A Building-Block Approach to Dynamics

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Abstract

The transition from memorization of formulae to the independent thinking required in engineering courses is accomplished via courses typically entitled "Statics" and/or "Dynamics". These courses, in particular Dynamics, pose a major hurdle for some students who wish to become engineers. They are known at many universities as "gate" or "weed-out" courses. Since competency in the principles of these courses is necessary for success in the higher-level courses, teaching practices that improve a student's learning and motivation in the course are desired. This paper discusses a practice that has proven successful for a dynamics course that included students in different years and majors, as well as a class of sophomores of one major.

Introduction

The transition from memorization of formulae, a process that can succeed in high school and collegiate Physics courses, to the independent thinking required in engineering courses is accomplished via courses typically entitled "Statics" and/or "Dynamics". These courses, in particular Dynamics, pose a major hurdle for some students who wish to become engineers. Not only must the student recall the principles learned in calculus and physics, but the student must also utilize basic geometric and trigonometric concepts that have may been buried since middle and early high school.

Competency in Dynamics can be viewed as successfully building a bridge between science and engineering. The pre-requisite mathematics and physics are crucial to developing a stable foundation. Each new concept - the kinematics and kinetics of translating and rotating bodies - is a block necessary to building this bridge. The lack of one of these concepts will cause an instability in the learning structure since concepts introduced as the course progresses require that all previous material be thoroughly understood.

The traditional collegiate method of lecturing and testing in these classes may cause some promising students to falter in these courses. Traditionally, three to four tests are given during the course, each accounting for 15% to 25% of the final grade. Because testing is infrequent, each test requires the utilization of concepts in multiple problems. Recognition by the student and professor that a concept is not well understood comes too late to help the student's grade and self-esteem. Subsequently, some students may drop the course, change majors, or give up on succeeding in the course and/or engineering.

A Description of the Course

The Dynamics course at Georgia Tech has undergone some major changes over the past five years due to curricula changes during conversion from a quarter to a semester system. During the quarter system, students from all engineering majors - Aerospace, Mechanical, Electrical, Industrial, and Civil - chose the dynamics class that best fit their schedule. Professors from any one of these majors may have been the course instructor. Thus problems within the class tended to range the gamut of these majors, and the students ranged from sophomores to seniors, depending on their major. The material covered in this quarter course included the kinematics and kinetics of linear and rotational motion of planar bodies. This followed a pre-requisite Statics course.

During semester conversion, each engineering school independently decided how to modify the Statics and Dynamics sequence to fit their curriculum's needs. In Aerospace Engineering, the Statics and Dynamics courses were expanded to include the aspects of three-dimensional motion that had been covered previously in a flight controls course. Because of this, the courses now tend to include only sophomore Aerospace Engineering majors.

The text for this course at Georgia Tech remains *An Introduction to Dynamics, 3rd Edition* by David J. McGill and Wilton W. King. The syllabus for the semester course is constructed as shown in Figure 1.

Course Structure

The traditional course structure in an undergraduate course beyond the freshman year usually includes graded homework, two or three quizzes, and a final exam. The homework will typically contribute 15% to 20% of the final grade, with similar weighting of each quiz, and a final exam of 30% to 40%. This course structure has been significantly changed, as shown in Table 1 in an attempt to improve learning within the course, as well as to incorporate a design component in response to ABET 2000 Outcome criteria [1].

