Bringing Engineering Dynamics Online for Improving Student Engagement and Opportunity

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December 27, 2021

Abstract

This paper presents design, development, and implementation of a new online Engineering Dynamics class for post-secondary sophomores offered every summer at Stony Brook University. Engineering Dynamics, which deals with the science of motion is a core undergraduate class in Mechanical Engineering major. The extensive list and complexity of topics in this course often encountered for the first time by students puts significant cognitive load on them, which can lead to poor class performance and disengagement. If the students do not receive minimum grade, they have to repeat the course, which can delay their graduation. We show that these challenges also present an opportunity to create an online version of this class, which can help students overcome learning challenges, offer them flexibility, and also help departments meet their programmatic outcomes. We present an online version of the class consisting of topical videos, on-line quizzes, notes, homework, and assessments, which helped 1) facilitate self-study and -pacing of the material, 2) enable problem solving and critical discussion among students and instructors using an online forum, and 3) scale-up the class to students from both inside and outside our university. Such a class improved students' engagement while also providing better access and availability to students. Moreover, this class presents a unique and effective model grounded in research and well-established course design principles, which could be replicated to create similar such classes elsewhere.

Index Terms: Online Class, Engineering Dynamics, Mechanical Engineering, OSCQR

1 Introduction

This paper presents design, development, and implementation of a new online Engineering Dynamics class, which was offered for the first time at Stony Brook University (SBU) in the summer of 2016. In the inaugural version of the class, there were 70 students from 11 different universities enrolled. Since then, this online class has been offered every summer and has opened up access to students residing anywhere in the world.

Prior to the online version of this class, Engineering Dynamics in the summer session at SBU was always offered in-person only over a compressed schedule of six-weeks and the enrollment figures varied between 35 to 45 for almost a decade. Such low enrollment numbers meant that the class was always at a risk of being cancelled. At SBU, students have to receive a grade C or better in this class to continue in the major. Students who wished to progress further in the major by taking this summer class were impeded because of their summer job and internship. Several students traveled back to their home during the summer, which prevented them access to this on-campus class. Therefore, the class proved to be an obstacle to timely graduation [1]. Moreover, the short duration of the course meant that there was insufficient time for students to be fully engaged in the class and learn some of the most difficult concepts that they encountered for the very first time in the major [2, 3].

To alleviate the subject-matter difficulties, a few researchers have created online learning objects for enhancing learning of the material in Dynamics [4], and some have used flipped class material into an online class [5]; however, there have been meagre efforts in creating a scalable and widely available university credit-bearing online Engineering Dynamics class, which could address some of the aforementioned challenges. 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. A completely online class could relieve some of the pain points mentioned above and improve access and enhance student engagement for better learning outcomes. An online version of the class with instructors' created videos and course notes could provide the foundation for self-paced learning while the low-stakes quizzes would prepare students for tests. An online discussion forum would provide a social, interactive environment where students could ask questions, even anonymously, and answer other students' questions, which could lead to better engagement. By trading the constraints of a class-room space and a fixed time duration for an person-class with little constraint on location and time, an online class could provide the flexibility and freedom to students not afforded to them before.

With those as our goals, we created an online Dynamics class following the OSCQR (Open SUNY Course Quality Review) rubric [6], 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. We created 8 online learning modules each consisting of several self-contained videos, which demonstrate the concepts, process, and problem solving approach. Each module also contains several formative quizzes and a summative quiz. The formative quizzes are meant to test the formative understanding of the topic covered in a video and can be taken as many times as needed without any grades assigned to them. A summative quiz tests the summative understanding of the entire module and can be taken only once with a fraction of the course grade assigned to them. Nonetheless, each type of quiz is still a low-stakes quiz meant to prepare students for the tests with higher stakes. Each module mirrors a chapter in a typical Engineering Dynamics textbook. However, the class requires no textbook since we also provide our notes for each module. A total of 94 videos spanning more than 1500 minutes were created in Khan-academy style and are available at the author's youtube channel at https://www.youtube.com/PurwarSBU. The class utilized both synchronous and asynchronous modalities to facilitate students-to-students and students-to-instructor interaction. In the rest of this paper, we 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; in section 4, methodology and results are presented; and in section 5, we present future research opportunity before making concluding remarks.

