answering questions and facilitating students-to-students and students-to-instructor interaction. Most digital course management systems, such as Blackboard, Moodle, etc. implement an online discussion forum to enable such interactions. Some instructors may also choose to have a modicum of regular interaction with the students using an online, synchronous tool, such as Adobe Connect [9] or Google Hangouts [10] to help with conceptual- and home work-questions or merely to provide assurance to the students that there is a human being, not a robot, who is in-charge of their learning.

Considering some of the aforementioned challenges for both the instructor and the students, it became apparent that an online Engineering Dynamics class, if designed and delivered properly, could help address the difficulties faced by the students and the instructor, enable scaling of the class, improve grades and graduation rate, and ultimately help meet student outcomes set by accreditation agencies (ABET). With the availability of the emerging technologies, such as 1) an open and flexible video platform (youtube.com) that conforms to both desktop and mobile delivery, 2) collaborative social media-frameworks, 3) synchronous online communication tools, that implement internet-based whiteboard and screen sharing, 4) online proctoring and homework assignment system, and 5) software and hardware platforms for video recordings and stylus-based capture of lectures, a fully online version of the Engineering Dynamics class was at least possible. With that, the lead author set out to create an online class, which would have short topical videos of concepts and worked out examples, on-line quizzes, exams, and homework, and assessments. We also constrained ourselves to deliver all of these completely online only so that the class could be scaled without sacrificing the learning outcomes.

2.3 Course Learning Outcomes

Both the F2F and the OL versions of this class have the same course learning outcomes (CLO). It is expected that upon completion of this course, students will be able to:

CLO.1 determine the position, velocity and acceleration of a particle and system of particles in Cartesian, Polar as well as Normal and Tangential coordinate systems.

CLO.2 draw Free Body Diagrams and apply Newtons laws of motion to calculate (1) the displacement, velocity, and acceleration of a particle system caused by given forces, and (2) the forces needed for a particle system to move in a prescribed way.

CLO.3 compute work, potential energy and kinetic energy for particle(s), and apply work-energy approach to problems where forces and acceleration are not primary quantities of interest and to use these principles to obtain velocity, displacement, and the work done by external forces

CLO.4 compute Momentum and Impulse of particle(s) and apply Momentum-Impulse approach to problems where velocity, time, and forces are related in a more natural way.

CLO.5 determine the velocity and acceleration components of a system of connected rigid bodies with pinned, sliding and rolling connections.

CLO.6 draw Free Body Diagram and apply Newton-Euler equations to relate forces and moments acting on rigid bodies in planar motion with their linear and angular acceleration.

CLO.7 compute potential- and kinetic-energy for a system of interconnected rigid bodies moving in a plane, and apply work-energy principle to the problems where forces and acceleration are not primary quantities of interest and to use these principles to obtain velocity, displacement, and the work done by external forces.

CLO.8 derive and solve differential equation of motions for particles and rigid bodies under free, forced, and damped vibrations.

3 Design, Implementation, and Challenges of Online Class

3.1 Design and Implementation

An online version of the Engineering Dynamics was offered for the first time in the summer of 2016 and since then it has been offered in the OL format only every summer, while the Spring class has continued to be offered F2F only. The course design was based on the OSCQR (Open

SUNY Course Quality Review) Rubric [1] created by the Open SUNY Center for Online Teaching Excellence (COTE). This rubric is concerned with the instructional design and accessibility of an online course. The summer OL course offered over a period of six-weeks is organized in eight modules each corresponding to one of the CLOs. Each module consists of 8-10 self-contained videos, which demonstrate the concepts, techniques, and vector-based problem solving approach. These videos are also embedded inside the Blackboard course management system. Every video has a formative quiz associated with it to ensure that the students were indeed watching the lectures and had at least a formative understanding of the material covered in the video. However, it serves more as a self-assessment tool for the students rather than an evaluation instrument for the instructor. Therefore, the students are allowed to take the formative quizzes as many times as they wish without any grade penalty. There are no grades assigned for watching the videos or for taking formative quizzes; however, the formative quizzes are tracked for completion.

