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Evaluating the Usage and Value of Supplemental Materials in a Dynamics Class

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Abstract

Engineering dynamics is a subject area that many engineering students find among the most difficult encountered in their course of study. At East Carolina University, the required course in dynamics is especially important in that students are required to earn a grade of at least a C in order to proceed with some subsequent courses. In order to help students succeed, supplemental materials have been created to complement the traditional class elements of lectures, homework assignments, and readings from the textbook. These materials include Questions of the Day which are emailed to students every weekday morning, class summaries which are emailed the day before each class, and videos illustrating some topics with motion simulations. In addition to describing these supplemental materials, this paper describes an effort to track how often students use them and relate their use to success in the course.

A paper-based survey was given to students at the end of each week. This survey asked the students to recall how often they used the resources that week as well as to estimate how many hours they spent outside of class. Among the findings were that utilization rates for the Question of the Day and the class summaries were around 50%, while only about 20% of students read the textbook before class. The viewing rate for the videos was very low – an average of 8% watched a video completely, with an average of 19% watching a portion of a video. While these utilization rates could certainly be improved by making them mandatory, the philosophy of the instructors is to provide resources and allow the students to take responsibility for choosing the ones that work best for them. In the paper, the authors discuss ways in which they encourage the students to do so. In an end-of-semester survey, a majority of students rated all of the resources as "very helpful" or "moderately helpful."

Of the 99 students in the class, 64 completed at least 11 of the 14 weekly surveys and voluntarily identified themselves by name or student ID. After the semester, the student data was organized into quartiles by overall class average and improvement after the first of four mid-term tests.

While no significant differences were seen in utilization of resources among the groups, the average number of hours spent per week was highest for the most-improved quartile. Based on this result, the authors conclude that continuing to develop and refine multiple resources is worthwhile, as long as students are aware that the key to improving is to spend more time with whichever of the resources they find most helpful.

Background

At the university level, learning involves knowledge transfer and higher order thinking. According to Bloom's Taxonomy of Educational Objectives, students should be able to move beyond mere calculations, or procedural knowledge, to the application and transfer of knowledge at this stage of learning. [1]

When entering the engineering mechanics courses, both statics and dynamics, students have difficulty because it is the first time they are required to think like an engineer, with various ways to get to an optimal answer. While in statics there is one clear method of analysis, dynamics introduces several methods to choose from to reach a solution. As instructors, we should develop ways to help align the teaching and learning in order to aid students in developing both the conceptual knowledge and the type of thought process required for engineering.

According to research by Goldfinch [2], procedural knowledge is the main type of knowledge being tested by most dynamics instructors. Yet the most important goal is conceptual knowledge, not procedural. Our aim should be for students to achieve true conceptual knowledge and understanding of the subject of dynamics.

Two learning theories come into play when students are learning dynamics: Cognitive Load Theory and Threshold Concept Theory. An understanding of these theories will help instructors guide their teaching model. In a study on cognitive load during problem solving, Sweller [3] found that there are two processes occurring during problem solving that compete for cognitive capacity. These are schema acquisition and the problem-solving process. Schema acquisition involves the student identifying the type of problem at hand, while problem solving involves picking an appropriate solution method from a set of possible methods. The cognitive capacity of the novice brain (our students) cannot support both processes at once. While solving the problem using a selected method, the novice does not also identify the problem schema and place it in a group of like problems. Therefore, the schema acquisition that is needed does not occur during solving problems, as when a problem set is assigned as homework. Acquisition of this knowledge is necessary for knowledge transfer later, yet it will need to be acquired in a different manner. Problem sets have traditionally been used to help students improve in the problem-solving process, but also so that they see a variety of problems that they can draw upon later when they encounter a similar set up. Instructors will need to be aware of this limitation of cognitive capacity and work on classifying problems with students, apart from the problem-solving process.

Tang and Bai [4] describe how they have used Cognitive Load Theory to design effective learning exercises in an engineering dynamics class. By focusing on a specific step within a five-step problem solving process, each exercise is designed to build competence related to that step, without overloading the students' cognitive load. As knowledge and skills related to each step are developed, students can progress toward acquiring better schema for identifying and solving problems more efficiently.

The second theory of learning, Threshold Concept Theory, can be used to explain how students learn the material and develop expertise in it. Threshold concepts can be defined to be those critical concepts that are both difficult to comprehend, but once understood, open up new ways of thinking and understanding for the student. Hesterman et al [5] presented research on threshold concepts in engineering dynamics. The threshold concepts that they named from their research are as follows:

- Vectors and vector calculus,
- System identification and definition,
- Temporal and spatial frames of reference, and
- Conservation principle

Vectors and vector calculus are concepts taught in previous courses and instructors assume that students have a basic understanding of them before beginning dynamics, yet students still have major difficulties in this area. An example of this difficulty is seen in the vector quantities of velocity and acceleration. The difference between speed (a scalar quantity) and velocity (a vector) is a concept that must be well understood if a student is to then understand that acceleration is not the rate of change of speed (scalar) but of velocity (vector). Therefore, a body moving along a curve at constant speed will still have acceleration. Moving students to a higher understanding of how vectors represent the real world pushes them past the conceptual threshold.

System identification and definition refers to the ability to develop an appropriate model of the physical system. This model includes constructing appropriate free body diagrams, recognizing correct force and moment interactions, understanding action and reaction within the system, interpreting terminology used in the problem description (smooth surface refers to no friction), making reasonable assumptions (which is tacit knowledge for instructors), and realizing that the free body diagram may only be true for one point in time. Many times in teaching dynamics, the system is so specifically laid out, with all the information given, and only the information necessary given, that this skill is not being taught. Instructors need to be aware of this and consciously work to provide students with a means to gain this skill. This threshold concept is a major skill in dynamics that when learned, will lead to greater understanding and new ways of viewing the physical world.

Temporal and spatial frames of reference are difficult concepts as they involve spatial visualization skills. This skill involves the selection of an appropriate coordinate system, yet realizing that absolute motion is independent of the coordinate system chosen. Relative motion uses a rotating frame of reference and involves vector calculus, which itself is a threshold concept. Skill in this area is developed over time and with practice, yet many students and instructors do not take the time to develop the skill.