2 Motivation, Goals, and Learning Outcomes

2.1 Motivation

Engineering Dynamics, offered every year in the 13-weeks long Spring semester and in the six-weeks long Summer session 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. Another class Engineering Statics is a prerequisite for this class. 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 prerequisite for the Dynamics class. Engineering Dynamics deals with the kinematics and kinetics of particles and rigid bodies and at SBU, we advocate and rigorously enforce 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. It is critical that this class is accessible, widely available, and does not hinder timely graduation.

At SBU, this class has always been offered as a traditional face-to-face (F2F) class. Beginning in 2005, the first author taught the F2F class for five years every year in the Spring semester with an average enrollment of 175 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 class was primarily taken by the students from our own university only with less than 20% students from other schools taking the class in the summer. 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 many of the students from our own university took 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 prerequisite 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 assistance from the instructor. Despite these efforts, the summer F2F classes were challenging to teach and even more so for the students to take. More than half the students performed below average year after year in the F2F class.

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 [9]. 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 asynchronous OL format, students watch video lectures, work on problem based assignments, complete knowledge check (formative) quizzes and summative exams at their own time and pace, with restrictions on due dates 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 through an online discussion forum, allowing for engagement between the students and faculty. Some instructors may also choose to have a modicum of regular interaction with the students using an online, synchronous tool, such as Adobe Connect [10] or Google Hangouts [11] to help with conceptual- and homework-questions or merely to provide assurance to the students that there is a human being, not a robot, who is in-charge of facilitating 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

Using Bloom's Taxonomy (2001) [12], we created outcomes that were specific and measurable. This allowed the students to easily identify and understand what skills were expected of them by the end of the course and how they would be assessed on each of these skills. Bloom's taxonomy allowed us to create both higher and lower order thinking outcomes that would help to develop new knowledge and build on prior knowledge. 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:

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,

2 draw Free Body Diagrams and apply Newton's 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,

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,

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,

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

6 draw Free Body Diagram and apply Newton-Euler equations to relate forces and moments acting on rigid bodies in planar motion,

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

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

3 Design, Implementation, and Challenges of Online Class

3.1 Course Design

The instructional design process of converting an F2F course to an online one begins by addressing the course alignment. Alignment addresses the relationship between learning outcomes, assessments and activities [13, 14]. The goal of alignment is to check that all parts of the course are supporting the learning outcomes, reducing or eliminating activities that are not focused on the main goals of the course, and creating outcomes that are specific, measurable and attainable. An example of this is how the course meets the following learning outcome: determine the position, velocity and acceleration of a particle and system of particles in Cartesian, Polar as well as Normal and Tangential coordinate systems. We assess the learning outcome at multiple points with formative and summative quizzes, online homework before a final assessment during the exams. This gives the student multiple opportunities to develop their competency and learn the process of kinematic analysis of particles in different coordinate systems. These assessments are supported by recorded lectures of the process, that students can stop and review as many times as needed, study course notes, and engage in discussion on an online forum that allows for student-to-student and student-to-instructor interaction to help with answering questions, providing feedback and problem solving processes. This process allows us to see that we are correctly supporting the learning objectives and checking for understanding.

Throughout the development of the course, the Community of Inquiry model [15, 16] was applied to check for opportunities for student engagement and create varied interactions with the course, students, and instructor. The Community of Inquiry framework supports student learning in the online environment by supporting three presences that overlap and build to create the educational experience: teaching presence, social presence and cognitive presence; see Fig. 1. Teaching presence focuses on

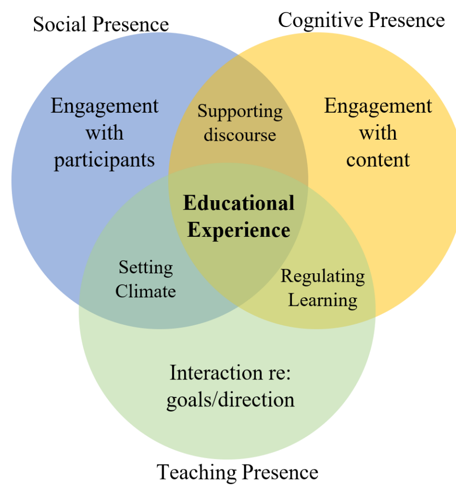

Figure 1: Community of Inquiry Framework [15, 16]

how the instructor engages with the students, delivers the content, addresses student concerns and shows how they are engaged with their discipline. Beginning of the course sets a tone for the rest of the session. Instructor welcomes each student individually in an introduction thread on the online forum; see an example exchange in Fig. 2 from the first time this course was offered in 2016. Social presence is based on creating opportunities for the students to interact with each other, involvement in peer learning and student-to-student discussion. Figure 3 shows an example exchange where the answer to a student's question is co-constructed by the instructor and another student. Cognitive presence refers to the academic content itself and how the course is structured to build on pre-existing knowledge and concepts. The overlap of these areas is the Educational Experience where students are engaged and able to learn from the curated content, their peers, and the instructor.

