There is considerable concern that current engineering education practices do not adequately prepare students for the practice of engineering. This statement goes far beyond the often stated requirements that to be successful in their careers engineering graduates must have good communication skills, must be able to work in multidisciplinary teams, etc. There is a fundamental disconnect between how engineering professionals operate and how engineering students are taught. This paper describes a technical elective course, Introduction to Automotive Powertrains, which is designed to bridge the gap between ‘engineering student’ and ‘engineering professional.’ Furthermore, it is shown that the professionally-oriented approach that was used to develop this course is an excellent approach for addressing many of the program outcomes specified by ABET Criterion 3.

Introduction

Starting in the early 1960s, engineering education shifted away from engineering practice and more towards engineering science. Before this, engineering programs typically were five year programs with a focus on applications and applied design. Declining enrollments forced universities to reduce program length. In order to accomplish this, many programs reduced application oriented courses and laboratories. This shift has resulted in an increasing gap between what engineers are expected to know and how they are to perform in industry, and what universities are teaching. Engineers in industry spend much time working on complex system integration, yet few engineering graduates understand this process. Reference 2 adds “the state of education in this country, especially in science, engineering and technology, has become a matter of increasing concern to many of us in American industry.”

In order to meet the professional needs of industry, engineering educators must place a renewed emphasis on teaching the practice of engineering. In order to teach the practice of engineering, students must be challenged to study the complex interactions of real engineering systems. Further, students must be exposed to professional standards and organizations, governmental regulations, team dynamics, current and future trends and societal concerns. In short, students must be afforded the opportunity to practice engineering, learning how to apply the underlying scientific principles to the design of these systems.
The challenge for engineering educators is to be able to accomplish this task in a four year curriculum without radically reducing the scientific content. Engineering educators often feel hard-pressed to cover required course material in the existing curriculum. Fortunately, teaching the practice of engineering can be incorporated into the existing engineering curriculum. It does not have to be spread evenly over all courses, but can be concentrated more heavily in some courses.

Concepts designed to teach students about the practice of engineering can be introduced into various courses. In core courses, because of the need to cover many fundamental engineering topics, often there is not sufficient time for extensive, hands-on work. The introduction of engineering practice into these courses would be very limited. For example, students can be given assignments which require them to study professional standards.

Laboratory experiments are often combined into specific laboratory courses where students tend to be given detailed, step-by-step instructions on how to use the laboratory equipment and calculate the results. This approach is not the best way to learn the material, since (a) the lecture and the lab are not presented at similar times and (b) it does not accurately reflect the reality of professional engineering practice. Further, the laboratory experiments used in these courses often are intended simply to illustrate fundamental physical principles. While this can provide insight into the science of engineering, it does not expose students to the complex interactions present in nearly all engineering systems. Laboratory courses can be restructured around the use of professional standards when appropriate to study complex engineering systems. Also, when practical, elements of these courses can be introduced back into the core courses where they fit best.

In technical electives, the need to cover a vast range of new fundamental material is smaller and more time is available for other activities. For example, technical electives can be introduced which are focused on specific professional areas in engineering. The course described here, Introduction to Automotive Powertrains is dedicated to the study and design of the powertrain systems and their interactions with the rest of the vehicle system. This course has been designed to prepare students to work as professionals in the automotive industry. Specifically, it introduces students to the use of professional standards, standard terminology, current and future trends, and restrictions imposed by society through the use of governmental regulations.

The new ABET requirements support a renewed emphasis on teaching the practice of engineering. In part, this reform was undertaken in order to help academia to become more responsive to the needs of industry. By working to emphasize engineering practice, engineering programs are actually working to meet ABET requirements. However, meeting ABET requirements is now not the goal in and of itself, but simply a measure of how well engineering programs are meeting the needs of industry-and their students.
This remainder of this paper describes a technical elective course, *Introduction to Automotive Powertrains*, which is designed to bridge the gap between ‘engineering student’ and ‘engineering professional.’

**Course Description**

The course described here, *Introduction to Automotive Powertrains*, is an elective course in mechanical engineering. Although, the course is not intended to be a capstone course, it shares a key characteristic in that students are asked to synthesize the fundamental knowledge gained in previous courses and to apply this to the design of an engineering system.

The four-credit hour course meets in two two-hour blocks over a 10 week term. The first block is generally a traditional lecture covering the relevant physics behind longitudinal vehicle performance. Topics include vehicle aerodynamics, tire-mechanics, combustion engine basics, transmission basics, and system integration issues; specifically how the engine/transmission/chassis interact to determine a vehicle’s acceleration, gradeability, and fuel economy performance.

