Assessing the Effectiveness of a Racecar-Based Laboratory Course

Jed Lyons, Edward F. Young and Susan D. Creighton
University of South Carolina

Abstract

A new capstone mechanical engineering laboratory course was recently institutionalized at the University of South Carolina. The course is based upon an integrated sequence of laboratory experiments on a Legends-class racecar, chosen because it involves many fundamental mechanical engineering principles. It's also exciting to the students. As the students progress through the series of experiments, they are increasingly involved in experimental design. In this way, the course develops the student's abilities to analyze complex mechanical and thermal systems, to design experiments, and to practice life-long learning. The course development was supported by the National Science Foundation's CCLI and ILI programs and the University of South Carolina. Previous presentations described the test vehicle and instrumentation. This paper focuses on project evaluation and assessment results that are being used to improve the course's effectiveness.

Introduction

The mechanical engineering program at the University of South Carolina includes a capstone senior laboratory course, *Mechanical Systems Laboratory*. Prior to 1997, the primary goal of this course was to illustrate upper-level mechanical engineering topics. Since 1997, however, the department has been improving the course to help meet the following program objectives. The graduates shall:

1. Have the ability to analyze, design and realize mechanical and thermal systems.
2. Have the ability to use contemporary computation techniques and tools.
3. Have competence in design of experiments, experimental practices and data interpretation.
4. Have the ability to apply statistical methods to analyze and interpret data.
5. Have the ability to plan, schedule and execute engineering projects.
6. Have effective oral and written communication skills.
7. Have the ability to function on multi-disciplinary teams.
8. Have an understanding of and the ability to engage in life-long learning.
9. Have an appreciation for the role of engineering in modern society.

The strategies followed for developing outcomes 1-7 primarily involve a sequence of laboratory experiments that are conducted with one complex thermal-mechanical system of study. As the students progress through the series of experiments, they are increasingly involved in experimental design (selecting sensors, sensor locations and experimental operating conditions). In this way, the students develop a systems approach to engineering problems, the ability to design and conduct experiments, and further develop their professional skills.

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The System of Study

The students in the *Mechanical Systems Laboratory* course perform a sequence of experiments on one complex system, investigating it in detail. The selected system provides opportunities for the students to apply the spectrum of their mechanical engineering knowledge, including the principles of mechanics, dynamics, thermodynamics, and heat transfer. A Legend's class racecar (Figure 1) is the ideal system for this laboratory, for many reasons. Perhaps most important is that the students get excited about applying their engineering knowledge and experimenting it. Such enthusiasm can be a tremendous asset to a required laboratory course.

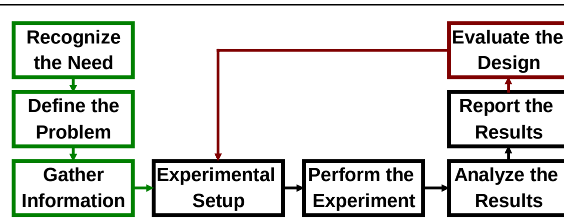
The racecar is instrumented with approximately $60,000 in sensors, signal conditioning units, an on-board computer, and a remote wireless telemetry system. The telemetry system allows the entire lab section to control and monitor the experiments while the car is driven. Additional details on the instrumentation have been previously described (Lyons 1999). It should be noted that the instrumentation is of general purpose so the experiments can be modified from semester-to-semester to keep them from getting "stale."

Figure 1. A Legends racecar is used in the *Mechanical Systems Laboratory*. It is compact, incorporates many fundamental principles of mechanical engineering, is relatively inexpensive, and is in the realm of student experience.

The Laboratory Design

A major role of the laboratory is to teach students how to design experiments. The focus is on the physical design of experiments (Figure 2). The physical design of experiments deals with identifying a problem and solving it. It includes the determination test variables and data requirements, the selection of sensors and the design of the instrumentation system. Details on the approach to developing this ability have been previously published (Lyons 2000). Essentially, a scaffolding approach is followed where the amount of student input into the design of the experiment is increased with each experiment during the semester. In the first labs, the students perform experiments under well-established conditions. Subsequently, they are involved in the redesign of certain aspects of these experiments. Then, they become involved in determining sensor locations, data acquisition parameters (e.g. sampling rate), and physical conditions of the experiment. The final weeks of the semester are for the students to perform an "open-ended" experience where they select sensors and define the compete experimental design.