One of the main features of this course was the creation of videos covering course content. These videos were created with an average duration of 16 minutes to encourage students to watch very specific content breaking down the

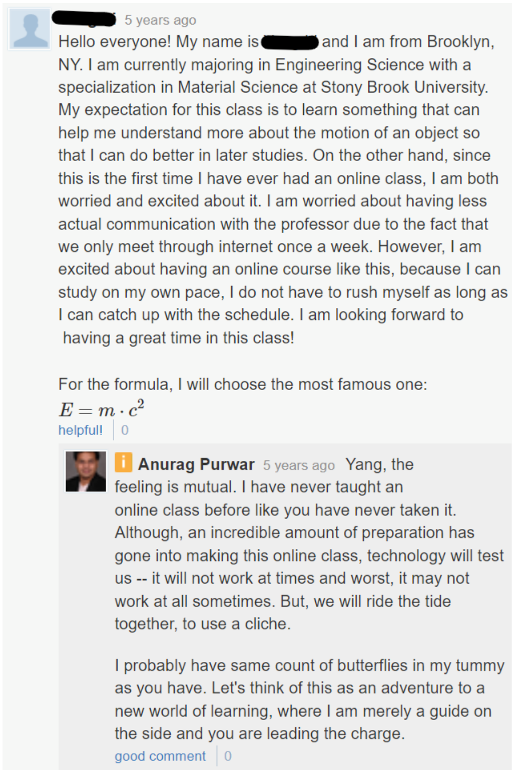

Figure 2: An example welcome message exchange with a student from the first-ever Summer 2016 online class reflects on a new forthcoming experience.

Figure 3: An example message exchange where answers are created and endorsed collaboratively by students and the instructor.

steps of solving problems in dynamics. This process is called "chunking" [17] where content is broken down into smaller, more manageable sections. When creating video content, short videos about a specific topic are more likely to be remembered over time then longer videos with many topics. Creating videos in this format allows students to control their learning better by letting them set when they are learning about concepts, and easily find and review content as needed. For instructors, it allows the ability to break down concepts and ideas, reuse content more easily for student questions, share content across multiple courses to support learning and retention of prior learning, and remake content more easily as needed. In fact, this strategy of sharing content has been used by the author quite effectively. For example, the playlist for this class begins with a review of the videos created from another freshman class which covers fundamentals of engineering topics, such as scalars and vectors, technical computing, and basic Statics.

In the creation of the online course, the OSCQR Rubric, the Open SUNY Course Quality Review Rubric, was applied to address: what are the best practices for online learning, and to serve as an assessment tool of the course design itself; see Fig 4. OSCQR was created by State University of New York (SUNY) to begin a reflective process of evaluating the course quality and accessibility of online courses. The OSCQR rubric was created specifically to evaluate the design of the course, not the content or the delivery. In instructional design practice, the course design is everything that can be developed and built until the course launches. This includes: outcomes, assessments, activities, descriptions, the syllabus, course layout, video materials etc., while delivery focuses on what happens after the course begins. The OSCQR consists of 52 research-based standards that describe qualities that have been found to increase engagement and ease of learning and use in online courses. Using this framework, the course was designed to ensure ease of use, organization of content, opportunities for students to engage with the materials and their peers, and multiple levels of assessment.

3.2 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 summer OL course offered over a period of six-weeks is organized in eight modules each correspond-

OSCQR Course Design Review

OLC Quality Scorecard Suite: OSCQR 3.1

Need ideas? Click on a standard below for explanations and examples from https://OSCQR.suny.edu

