Analysis of Student Success and Retention in a Well Engaged Large Scale Flipped Engineering Classroom

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Abstract

For many years, universities organized the learning environment around face-to-face classrooms. However, a new generation of students relies on the Internet and all of its affordances as a mainstay for their education. A caveat though is that although the World Wide Web can be an effective aid to student learning, it can also be time-consuming, leading to inefficiency and, at times, misinformation. This reinforces a need for more modern teaching styles that accommodate students' learning preference and engage them in an incremental approach that resonates with their intelligence, capability and availability. For this study, researchers investigated a flipped classroom approach. The course, Engineering Dynamics, at the University of Central Florida—is a large-scale format with 450 students; augmented by adaptive learning with outcomes indexed by 90% success, retention and eventual graduation.

Key words: Flipped classroom, Engineering Dynamics, 450 students, students' success and retention

Introduction

Traditionally, students in higher education have experienced a face-to-face educational environment as per Scott Freeman et al.[1]. However, with developing instructional technology, they find it more appealing and effective to learn in an online environment that accommodates their individual circumstances. Often, students use the Internet to reinforce their understanding of difficult concepts and solve their assigned problems as described by Gehringer & Peddycord III[2]; Chegg (http://www.chegg.com)[3], YouTube[4] and Khan Academy[5] as described by Bishop & Verleger[6]. Internet information, however, can be overwhelming, making it difficult for them to find accurate resources and work efficiently, Dziuban et al.[7], especially when that information is not found at the first pass in sites according to Gehringer & Peddycord III[2] like Course Hero (www.coursehero.com)[8]. In this new learning environment one of the more promising developments is the flipped classroom described by Bishop & Verleger[6], where students acquire content knowledge outside the class session then solve problems and develop concept formation cooperatively with each other with support from their faculty members. This seems to offer promise as an effective method for delivery to enhance learning via problem solving. Several papers have been written about flipping in engineering courses, addressing the issue, however predominantly with smaller class sizes averaging about 100 students as per Schrlau et al.[9]; Webster et al.[10]; Nissenson et al.[11]. Particularly, Freeman et al.[1] discussed these active learning approaches as most beneficial in smaller classes. The question is what happens with today's large-scale classroom, averaging 400-500 students—that make 100 attendees seem small.

The problem is somewhat more complex than managing a small classroom because scale presents logistical challenges, thus complicating the engagement process with the underlying danger of chaos. However, with strategic management and organization, very large flipped classes can be effective. However, it has been documented that some students do not favor this approach because of the additional responsibilities placed on them explained by Schrlau et al.[9] such as preparing for class session and performing the pre-class assignments.

Course Overview

The investigation compares the success rate of the course Engineering Dynamics, at the University of Central Florida for Spring 2017, a flipped classroom of approximately 450 students to the Accreditation Board for Engineering and Technology (ABET) requirements. In the course, the instructor adopted a new motto: “Motivate them and they will succeed. Excite them and they will excel!” The motto proved motivational to the students, and the instructor’s industrial experience helped them envision their future as engineers.

Course Design

Students watched 1 to 3 screenplay videos on a weekly basis that lasted no more than 12 minutes each—70 in all for the course, averaging about 1 hour per week for viewing and imbedding concepts and solved examples. Also, students solved adaptive weekly pre-class assignments (LearnSmart-Connect, McGraw Hill). In class, they solved problems two or three times a week, followed by the instructor’s explanations and solution examples. A noticeable result was that the students asked many more questions than in the other class formats. Tests included a weekly quiz from the homework with items randomly chosen[12,13] to test their knowledge and avoid using results from the student solutions manual. During the weekly classes, students not only interacted with each other, but also with any of the four teaching assistants and the instructor.

Course and Class Engagements

The course was conducted for 50 min, three times per week for a total of 2.5 hours for 13 weeks followed by a final revision week. The evaluation protocol is contained in Table 1 indicates the different methods and levels of positive student engagement. The extra 10% shown below in the course grading structure was used to increase student motivation.

Table 1. *Course Marking-Scheme*

Pre-assignment (Connect)	10% LearnSmart (LS)
Assignments (Connect)	10% Bonus
Weekly Quizzes	10% - 5 quizzes
Weekly Class Participation	5%
5 Tests	75% (15% each)
Final Examination (cumulative)	75% - Optional
Total	110%

From Table 1, the course included a pre-assignment, an assignment, a quiz, a class participation on a weekly basis and a test every three weeks on topics depicted in Table 2.

Table 2. *Topics Studied*

Topic
Particles Kinematics
Particles Kinetics
Kinematics of RB
Kinetics of RB
3D Dynamics

The following sections describe each method of engagement implemented throughout the course.