The final threshold concept is the conservation principle. The laws of conservation (of energy and of momentum) may be used when only conservative forces are involved. However, they ignore certain real-world forces, like air resistance, and therefore, may confuse students in when they may be applied. In real systems, mechanical (kinetic and potential) energy is always lost to a degree so how can these laws be applied? Oversimplified examples in the classroom only reinforce this confusion. Showing how and why these laws may be used in real systems and using authentic examples in the classroom is needed to equate these laws with the students' experience of the physical world around them.

If students understand these threshold concepts, common misconceptions can be avoided. It is moving the students past this threshold that will lead to the knowledge, understanding, and the ability to use this knowledge in the future.

Cognitive Load Theory and Threshold Concept Theory provided the basis for the creation of the supplemental materials that are described below.

Course Description

At East Carolina University, ENGR 2450 Dynamics is a required course for all students in the BS Engineering program. For four of the six concentrations, a grade of C or better in ENGR 2450 is required to register for a subsequent required course. Over the past three years, instructors have developed supplemental materials to help students better learn the concepts of dynamics. These supplemental materials include:

- class summaries intended to supplement the material from the textbook to be covered in each class,
- Questions of the Day to be emailed to students every weekday, and
- videos with computer simulations intended to help students visualize the motion of certain problems.

During the Spring 2017 offerings of the class, students were surveyed weekly to determine how often they utilized these supplemental materials, as well as how often they read the textbook and the total number of hours they spent on class activities. For weeks in which a test was given, students were asked what resources they used when preparing for the test. The surveys were conducted each Friday at the beginning of class, except for the two weeks for which there was a test on Friday and the week of the Good Friday holiday. On those weeks, the survey was conducted the following Monday.

There were four sections of the course offered during Spring 2017; all met on a Monday-Wednesday-Friday 50-minute schedule. There were four tests given during the semester. There was a review class before each test, and two days to review the course before the comprehensive final exam. The 32 instructional periods were organized as follows:

- Particle Kinematics (9)
  - Rectilinear Motion (2)
  - Graphical Methods (1)
  - Curvilinear Motion, Including Projectile Motion (4)
  - Relative Motion (1)
  - Dependent Motion (1)
- Particle Kinetics (11)
  - Equations of Motion (4)
  - Work and Energy (4)
  - Impulse and Momentum, Impact (3)
- Rigid Body Kinematics (5)
  - Rotation (1)
  - General Plane Motion (4)
- Rigid Body Kinetics (7)
  - Equations of Motion – Translation (1)
  - Mass Moment of Inertia (2)
  - Equations of Motion – Rotation and General Plane Motion (2)
  - Work and Energy (2)

Homework was assigned after each class period. A typical assignment was two problems from the required textbook, Hibbeler's *Engineering Mechanics: Dynamics, 14th Edition* [6], and one or two original problems. The authors have been reluctant to switch to on-line homework assignments, as we feel that documenting calculations is an important skill for engineers to develop. However, in recent years the availability of solution manuals and other posted solutions to textbook problems has become widespread. To level the playing field for all students, we now post solutions to the textbook problems at the time they are assigned. In addition to making the solutions available to all students, our posted solutions demonstrate the format that we expect students to follow: problem statement with sketch when appropriate, all steps of the solution including a properly drawn free body diagram for kinetics problems, and the final answer clearly identified, rounded to a reasonable number of digits and with correct units shown. We try to emphasize throughout the course that copying the solutions will result in a good homework grade (15% of the final grade) but will result in poor performance on the tests (15% each or 60% of the final grade) and final exam (25%). But when students use the posted solutions to check their own work and find errors, then the solutions can be an aid in learning the material. The original problems, for which solutions are not provided until after they are graded, tend to be less complex geometrically and/or mathematically than the textbook problems. Therefore, students can focus on the conceptual aspects of each problem – selecting the best solution method and identifying the important information in the problem statement. These problems provide the instructors good feedback on how well the students are learning the concepts of the course.

The four tests consist of five to ten multiple-choice or true-false conceptual questions and four or five problems. Since the tests are only 50 minutes long, the problems must be carefully chosen so that students have enough time. Prior to each test, a review session is held during which some of the "Fundamental Problems" from the textbook are worked and discussed. (The Fundamental Problems are a nice feature of the Hibbeler text. In addition to the answers, partial solutions are included in the back of the book.) The solutions to the review problems as well as a study guide and an old test and its solution are posted several days before each test.

Supplemental Materials

The first of our supplemental materials to be developed was a series of Questions of the Day (QOTD). The intent of the QOTD is to make students think about dynamics on a regular basis. Otherwise, the natural habit of procrastination leads students to attend class on a Monday morning and not look over the covered material until Tuesday evening. A QOTD is emailed to students early every weekday morning, except on test days. When creating the QOTDs, the goal was to make the question require little or no calculations, so that the focus is on conceptual understanding rather than procedure. Walchko [7] showed that students' understanding of concepts was improved after adopting a "no-numbers" approach throughout an entire dynamics class. We prefer to retain numerical values for homework and test problems in order to force students to retain and enhance their calculation skills and to develop a better feel for the magnitudes of numerical results. We considered different ways of presenting the answer to the QOTD, such as posting it on-line, including it with the next day's question, or simply including it along with the question. An analogy is the crossword puzzle in a newspaper. If the answer appears in the next day's paper, then a reader may never check the answer to the portions that they struggle with. On the other hand, if the solution appears on the same page as the puzzle, there is a temptation to glance at the answer before making a good attempt at solving it. A good compromise is to place the solution on another page, removing the possibility of a quick glance but still allowing for an immediate access to the solution. For the QOTD, the question itself is given in the body of the email, while the solution is provided as an attachment to the same email message. A sample QOTD and its solution are shown in Figure 1.