	Estimated time needed for revision:	Sufficiently Present	Minor Revision 1/2 hour or less	Moderate Revision 1/2-2 hours	Major Revision 2+ hours	Not Applicable	Action Plan
1. COURSE OVERVIEW AND INFORMATION							
1.	Course includes Welcome and Getting Started content.						
2.	An orientation or overview is provided for the course overall, as well as in each module. Learners know how to navigate and what tasks are due.						
3.	Course includes a Course Information area that deconstructs the syllabus for learners in a clear and navigable way.						
4.	A printable syllabus is available to learners (PDF, HTML).						
5.	Course includes links to relevant campus policies on plagiarism, computer use, filing grievances, accommodating disabilities, etc.						
6.	Course provides access to learner success resources (technical help, orientation, tutoring).						
7.	Course information states whether the course is fully online, blended, or web- enhanced.						
8.	Appropriate methods and devices for accessing and participating in the course are communicated (mobile, publisher websites, secure content, pop-ups, browser issue, microphone, webcam).						
9.	Course objectives/outcomes are clearly defined, measurable, and aligned to learning activities and assessments.						
10.	Course provides contact information for instructor, department, and program.						

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Figure 4: Criteria 1-10 of OSCQR (SUNY Online); see complete list at `https://oscqr.suny.edu`

ing to one of the CLOs. Each module consists of 8-10 self-contained videos and associated notes, 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 homework assignment associated with that module; see Fig.5 and 6 for example questions.

The quizzes are delivered using an online proctoring system called Respondus Lockdown browser [18], 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 to 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. 7 for an example of a student's recording screenshot.

The homework assignments are delivered and graded through McGraw Hill Connect system [19], a web-based assignment and assessment platform, which costs students about \$100; however, it includes access to the textbook. The Connect system provides adaptive evaluation and as-

A particle starts from the rest and then accelerates. Its acceleration as a function of time is given as $a(t) = 8t^2$ m/s². 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 5: 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 6: 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.

signment of the questions, which has helped with scaling of the class, but the students have at times reported technical difficulties in loading of the homework assignments.

This OL class uses Piazza [20], a web-based Wiki-style Q&A forum, where students can ask questions and both the class 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 within a reasonable time and the overall class participation is much enhanced; see Fig. 8 for an overall summary of the class from Summer 2017. In the Summer of 2016, the author also organized weekly synchronous web-based office hours to answer students' questions using Adobe Connect and screen sharing technology [10]; 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 average response time of 23 minutes; see Fig. 8.

3.3 Challenges

For those teaching engineering courses in an F2F format, the biggest challenges are 1) how to effectively create learning material without diluting the rigor of the class or oversimplifying the concepts and 2) how to properly assess students' learning without affecting the scalability of the class. One of the 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 in the F2F format used chalk and blackboard or a smart screen 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 doing kinematic analysis, drawing free body diagrams, and then applying Newton-Euler equations. 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.

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 [21]). The second challenge of the quiz and test questions required 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 ques-