Other topics covered in the lecture include a discussion of relevant professional standards, such as Society of Automotive Engineers (SAE) standards (e.g. J1263 on how to properly conduct a coast down test to determine the road loads on a vehicle), and government standards (e.g. Environmental Protection Agency (EPA) standards on how to determine a vehicle’s fuel economy and on Corporate Average Fuel Economy (CAFE) regulations).

Many of the concepts introduced in the lectures have been introduced to the students in previous course work. The basic equation for vehicle motion is \( F = ma \), which is well known to the students from their courses in mechanics. Another important principle is aerodynamic drag, which was introduced to the student in their fluid mechanics course. The main focus of the course is for the students *apply* their previous knowledge (along with additional topic-specific knowledge) to determine behavior of the vehicle *as a system*.

One of the best ways to understand behavior of the vehicle system is to develop mathematical models to predict the linear performance (acceleration, gradeability, and fuel economy) of a vehicle. The models that students develop in this course are relatively crude, but they are surprisingly accurate and give the students great insight as to how professional-level vehicle modeling software works. By the end of the course students are using one such program (ADVISOR\(^4\)) to conduct parameter studies on vehicle performance.

The second two-hour block during the week is generally devoted to experimental work. The experiments are designed to familiarize the students with tools that are used in industrial practice and to reinforce the concepts introduced during the lecture. During the two-hour block a portion of the time is spent going over the relevant theory for the
experiment to be performed and a brief introduction to the equipment to be used is given. A list of the hands-on labs is given in Table 1.

Table 1. List of hands-on labs used in the *Introduction to Automotive Powertrains* course.

<table>
<thead>
<tr>
<th>Lab</th>
<th>Objective</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicle Coastdown</td>
<td>To determine the road loads acting on a vehicle</td>
</tr>
<tr>
<td>Wind Tunnel</td>
<td>Do determine the aerodynamic drag force on a vehicle using a scale model</td>
</tr>
<tr>
<td>Inertial Dynamometer</td>
<td>Measuring vehicle accelerations using an accelerometer</td>
</tr>
<tr>
<td>Fifth-Wheel</td>
<td>Determining vehicle acceleration from position data</td>
</tr>
<tr>
<td>ODBII Scanner</td>
<td></td>
</tr>
<tr>
<td>Chassis Dynamometer</td>
<td>Underdevelopment</td>
</tr>
<tr>
<td>ADVISOR</td>
<td>Parametric analysis using commercial vehicle performance modeling software</td>
</tr>
<tr>
<td>Transmission Teardowns</td>
<td>Students teardown and reassemble: manual transmission, automatic transmission, and four-wheel drive transfer case.</td>
</tr>
</tbody>
</table>

For lab work the students in the class are placed into groups of 4-5 to conduct the lab and to write a short engineering report on their work. While the teams are not multi-disciplinary (generally all the students are mechanical engineers), the members of each team have a diverse background. Some of the students are ‘gear heads’ and others are pure academics who don’t know which end of a wrench to hold. Some are very conscientious and others cannot be relied upon. Successful groups find ways to work around their differences. Bad ‘group dynamics’ is one of the two main causes of frustration in the course for both the students and the professors.

In order to help students transition to practitioners, most of the data collection is done independently outside the schedule class period. In order to facilitate this, each week one of the lab groups is assigned to be the ‘host group’ for the lab. They have the responsibility of learning to use the equipment, running the lab prior to the other students (to be sure that the equipment is working) and to be available to assist the other students when they conduct their labs. They are also responsible for scheduling the other groups.

It should be noted that students are not given detailed instructions on how to conduct the experiment. Instead, they are given the equipment and the objective and are responsible for learning how to use the equipment to meet the objective. Students quickly learn about the difficulties in acquiring usable data in a ‘real’ environment. They also learn that taking the data may be the easy part, as analyzing ‘real’ data can be very difficult due to noisy signals and other problems.

For example consider a typical set of results for a coastdown test, as shown in Figure 1. A coast down test is conceptually very simple experiment, but in reality it presents a
number of difficulties. The data comes from four consecutive coastdown runs on a given vehicle. Note the variation in the results. This leads to a discussion of the statistical methods that must be used to evaluate the data. Figure 2 shows the consequences of attempting to calculate the acceleration of the vehicle from the data by simply using \( a = \Delta V / \Delta t \). This leads to a discussion on the necessity to filter or fit the data, prior to manipulating the data.

Final grades in the course are determined primarily based on the student’s project work (computer models) and laboratory assignments. Students are told at the beginning of the course that a large portion of their grade would depend on their ability to adequately communicate their work in the form of short engineering reports. This is the other main source of frustration in the course for both the students and the professors. Although the students have taken courses in Language and Technical Communication, they are typically not prepared to write short engineering reports. The main cause for this problem is that the student’s Language and Technical Communication professors are not familiar with how engineers are expected to write. This is a rather dramatic symptom of the gap between engineering education and engineering practice.