Dynamics Question of the Day #24-1

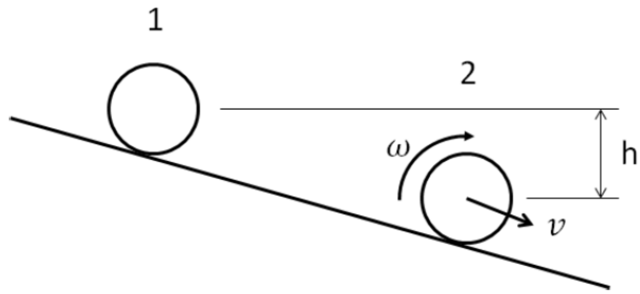
A cylinder of radius r, mass m and mass moment of inertia I starts from rest at position 1 and rolls without slipping to position 2. Since there is no slipping, the speed v is equal to ωr. Which of these conservation of energy equations can be used to solve for ω?

a) $mgh = \frac{1}{2}m(\omega r)^2 + \frac{1}{2}I\omega^2$

b) $mgh = \frac{1}{2}I\omega^2$

c) $0 = \frac{1}{2}m(\omega r)^2 + \frac{1}{2}I\omega^2 + mgh$

d) $mgh = \frac{1}{2}m(\omega r)^2$



Answer: **A**

Initial kinetic energy: $T_1 = 0$ (started from rest)

Initial potential energy: $V_1 = Wh = mgh$ (with the lower position selected as the datum)

Final kinetic energy: $T_2 = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2 \quad = \frac{1}{2}m(\omega r)^2 + \frac{1}{2}I\omega^2$

Final potential energy: $V_2 = 0$

Conservation of energy:

$$T_1 + V_1 = T_2 + V_2$$

$$mgh = \frac{1}{2}m(\omega r)^2 + \frac{1}{2}I\omega^2$$

Figure 1 Example of a Question of the Day

It will come as no surprise to anyone teaching mechanics courses that students often resist reading the textbook before class. Part of this resistance may be that compared to many other subjects, mechanics textbooks are difficult to read. This is not a criticism of textbook authors, but rather a realization that in order to be complete, textbooks must present a thorough explanation of concepts that are new to students and may need some explanation and interpretation from instructors to aid in understanding. However, coming to class with some preparation beforehand is certainly beneficial. Accordingly, we have written brief (usually one to one and one-half pages) summaries of the important concepts for each class. The first time that we used these summaries, we emailed them to students the morning of each class. In a student survey at the end of the course, a few students noted that they did not always have time to read the summaries before class or that they would have liked to have had the opportunity to print them before class. We now send the summaries out the morning before each class, along with that day's QOTD. The summaries now include the example problems to be worked in class. This gives students a reason to print the summaries and bring them to class, as they don't need to write down the problem statements when taking notes in class.

The third category of supplemental materials provided to the students is videos to illustrate the motion described in dynamics problems. The concept of using SOLIDWORKS Motion simulations to illustrate dynamics concepts to high school students had been explored during summer programs at East Carolina University [8]. Many concepts such as projectile motion, conservation of energy, impact, and velocity and acceleration analysis of mechanisms can be simulated with SOLIDWORKS Motion models. For the class, 14 videos were made and posted to YouTube. Each video presents a problem, shows the solution, and then illustrates and verifies the solution with a simulation. The lengths of the videos vary from seven to 15 minutes. The screen captures of Figure 2 illustrate four of the video problems. Links to each video are emailed to students when the relevant theory has been covered in class.

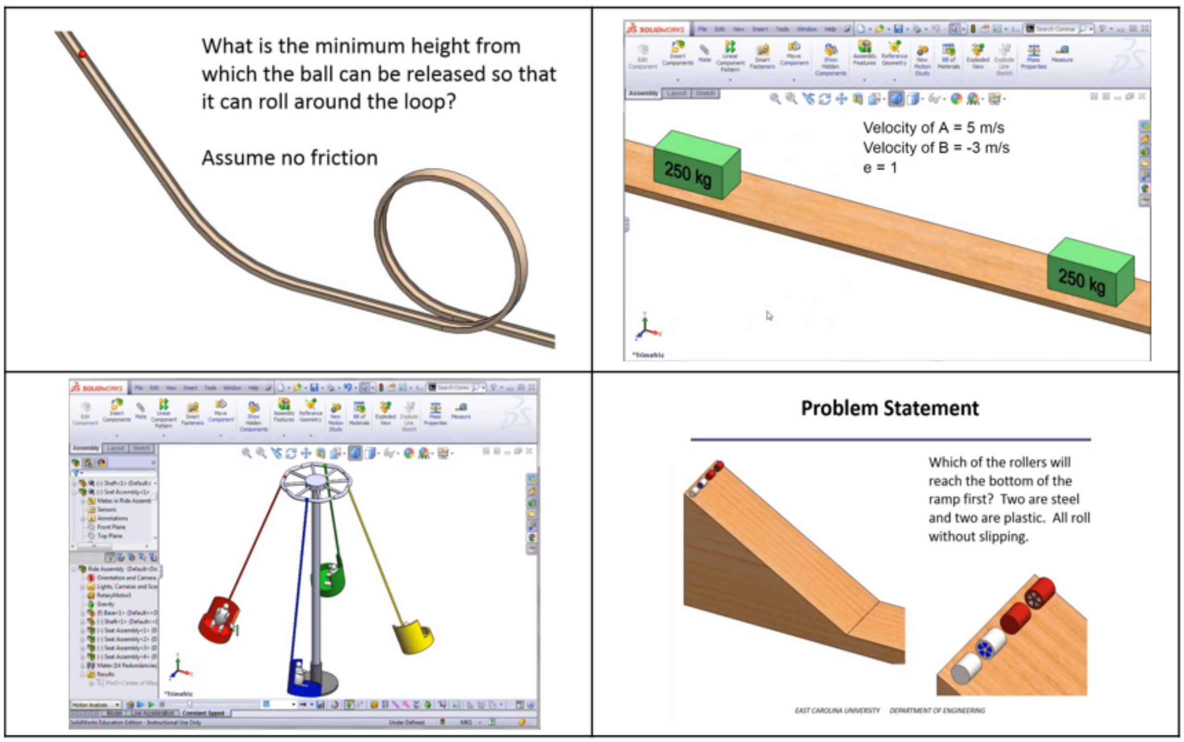


Figure 2 Screen Captures of Four Supplemental Videos

One way in which we have encouraged the use of supplemental resources, in addition to promoting better study habits, is by presenting what we call the "Process Matrix" that is shown in Figure 3. We present this matrix to students after the first test, as we don't think students will pay much attention to it at the beginning of the semester. The intent is to make students realize that there are many ways in which to improve their understanding of the course material. While it is doubtful that any student does everything to the far right of the chart, moving even one or two habits in that direction can have positive results.

