Session 1168

Evolution of an Introductory Dynamics Course Through Continuous Assessment

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Abstract

Two years ago, instructors at the United States Air Force Academy supplemented their introductory dynamics class with demonstrations, projects, laboratories, computational problems, and student presentations. Goals of the enhancement were to increase motivation and understanding, and also to make the class more enjoyable for the students. Labs included a rocket launch, a lego car design project, and a catapult launch. While these labs increased the motivation and enjoyment in the class, there is a danger of overloading the students with projects and decreasing the coverage of critical material. Extensive surveys were completed after each semester by both the instructors and the students, and appropriate changes to the course were made. The surveys consisted of the typical student critiques, followed by thirty additional questions. Some were multiple choice, while many were open ended. More in-depth feedback was obtained by the use of a Student Management Team (SMT) and a focus group. The SMT was a group of 6-8 students that met every 3-4 lessons, and provided feedback on course progress. The group was sometimes tasked with specific objectives (e.g., review the upcoming project), and other times simply commented on student perspectives on the recent material or assignment. The focus group met at the end of the semester and was given ten major questions to address. Both groups were held outside of regular class time, and participation was completely voluntary. Through the constant use of assessment, we have been able to fine tune our introductory course in dynamics to a challenging, yet enjoyable course.

Introduction

Several different new projects and techniques were introduced in our introductory dynamics class two years ago. The main goal was to increase motivation and understanding for one of the most challenging of all engineering courses. These projects were discussed in detail previously (Self and Redfield, 2001), but included a model rocket launch, computational mechanics projects, a catapult laboratory, a three dimensional kinematics project, student team presentations, and class demonstrations. Throughout the following five semesters, several different assessment techniques were utilized to determine if these new teaching ideas were successful.

Before discussing the various projects and use of assessment tools, it is first necessary to discuss the differences between the US Air Force Academy and a traditional institution. Time is very limited, as military and physical demands are routinely placed on the cadets. Fortunately, our dynamics course is a double hour class – the cadets' schedule is cleared for two full hours each class lesson. Additionally, we are on a fortnight schedule, which means that each class meets for only 50 minutes (one week the class will meet on Monday, Wednesday, and Friday, while the next week it will meet on Tuesday and Thursday). The students are given the option to remain in the classroom during the second hour to work on homework problems, and occasionally we have mandatory labs or projects during the second hour.

Finally, USAFA is an undergraduate only institution where education is the top priority. Class sizes are small, averaging 15 students per class section. This allows us opportunities that may not be practical at traditional universities with large class sections. Many of the projects that we use might serve as interesting class demonstrations, or could be used in a recitation section.

Assessment Tools

Many universities have now established departments to assist with educational research and techniques. The Center for Educational Excellence (CEE) at USAFA offers numerous brownbag lectures as well as expertise in assessment and pedagogical improvement. Working with professionals in CEE, we were able to develop a number of assessment tools. These included traditional surveys, a student management team, and a focus group. Other assessment tools used by our department include instructor surveys (three to six instructors under the guidance of a course director teach each semester) and end of the year course reviews.

Course Survey. At USAFA, traditional course surveys are given in all courses. These are often not course specific, and often it is difficult to assess course goals through their use. Instead, we have developed a forty question survey that addresses our course objectives, specific projects, and course workload. Throughout the survey, we ask short questions to obtain written feedback from the cadets. These answers have been used as much as any other type of assessment tool to help shape the course. CEE professionals then grouped the comments in categories (e.g., grade related, project related, instructor specific) and rated them as positive or negative comments. This helped the instructors analyze the hundreds of comments received each semester.

One of the questions asked students to rate three strengths and three weaknesses of the course. Some representative responses are shown in Table 1. Each row corresponds to the answers from one individual student (who may have only given two strengths or weaknesses) . CEE color coded each of the areas of responses (e.g., projects are in yellow). After analyzing the responses from all of the sections during that semester, the total number of strengths and weaknesses for each topic area were tallied. This is shown in Table 2 below.

Table 1. Representative comments on three strengths and weaknesses of the course.