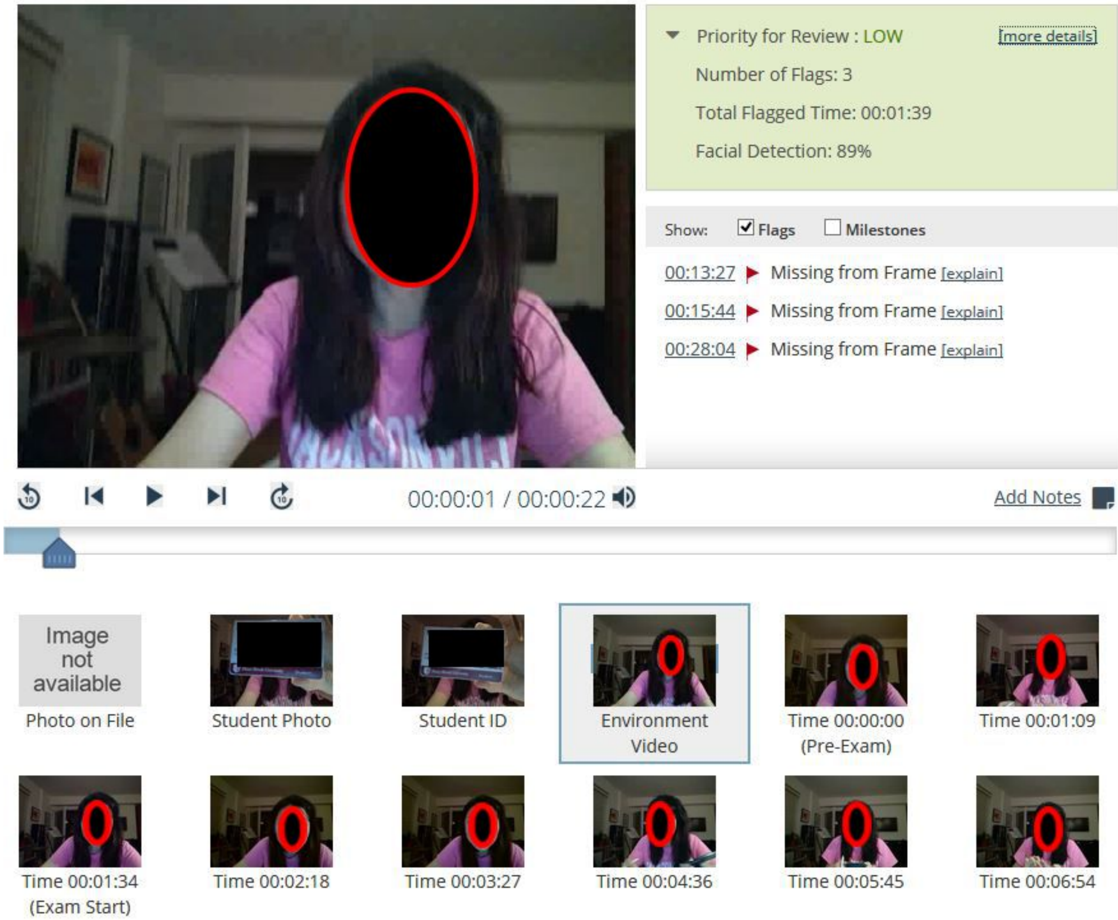

Figure 7: This screenshot of a student's webcam video shows review priority using facial detection and flagging of the events like *Missing from Frame* and *Different person in frame*. The entire session can be replayed as well.

tion 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 1,000 questions for the formative and summative quizzes and exams. This was the most time consuming effort 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.

3.4 Continuous Improvement

The process of course development is also one of continuous improvement where we reflect back, evaluate past experiences and make changes for the future. The OSCQR rubric is more than a course evaluation tool. It is also a process centered on continuous improvement. The process of continuous improvement illustrated in Fig 9 is based on a cycle of three steps:

1 A course review utilizing the OSCQR rubric. In the process of reviewing the course against OSCQR's standards to look for areas of improvement while reflecting back on the course and looking ahead to the next group of students. This creates an Action Plan with a list of recommendations for improvement.

2 A course refresh where the Action Plan is reviewed, items are given priority levels and then changes are implemented based on OSCQRs best practices.

3 A learning review where changes are evaluated and decisions are made that lead to future improvements. This process takes place in a cycle that is continuous and evolving as the course, students and faculty change.

In 2021, OSCQR was updated with new standards to meet the federal guidelines for Regular and Substantive Interaction (RSI) [22]. RSI was established to help create distinct characteristics for distance learning courses

