AC 2012-5069: USING AUTOMOTIVE SAFETY IN A SERVICE-LEARNING PROJECT FOR UNDERGRADUATE DYNAMICS

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Abstract

Automotive safety was used as a service-learning, overarching term-long theme in an undergraduate Engineering Dynamics course. The service-learning objective of the project was to prepare a small scale lab related to automotive crash testing and bumper design for a high-school student science summer camp program. The college students in the Dynamics class were tasked with performing analysis to help design and test the apparatus and also write procedures that would be given to the high-school students. In addition to traditional textbook homework problems and quizzes, the Dynamics students were tasked with working in small groups to analyze car crash mechanics as they related to the topics throughout the course. They were given weekly project assignments that involved addressing open-ended questions, conducting research outside of the scope of the course, performing analysis, working in groups, and summarizing the results in a short memo. At the end of the course a physical experimental apparatus was assembled that resembled the student's design. Students assisted in conducting a crash test and recorded acceleration data and high speed video which they used to analyze the results to determine the effectiveness of their own bumper design. Also students prepared a poster for a poster session on the last day of class where they compared their results with all of the other teams and were asked to explain the properties of a good bumper. Assessment of the project included surveys that asked the Dynamics students to compare the amount of time they spent outside of class for the course and the effectiveness of the project in helping them to learn the course material compared with the other course components. The surveys were given at the middle and end of the course to identify trends and compared with results from a control group.

Introduction

Many agree that Engineering Dynamics is among the more challenging courses in undergraduate engineering programs.[1, 2] It is often presented to students in the first or second year of college before they have developed a mature sense of perspective and experience. It requires students to integrate physics, calculus and geometry. It requires students to solve complex problems where the methods and solutions are not immediately apparent and the results can be counterintuitive. It is often taught to diverse student populations and with varying majors. In Mechanical Engineering, Dynamics is near the beginning of a series of mechanics courses, but in Electrical Engineering it stands alone (if it is required at all). Therefore different students have different levels of motivation which affects their attitudes, effort and performance.[3]

A traditional Engineering Dynamics course is often taught in large sections with chalkboard lectures, weekly problem sets from the textbook and quizzes or midterms and a final exam. Most learning occurs in solving textbook homework problem sets. Each problem is designed to illustrate one or more specific concepts. Students learn that they must simply look in the previous pages for the "right equation" apply it correctly and find the "right answer." The proliferation of online solution manuals also corrupts the process allowing students to see the entire solution without the effort of synthesizing the course material[4,5]. Although solving a wide variety of problems gives students more practice and may illustrate more concepts, it does not encourage students to go in depth on any one problem, apply critical thinking or conduct outside research.

Furthermore this pedagogy does little to develop important skills such as teamwork, verbal and written communication which employers indicate are among the most important of all engineering skills.[6,7] Neither does it address larger issues such as critical thinking, encouraging outside research, real world applications, service learning, or ethics.

Alternative methods have been used to address theses issues. Hake[8] reported that physics courses with "interactive engagement methods as those designed at least in part to promote conceptual understanding through interactive engagement of students in heads-on (always) and hands-on (usually) activities …" resulted in significant improvements in learning outcomes.

Many have adopted project based learning in Dynamics in an effort to address some of these issues. Mikesell[9] reports incorporating design projects, Njock-Libii[10] describes a project analyzing the bounce of NBA basketballs, Jolley[2] describes using Lego kits to construct and analyze four bar linkages. The authors report improvements in student attitudes and learning outcomes.

Automotive safety is another topic that is ideal for project based learning in a Dynamics course and has many advantages. For example, most students can relate through their personal experience to issues such as position, velocity and acceleration while driving in a car. The focus on safety appeals to the student's altruistic motivations for studying engineering. Advances in automotive safety such as seat belts, ABS braking, radar systems and dynamic stability control have resulted in millions of saved lives. It is also an area of rapid growth in the industry with new technologies that spark student's imagination, on the horizon such as automatic braking, driver assistance systems, intelligent cars and highways, infrastructure to vehicle communication, autonomous crash avoidance, etc. Also this area of engineering is truly multidisciplinary and requires input from electrical, industrial, civil, mechanical, biomedical and other engineering disciplines.