Section M1A					
Strength 1	**Strength 2**	**Strength 3**	**Weakness 1**	**Weakness 2**	**Weakness 3**
The rocket project	The egg catapult	The homework being collected	Very fast paced	More problems to pick the equations and not necessarily solve	
The labs	The teacher		Homework should count as full credit as long as it is turned in before the test.		Try not to have the tests on other major's courses tests/labs
Flexibility	Board work		Allowing us to select our group partners	More Application.	
Awareness of dynamics	Reinforce EM120 (statics) better		The difficulty	The continuity	The textbook
understand why things happen	Very challenging- good sense of accomplishment	Good teacher made stuff interesting	No new material after final test	Have the labs relate more to airplanes	

Table 2. Talley of top strengths and weaknesses – common thread.

Top Seven Strengths and Weaknesses			
Number of Occurrences Strengths	**Common Thread**	**# Occurrences Weaknesses**	**Common Thread**
28	Labs and projects	43	Assessment related
25	2nd hour for EI	22	Homework
22	Applicable or relevant	16	Workload
16	Teacher related	15	Labs and projects
15	Homework	12	Derivations
6	Challenge	12	Pace or Schedule
6	Assessment related	10	Examples and applications

Student Management Team. A student management team (SMT) can provide in-depth feedback to the instructor and is invariably much more rewarding for both students and professors. An SMT is usually formed a few lessons into the course and consists of 3-7 students from the class. Meetings are held approximately every three lessons in a neutral location to discuss concerns that the students may have. The team members are given a managerial role and feel some ownership of the course.

It should be established early that the students should seek to provide constructive criticism, not simply complain about the course. It is also imperative that suggestions made by the team are enacted by the professor – otherwise the students will feel like the SMT is simply a waste of time. It is a good idea to provide the team with some initial tasks; examples are choosing a new textbook, reviewing CD-ROM teaching aids, or helping determine when different assignments should be due. A student on the team is assigned each meeting to keep notes of suggestions and concerns, and these meeting minutes should be provided to the rest of the students in the course.

Benefits of having an SMT are numerous: students begin to understand the point of view of the instructor, and the professor can understand the demands on students (particularly important with U.S. Air Force Academy cadets). Real-time feedback can be given regarding different projects, homework assignments, and tests. Things that seem like great ideas to an instructor can prove to be too much work, too daunting, or too open-ended for students to complete. While some suggestions may only benefit future offerings of the course, many will help the learning process during the current semester. Cadets have suggested scheduling changes, additions to the course website, and have reviewed handouts before they were given out to the other students. The SMT students realize that Undergraduate Dynamics is a very challenging course for them, but also begin to recognize that it is also a difficult class to teach.

Focus Group. A focus group is similar to an SMT in the way in which in-depth feedback is provided by the students. Towards the end of the Fall 2002 semester, students were randomly chosen and asked to participate. Care was taken to invite a population of students that was representative of the majors (Engineering Mechanics, Mechanical Engineering, Aeronautical Engineering, and Astronautical Engineering) and gender. No instructor was present during the actual session – a representative from CEE was present to facilitate and record the discussion. Ten open ended questions were provided to the group (nine out of the twenty invited cadets participated).

Questions included: (1) What is the most significant thing you learned in the course, (2) Which project do you feel was the most useful, (3) How well prepared for class were you? (4) Comment on the evaluation methods used in the course. Other questions asked about group work, difficulty and workload, peer grading, understanding of different course topics, and usefulness of the second hour. Cadets then discussed the questions with their peers, and CEE representatives recorded responses and provided a report to the instructors. Cadets are more willing to discuss problems with the course when an instructor is not present, but the drawback is that the CEE representative is not familiar with the course and is not able to really probe into some of the issues that the cadets bring forward.

End of Course Review. At the end of each school year, there is a Course Review for each class offered in our department. Instructors throughout the year attend, as well as representatives from follow-on courses. The course director presents assessment data from the year, and the attendees then discuss what changes might be needed in the course. Sessions typically take about an hour, and often result in changes for the upcoming year. At USAFA, we have a visiting professor program where we invite professors from traditional universities to come teach for one year at our institution. We often get very useful feedback from them during the Course Reviews and throughout the year. Additionally, a professor from the US Naval Academy is currently on an exchange with one of our instructors. He has also provided valuable outside feedback on the course.

Projects

Rocket Launch. Some difficult material in a dynamics class comes very early in the course. Students are often faced with long, daunting homework problems with little real-world applications. In order to give the students some hands-on experience and provide some fun in the course, we introduced a model rocket project. The students built a simple Viking model rockets with an Estes A8-3 engine (2.5 N-sec impulse), without including the descent parachutes. Given initial conditions at rocket burnout, they were required to predict the overall range and maximum altitude of the rocket using simple projectile motion equations.