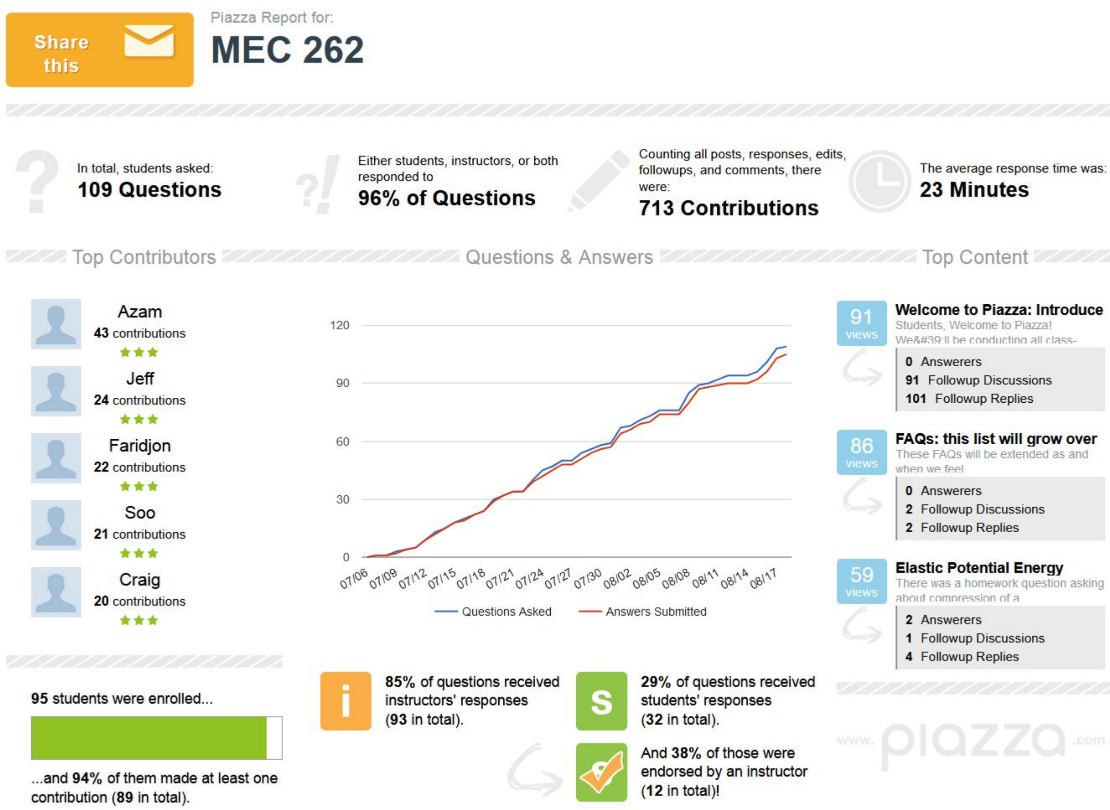

Figure 8: This Piazza report of the Summer 2017 OL class shows a statistical summary of the number of questions asked, contributions, and average response time.

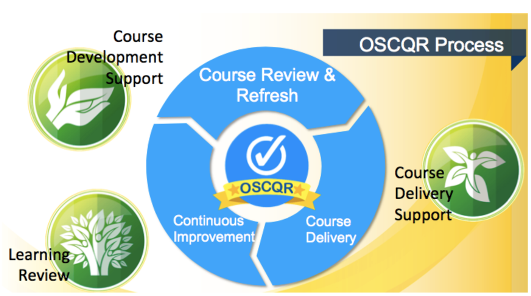

Figure 9: OSCQR Process (SUNY Online)

that receive federal funding and correspondence courses that do not receive funding. Our course works to meet many of these criteria, but will develop an action plan with the intention of ensuring that continuing positive Teaching Presence is demonstrated in the class which leads to regular contact between instructors and students, clear expectations, supported learning, and the establishment of trust between students and faculty. Our course also demonstrates RSI by creating opportunities for Student Presence where students can engage with each other, solve problems as a community, and share their resources and knowledge.

4 Methodology and Results

To determine trends and measure the effectiveness of this newly designed online course, data was collected from Summers 2015-2018. Data includes a mix methods approach. Both quantitative and qualitative methods were used that were designed to assess the specific course learning outcomes (CLOs); see Table 1. There were a total of eight (8) course learning outcomes that all align with the eight (8) modules assigned to the course. Data is also identified as direct and indirect forms of assessments and in particular, the following data was considered for assessment:

1. OSCQR Rubric- To strengthen the course quality of this new online course, the OSCQR rubric was utilized.

2. Institutional Data- To measure whether or not this new online course created more opportunity for students from other universities to meet their programmatic and graduation requirements, institutional data was obtained and analyzed.

Table 1: Assessment Methods and Method Approach

Assessment Methods	**Method Approach**	**Forms of Evidence**
OSCQR Rubric	Qualitative	N/A
Institutional Data	Quantitative	N/A
Exam Data	Quantitative	Direct
Course Evaluation Data	Quantitative and Qualitative	Indirect

3. Exam Data-The course learning outcomes were mapped to specific questions on the Midterm Exam I, Midterm Exam II and the Final Exam.

4. Performance benchmarks-To measure whether or not a student met the CLOs, performance benchmarks were established. In order for the CLO to be met, 50% of the students needed to get 70% or more of the specific questions aligned with the CLOs. Per SUNY's Number Grade Conversion Chart, 70% is a C grade. Since a C grade is satisfactory work in accordance with the Stony Brook University's 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. For example, if there are 10 students and 20 questions aligned with an outcome, then 5 or more students need to get at least 14 of the questions correct to meet the performance benchmark for that particular learning outcome.