Much effort is expended by professors of this course to correct this problem. Typically, a full lecture is devoted to how to write engineering reports. Basic instruction is given on what to include in the report and on formatting issues. Students are often unaware that there are only two types of objects in an engineering report; a Table or a Figure. Similarly, they are often unaware that symbols and lines on a plot have certain specific meanings.

**Accreditation Issues**

One of the goals of the ABET 2000 reform was to make academia more responsive to the needs of industry. To that end, thirteen program outcomes (a-k) were established as specified in ABET Criterion 3. These outcomes detail the expected characteristics of successful engineering graduates. The *Introduction to Automotive Powertrain* course, which was not designed to meet ABET outcomes, but designed to be a professionally...
oriented course for automotive engineers, turns out to naturally meet many of the ABET program outcomes. In particular, the course addresses some outcomes that are considered to be hard to meet, such as outcomes (f) and (h).

A summary of some of the key ABET program outcomes met by the course are:

Outcome (b): an ability to design and conduct experiments, as well as to analyze and interpret data. This is accomplished through the various automotive laboratories integrated into the course, as described previously.

Outcome (d): an ability to function on multi-disciplinary teams. This was described previously.

Outcome (f): an understanding of professional and ethical responsibility. This is addressed by introducing the students to professional standards and regulations, including SAE standards and EPA regulations, discussed previously. These standards provide automotive engineers with recommended practices and regulations for building and testing automobiles. Although students are not required to read the standards and regulations in their entirety (they are generally very long and boring), they learn that they exist, the key requirements of the standards, where to find them, and why they were developed.

Outcome (g): an ability to communicate effectively. This was described previously.

Outcome (h): the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context. Many of the issues which drive the design of automobiles are driven by global, economic, environmental, and societal issues. For example national security and economic pressures lead to the development of the CAFE fuel economy standards and societal pressures lead to the development of Clean Air standards, both of which are discussed in context in the course.

Outcome (i): a recognition of the need for, and an ability to engage in life-long learning. This is addressed by example. The field of automotive engineering is constantly changing (see next paragraph). The professors make clear that they are continually required to learn about new technologies, so that they can stay abreast of the current state of the art in automotive engineering.

Outcome (j): a knowledge of contemporary issues. The field of automotive engineering is constantly changing. New engine technologies (such as gasoline direct injection) and powertrain topologies (such as hybrid electric vehicles) are being developed and introduced in production vehicles. An important part of this course (and a part that the students find most interesting) is the discussion of future automotive technologies.

Outcome (k): an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.
Assessment

Students typically come to Kettering because of the university’s automotive heritage and their desire to become automotive engineers. This course is one of the first, purely automotive courses that they are allowed to take, so the students motivation level is very high. Students often complain that the course work load is way too high, yet the course is overloaded whenever it is offered. Student feedback on the course is overwhelmingly positive. Overall student evaluation scores for the course, hover in the 4.75/5.00 range, which is exceptionally high. The real reward (for the professors) is the number of students that return to the campus to thank them for the course, because they have found that this course is particularly useful in their careers. As a side benefit, the professors have been able to develop a successful continuing-education class for industry, based on the course.

Conclusion

This course was specifically developed to prepare automotive engineering students for careers in automotive engineering. It is a practice-oriented course, as opposed to a science-oriented course. The feedback from this course suggests that the engineering education community should consider re-introducing professionally oriented courses to the curriculum, since (1) they better prepare students for their careers, and (2) these types of courses naturally meet ABET program outcomes (particularly, some of the harder to meet outcomes).

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References


Biographical Information

DR. CRAIG J. HOFF is an Associate Professor of Mechanical Engineering at Kettering University. He teaches in the areas of thermal design, mechanical design, and automotive engineering. His research interests include fuel cell and hybrid electric vehicles. Dr. Hoff is the co-faculty advisor to Kettering’s Student Chapter of the Society of Automotive Engineers (SAE), faculty advisor to the Kettering Formula
SAE racecar team and serves on several committees for SAE International. He is a licensed professional engineering in the state of Michigan and has provided consulting to services to many companies, including ArvinMeritor, Magna, and Ford Motor Company.

DR. GREG DAVIS is a Professor of Mechanical Engineering at Kettering University, formerly known as GMI Engineering & Management Institute. Acting in this capacity, he teaches courses in the Automotive and Thermal Science disciplines. He also serves a Director of the Advanced Engine Research Laboratory, where he conducts research in alternative fuels and engines. Currently, Greg serves as the faculty advisor for the world's largest Student Chapter of the Society of Automotive Engineers (SAE) and the Clean Snowmobile Challenge Project. Greg is also active on the professional level of SAE, serving as Chair of the Student Activities Committee and Chair of the Engineering Education Board. Dr. Davis is a registered Professional Engineer in the State of Michigan.