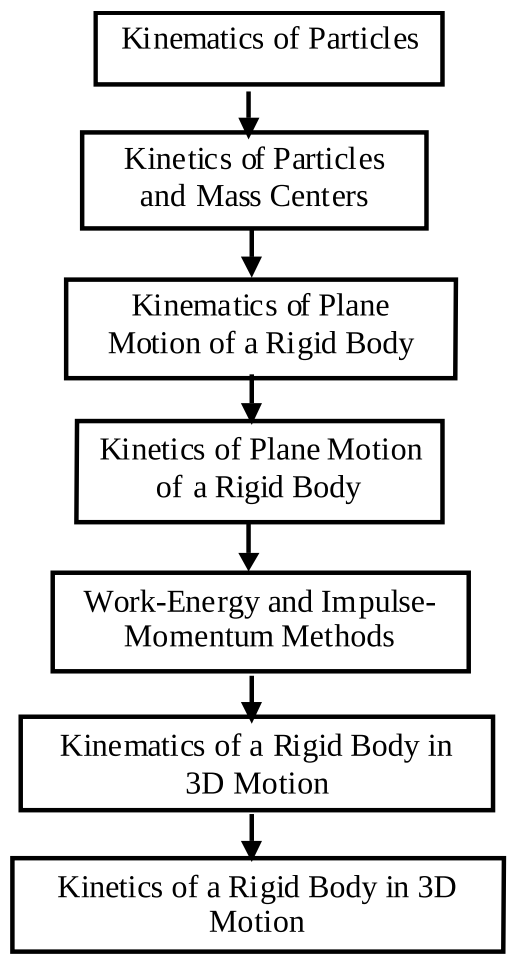

Figure 1. Sequential Syllabus for Dynamics Course

Table 1. Dynamics Course Components and Grading Structure

Course Component	Original	Modified
Graded Homework	15%	0%
Quizzes	60% (3 quizzes)	50% (7 quizzes, drop lowest grade)
Final	25%	25%
Design Project	none	25%

Grades constitute the classic measure of learning. As these grades remain on a student's permanent record, they become a source of stress within a course. The primary contributions of stress within the traditional course structure are thus the quizzes and final. One of the most stressful portions of the course, as identified by students, is the fact that if a student does poorly on one exam, it will usually cost them a letter grade or more in the course. In addition, these quizzes must cover a fairly substantial portion of the course material. If a student does not understand a portion of the material, or if a large portion of the class is having trouble understanding a concept, then it is usually not until the quiz that the professor is aware of the extent of the deficiency. At that time both the professor and students become frustrated, albeit usually for different reasons.

Each topic within the new Dynamics course is presented in a definite style: a) basic theory or introduction of the equations, b) initial observation of the material via lecturer-worked problems, c) initial learning via a class problem worked in groups during class time, and d) assigned homework. This provides immediate feedback to the professor and alerts the students to nuances in the problems not seen during the theoretical presentation or the lecturer-worked problems.

Graded homework is usually utilized as an intermediate indicator of student progress within a course between quizzes and/or to permit students to perform problems that cannot be examined on a quiz due to time or computer restraints. However, for a course such as Dynamics, there are more negatives than positives associated with graded homework. On the negative perspective, it must be recognized that graded homework can become a time burden for a professor with a large number of students in the class, which tends to be the case for sophomore-level courses. A grader can alleviate this problem, but then the professor does not have the opportunity to determine if students are missing simply a small concept within a problem or the entire problem. From the students' perspective, partial credit on a problem is a plus, but usually requires the professor's intervention, rather than a grader's. Graded homework is also supposed to be the work of the individual receiving the grade. Unfortunately, some students will collaborate on homework to an unacceptable degree, giving rise to false levels of the class' perception to both the professor and the students themselves. Other students who do not collaborate will not obtain any help from their peers, leading to both grade and learning frustration, or they will seek help from the professor, which tends to lead to long office hours, a frustration to the professor.

An alternative to this dilemma is to modify the structure of the course, as seen in Table 1. In the modified course, there are now 7 quizzes rather than 3. This first appears to be much more additional work for the professor and to diminish the lecture time. However, in addition to doubling the effective frequency of the exams, the length of the exam is halved. Thus, instead of a one-hour exam given three times a semester, requiring 3 hours of class time, 7 one-half hour exams are given, requiring 3.5 hours of class time. The effective grading time of the professor is approximately the same and the cost to lecture time is 1/2 of a class period. Now, a quiz will only count roughly 8.3% of their grade if a drop quiz is added. This tremendously alleviates the students' stress levels, as stated per the end of semester evaluations filled out by the students. A bonus to this higher quiz frequency is the direct feedback to the professor on the true comprehension level of each individual student, so that the appropriate corrective action can be taken before a heavy toll on grades and self-confidence occurs.