Each module also consists of a HW assignment and a summative quiz, both of which are part of students' grade. Students are given at least a week to complete all activities associated with a module; however, due to the compressed schedule in the summer, there is an overlap between two modules in any given week. While the formative quizzes can be thought of as test quizzes, the summative quizzes are meant to assess the students' summative understanding of a given module and are graded. They can be taken only once and can be thought of as mini exams. The level of difficulty of the summative quiz questions is an order of magnitude higher than the formative quizzes owing to the fact that the students would have completed the home work assignment associated with that module; see Fig.1 and 2 for example questions.

A particle starts from the rest and then accelerates. Its acceleration as a function of time is given as $a(t) = 8t^2$ m/s^2. It's velocity at $t = 2$ s is,
a) 32 m/s
b) 16 m/s
c) 8.5 m/s
d) 21.3 m/s

Figure 1: An example formative quiz question from the *Kinematics of Particles* module; this question requires a direct integration to determine the velocity.

The velocity of a particle as a function of distance is given as, $v(s) = s^2 - 5s + 3$. The acceleration of the particle when $s = 2$ m is,
a. 2 m/s^2
*b. 3 m/s^2
c. - 3 m/s^2
d. -1 m/s^2

Figure 2: An example summative quiz question from the *Kinematics of Particles* module; this question requires first introducing change of variable and then a differentiation to determine the acceleration.

The quizzes are delivered using an online proctoring system called Respondus Lockdown browser [11], which is a specialized web-browser that uses facial recognition technology in conjunction with a webcam and microphone to track students' audio-visual presence. This browser also disallows opening any other application during the tests. Any anomalies are recorded and flagged for the teaching team to review. Use of Respondus has allowed students to take quizzes and tests from anywhere in the world as long as they have a solid internet connection and a working computer with a webcam and microphone. Students do not have to go a testing center, although they are not precluded from doing so. While the quizzes can be taken over a period of time, exams are scheduled on a certain time and day. Although, the Respondus is not a synchronous proctoring system without a live person watching students during the exam, it has proven to be very effective in the three years of the offering of the OL class; see Fig. 3 for an example of a student's recording screenshot.