ENGR 2450 Dynamics Learning Process

Learning is a process, and some techniques work better for some students than for others. If you are having trouble and want to better, try moving from left to right in one or more of these categories:

→ → → → → → → → → → → → → → →

Attendance	I can learn this on my own – I'll go on test days	I go sometimes, but I'll skip for almost any reason	I go, but sometimes I'm late and I don't mind interrupting the class	I go every day	I go every day, prepared to learn
Reading the Book	I don't have access to the book.	I only use the book for the problems.	I look over the example problems if I get stuck on homework.	I read the sections of the book before class.	I read the sections of the book before class and try to work the example problems.
Taking Notes	Why bother?	I write down the stuff on the board, but never look at it again.	I write down the stuff on the board, and don't look at it until test time.	I look over my notes after class, work the in-class problems myself, and write down important concepts.	
In-Class Participation	I figure that as long as I'm there, that's enough	I pay attention and try to understand the lesson, but I think I'll look dumb if I ask a question	I pay attention, try to understand the lesson, and ask questions when I don't		
Homework	It's only 15% of the final grade. Why bother?	I copy from the posted solutions and skip the other problems	I give it a try, but don't bother to check my solutions and find my errors	I always look at the solutions first so I know where to start, then work the problems myself.	I try to do the problems myself, then look at the solutions. I make sure that I understand the solutions and ask questions if I don't.

→ → → → → → → → → → → → → → →

Preparing Sheet for Tests	I don't really need one.	I copy down the equations from the summary sheets.	I copy as many problems as I can. I don't really understand them, but maybe the test problems will be similar.	I review my class notes and HW problems and write down and organize only the important equations that I will need.
Daily class summaries	What are those?	I save them to look over before tests.	I read them before class and often refer to the referenced section of the book.	I read them over before class and then review them after class.
Question of the Day emails	I ignore them	I look at them and guess at the answers, but opening the solutions takes an extra mouse click and I'm a busy person.	I look at most of them and check the answers.	I look at them every day and check the answers.	I look at them every day, check the answers, and go back and look at them as part of my test preparation.
Videos	I start to look at them, but I have a short attention span and end up looking at cat videos instead.	I watch some of them.	I watch most of them.	I watch them all, replay portions I don't fully understand, and ask questions if I still don't understand.
Office Visits	I don't know where the Slay Building is.	I don't like to bother to the instructor	I'll sometimes drop in 5 minutes before class and ask for help in starting the HW that is due that day.	I go to ask questions whenever I don't understand something.
Pirate Academic Success Center	I don't know where it is	I'm aware of it, but I don't like to ask for help	I'll go before a test	I'll go whenever I think it will help me understand the material better
Working in Groups	I don't like people; besides, I'm smarter than everyone else and other students would drag me down.	I work with other students, but we just copy from the solution manual and each other	I work with other students, and we split up the work and copy from each other	I work with other students, and we help each other learn and understand the material

Figure 3 Learning Process Matrix

Surveys

Examples of the weekly surveys are shown in Figures 4 and 5. The survey shown in Figure 4 is for a week without a test, while the survey shown in Figure 5 is for a test week. Students were told that they could either put their name or student number (Banner ID) on the survey or submit it anonymously. They were told that the data from the surveys would not be evaluated until the semester was over, but that identifying themselves would allow us to attempt to correlate use of the supplemental materials with performance in the class. There were 99 students initially enrolled in the class. Three dropped during the semester and two did not take the final exam. The number of surveys completed averaged 78 per week, varying from a high of 94 during the first week to a low of 66 during the last week. More than 90% of the completed surveys were identified by name or student ID, with the number of anonymous surveys during a week varying from 3 to 10.

ENGR 2450 Weekly Survey – Jan. 27

Name or Banner ID#______________________

Please circle the appropriate answer:

How many of the Questions of the Day did you read and try to answer?

0 1 2 3 4 5

How many of the class summaries did you read before class?

0 1 2 3

How many times did you read material from the book before class?

0 1 2 3

Did you watch the video "Particle Curvilinear Motion Example"?

No Part of It All of It

About how many hours do you estimate that you spent doing homework, studying, and reading for this class this week?

____

Thank you for your responses!

Figure 4 Example Survey – Non-Test Week

ENGR 2450 Weekly Survey – Feb. 6

Name or Banner ID#______________________

Please circle the appropriate answer:

Last week, how many of the Questions of the Day did you read and try to answer?

0 1 2 3 4 5

How many of the class summaries did you read before class (for last Monday's class)?

0 1

How many times did you read material from the book before class (for last Monday's class)?

0 1

In preparing for the test, which of these did you use (check all that apply):

- ☐ Class summaries
- ☐ Class notes
- ☐ Textbook
- ☐ Homework
- ☐ Review problems (from Wednesday's review session)
- ☐ Old test
- ☐ Questions of the day

About how many hours do you estimate that you spent doing homework, studying, and reading for this class last week?

__________ *Thank you for your responses!*

Figure 5 Example Survey – Test Week

Results

Each week's survey had these three questions:

- How many of the Questions of the Day did you read and try to answer?
- How many of the class summaries did you read before class?
- How many times did you read material from the book before class?