With the halving of the quiz time, leaving either only 30 or 45 minutes to complete the exam, fewer problems can be asked. This may appear to punish a student if he or she can't work the problem. However, the amount of new material covered on the quiz will be less, and multiple part problems can easily be contrived to provide effective grading feedback.

A bonus to the higher quiz frequency is that it forces procrastinating students to keep up with the material and work homework problems within a few days (or hours) of the lecture. Again, problems the students have in understanding the lecture material is quickly brought to the professor's attention. As part of the curriculum change, the homework is now not graded. This is partly because of the logistics of the frequency of the examinations, but it also requires the students to become more responsible.

Since the homework is not graded, the students can now be formed into study groups. This helps students to learn working as both tutors and learners within the same group, as well as to learn to work in teams, as required by ABET 2000 [1]. To help the students keep on track with the homework, a weekly recitation time of one hour was set up. This time was coordinated to ensure that no students had other class or work commitments that conflicted. During this time, students could ask questions on the assigned homework problems or as a study hall to work on the problems. When a large majority of the students have problems with a particular problem or concept, explanations can be proved to the group as a whole.

Since homework was no longer graded, an additional element to the course was needed to ensure that the final exam grade was not overwhelming. A design project was thus added to the course. A design project is an enhancement to any course since it enables students to translate classroom time into an engineering experience. Georgia Tech is world-famous for its fight song, the first line of which is “I’m a Ramblin' Wreck from Georgia Tech….”. There has developed a tradition during Homecoming of an annual contest and parade where organizations build “Ramblin' Wrecks” from scrap components. These wrecks must travel a set course on their own power, and the successful vehicles are then judged for ingenuity of design. To parallel this concept, the design project in this course was to build a miniature Ramblin' Wreck. The scope of the design project is such that it can be assigned to each class without loosing its freshness or its appeal, and it fosters school spirit. Students were told to build a miniature wreck to the specifications in Table 2. The projects were graded per the guidelines in Table 3.

Table 2. Design Project Specifications

- Constructed of "household" material; no construction kits or toys can be utilized
- Size: Width and depth must be less than 10 inches. Height must be less than 24 inches.
- Must roll down a 60-inch length, 14-inch width board at either 40 ^{o} or 15 ^{o} inclination
- Provide a 3-View Drawing and Written Description of the Model
- Compute the moments and products of inertia of the model

Table 3. Design Project Grading Criteria

Working Model	25 pts.
Originality	25 pts.
Calculations	35 pts.
Drawing	15 pts.
Total	100 pts.

As seen in Table 2, the imagination of the student is somewhat tempered by the fact that he or she must create a three-view drawing of the wreck and perform the calculations for the moments and products of inertia of the vehicle. To illustrate a potential design, a two-wheeled axis vehicle is described and demonstrated to the students. In Table 3, it is noted that originality counts for 25% of the grade. It is explained to the student that the farther the design looks from the original demonstrator model, the higher the grade will be. Originality in material or component utilization is also awarded.

In addition to the grade, on the day that the projects are due, a contest with small token prizes is held. In this contest, different criteria (announced at the project assignment) are used. For example, awards have been given for the most original design; the best utilization of materials related to the student's major, fastest down an incline, slowest down the incline, etc. Instead of giving grades or bonus points, the token prizes such as school mugs or stickers are given. This makes the actual contest an enjoyable part of the class and does not add stress to the students in worrying about grades.

The one constant item in the course is the final exam. The final exam is of course the evaluation of the students' assimilation of all the material in the course.