Because of these strengths, automotive safety was chosen as the subject for a project based learning component in an undergraduate Engineering Dynamics course. The goals of this project were to address the higher level outcomes listed above, while maintaining the core Dynamics course content and without overburdening students with excessive work.

A similar crash testing lab based project was implemented by Ludwigsen[11] in an introductory physics course with evidence of significant improvements in learning outcomes. This program included 10 weekly 2 hour labs over the course of a semester. The goals and technology used in Ludwigsen's study were similar to those used in this work. However in this work the intention was to include the project within the constraints of a normal lecture course that does not include a separate weekly lab period. Instead, students were assigned weekly take home team projects plus a one hour lab experience near the end of the course. To compensate for the project, fewer textbook homework problems were assigned each week as compared to the number normally assigned without a project.

A service learning component was included in the project to further enhance the student's motivation. Cal Poly EPIC (Engineering Possibilities in College) is a one-week summer program for high school students (9th-12th) who live on campus for a week and participate in several 3 hour labs in different engineering disciplines. The Dynamics students were tasked with helping to design the apparatus and procedures that the high school students would use during the summer camp.[12]

Goals

Adding a project based component to a Dynamics lecture course requires time and effort from the instructor and the students. However it is worth the effort because the promise of enriching the course outcomes is great. Below is a summary of the goals of the project based component. It should be noted that these are in addition to all the learning objectives of the traditional Dynamics course.

Service Learning – EPIC Summer Camp – The project included a service learning component to develop equipment and procedures for high school engineering summer camp. The hope was that adding the service learning component would motivate the Dynamics students and give them a sense that their work would be useful to the community.

Save Lives - Improving automotive safety results in fewer injuries and deaths from car crashes. Though students understood that this project would not directly save lives, interest in the subject may motivate students to work in this industry after college.

Cohort Building –Students were assigned to teams of 3 students to complete the weekly projects. Each team turned in one report. Some time was given in class but most students met outside of class as well. The teams were changed several times during the term. The intent was to get students to work together, form study groups, and collaborate with diverse students from different backgrounds and disciplines. This had a significant positive effect on the mood of students in the class. Students were generally more social and excited during class compared to the instructors experience with Dynamics classes without a project.

Technical Writing - Each project assignment required the students to write a short one page description of the method and results of the analysis. The intent was to reinforce the importance of written communication in every aspect of engineering.

Encourage External Research - Each project assignment included some undefined parameters that required the students to assess what information was missing and to make reasonable assumptions based and cited sources. For example students were asked to design a system that would be "safe" to operate by high school students. They had to assess what risks might result from their design and justify how they chose the limits, such as maximum velocity of the crash sled.

Encourage Open-Ended Problem Solving and Critical Thinking - The students were repeatedly told that there is no correct answer to each problem. It was their job to make reasonable assumptions, cite reference when possible and explain their methodology. Provided they did not violate the laws of physics or the assignment guidelines they received full credit. It should be noted that grading project reports is very subjective when there is not one correct answer. The intent was to encourage critical thinking and outside research as much as possible.

Project Components

The overall theme of the project was to design a small scale lab based car crash test system to compare the performance of different bumper designs and materials. Each week student teams were given an assignment of increasing complexity and required to write a report that included calculations, drawings, graphs and a one page description of their methods, assumptions and results. The initial assignments were paper studies and the final assignment was an experimental test and analysis.

Week 1 - Rectilinear Kinematics – Position, Velocity and Acceleration

Students were asked to use Excel to graph the position, velocity and acceleration for a car (Figure 1) in a laboratory crash test where the car starts from rest, is accelerated until it hits a barrier and then comes to rest. This required students to consider the relationship between position, velocity and acceleration, to consider the desired maximum dimensions of the track, and maximum velocities and accelerations and to use Excel to plot the results.