The answer choices varied from week to week, depending on how many QOTDs and class summaries were sent. For a "normal" week (no test or test review days), there were five QOTDs and three class summaries sent. The percentages of students reading each item throughout the semester were:

- Question of the Day: 48%
- Class Summary: 45%
- Textbook: 20%

The percentages by week are plotted in Figure 6. The number of students reading the QOTDs and class summaries trended downward as the semester progressed, with upward spikes during test weeks. The number of students reading the textbook before class was relatively consistent throughout the semester.

Students were also asked to estimate the number of hours that they spent on the course outside of class each week. The results are shown in Figure 7. As expected, the number of hours peaked during test weeks.

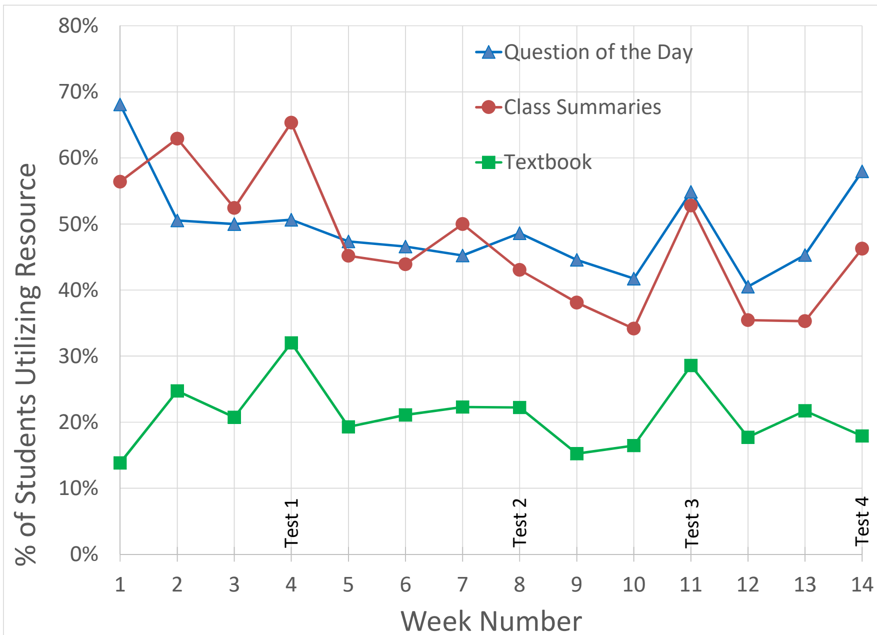


Figure 6 Utilization of Class Resources by Week

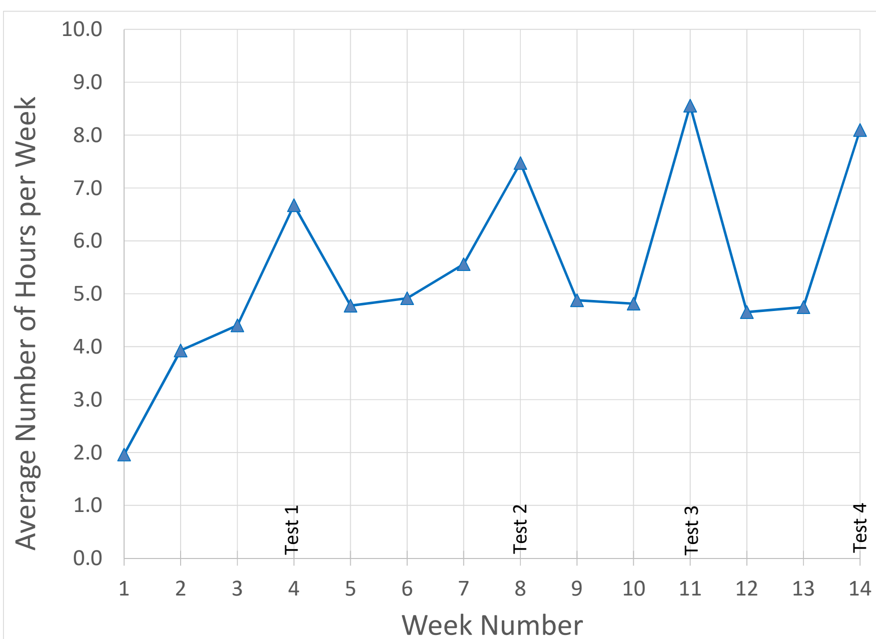


Figure 7 Number of Hours Spent Outside of Class by Week

The average number of hours per week was 5.39. Note that Week 1 was a short week because of a weather-related class cancellation, and so students only had to complete one homework assignment that week. If this week is excluded from the calculations, then the average number of hours per week is 5.65. In past semesters, we have asked students to estimate this number at the end of the semester, and the results were very consistent with the weekly-reported hours. In 2015 and 2016 the average number of hours reported per week were 5.5 and 5.6, respectively. One other note of interest is that spring break occurred between Week 8 and Week 9, and the number of hours spent after the break seems relatively consistent with the hours before the break. In other classes, particularly freshman classes, we have seen a drop-off in attendance and homework completion after spring break.

Links to the 14 videos were sent to students as the associated topics were covered. For the weeks in which one or more video links were sent, students were asked whether they watched all the video, some of the video, or none of it. Results are shown in Figure 8. On average, 8% were watched completely, 19% were watched partially, and 73% were not watched at all.