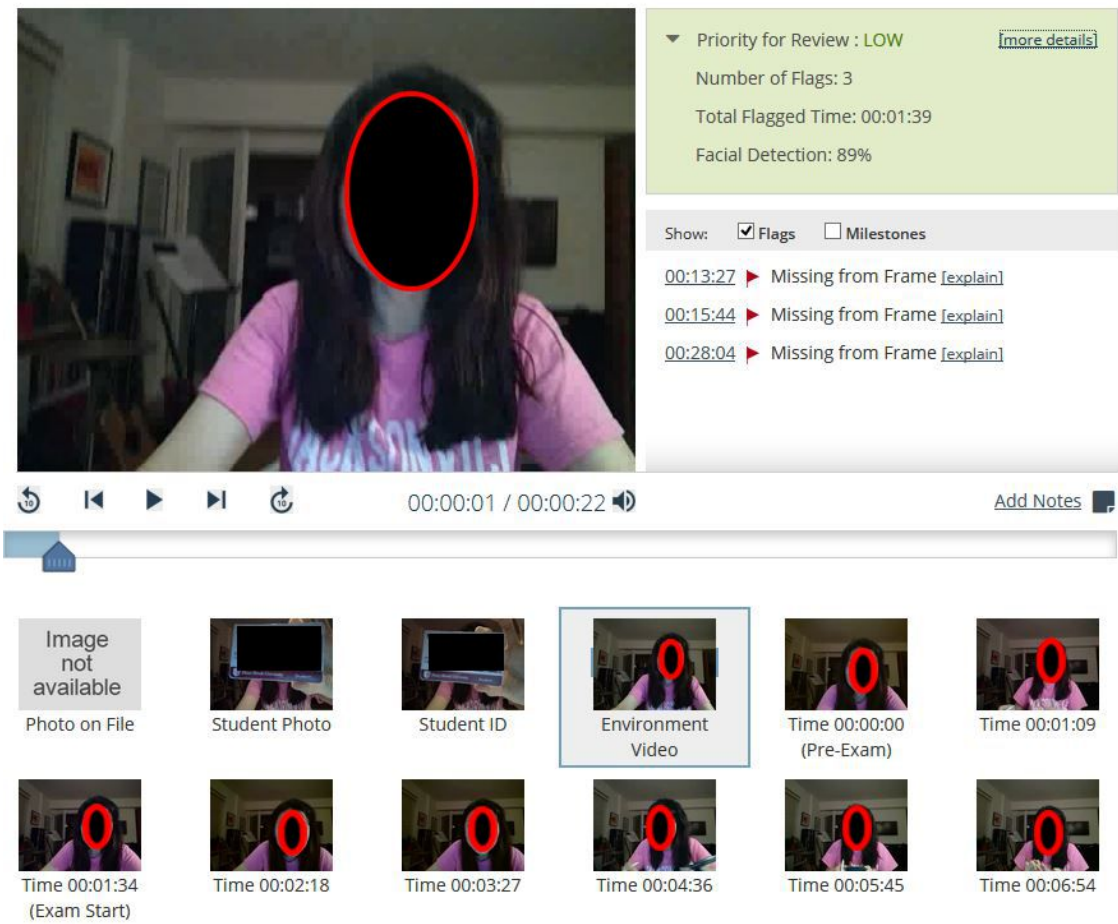

Figure 3: This screenshot of a student's webcam video shows review priority using facial detection and flagging of the events like *Missing from Frame* and *Different person in frame*. The entire session can be replayed as well.

The homework assignments are delivered and graded through McGraw Hill Connect system [12], a web-based assignment and assessment platform, which costs students about $120; however, it includes access to the text book. The Connect system provides adaptive evaluation and assignment of the questions, which has helped with scaling of the class, but the students have at times reported technical difficulties associated with loading of the home work assignments, which uses now obsolete Adobe Flash technology. However, at this time, the text book *Engineering Mechanics: Dynamics* used in this class by Gray et al. uses the Connect platform only and thus a better alternative is not available.

This OL class uses Piazza [13], an web-based Wiki-style Q&A forum, where students can ask questions and both the students and teaching team can contribute to an answer. The system is designed to be intuitive and easy to use. For this class, which uses a lot of mathematics and equation writing, the support for LateX in the system is hugely beneficial. This is the single most important reason for the author to use Piazza. It has been the author's experience that Piazza has managed to bring the best out of his students – students who are typically shy and would never ask a question or raise their hand find it easy to ask and answer questions. The teaching team is able to provide answers to questions almost instantly and the overall class participation is much enhanced; see Fig. 4 for an overall summary of the class from Summer 2017. In the Summer of