Discussion

Students reported anecdotally via the course evaluations that the fact that the homework was not graded made the class much more enjoyable. Also receiving positive reports was the fact that each exam was weighted less than 10% of the course final grade so that a poor exam grade did not "ruin" their grades.

Quantitatively, the quiz scores from the classes have been averaged, and a composite is provided in Table 4. A letter grade is provided for the class average on each quiz. In addition, the relative difference between the average and the median for each quiz is given. A negative number indicates that the average was lower than the median, indicating that there were a few students who performed much poorer on the exam than the majority of the class. It was especially evident for the last portion of the course when the students have many items due and feel the pressure of all of the classes in which they are enrolled. What is interesting is that the first quiz, which encompasses material that is essentially review material from physics and mathematics, is one of the poorest grades. This appears to be due to the fact that many students - in particular the sophomores - believe that the course is a repeat of their physics classes where they can memorize the material. This is quickly dispelled at a lower grade cost to the student, as well as earlier in the course so that more attention is paid to the lectures.

Table 4. Composite Performance of Classes with Modified Course Syllabus

Quiz	1	2	3	4	5	6	7
Average	C	B	B+	C	C+	C+	C-
Relative Difference Between Average and Median	-5	-9.9	-9.5	-3.4	-7.1	-15	-14.4

The design portion of the class proved to be the most popular feature of the class. Students with lower grades felt that it helped their grades, while all students reported that they wished all classes had a contest similar to this. The connection to the larger scale Ramblin' Wreck parade was noted, and many students displayed their projects with pride. On an interesting note, the most original and well-thought-out designs were those of the highest and lowest performing students in the class. Students who typically received a “C” in the final grade tended to spend less time on the project and their designs were closest to the two-wheeled demonstrator. Materials for the projects have varied from an all-recyclable vehicle made of food, a street-cleaner made of items found from a trash can selected at random on campus, an “ice” machine made of ice, and an electrical and computer engineering student's computer component vehicle. A sample of the efforts of one class is shown in Figure 2. Various shots of the contest are shown in Figures 3 and 4.

Figure 2. Sample of Design Projects

Figures 3 & 4. Examples of Design Contest

Overall, little difference in the final exam or final grades was observed in this course, as compared with other Dynamics courses taught using the traditional syllabus. A very small increase in class GPA is seen (< 0.2), but this requires additional samples for publishable correlation. Fewer students appeared to earn "D" grades, but similar numbers of students received failing ("F") grades. Qualitatively, the students appeared to enjoy the new class structure more than the old class structure.

Conclusions

The traditional classroom lectures and testing in Dynamics has been modified to enhance learning of the material. Shorter quizzes at more frequent intervals were designed to provide more timely feedback of learning to both the student and professor and to alleviate stress due to quizzes that count a large portion of the course grade. A weekly recitation outside of class hours, in addition to office hours, aided students with the ungraded homework. The ungraded homework promoted learning via student teams. A design project tied to school spirit helped the students to transform coursework into engineering experiences. While there is currently not enough quantitative information to state that this method improves grades and retention, course evaluation feedback indicates a higher level of satisfaction with the course by the students.

Acknowledgment

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References

1 . http://www.abet.org/eac/EAC_99-00_Criteria.htm

Biographical Sketch

MARILYN J. SMITH
Marilyn J. Smith earned her Ph.D. in aerospace engineering at the Georgia Institute of Technology in 1994. She joined the faculty as an Assistant Professor in the School of Aerospace Engineering at Georgia Tech in 1997 after fifteen years of industry experience at Lockheed-Georgia (now LMAS), McDonnell-Douglas Helicopter (now Boeing Helicopter-Mesa), and the Georgia Tech Research Institute. She was awarded the 1999 Outstanding Faculty Member by the GIT Women's Leadership Conference. She is an Associate Fellow of AIAA and a past member of the AHS Fluids Technical Committee.