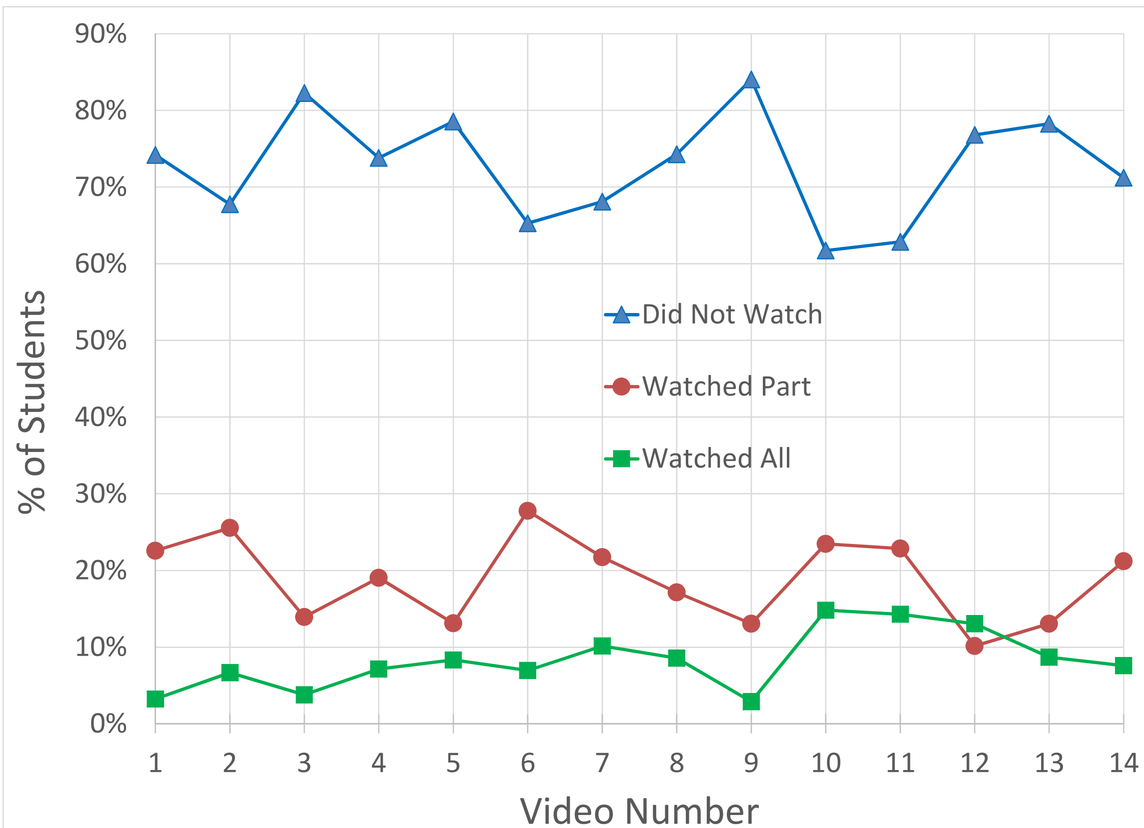


Figure 8 Viewing Percentages of Videos

During test weeks, students were asked what resources they used to prepare for the test. Those results are summarized in Table 1. What may be most surprising about these results is that there were a significant number of students who did not use an old test in their preparations.

Table 1 Percentages of Students Using Specific Resources to Prepare for Tests

	Test 1	Test 2	Test 3	Test 4
Class Summaries	50%	51%	53%	57%
Class Notes	86%	81%	86%	82%
Textbook	36%	50%	38%	30%
Homework	82%	86%	86%	85%
Review Problems	78%	85%	86%	88%
Old Test	70%	75%	90%	90%
Questions of the Day	43%	44%	43%	60%

In addition to examining the overall usage rates of the various resources, a goal of this project was to see if the most successful students used certain resources more than less successful students. As noted above, most participants in the survey identified themselves by name or student ID number. But not every student completed each week's survey. Only 23 students completed all 14 surveys. In order to have a larger sample, students who completed at least 11 of the surveys were included in this phase. The number of students completing 11 or more surveys was 64. The average final grade for these 64 students (the final grade was weighted as 15% for homework, 15% each for the four tests, and 25% for the final exam) was 84.0, with grades ranging from 102.3 to 45.5 (several homework assignments as well as two of the tests contained extra credit portions, hence the highest average greater than 100). For comparison, the average grade for the 93 students who took all four tests and the final exam was 82.2, with the same range of grades. So although the average grade for the sample of 64 students was slightly greater than that of the entire class, the sample is a reasonable representation of the entire class.
These 64 students were divided into quartiles corresponding to final grade. We also grouped students by *improvement* after Test 1. The improvement was defined by plotting the four test grades and performing a least-squares fit (linear trend line in Excel) and finding the slope of the fit line. For example, one student had test grades of 58, 71, 85, and 79 on Tests 1-4, respectively. Those grades are plotted in Figure 9, and a linear trend line shows the slope value for this student to be 7.7. The average slope for the 64 students was 4.5. The positive slope is due in part to the fact that extra credit points were available on Tests 3 and 4. The averages for the four tests were 79.1, 78.6, 82.0, and 93.0 for the 64 students.

Characteristics of the quartile groups are shown in Table 2. Not surprisingly, there is somewhat of an inverse relationship between the quartiles grouped by grades and by improvement. Many of the top-performing students did well on the first test, and therefore had less room for improvement on the subsequent tests (although most did have positive slope values, as the top students were most likely to earn the extra credit points available on Tests 3 and 4). In fact, eight of the 16 students in the bottom quartile as ranked by improvement were in the top quartile as ranked by grade.