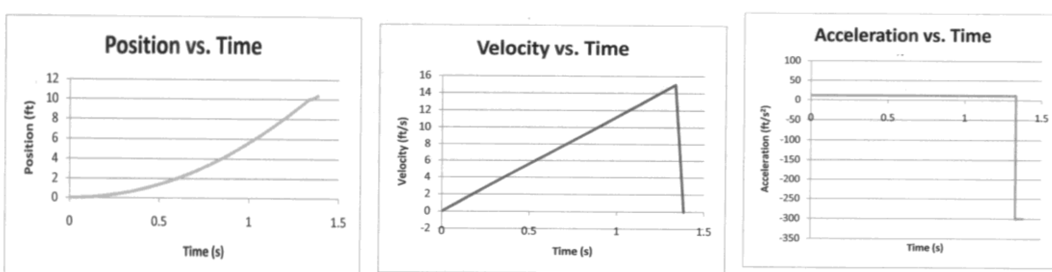

Figure 1. Position, velocity and acceleration of theoretical crash test system

Week 2 - Technical Paper Review - Theoretical model of crash pulse

Students were asked to read a technical paper[14] that presented several different mathematical models that are used to represent typical lab based car crash acceleration pulses. Figure 2 shows a sine wave model superimposed over an experimental crash acceleration pulse. They were asked to choose one of the models and scale the results to dimensions consistent with a small scale crash test system and plot the position, velocity and acceleration versus time.

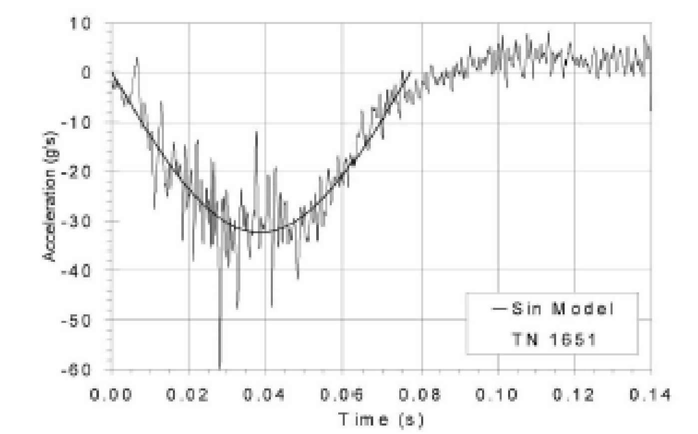

Figure 2. Sine model of a crash pulse compared with experimental data

Week 3 – Kinetic Analysis – Design the crash test system using a counterweight and pulleys
Students were asked to design a mechanism to accelerate the crash test vehicle using a counterweight and pulleys. They were given design constraints such as maximum length (10 feet), maximum height (3 feet), desired speed at impact with the barrier, weight of the car (5 pounds), etc. Students had to determine the ideal counterweight mass and produce a sketch of the system. This required use of the work-energy analysis and kinematic constraint equations for the pulley system.

Week 4 - Dynamic Analysis – Predict the results from theory
Students were asked to predict the results of the crash test system from theory before the experimental testing. The performance of the system is strongly influenced by the design and material of the car bumper; furthermore most bumper systems have nonlinear stress strain responses which would make the computations beyond the scope of the course. Therefore to simplify the analysis students were asked to make a simplifying assumption that the bumper behaves like a linear spring when in contact with the crash barrier. This allowed them to make closed formed calculations of various parameters such as the maximum speed of the car before impact, the maximum acceleration during the crash, maximum deformation of the bumper, the impulse, forces on the bumper, etc.