LearnSmart (LS) Pre-assignments – McGraw Hill Connect

The students did the pre-lecture assignments via LearnSmart through the McGraw Hill Connect, the adaptive learning tool on a weekly basis prior to the lecture or prior to solving problems. These activities helped the students understand some concepts, if not all, before attending to class and prepared them to ask questions more frequently and at a higher level. The knowledge they gained by doing the pre-assignments appeared to increase their confidence to ask more questions and clarify misconceptions. Therefore, the preparation before class increased their knowledge, which in turn was reinforced in class. One result was that many students seemed to know the material before they come to class. Interestingly, however, LearnSmart included no calculations so the students needed to see examples solved on how to apply their knowledge in order for them to learn the material more effectively. The pre-prepared videos were used as a vehicle to help the students learn the concepts more in depth, as well as learn from some solved examples.

Weekly Videos

Screen-capture videos were about 12 minutes long each and included 1 or 2 simple examples of course material using the textbook[14]. Supplemental videos provided extra examples, on average 4 extra video-examples per lecture. A total of 70 videos were made for the semester using a combination of McGraw Hill textbook[14], Tegrity (https://www.mheducation.com)[15] and Snagit (https://www.techsmith.com/contact.html)[16]. Students were required to view the videos before coming to class, where problem solution models were presented.

In Class

The pre-assignments gave the students background exposure to the material before they came to class, enabling them to ask questions at the beginning of the session to clarify concepts they did not understand when solving the pre-assignments. Once their questions were answered, recitation of problems commenced. Students were asked to solve problems followed by the Instructor's solutions, explanations and clarification of concepts. Although it was typical to solve six to nine practice problems per week, occasionally, one problem took a full class time, especially for a large class of 450 students.

a. *Weekly Class Participation (CP)*

Apart from the problem recitation performed by the instructor once a week the students were given 15 minutes to solve a problem and demonstrate their understanding based on the material that was discussed. They discussed the problems in groups of their choice and were also allowed to ask any of the four graduate teaching assistants that accompanied the instructor to class during the weekly class participations.

b. *Weekly Quizzes*

The day in which there was no class participation, the students completed a quiz based on a previous assignment. They were aware of this arrangement in the syllabus and were reminded about it in class in order to prepare themselves for those quizzes. The quizzes were designed to decrease academic dishonesty by encouraging the students to do their work instead of copying assignments.

Assignments

After being exposed to the material by doing the LearnSmart assignments and watching the videos the students came to class to solve problems and check them with their instructor. At this stage the students had enough knowledge to embark on the more elaborate assignments on their own or in collaborative groups. These assignments consumed substantial time in spite of the scaffolding done by the pre-class work, the videos and the class work. In this phase of the class the students spent a good deal of time troubleshooting and completing solutions to their assignments, which were automatically corrected by Canvas (https://www.canvaslms.com)[17].

Tests and Optional Final Examination – Make up Final Exam

Each of the five tests was given to the students during the semester on topics studied in class presented in Table ***2*** The overall percentage of the course associated with the tests was 75% of the grade with the remainder coming from the different assignments constituting the 110% of the course requirement. The final examination was optional and constituted 75% of the grade and replaced all five tests for those who did not do well in the course during the progression of the semester. In the case where students passed the course without the final, but wanted to do better in the course, they were given the opportunity to get a higher grade by sitting for the final examination. However, those who came to the final examination and did worse, they were given the better grade.

The students were given the opportunity to be exempt from the final examination to alleviate pressure from them during the final examination schedule so that they would be able to focus on other courses.

Results and Discussion

From Table 3 it may be observed that for Particles Kinematics at least 97% of the students passed the LS assignment with 70% or greater. This indicates that a large percentage of students come to class with some background information. The students learn more in class when they see the instructor solve problems and subsequently, they do class participations. They did well in class participation as indicated by the general trend in the CP column, except for Kinematics of Rigid Bodies where 80% of the students pass with 70% or greater.