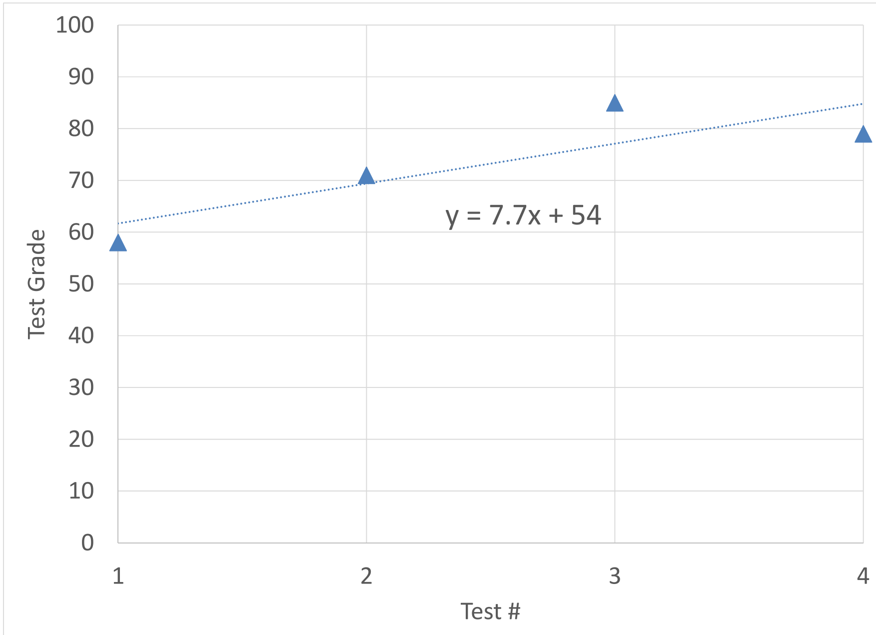


Figure 9 Least-Squares Fit of One Student's Test Grades

Table 2 Characteristics of Quartile Groups

RANKED BY GRADE		
	Average Grade (High/Low)	Average Slope (High/Low)
Top Quartile	95.6 (102.3 / 91.1)	1.8 (10.6 / -2.2)
Second Quartile	88.0 (91.0 / 85.0)	3.5 (9.5 / -1.3)
Third Quartile	82.3 (84.8 / 78.1)	5.4 (11.9 / -6.2)
Bottom Quartile	70.3 (77.7 / 45.0)	7.3 (13.8 / 0.1)
RANKED BY IMPROVEMENT (SLOPE)		
	Average Slope (High/Low)	Average Grade (High/Low)
Top Quartile	9.9 (13.8 / 8.0)	78.1 (91.1 / 57.6)
Second Quartile	6.3 (7.8 / 4.2)	83.2 (94.1 / 75.1)
Third Quartile	2.4 (4.2 / 0.9)	86.3 (102.3 / 45.0)
Bottom Quartile	-0.6 (0.8 / -6.2)	88.5 (99.6 / 54.5)

In Tables 3 and 4, the percentage of students in each quartile utilizing the QOTD, class summaries, and the textbook are shown. Note that for the quartiles ranked by improvement, only activities after the first test are included in the calculations, as the rankings reflect the improvement of a student's scores after the first test. The hours per week spent outside of class by quartile are summarized in Table 5.

Table 3 Utilization of Resources by Quartiles

	QUESTION OF THE DAY		CLASS SUMMARIES		TEXTBOOK	
	Ranked by Grade	Ranked by Improvement	Ranked by Grade	Ranked by Improvement	Ranked by Grade	Ranked by Improvement
Top Quartile	55%	47%	37%	38%	20%	13%
Second Quartile	48%	47%	46%	42%	13%	23%
Third Quartile	51%	57%	57%	49%	23%	15%
Bottom Quartile	51%	45%	49%	39%	19%	25%

Table 4 Percentage of Students Watching All or Part of Videos by Quartiles

	Ranked by Grade	Ranked by Improvement
Top Quartile	29%	27%
Second Quartile	30%	29%
Third Quartile	25%	22%
Bottom Quartile	25%	20%

Table 5 Hours per Week Reported by Quartiles

	Ranked by Grade	Ranked by Improvement
Top Quartile	4.43	6.03
Second Quartile	5.07	4.98
Third Quartile	5.90	5.76
Bottom Quartile	5.81	4.41

In Table 6, the percentage of students using each resource to prepare for tests is shown, sorted by quartiles. As noted above, results for the columns ranked by improvement consists of data reported after the first test.

Table 6 Utilization of Resources for Test Preparation by Quartiles

	CLASS SUMMARIES		CLASS NOTES		TEXTBOOK	
	Ranked by Grade	Ranked by Improvement	Ranked by Grade	Ranked by Improvement	Ranked by Grade	Ranked by Improvement
Top Quartile	44%	39%	83%	83%	44%	29%
Second Quartile	60%	56%	79%	83%	23%	49%
Third Quartile	50%	60%	89%	84%	37%	44%
Bottom Quartile	44%	46%	80%	76%	45%	37%

	HOMEWORK		REVIEW PROBLEMS		OLD TESTS	
	Ranked by Grade	Ranked by Improvement	Ranked by Grade	Ranked by Improvement	Ranked by Grade	Ranked by Improvement
Top Quartile	71%	95%	85%	85%	80%	83%
Second Quartile	84%	88%	88%	93%	93%	85%
Third Quartile	93%	89%	78%	89%	74%	89%
Bottom Quartile	93%	71%	85%	80%	76%	78%

	QUESTION OF THE DAY	
	Ranked by Grade	Ranked by Improvement
Top Quartile	47%	44%
Second Quartile	51%	71%
Third Quartile	50%	53%
Bottom Quartile	49%	39%

In addition to the weekly surveys, an end-of-semester survey was conducted. In this survey, students were asked to rate the value of the supplemental materials. Results from that survey are shown in Table 7.

Table 7 Student Evaluation of Value of Supplemental Materials

	Very Helpful	Moderately Helpful	Slightly Helpful	Not Helpful
How helpful did you find reading the *class summaries* and/or printing them out *before class*?	34%	27%	29%	10%
How helpful did you find reviewing the *class summaries* when *preparing for a test*?	47%	21%	21%	10%
How helpful did you find reading the *Questions of the Day* on the *days that they were sent*?	44%	24%	27%	4%
How helpful did you find reviewing the *Questions of the Day* when *preparing for a test*?	59%	19%	11%	11%
How helpful did you find watching the *videos*?	24%	33%	26%	17%

Discussion

As instructors, we would like to believe that every student will want to take advantage of every resource that we make available. Of course, we can attempt to force students to use the resources by adding quizzes or by tracking the amount of time that a student is engaged through a course management system, but we desire to have students determine for themselves which resources are most valuable to their habits and abilities. The overall utilization rates of the QOTD and the class summaries of less than 50% may seem low, but as voluntary activities may be as high as is reasonable to expect. The low utilization of the videos should not be surprising, as they may be too long to hold students' attention. However, when asked about the value of the resources, a majority of students found all to be very or somewhat helpful. When preparing for a test, 68% found the class summaries to be somewhat or very helpful, while 78% found the Questions of the Day somewhat or very helpful. Even the videos, each of which were viewed by less than half of the students, were rated by 57% as somewhat or very helpful. Perhaps many students only watched the videos when they wanted more explanation on a specific topic.