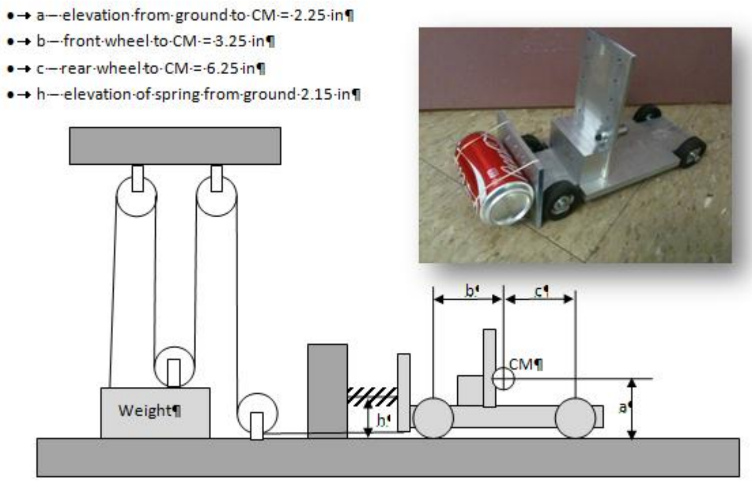

Figure 3. Crash test apparatus for theoretical analysis

Week 5 - Bumper Design and Testing

Students were asked to design a bumper made only of cardboard and tape, subject to maximum overall design dimension limits. They were asked to prepare 3 identical copies of the bumper in case the crash test was not successful on the first or second trial.

All of the bumper designs were tested during a one hour period in place of a lecture. Each team took approximately 5 minutes fastening their bumper to the front of the vehicle, setting up the test and monitoring the results. The instructor operated the accelerometer and video data collection hardware and provided students with a video file on their flash drive and a plot of acceleration versus time over the short duration of the impact. A toy doll was used in the place of a crash test dummy to visualize the motion of the passenger during the crash.

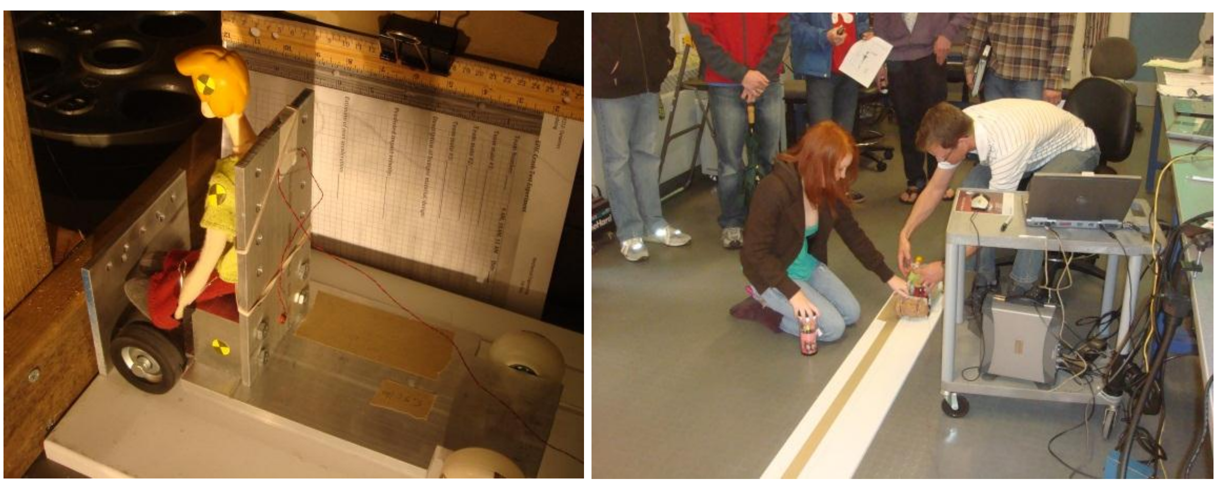

Figure 4. Photo of crash test vehicle and dummy on track at impact barrier (left) and student setting up experiment (right)