5. Course evaluation data-To assist in measuring course effectiveness, course evaluation data from Summers 2015, 2016, 2017, and 2018 were analyzed. Towards the end of the semester, invitations are sent to Stony Brook students encouraging them to complete their course evaluations. Students are asked approximately 18 questions to evaluate the course and instructor effectiveness. The four questions supporting this assessment are:

   (a) Overall, I would give this course a grade of...[A-F, 5-point scale]

   (b) The instructor was effective in teaching the subject matter [5-point scale, Strongly Agree (5) to Strongly Disagree (1)]

   (c) What, if anything, did you find most valuable about this course? (Open)

   (d) In what ways, if any, could the course be improved? (Open)

As indicated previously, utilization of the OSCQR rubric shows this course meets many of the criteria required for creating an efficient online course. This course demonstrates RSI by creating opportunities for Student Presence where students can engage with each other, solve problems as a community, and share their resources and knowledge.

The OL version of the Engineering Dynamics has been taught every summer since 2016. Before 2016, the class was always offered F2F only and most 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 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. See this enrollment data from 2015-2018 in Table 2.

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. Only outcomes 1-7 were chosen to be assessed. Table 3 shows the results and whether the outcomes were met for the Summer 2016 OL class. The Mean, Median, and standard deviation in the table are the 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

Table 2: Enrollment Data from 2015-2018

Year	Enrollment Type	Total # of Students Enrolled	Percentage From SBU	# of Different Universities
2015	Face to face	33	90%	N/A
2016	Online	70	70%	11
2017	Online	87	71%	12
2018	Online	72	62.5%	12

Table 3: Summer 2016 Online Class CLO Data

CLO #	1	2	3	4	5	6	7
Mean	61.05	52.15	54.28	46.35	53.38	55.40	44.44
Median	67.16	59.70	59.70	54.68	56.71	67.18	42.18
STDEV	28.42	27.87	18.59	35.12	20.43	26.18	21.25
Performance Benchmark	70% (15)	70% (13)	70% (8)	70% (2)	70% (13)	70% (6)	70% (6)
Outcome Results	81% (17)	70% (13)	70% (8)	70% (2)	58% (11)	63% (5)	33% (3)
Outcome Met Y/N	Y	Y	Y	Y	N	N	N

19 questions in the midterm I and two questions in the final exam. 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.

Table 3 shows that four of the seven CLOs were met per the established performance benchmarks. 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 fewer 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. Table 4 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.6 were not met. While CLO.3 is concerned with the work-energy approach for particles, CLO.6 is concerned with the kinetic analysis of an interconnected rigid body under planar motions. Both of these are among the most difficult topics of this class. This is an indication that the modules corresponding to these two CLOs deserve more attention.

In general, the qualitative comments from the students of the OL classes were positive and encouraging; see a few examples from the 2016 OL class:

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 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, notes, 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. Figures 11 and 12 present answers to two 5-point scale questions from the course evaluation.

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 midterm I and the final exam that map to the CLO.1

Table 4: Summer 2018 Online Class CLO Data

CLO #	1	2	3	4	5	6	7	8
Mean	68.99%	60.59%	50.43%	63.77%	67.33%	52.73%	53.55%	69.26%
Median	71.02%	68.99%	49.30%	69.57%	67.87%	48.49%	58.47%	70.15%
STDEV	20.82%	17.82%	12.13%	22.48%	12.75%	10.68%	7.49%	5.54%
Performance Benchmark	80% (4)	80% (4)	80% (4)	80% (4)	80% (4)	80% (4)	80% (4)	80% (4)
Outcome Results	80% (4)	80% (4)	40% (2)	60% (3)	90% (9)	40% (2)	80% (4)	100% (5)
Outcome Met Y/N	Y	Y	N	Y	Y	N	Y	Y

5 Future Research Opportunities

1. The instructor on record and an instructional designer should continue to utilize the OSCQR rubric to evaluate the current online course components to determine if they still meet the criteria. If not, they should outline a plan for improvement and implement changes in the following summer.

2. The institutional data should include a full analysis of data included in this study, for all of the terms discussed. Also, additional demographic information should be reviewed and analyzed to examine if there are any differences in the demographics of students. For example, are the female students more active than the male, or vice versa? What else can be learned from the institutional data?

3. There should be a more thorough collection and analysis of the exam data. Which outcomes were met, during which terms? Currently, we only focused on one term. However, this study includes a discussion on the comparisons of students' success from summer 2015 to 2018.

4. A survey should be designed and administered to all students to thoroughly assess effectiveness, engagement, satisfaction, etc. Further, specific questions asked to non-SBU students should be included to determine the impact of the online course offerings on their programmatic and degree completion.