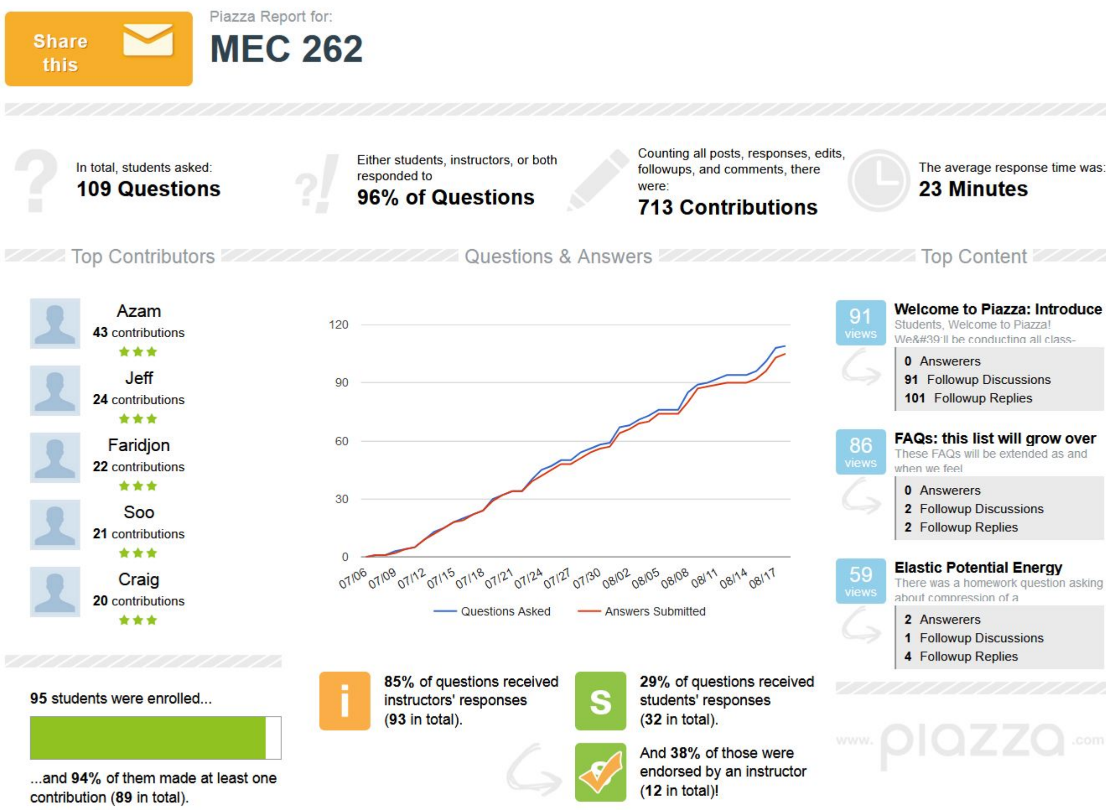

Figure 4: This Piazza report of the Summer 2017 OL class shows a statistical summary of the number of questions asked, contributions, and average response time.

2016, the author also organized weekly synchronous web-based office hours to answer students' questions using Adobe Connect and screen sharing technology [9]; however, this experiment was discontinued in later years due to the lack of interest from the students. The students preferred to interact with the instructor and fellow students over Piazza only, which served as an on-demand office hours. The mobile app for the Piazza allowed the instructor to remain in contact with the students even when he was not in front of a computer, which helped with a low response time of 23 minutes; see Fig. 4.

3.2 Challenges

Apart from the tools of creations and delivery; however, there were still challenges associated with the creation of the content and the assessment instruments, which would ensure meeting learning outcomes. One of these challenges as perceived by the author was the belief that the Engineering Dynamics is a very organic class not amenable to power-point based delivery of material. His style of teaching this class F2F involved using chalk and blackboard or a smartscreen and stylus so that he could show step-by-step development of a formula, derivation, or governing equations. This is crucially needed as the material usually builds upon fundamentals and begins to develop complexity very rapidly. Another challenge was creation of adequate questions for the quizzes and the exams, which could be delivered in a scalable way without compromising the learning outcomes. At first, it seemed a herculean task as having taught this class F2F for over a decade, the author found it challenging to conform to the constraints of a new medium that seemingly imposed restrictions, which were absent in the F2F class. For example, a typical rigid body dynamics problem would require drawing free body diagrams and then applying Newton-Euler equations in conjunction with kinematic analysis to find answers. In an F2F class, a student would spend as much as 20-30 minutes to solve a medium-difficulty problem, but in an OL format, where the goal is for the system to evaluate the solution, this would be difficult to implement and could spell disaster for the students' performance.

The first challenge was easier to navigate with the use of a tablet (Microsoft Surface Pro) and a pen to record the lectures using a recording software called Camtasia Studio [14]). The author created a total of 94 videos spanning more than 1500 minutes in Khan-academy style and has made them available at his youtube playlist. The second challenge of the quiz and test questions required a careful planning to create multiple choice questions that were of the right complexity and length and could adequately satisfy the requirements of the CLOs. Typically, this involved reducing multi-step problems to many questions and ensuring that each question only tested students on a single core concept. This ensured that there was enough atomicity and differentiation among the question and at the same time they could be graded autonomously by the system. In the end, the author created more than 1000 questions for the entire course. This was the most time consuming task after the creation of the videos. However, the rewards of this effort could be reaped over time and with the continued improvement and addition of new questions, it became clear that this might prove to be an effective and scalable strategy.