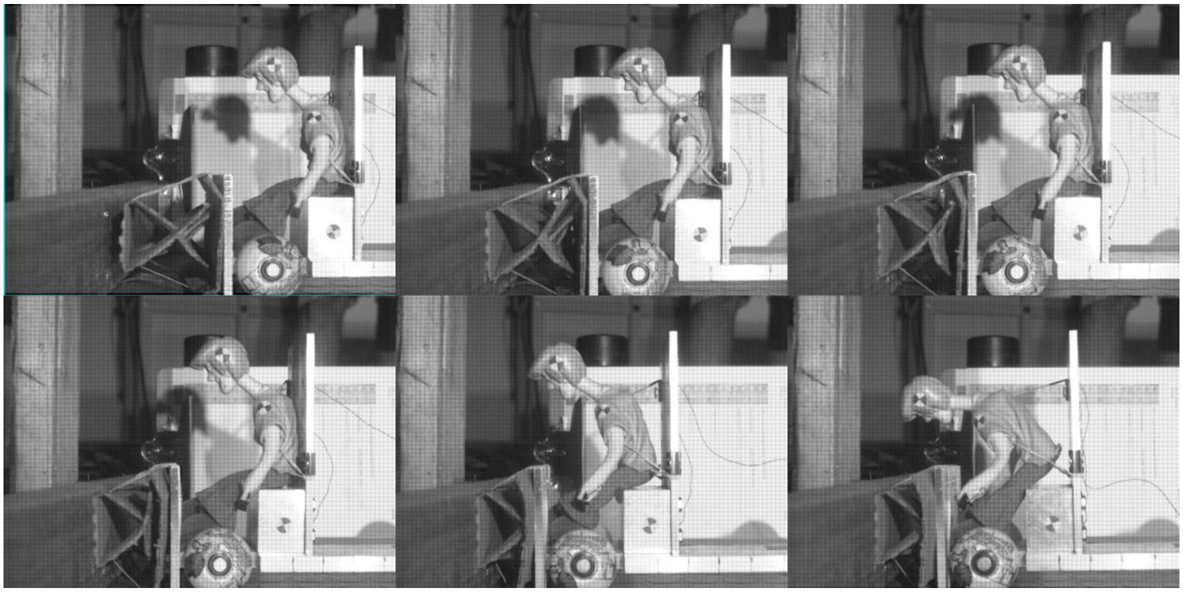

Figure 5. Time elapse images of barrier impact from high speed video showing bumper crush and dummy motion

Week 6- Test Results Analysis Report

Students were asked to analyze the test results and compute several measures of the severity of the crash test to determine the effectiveness of their bumper design. From the acceleration versus time plot they were asked to determine the peak acceleration, the impulse and the maximum force. From the high speed video they were asked to determine the impact speed, maximum bumper deflection and final speed. They were also asked to determine the maximum angular velocity of the test dummy's head during the impact. In addition, they were asked to write procedures for high school students to conduct a similar test and to make recommendations to the instructor regarding what aspects of the project would be most interesting to high school students during the EPIC Summer Camp program. All the method and results were included in a written final report.

Week 10 –Poster Session

During the last day of the term, students were asked to bring in a poster to present their results to the class in a poster session. The poster was required to include graphs of acceleration versus time, a table of the numerical results, a photograph of the bumper and a written assessment of the bumper performance as shown in Figure 6. During the poster session students were asked to take turns answering questions from classmates while their teammates viewed the other posters. Each team was given a worksheet that asked them to compare their results with what they deemed to be the best performing bumper. Finally at the end of the hour the instructor asked the class to answer the question, "What are the properties of a good bumper?" Most students came to the correct conclusion that the ideal bumper will spread the impulse over the longest time period thus reducing the maximum acceleration of the vehicle and passenger during the impact.

Epic Summer Camp

During summer 2011 the crash test apparatus was used as a 3 hour lab experience in the Cal Poly EPIC Summer Camp program for three different groups. The Dynamics students suggested that the experimental testing was the most interesting part and most appropriate for the EPIC campers. High school students had 3 hours to design a bumper on paper, then form groups and choose aspects of the different designs to include in a prototype (Figure 7). They manufactured a prototype from cardboard and tape and then tested their prototype in the crash test apparatus. They were then given a chance to improve their design and test it a second time. The lab was very popular and received positive feedback from the campers when compared with all the other lab experiences during their week long camp.