Figure 2. A process model for the physical design of experiments.



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Evaluation and Assessment

Evaluation of the effectiveness of the racecar laboratory has been completed primarily though two types of student surveys. The first type is the typical end-of-the-semester student satisfaction survey that is administered in all mechanical engineering courses at USC. The second type is a Pre-to-Post Survey, where the students are given the same set of questions at the beginning and end of the semester. An additional component of the assessment plan to be implemented in the next semester involves a peer-review of the course and course materials by a number of educations on a National Visiting Committee.

Of the two surveys, the Pre-to-Post Survey has provided the greatest insight into perceived student achievement in the course. Survey responses were divided into three categories: "limited," "moderate," and "proficient" levels of skill opportunity and attainment. It was anticipated that the opportunities provided in the laboratory course would greatly enhance student capabilities. This improvement would be noted by a marked increase in the proportion of student exhibiting a proficient rating for each competency. The results of this survey from one semester are shown in Table 1, and are discussed below.

Table 1. Pre-to-Post Survey Questions and Results from Spring 2000.

	Limited		Moderate		Proficient	
	Pre	Post	Pre	Post	Pre	Post
1. I can analyze mechanical systems.	10%	4%	55%	26%	35%	70%
2. I can analyze thermal systems.	10%	9%	65%	30%	25%	61%
3. I can use contemporary computation techniques and tools.	16%	4%	47%	30%	37%	65%
4. I can apply computer-based instrumentation to engineering systems.	35%	4%	35%	48%	30%	48%
5. I can design experiments.	40%	26%	40%	30%	20%	44%
6. I can perform experiments.	15%	4%	25%	22%	60%	74%
7. I can apply statistical methods to analyze and interpret data.	20%	4%	40%	44%	40%	52%
8. I have effective oral communication skills.	10%	4%	25%	22%	65%	74%
9. I have effective written communication skills.	10%	0%	25%	30%	60%	70%
10. I can plan and schedule engineering projects.	20%	0%	30%	26%	50%	74%
11. I can execute engineering projects.	15%	0%	30%	17%	55%	82%
12. I can function on a team.	0%	0%	20%	4%	80%	96%
13. I can function on a multi-disciplinary team.	10%	9%	10%	13%	80%	79%
14. I understand what is life-long learning.	10%	0%	10%	4%	80%	96%
15. I can practice life-long learning.	10%	0%	10%	0%	80%	100%
16. I appreciate the role of engineering in modern society.	5%	0%	15%	4%	80%	96%

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I can analyze mechanical systems. On the pretest, 90 percent of the students stated that they can analyze mechanical systems to a "moderate" or "great' extent. By the end of the course, 96 percent of the EMCH 467 students believe this to be true indicating an overall increase in their practice opportunity and competency level. Most importantly, however, the percentage of students who rate their skill at the highest level increased from 35 to 70 percent.

I can analyze thermal systems. At the beginning of the course, a majority of the students, 65 percent, indicated a moderate level of experience in analyzing thermal systems. The posttest data shows that half of the students in the category believe they can analyze thermal systems to a great or very great extent indicating a shift in the competency level of a substantial proportion of the students.

I can use contemporary computation techniques and tools. Overall ratings shifted from lower to higher levels of competency. Students choosing the higher levels of proficiency rose from 37 to 65 percent pre-to-post testing.

I can apply computer-based instrumentation to engineering systems. Proficiency levels increased moderately for this skill from pre-to-post surveys. Student ratings for the "moderate" and "proficient" categories increased 13 percent and 18 percent, respectively, giving each level a total of 48 percent.

I can design experiments. The proficient category increased 24 percent from pre-to-post testing raising the total to 44 percent. This is the lowest rating of any of the 16 skills on the survey.