4 Data and Assessment

The OL version of the Engineering Dynamics has been now taught every summer since 2016. Before 2016, the class was always offered F2F only and more than 90% of the students enrolled were from our own university only. The inaugural OL class had 70 students enrolled from 11 different universities from seven different majors; however, 75% of the students were still from our own school. In Summer 2017, there were 87 students from 12 different universities representing 10 majors; however, this time the enrollment from our school was 71%. In 2018, there were 72 students enrolled from 18 universities, such as Purdue, University at Buffalo, University of Delaware, Rensselaer Poly, University at Maryland, University at Texas, Case Western, University of Massachusetts at Amherst, James Madison, Dayton, etc. In this year, we saw the enrollment from our school drop to 62.5%. This was an indication that the class was now better known to students and administrators from other universities. In contrast, the enrollment from the years

Overall Grade

	A	B	C	D	F	Mean	Standard Deviation	Did Not Answer	Total Responses
A	21.43% (3)	50% (7)	28.57% (4)	0% (0)	0% (0)	3.93	0.7	0	14
B	23.08% (3)	30.77% (4)	30.77% (4)	7.69% (1)	7.69% (1)	3.54	1.15	0	13

The instructor was effective in teaching the subject matter.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	Mean	Standard Deviation	Did Not Answer	Total Responses
A	21.43% (3)	57.14% (8)	21.43% (3)	0% (0)	0% (0)	4	0.65	0	14
B	23.08% (3)	30.77% (4)	30.77% (4)	15.38% (2)	0% (0)	3.62	1	0	13

Figure 5: Summer 2015 F2F class Student Evaluation: Average for the lecture (labeled A) and the recitation (labeled B) are on par with the department average, but slightly lower than the university average.

before 2016 never crossed 50. It was apparent that an OL class could provide the same opportunity to students from far-flung schools as our own students and help them meet their program and graduation requirements.

While the increase in the enrollment must have been music to the ears of the administrators as the out-of-state students paid significantly higher tuition than in-state students, the authors were more interested in learning how this OL class would compare to the previous F2F offerings and how well the students performed in the class and satisfied the CLOs. In what follows, we will first look at the indirect assessment data obtained from the course evaluations and then examine direct assessment. Figures 5, 6, 7, and 8 show students' rating for the overall grade for the class and the instructor's effectiveness in teaching the subject matter on a 5-point Likert scale. It can be seen that, in general, the students reviewed the Summer 2016, 2017, and 2018 OL classes more favorably compared to the Summer 2015 F2F class.

In general, the qualitative comments from the OL classes were very positive and encouraging; for example:

1. *Wow, what a class! For this being the first time the class has been offered online, Purwar really did a great job. Knowing him, it'll only get better too. The videos were spectacular.*

2. *It was a tough, yet enjoyable course. Like most engineering classes, this course will require a great deal of your time to master the subjects. Expect to always be on your feet since the pace is so quick. Professor Purwar has a great teaching style in this class and it made learning the material smoother. I would recommend this summer class as a viable option for sophomore dynamics.*

3. *Being able to go back and rewatch the lectures was a very helpful feature. His teaching was very interesting. I loved looking at this subject beyond formulas and applying them onto the*

Overall Grade									
	A	B	C	D	F	Mean	Standard Deviation	Did Not Answer	Total Responses
A	52.17% (12)	34.78% (8)	8.7% (2)	4.35% (1)	0% (0)	4.35	0.81	0	23

The instructor was effective in teaching the subject matter.									
	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	Mean	Standard Deviation	Did Not Answer	Total Responses
A	52.17% (12)	39.13% (9)	8.7% (2)	0% (0)	0% (0)	4.43	0.65	0	23

Figure 6: Summer 2016 OL Class Student Evaluation: average score for the class and the instructor's effectiveness improved considerably from 2015. 87% of the students in this class also agreed that the instructor and the learning activities enabled them to achieve the course learning outcomes (not shown in the figure).

real world.

Similar comments were made for the 2017 and 2018 versions of the class as well; however, students also bemoaned the lack of sufficient time in a six-week period to complete all the tasks, having technical problems with the Connect system, and demanded more example problems. Overall, most of the students appreciated the videos, quizzes, and piazza. The ability to rewatch videos and take quizzes at their own time was considered to be the most valuable aspect of the OL class.