Figure 6. Dynamics student poster session

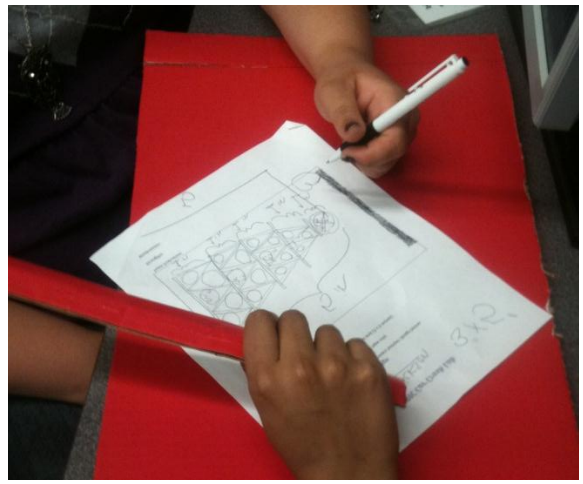

Figure 7. EPIC summer camp high school student conceptual design

Assessment

This study was assessed through surveys given to the 95 Dynamics students at various times during the 10 week quarter. These results were compared with a control group of 59 students from another instructor that used traditional teaching methods and no project. One concern was whether the project significantly increased the amount of time students felt they had to dedicate to this course. In the control group 47% of the students reported spending 6 or more hours a week outside of class preparing for the course compared with 69% of students from the test group. The difference can be partially attributed to varying instructional methods between the different instructors, though it is likely that the additional demands of the project increased the time.

Table 1. Comparison of hours outside of class to prepare for Dynamics – reported by students

	2-4	4-6	6-8	More than 8
Control Group (n=59)	10%	39%	27%	20%
Test Group (n=95)	7%	24%	36%	33%

Another set of survey questions asked students to rate the relative importance of different components in the course toward helping them to learn the subject matter. This set of questions was intended to compare how the students rated the relative importance of the new project as compared to more traditional components such as completing homework, attending lecture, etc.

The results from the control group (with no project) at the end of the term indicated that students believe homework is the most helpful component followed by attending lecture and lastly, reading the text. Results from the test group (with the crash test project) at week 5 in the term show similar results for homework, lecture and reading the text. In addition students rated completing the projects lower though still somewhat positive. It should be noted that these results were midway through the term before the experimental portion of the project was conducted.

Survey results from the test group at the end of the term indicate more positive results. This was attributed to the fact that the experimental portion of the project which tied all the theoretical analysis together was conducted in the last few weeks of the course. It also suggests that students appreciated the experimental more than the theoretical analysis. Also the results show that although students reported spending more time on the course than the control group they indicated that the project was a reasonable amount of work. This suggests that the they found the project interesting and worth their time.