Table 3. *Overall results for ABET Requirement – Percentage of students passing*

Topic	* LS % pass	** CP % pass	Homework Assignments (Connect) % pass	Quizzes % pass	Tests % pass	Overall Tests & Final Exam % pass
Particles Kinematics	97	99	78	20	57	70
Particles Kinetics	98	100	84	45	79	89
Kinematics of RB	98	100	61	38	70	75
Kinetics of RB	98	80	82	52	38	42
3D Dynamics	99	100	78	23	64	71

*LearnSmart **Class Participations

Once the students had some exposure to the material, they did their homework assignments via McGraw Hill Connect. In the case of Particles Kinematics, 78% of the students passed with 70% as per the ABET requirements. In the case of the quizzes, the students did not do as well perhaps due to lack of preparation and the challenging nature of the tests. However, there is a common trend between the tests in comparison to the final examination, i.e. the students did not do too well in the Particles Kinematics (57% and 70% pass), do better in Particles Kinetics (79% and 89% pass) and then do slightly less well in Kinematics of rigid bodies (70% and 75% pass). In Kinetics of Rigid-Bodies they do the worst (38% and 42% pass) owing to the higher difficulty involved and with equal time allocated to it as the other topics, which will be increased in the future for better results and finally they improve in 3D dynamics (64% and 71% pass). Clearly, Particles Kinematics and Kinetics of rigid bodies are two topics that the students find difficult and challenging. However, students tend to improve as the semester progresses, then get challenged by the fourth topic and rebound to improve in a 3D Dynamics. Two possible reasons for weaker results in Kinetics of Rigid bodies, the topic is new compared to the first three parts of the course, for which the students have had prior pertinent physics background knowledge. The other reason could be that the time spent on teaching should be increased to allow more understanding and digestion, when less time should be given to the first three topics of Table 2.

The question of import is how do the students prepare for the lectures, quizzes and the tests? Apart from the LS assignments, the students were supported by plenty of videos in their journey. Therefore, it is relevant to discuss the results and benefits of the videos associated with this course. Figure 1 indicates the total weekly viewings that add up to a cumulative 6,841 viewings for the semester of 40 videos that the students streamed using Tegrity - McGraw Hill. These videos were added in February. In January, however, there were 30 videos that the students downloaded—a total of 70 videos for which the number of viewings were not counted. Using simple regression analysis one can conservatively say that there were more than 12,000 viewings. Figure 1 shows a dip in viewing because of the March Spring break; however, the students used these videos extensively during tests and the optional final examination or prior to the make-up final examination. The videos positively impacted students' success as the survey indicates in Table 4.

Figure 1. *Total Videos Viewings for February-April, 2017*

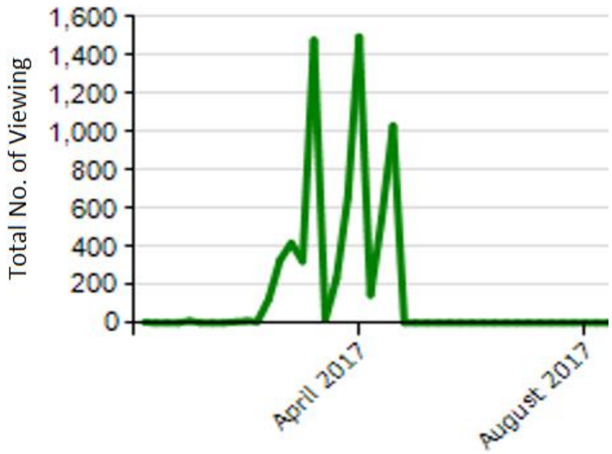

Table 4 shows the survey questions used depicts the overall results with the majority of students very well satisfied. The first seven questions of pertain to the concepts of the screenplay lectures and the last five questions pertain to the screenplay examples. Table 4 conclusively shows that in the opinion of the students, the videos strongly supported them in their learning and understanding, both in concepts and in practice with an average of 82% of them strongly favoring or favoring the approach.

Table 4. *Videos Survey*

Questions	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Were relevant to the course and are pertinent to the class sessions	60%	36%	4%	0%	0%
Were clear and understandable	29%	55%	13%	3%	0%
Addressed the concepts in a sequential manner	38%	52%	8%	2%	0%
Helped me understand the subject	34%	48%	13%	4%	0%
Were short and did not take too long for me to watch	29%	39%	26%	6%	0%
I wish more videos could be provided	31%	30%	32%	6%	0%
Overall, the videos helped me learn	42%	46%	9%	3%	1%
Were pertinent to the subject	47%	48%	5%	0%	0%
Reinforced my understanding	40%	48%	9%	2%	0%
Efficiently helped in my learning	32%	47%	17%	2%	1%
Prepared me to solve other problems	29%	48%	18%	4%	1%
The lecturer provided enough videos for me to learn, through the examples	29%	44%	19%	7%	0%
Average	37%	45%	14%	3%	0%
At times when I did not understand well, I stopped the video and repeated the section where I needed to understand and learned what I needed with ease at my own pace				Yes	No
				93%	7%

Below are some representative student perceptions of the overall course and the instructor:

"THIS MAN WENT ABOVE AND BEYOND THE CALL OF DUTY. Someone better read this. Nader tried his heart out to help us slay this beast of a course. And to be honest, failed with a majority of the class because the deck is stacked against him. I had the luxury of being able to learn in this inopportune environment but most will not. He gave Videos, detailed slides, and even extra help. He knew this material and even brought props! I hope he never lets the failure rate bother him because he really is incredible at Instruction if you give him enough time!" *

"I like that we did the problems in class" *

"Great energy and sense of humor. Creates a good learning environment and is overall fair with his expectations by allowing clear guidelines on study material." *

"He wanted us to pass. He made videos that helped us." *

"I liked how he posted videos about each section and gave a lot of practice problems. The best way to ace Dynamics is to do a lot of practice and Professor Nader definitely emphasized on it, resulting in my success in the course." *

"I like all the resources available to learn at home." *

"Dr. Nader is very enthusiastic about engineering and has a passion for it. I liked how he understood that the material was hard and would constantly motivate us almost every class." *

"I liked how the instructor tried to slow the class for the students that were struggling the most." *

"I liked his effort in making the class better. I also liked the videos he made." *

"Provides videos that helps students understand the material." *

"The professor did make it evident that he was trying to engage the class. At the beginning of the semester the professor used students to show the principle being taught for the topic being covered. Towards the end, he brought in objects to show the class what he was talking about, for more difficult subject matters. ALSO, the professor provided videos regarding subjects being taught. These were an invaluable asset for the students to use, and I am sure they improved test/quiz scores for the ones who took advantage of the opportunity." *

"He tried to show real world examples sometimes which was cool." *

*Proofs available upon request.

The ABET Requirement was considered in the overall students' evaluations, but it was not a compulsory requirement to pass the course; other factors, such as the class participations, LearnSmart, quizzes, assignments and pre-assignments were also considered.

Table 5 shows the percentage of successful students, namely 96%; the overall student retention rate was 90%. Most of the unsuccessful students failed to complete homework assignments

Table 5. *Overall Students Success and Retention*

	Succeeded	Failed	Dropped/ Withdrew	Total Failures + Dropped/Withdrew
Number of Student	407	15	28	43
%age out of 422	96%	4%		
%age retention out of 450	90%			10%

The final examination gave those who did not do well during the semester another chance to increase their success. Table 6, indicates the extra percentage of students (6.8%) that directly benefited from this option.

Table 6. *Percentage Increase of Student Success due to Optional Final Examination*

Students Who Succeeded Without Taking the Final Exam	Total Number of Students Succeeded in the Course	Increase in Success due to Optional Final	Percentage Differential Increase
381	407	26	6.8%

Conclusion

The results of this study suggest that the approach described here results in superior ailments and success rates in a typically daunting engineering course. Perhaps there are other successful approaches to teaching dynamics. Although the students were required by design to stay involved in this course, they indicated a high level of engagement and satisfaction. However, the opportunity cost for the instructor in preparing the material, organizing the course and conducting comprehensive student assessment in a large class was demanding. Because the classes were given in an average/slow speed form, students in jeopardy of non-success i.e. DWF status benefitted from the flipped approach. This approach encouraged them to ask questions and learn. Fostering success for the majority of the students.

In addition, dividing the material into short sections, e.g. 5 tests and a final examination also allowed the students to focus on small portions of the subject at a time and study them in depth. This decreased the amount of material that the students studied per test and increased their assimilation of the subject. The extra 10% bonus, however, did help numerically, but also psychologically as well. The compensatory opportunity gave the students more hope and encouragement to work harder and get better results. This had a positive impact and led the researchers to believe that the combined effects of the above factors increased the students' success and retention rates.

The outcomes here support the notion that "Flipping" a demanding STEM can be effective for student engagement and achievement. However, as previously mentioned there are opportunity costs involved. This approach requires an extensive supporting structure that combines content acquisition with concept formation, problem solving, working in ambiguous solution spaces, authentic assessment and presentation skills. Nevertheless, that cost is compensated fully by a course that is contextual, relevant and reflective grounded in active learning. Students experience something far different than teach then test model. However, the primary impact achieved here may not be the "Flip" but rather the required massive course redesign and accompanying altered pedagogy. Clearly both students, the faculty member and teaching assistants experienced substantial role-changes. In many respects this course resembles a complex system where how the redesign ripples through it cannot be accurately predicted. Often the outcomes are counter intuitive. For example, the more advanced students indicated some degree of boredom. Also, there will be unanticipated side effects as in the disproportional rate of video viewing. Ultimately however the final conclusion of this paper is that like all complex systems this course is emergent where the interaction of the components is more important and predictive than those elements considered individually. Going forward the next step will be to identify the rules that guide those interactions.

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