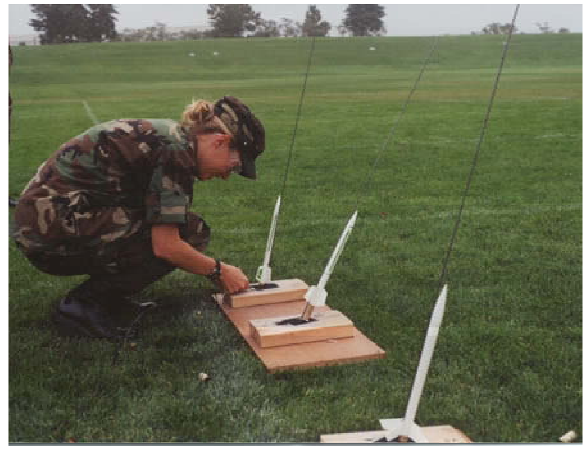

Figure 1. Rocket Launch.

As can be seen in Figure 3, the rocket lab has always been popular with the students. Cadets in the SMT as well as the focus group provided very positive feedback on the entire project. After the first semester using the rockets, a few commented that the rocket lab was quite a lot of work considering the simple topic (projectile motion). After this initial comment, we added two more steps to the overall project. Once we introduced Newton's laws for particles and impulse momentum, the project was expanded. Students were required to do a continuous calculation of the velocity and location of the rocket. Use of a project during the first block of material really helped to provide continuity in the course.

Computational Mechanics. Most homework stresses solving a dynamics problem at an instant in time. This makes it difficult for students to realize that dynamics really involves continuous time varying forces, velocities, and accelerations. To help alleviate this problem, we introduced several computational mechanics projects. As noted above, one of the first involved a continuation of the rocket lab by calculating the x and y coordinates of the rocket as a function of time. Other projects included plotting the kinetic and potential energies of a spring-mass system, and determining the acceleration and velocity of piston on the end of a crankshaft and connecting rod as a function of time and crankshaft angle.

Unfortunately, the computational mechanics (CM) projects have never been very popular with the students. Many simply do not appear to have good Mathematica or Excel skills to complete the projects. Since they struggle with the computer programming, they seldom reap the benefits of seeing how dynamic systems vary with time. A few comments show us the spread in the evaluation of the CM projects: "CM's were vital to understanding the course" and "the CM assignments just confused me". During the Fall 2002 semester, students struggled with the crankshaft problem mentioned above. In response to student comments, we have decided to provide them with a solution to a different homework problem using Excel. This problem is a simple rigid link rotating in space – very similar to the crankshaft. Provided a simple model to use for their own program, we hope that they will be more successful in the Spring semester.

Catapult Lab. One of the most successful of all projects introduced was the catapult laboratory. In this project, the potential energy of the rubber band is transferred into the kinetic energy of the projectile (which in our case was a raw egg). Students were required to use rigid body work-energy relationships and projectile motion equations to predict the range of the egg. They were then asked to calculate the forces on the pin at the bottom of the catapult arm, which required Newtonian kinetics. Finally, the force on the stopper pin was calculated using impulse-momentum equations. Cadets were also provided the opportunity to calculate the stresses on the pins, which were in double shear. Instructors in the course feel that almost all of the topics covered in the course are included in this project, plus launching raw eggs adds some excitement to the class.

Figure 2. Catapult Lab.

In general, assessment of the catapult is very good. Comments from the focus group included "I liked the catapult because it made me see the concept and gave me a visual", and "I liked the catapult but would have liked it more if it was organized like the rocket project." The students like to have intermediate turn-ins, which often prevents them from putting off the entire project until the night before it is due.

Other Projects and Demonstrations. Several other projects have been tried in the course but deleted due to instructor and student feedback. One popular assignment that was dropped due to time constraints involved having students do real-world presentations. Groups of two cadets would choose an example of where dynamics applies in everyday life then perform an analysis of the example. Some notable topics included: 1) examining a skier's dynamics in slalom skiing taking wind drag into account, 2) finding the impulse from expanding gasses on a shell fired from a rifle, 3) looking at the kinematics of a tennis serve, 4) studying the interaction between a gymnast and a high bar while performing "Giants," and 5) evaluating the forces during a football "goal line stand." After much discussion during the Course Review and analysis of instructor surveys, it was decided that the presentations took up too much valuable class time. The projects were discontinued during the Fall 2001 – Spring 2002 academic year. While instructors were given the leeway to re-introduce the projects in the Fall of 2002, none actually did.