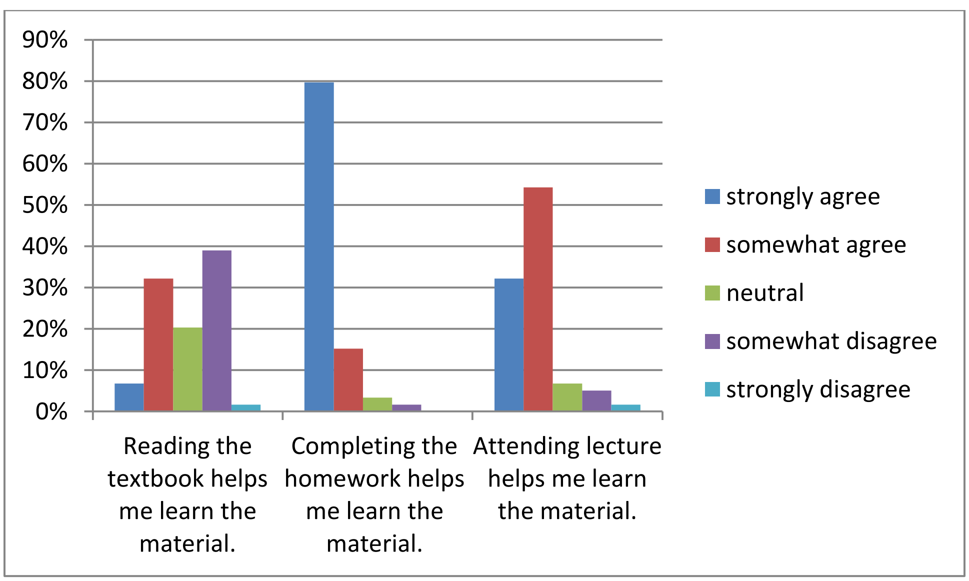

Figure 8. Student assessment of relative importance of course components for control group (no project)

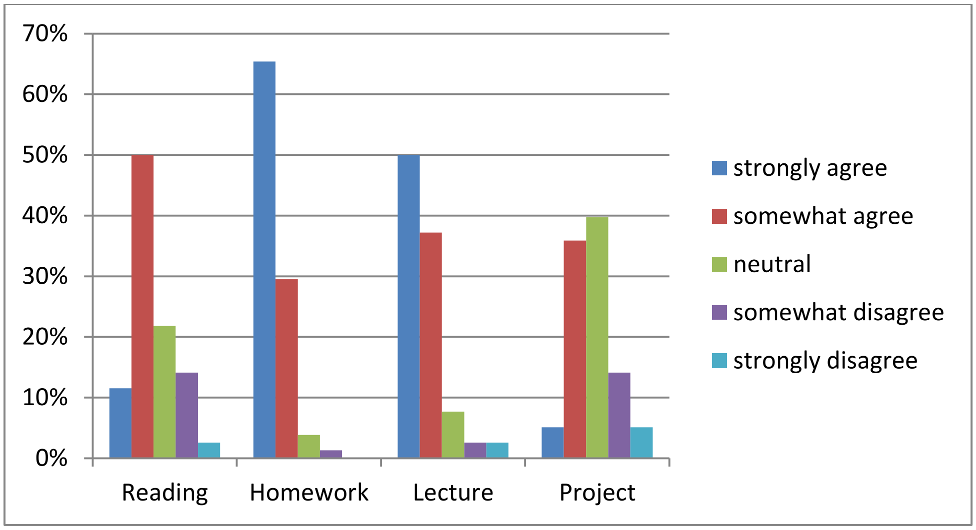

Figure 9. Student assessment of relative importance of course components for test group at the end of the course (including project)

Table 2. Results from End of Term Survey for Test Group

	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
The project helped me learn Dynamics	3	55	22	16	4
The project was interesting	14	61	15	8	2
The project was challenging	8	60	24	6	1
The project was a reasonable amount of work	5	62	17	12	4

Conclusions

Generally the addition of the automotive safety project in the Dynamics course was a success. Students provided positive feedback through surveys. Students seemed to form collegial groups and worked collaboratively. The written descriptions of their work and results that they turned in with each weekly assignment indicated that they successfully used outside resources and critical thinking to complete the project components. The project likely increased the amount of time students felt they had to dedicate to the course, though the positive survey results suggest that they that they spent additional time because they were engaged and interested in the project and the results.

Recommendations

Future work will repeat the project with some changes. More assessment will be employed to investigate the effect of the projects on collaboration and motivating student's interest in engineering compared to a control group. Some effort should be made to determine if the students spent more time preparing for the course because of the project or because of other course components as compared to the control group. Also assessment of improved understanding such as concept inventory at the start and end of the course may be useful to compare the effectiveness of the project compared to traditional teaching methods.

Instructors interested in implementing a similar project can do so without significant equipment costs using hardware that is available to most Mechanical Engineering departments. The crash test cart was manufactured in a student shop for approximately $100, or a similar device is available from Pasco Inc. The track and pulley system was constructed from lumber and hardware available at most hardware stores. An accelerometer and oscilloscope can be used to capture the acceleration pulse. The high speed video can be captured with relatively low cost digital camcorders that have a high speed capture option.

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