4.1 Direct Assessment of CLOs and Results

Several assessment instruments were utilized to assess the CLOs. For the Summer 2016 OL class, the primary assessment instruments were direct measurements from (a) Midterm Exam I, (b) Midterm Exam II, and (c) the Final Exam. Performance benchmarks were established to determine whether students met the CLOs. The performance benchmarks are as follows: 70% of the questions being utilized to measure each CLO needs to have at least 50% or more of the students getting the correct answer. Per SUNYs Number Grade Conversion Chart, 70% is a C grade. Since a C grade is satisfactory work in accordance to the Undergraduate Bulletin, it is ideal for an instructor to use these criteria to determine whether an outcome was met. The 50% benchmark supports the idea of designing test items that encourage a widespread distribution of scores, where 50% of the students will get the correct answer.

Figure 9 shows the results and whether the outcomes were met for the Summer 2016 OL class. Only outcomes 1-7 were chosen to be assessed. The Mean, Median, and STDEV in the figure are aggregate percentage of students answering the questions correctly. As an example, the raw data showing the percentage of the students correctly answering questions that map to the CLO.1 are provided in the Fig. 10. This figure shows that there were 19 questions in the midterm I and two questions in the final exam, which mapped to the CLO.1. Thus, the performance benchmark for the CLO.1 is 15 questions, which is 70% of the 21 questions. Out of these 21 questions, 17 questions met the benchmark of 50% or more students answering them correctly. As can be seen from the figure, four of the seven CLOs were met per the established performance benchmarks.

Overall Grade									
	A	B	C	D	F	Mean	Standard Deviation	Did Not Answer	Total Responses
A	37.5% (18)	41.67% (20)	16.67% (8)	4.17% (2)	0% (0)	4.13	0.83	0	48

The instructor was effective in teaching the subject matter.									
	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	Mean	Standard Deviation	Did Not Answer	Total Responses
A	47.92% (23)	35.42% (17)	16.67% (8)	0% (0)	0% (0)	4.31	0.74	0	48

Figure 7: Summer 2017 OL Class Student Evaluation: average scores are within one standard deviation from the previous year.

		A	B	C	D	F	Mean	Standard Deviation	Did Not Answer	Total Responses
Overall Grade	A	50% (20)	32.5% (13)	15% (6)	2.5% (1)	0% (0)	4.3	0.81	0	40

		Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	Mean	Standard Deviation	Did Not Answer	Total Responses
The instructor was effective in teaching the subject matter.	A	47.5% (19)	35% (14)	12.5% (5)	5% (2)	0% (0)	4.25	0.86	0	40

Figure 8: Summer 2018 OL Class Student Evaluation: average score for the class and the instructor's effectiveness were in the vicinity of scores from 2016 and 2017.

However, this analysis did not discard questions with poor discrimination index (< 0.1) and of extreme difficulty level ($< 30\%$). It is expected that with those filters in place, the performance outcome for the CLOs would improve. Nonetheless, it was recommended to consider using less questions to measure each CLO, pick better assessment instruments, and/or do a more extensive assessment that includes individual student response data.

We repeated this analysis for the Summer 2018 OL class; however, this time instead of choosing exam questions as the criteria for performance benchmark, it was decided that the summative quizzes that have questions decidedly mapping to a single CLO would be used for performance evaluation. Examination questions sometimes require students to apply multiple concepts in the same question, which makes it difficult to assess them. This also aligns closely to competency-style questions. Figure 11 shows the results of this analysis. For this analysis, we set the performance benchmarks as follows: 80% of the questions being utilized to measure each CLO needs to have at least 50% or more of the students getting the correct answer.