A few other projects have also been attempted over the last two and one half years. These included analyzing a Charpy Pendulum Impact test, using a mass-pulley system to analyze inertial effects, predicting the performance of a Lego Mindstorms racecar, and determining the damped natural frequency of a beam. Due to both instructor and student feedback, most of these projects have all been either dropped or are now class demonstrations. The Lego

Mindstorms project was used for the first time during the Fall 2002 semester. As with most first–time attempts, the project was not yet optimized. Students had fun with the project, but were sometimes frustrated with changing instructions and some ambiguous instructions. The project will be modified and used again in the Spring 2003 semester to see if we get a better response.

Course Content. The cadet and instructor surveys include an assessment of how well the students understood various concepts. Two major problem areas were three-dimensional kinematics and vibrations. Too little time was given to each of these difficult concepts to master either of them. An informal email survey of dynamics instructors at other universities revealed that many schools do not cover either of these advanced topics in their introductory course, and none covered both. During the course review, instructors from upper level mechanics courses mentioned that they thought the vibrations material was much more important than the three-dimensional kinematics.

Instructors in both Astronautical and Aeronautical Engineering were also consulted. They too agreed that the vibrations content was more important than the advanced kinematics. As a result, the three-dimensional kinematics was dropped (we still tell the students that the equations can be used for 3D problems), and more time was given to rigid body kinetics and vibrations.

Course Critique Evaluations

Figure 3 shows the responses for the statement "This item added *interest* and motivated my learning." As can be seen, most of the assessment is fairly consistent across semesters. Small changes are expected, but no major differences are noted. Some of the homework problems were changed between Fall 2000 and Spring 2001 to help motivate the students more.

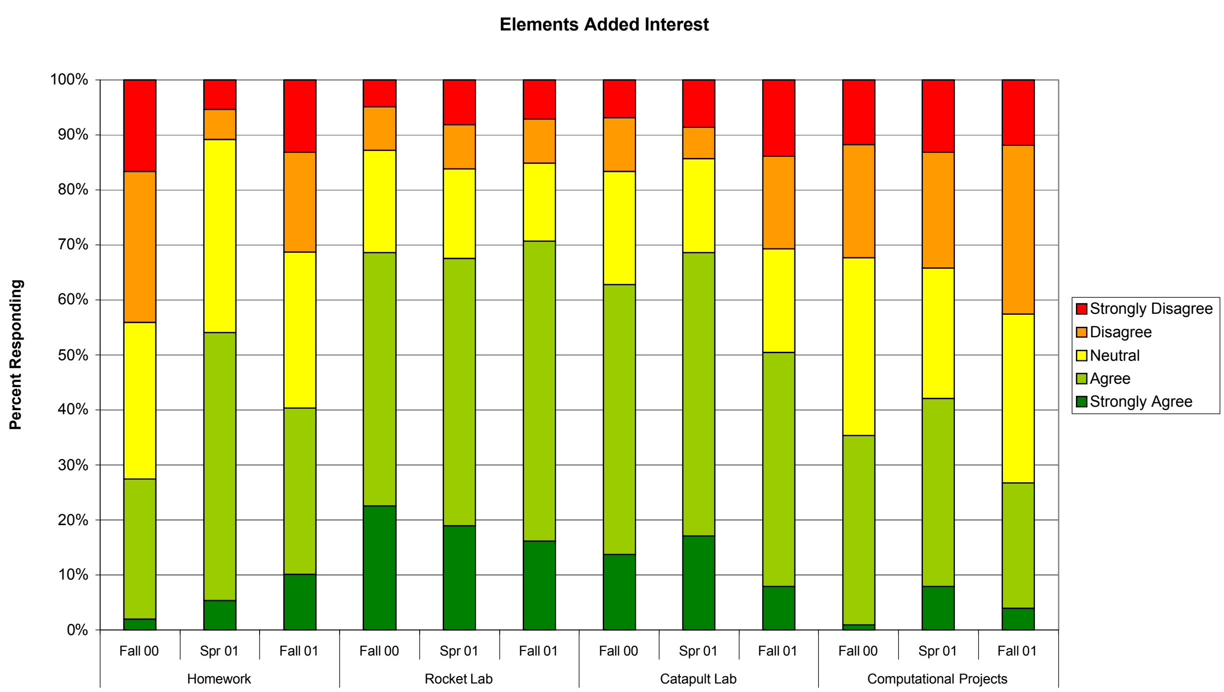

Figure 3. Percentage of student responses on a 5 point Likert scale.