I can perform experiments. Seventy-four percent of the students feel proficient in this area. Student ratings increased 14 percent from pre to post. An additional 22 percent believe they have a moderate level of expertise.

I can apply statistical methods to analyze and interpret data. On the posttest, slightly over half of the students selected a proficient category for this skill. This reflected a 12 percent increase. Also notable was the 16 percent decrease in the proportion of students selecting the lowest proficient category.

I have effective oral communication skills. Prior to this course, 65 percent of the students believe they were proficient in this area. This percentage rose to 74 percent on the posttest representing a small increase of nine percent.

I have effective written communication skills. The pre-to-post increase in the proficient category was only a modest 10 percent. At the end of the course, 70 percent of the students expressed agreement "to a great or very great extent" regarding effective written communication skills.

I can plan and schedule engineering projects. A significant proportion of students indicated a change in their proficiency level for managing projects. The proficient category increased from 50 to 74 percent.

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I can execute engineering projects. Significant pre-to-post changes were observed. The proficient category increased 27 percent with concomitant decreases of 13 and 15 percent for the moderate and limited categories.

I can function on a team. A significant 16 percent increase for the proficient category was noted for this skill. By the end of the course 96 percent of the students believe they have a lot of experience in working on a team.

I can function on a multi-disciplinary team. Although 79 percent of the students believe they are experienced in working on a multi- disciplinary team, this represents a negligible decrease from 80 percent on the pretest.

I understand the meaning of life-long learning. On the posttest, 96 percent of the students indicated they are experienced in this area. This represents a 16 percent increase from the pretest.

I can practice life-long learning. All of the students state that they can perform this skill. There was an increase of 20 percent from pre to post surveys.

I appreciate the role of engineering in modern society. Students also feel proficient in their appreciation of the role of the engineer. Ninety-six percent of the students rated it as proficient marking a 20 percent increase from the pretest.

Discussion of Survey Results

Overall results indicate that a majority of students express a high degree of confidence regarding their knowledge of various mechanical concepts and skills at the end of the course. More importantly, a majority of students indicated that their skill levels increased substantially form the beginning to end of the semester. The percentage of students selecting the top two categories, " a great extent" or "a very great extent" ranged from 44 to 100 percent of the 16 topics on the survey. Only two competencies, applying computer-based instrumentation and designing experiments, achieved less than a 50 percent level of agreement. Highest rated skills in the proficient category included: practicing life-long learning (100%), appreciating the role of engineering in society (96%), understanding life-long learning (96%), functioning on a team (96%), and executing an engineering project (82%).

Only a few students gave any of the skills the lowest level of proficiency at the end of the semester. There was one exception. Approximately 26 percent of the students believe they have only a limited ability to design experiments. This is significantly improved from the 40% of them that reported limited ability to design experiments at the *start* of the semester, but indicates that additional instruction in design of experiments is appropriate.

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Concluding Remarks

Assessment of the *Engineering Systems Laboratory* indicates that the course plays a positive role in developing many of the mechanical engineering program outcomes. Major areas identified for improvement include thermal systems analysis and design of experiments. As a result, a thermodynamics laboratory experiment is being implemented in the Spring 2001 semester. A fuel flow meter for measure fuel input (energy in) and a torque and rpm counter on the shaft for measure power output from the engine will be used to estimate the efficiency of the engine. Students will be involved in the design of the operating conditions of and data acquisition parameters for this experiment. Comparison of the pre-to-post survey results after Spring 2001 to the current results will be an indicator of the experiments success at meeting the desired outcomes. In this way, the educational experience of our future mechanical engineers is improved.

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JED LYONS is an Associate Professor of Mechanical Engineering at USC. He teaches engineering materials, manufacturing processes and mechanical design, conducts research on reinforced plastics and composites, and develops mechanical engineering laboratories.

EDWARD YOUNG is a Visiting Professor of Mechanical Engineering at USC. He teaches courses in the thermal-fluid area and is responsible for the senior mechanical engineering laboratory course. He has over thirty years of engineering experience including management of research and development organizations.

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