In contrast to the previous assessment analysis, this shows that the CLO.3 and CLO.5 were not met. While CLO.3 is concerned with the work-energy approach for particles, the CLO.5 is concerned with the kinematic analysis of interconnected rigid body under planar motions. This is

CLO 1	
Mean	61.05
Median	67.16
STDEV	28.42
Performance Benchmark	70% (15)
Outcome Results	81% (17)
Outcome Met (Y/N)	**Y**

CLO 2	
Mean	52.15
Median	59.70
STDEV	27.87
Performance Benchmark	70% (13)
Outcome Results	70% (13)
Outcome Met Y/N	**Y**

CLO 3	
Mean	54.28
Median	59.70
STDEV	18.59
Performance Benchmark	70% (8)
Outcome Results	70% (8)
Outcome Met Y/N	**Y**

CLO 4	
Mean	46.35
Median	54.68
STDEV	35.12
Performance Benchmark	70% (2)
Outcome Results	70% (2)
Outcome Met Y/N	**Y**

CLO 5	
Mean	53.38
Median	56.71
STDEV	20.43
Performance Benchmark	70% (13)
Outcome Results	58% (11)
Outcome Met Y/N	**N**

CLO 6	
Mean	55.40
Median	67.18
STDEV	26.18
Performance Benchmark	70% (6)
Outcome Results	63% (5)
Outcome Met Y/N	**N**

CLO 7	
Mean	44.44
Median	42.18
STDEV	21.25
Performance Benchmark	70% (6)
Outcome Results	33% (3)
Outcome Met Y/N	**N**

Figure 9: Course Learning Outcome Assessment for the Summer 2016 OL class

CLO1	**Assessment Instrument**	**Midterm I**																			**Final**	
	Question (N=21)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	1	2
	% of Students Who Got it Correct	95.52	73.13	62.69	85.08	85.08	62.69	92.54	85.08	68.66	59.70	82.09	58.21	68.66	43.29	67.17	2.99	55.23	0.00	0.00	78.13	56.25

Figure 10: Percentage of the students correctly answering questions in the miderm I and the final exam that map to the CLO1

CLO 1	
Mean	68.99%
Median	71.02%
STDEV	20.82%
Performance Benchmark	80% (4)
Outcome Results	80% (4)
Outcome Met (Y/N)	**Y**

CLO 2	
Mean	60.59%
Median	68.99%
STDEV	17.82%
Performance Benchmark	80% (4)
Outcome Results	80% (4)
Outcome Met Y/N	**Y**

CLO 3	
Mean	50.43%
Median	49.30%
STDEV	12.13%
Performance Benchmark	80% (4)
Outcome Results	40% (2)
Outcome Met Y/N	**N**

CLO 4	
Mean	63.77%
Median	69.57%
STDEV	22.48%
Performance Benchmark	80% (4)
Outcome Results	60% (3)
Outcome Met Y/N	**Y**

CLO 5	
Mean	67.33%
Median	67.87%
STDEV	12.75%
Performance Benchmark	80% (4)
Outcome Results	90% (9)
Outcome Met Y/N	**Y**

CLO 6	
Mean	52.73%
Median	48.49%
STDEV	10.68%
Performance Benchmark	80% (4)
Outcome Results	40% (2)
Outcome Met Y/N	**N**

CLO 7	
Mean	53.55%
Median	58.47%
STDEV	7.49%
Performance Benchmark	80%(4)
Outcome Results	80%(4)
Outcome Met Y/N	**Y**

CLO 8	
Mean	69.26%
Median	70.15%
STDEV	5.54%
Performance Benchmark	80%(4)
Outcome Results	100%(5)
Outcome Met Y/N	**Y**

Figure 11: Course Learning Outcome Assessment for the Summer 2018 OL class. Data analysis is based on the Summative Quizzes.

an indication that the modules corresponding to these two CLOs deserve more attention.

5 Conclusions

Digital technologies are transforming education and impacting students' learning in a positive way in an unprecedented fashion. Despite the evolutions happening in the digital education space, a completely online offering of a core Mechanical Engineering class Engineering Dynamics has been missing. To the best of the authors' knowledge, this is the first attempt to create a 100% online class, which does not require any face to face contact between the students and the instructor. This has proven to be a major benefit to the students from around the world, who have taken this class offered currently only in the summer. Post course evaluation and assessment of the course learning outcomes have demonstrated both the viability and the effectiveness of this class.

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