Figure 4 depicts the level of understanding that each of the assignments added to the class. As can be seen from Figure 3, the students are not very motivated to do the homework, but realize that they must practice to do the problems on the tests and exams. While we could simply assign more homework problems to improve performance on these assessments, the authors feel that the real world problems and projects will contribute much more to their long term learning.

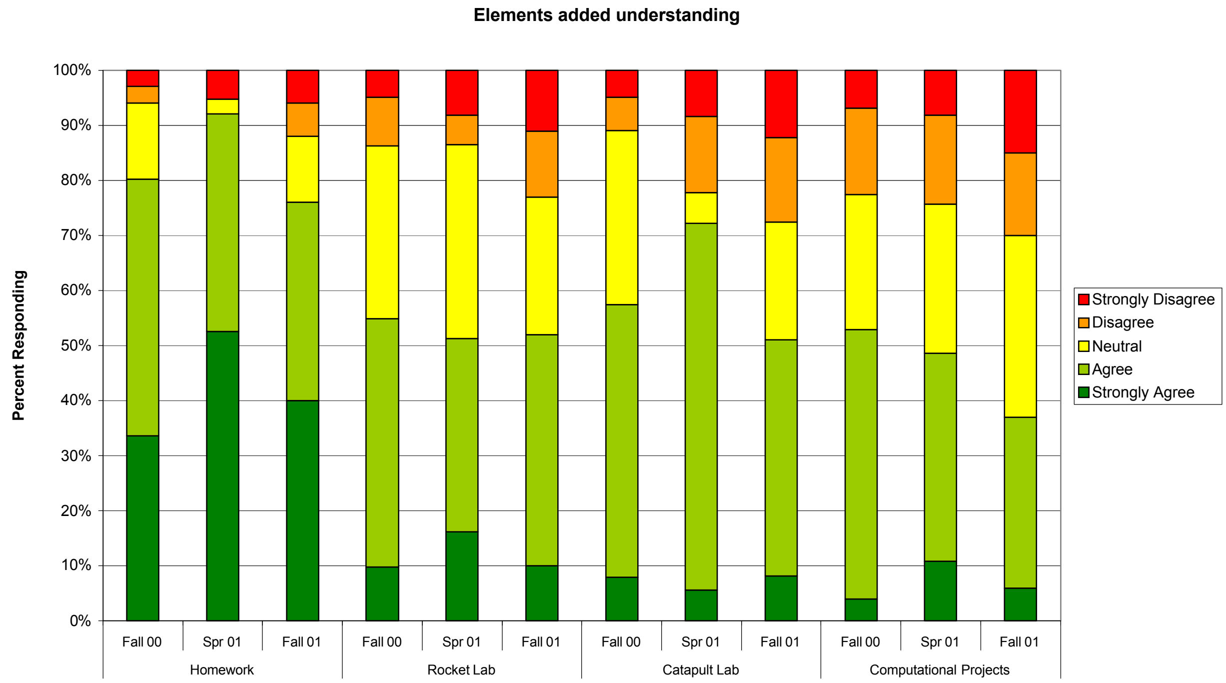

Figure 4. Percentage of student responses on a 5 point Likert scale.

Conclusions

Undergraduate dynamics continues to be one of the most difficult of all engineering courses to take and to teach. At the US Air Force Academy, we continue to try different projects and techniques to improve student motivation and understanding. To ascertain how well these various approaches are working, we have employed a number of assessment techniques. In-depth student feedback is obtained through use of student management teams, focus groups, and open ended survey questions. Some more quantitative data has been received by using modified Likert scale questions on the surveys. Finally, feedback from the instructors teaching the course allows us to analyze the perceived workload and performance of the students.

This type of feedback has allowed us to continuously modify our course. Most of these changes are not dramatic, but incremental. We plan to continue evaluation of computer visualization tools, hand-on projects, and new learning tools to make undergraduate dynamics more interesting to students are easier for them to understand.

References

Self, B and Redfield, R (2001) New approaches in teaching undergraduate dynamics. Proceedings: American Society for Engineering Education Annual Conference and Exposition.