When looking for trends that separate the highest-achieving students from the lower groups or that separate the most-improved group from less-improved groups, no clear answers were evident in the results shown in Table 5. The top-performing quartile was slightly more likely to read the Questions of the Day, but the difference from the other quartiles was not significant. Students in other quartiles were slightly more likely to read the class summaries or watch the videos then those in the top-performing quartile. When preparing for tests (Table 6), students in all quartiles utilized resources at similar rates, except for the somewhat surprising result that the top-performing students utilized their homework solutions *less* than the lower-performing students. This is possibly related to the fact that students were permitted to prepare a single-sided, hand-written page of notes for each test. Students often copied homework problems onto the sheet, hoping to make the test problems fit a homework problem, while many of the top-performing students simply wrote down equations that they expected to be useful. (In the future, it might be interesting to collect the students' sheets and attempt to identify correlations between the type/quantity of information written down and performance on the test.) However, the most improved quartile of students had the highest utilization of homework as part of test preparation. Since the original (not from textbook) homework problems were naturally more similar to the test problems, perhaps these most-improved students focused on learning the concepts from those problems.

The most significant result from the surveys is probably in the number of hours spent per week. Many instructors would guess that the top-performing students are more likely to put in the most time. However, our results show the opposite: the top-performing quartile of students devoted the least amount of time to the course. With better preparation from statics, physics, and calculus classes, apparently these students did not need to put in as much time to be successful. On the other hand, the most-improved quartile of students averaged more than 1-1/2 hours more time per week then the least-improved quartile (which included many of the top-performing students). Perhaps this is the key finding of these surveys: While providing a variety of supplemental resources will help many students, the key to improvement for a student is to put in more time to the course, regardless of which resources are most effective for that student.

The overall impact of adding the supplemental materials is difficult to assess when looking at year-to-year student performance, which is summarized in Table 8. This table includes only the spring semester offerings of the course and not the "off-track" fall and summer sessions. While the 2017 offering of the course had the highest overall grade average to date, the number of students earning D's and F's was at 12%, up from the single-digit values of the previous two years. However, significant changes in the student population have occurred over the time period. Admission standards have increased over the past few years, and many more transfer students from community colleges are now being admitted to the program. We should also keep in mind that while looking for trends is important, we should not ignore informal feedback from individual students who say that one of more of the supplemental materials has helped them to succeed.

Table 8 Year-to-Year Grade Summaries

Year	Number of Students	% of D and F Grades	Grade Average (4-Point Scale))
2012	60	18%	2.45
2013	85	11%	2.73
2014*	82	12%	2.66
2015	75	7%	2.99
2016**	105	8%	2.90
2017	96	12%	3.03

*QOTD and Video Introduced ** Class Summaries Introduced

Future Work

We plan to continue to provide the Questions of the Day and the daily class summaries in future offerings of the course. We may increase the homework assigned slightly, with two original problems for every assignment. The additional original problem allows a good opportunity for *interleaving*, a technique in which prior material is mixed in with the new material. [9] This technique has been shown to improve long-term retention of concepts. Even though the percentage of students watching the videos was low, the fact that a majority of students found them to be helpful is a good reason to keep making them available. However, more students may benefit from seeing the simulations if shorter video clips are shown in class in conjunction with example problems. Also, some of the simulations can be assigned to the students, all of whom have access to SOLIDWORKS through a network license. The extra-credit assignment for the third test required students to simulate a problem from the test. We may add a few exercises of this type to the homework assignments. One other idea to be considered is to make five-minute video recaps for every class.

Conclusions

In the analysis of the usage and effectiveness of the supplemental materials provided to students, there was no “silver bullet” that provided a clear path to mastery of the important concepts of dynamics. However, we feel that students who have successfully completed the prerequisites of statics and calculus can succeed in the course. The supplemental materials, along with encouragement from faculty, can help students succeed in the course and at the same time learn to take responsibility for finding the study habits that are most effective for them.

References

[1] D. Krathwohl, “A revision of Bloom’s Taxonomy: an overview,” *Theory Into Practice*, vol. 41, n. 4, p. 212+, June 2010.

[2] T. Goldfinch, A. Carew, and J. McCarthy, “A knowledge framework for analysis of engineering mechanics exams,” in *Research in Engineering Education Symposium, Palm Cove, Australia, July 20-23, 2009.* Curran Associates, Inc., pp. 247-252.

[3] J. Sweller, “Cognitive load during problem solving: effects on learning,” *Cognitive Science*, vol. 12, n. 2, pp. 257-285, April 1988.

[4] Y. Tang and H. Bai, “Develop a better way to practice to enhance students’ experience in learning dynamics,” in *Making Value for Society: Proceedings of the 122nd Annual ASEE Annual Conference and Exposition, Seattle, WA, June 14-17, 2015.*

[5] D. Hesterman, S. Male, and C. Baillie, “Some potential underlying threshold concepts in engineering dynamics,”. Australasian Association for Engineering Education Conference 2011, Fremantle, Western Australia.

[6] R. Hibbeler, *Engineering Mechanics: Dynamics, 14th Edition*, Pearson Prentice Hall, 2016.

[7] J. Walchko, "No numbers: concepts-based testing in engineering," in *Incorporatig Diversity and Glabalization in Engineering Education: Proceedings of the 116th Annual ASEE Annual Conference and Exposition, Austin TX, June 14-17, 2009.*

[8] W. Howard, R. Williams, and J. Yao, Simulations of Carnival Rides and Rube Goldberg Machines for the Visualization of Concepts of Statics and Dynamics, *Engineering Design Graphics Journal*, vol. 74, no. 2, Spring 2010.

[9] S. Pan, "The Interleaving Effect: Mixing It Up Boosts Learning," in *Scientific American*. Published August 14, 2014. Available: http://www.scientificamerican.com/article/the-interleaving-effect-mixing-it-up-boosts-learning/. [Accessed February 4, 2018].