6 Conclusions

Digital technologies are transforming education and impacting students' learning in a positive way in an unprecedented fashion. Despite the evolution 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 fully 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 in improving student engagement and widening access and availability. During the peak of the COVID-19 pandemic, we also offered the contents of this course to the Mechanical Engineering Chairpersons through an ASME list serve.

7 Acknowledgement

This work has been partially supported by a Summer Online Teaching (SOLT) grant from Stony Brook University to the PI Anurag Purwar.

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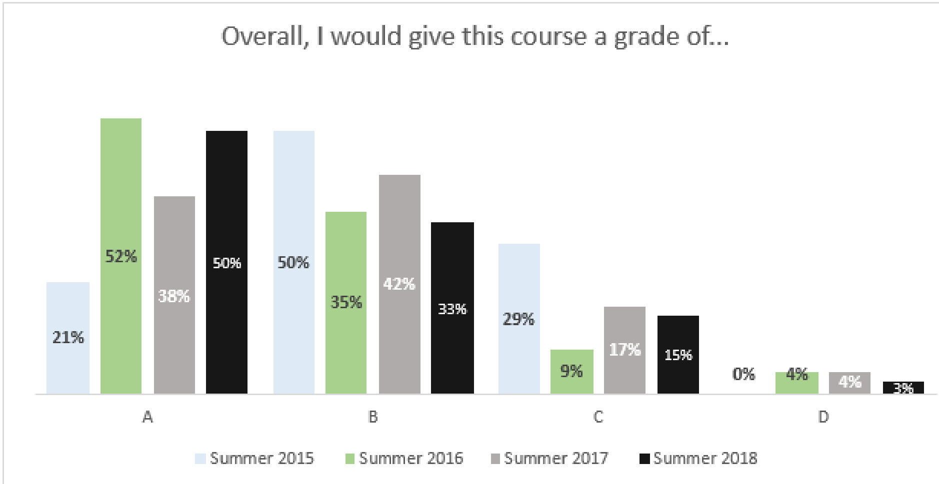

Summer Year	A	B	C	D	F	Mean	Standard Deviation	Did Not Answer	Total Responses
2015	21.43%	50%	28.57%	0%	0%	3.93	0.7	0	14
2016	52.17%	34.78%	8.70%	4.35%	0%	4.35	0.81	0	23
2017	37.50%	41.67%	16.67%	4.17%	0%	4.13	0.83	0	48
2018	50%	32.50%	15%	2.50%	0%	4.3	0.81	0	40

Figure 11: Course Evaluation Data

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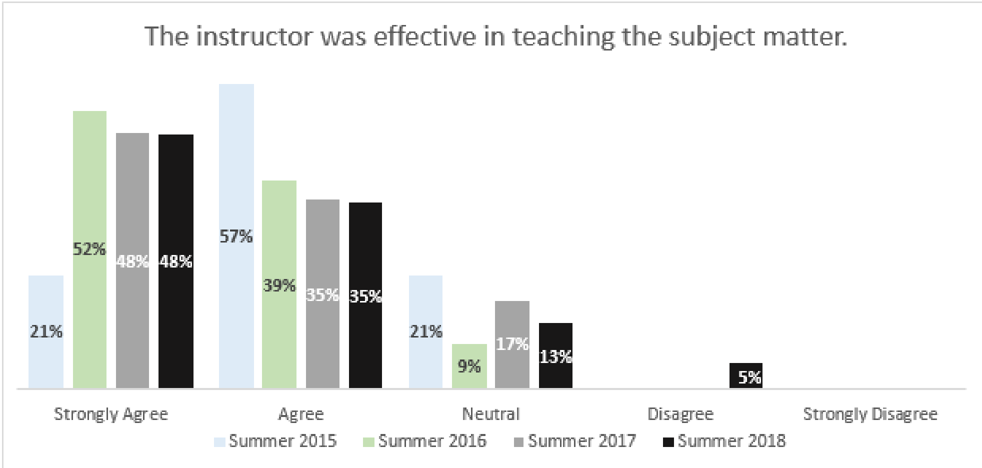

Summer Year	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	Mean	Standard Deviation	Did Not Answer	Total Responses
2015	21%	57%	21%	0%	0%	4.00	0.65	0	14
2016	52%	39%	9%	0%	0%	4.43	0.65	0	23
2017	48%	35%	17%	0%	0%	4.31	0.74	0	48
2018	48%	35%	13%	5%	0%	4.25	0.86	0	40

Figure 12: Course Evaluation Data

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