Implementing an Interdisciplinary Curriculum in Internal Combustion Engines

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Abstract

This paper describes the design and implementation of an interdisciplinary curriculum in internal combustion engines at Michigan Technological University. This curriculum enhancement is part of the newly formed Interdisciplinary Center for Advanced Propulsion (ICAP) which is a United States Department of Energy Center of Excellence funded under the GATE program. One of the main goals of this Center is to provide multi-disciplinary engineering training for both undergraduate and graduate students specializing in this important area of national need. Now in it's second year, ICAP has significantly stimulated team teaching and research across departmental and college boundaries and provided a unique opportunity for students in mechanical engineering, chemical engineering, electrical engineering, and metallurgical engineering to pursue their interests and develop careers in an otherwise traditionally mechanical engineering area. Although difficulties existed at the onset, and problems still exist, traditional barriers are being bridged by a successful teambuilding.

I. The Nature of Interdisciplinary Work

Although interdisciplinary teambuilding within the academic setting makes sense, fostering teams and encouraging growth across departmental and college lines, can be a difficult task. Problems lie not only in technical language barriers, i.e., different disciplines think and speak with different approaches in different terms, but managerial barriers as well. For the most part, faculty easily overcome technical language barriers. This is the challenge of interdisciplinary work and the thrill of examining someone else's approach to a shared problem; this is a rewarding experience. Inevitably though, there are the 'productivity measures' which are imposed by those involved with tenure, promotion, and merit. These productivity measures are often attempts at labeling (or evaluating) one's work in a *quantitative* fashion. When it comes to merit assignment, department heads, chairs, deans, and provosts often ask:

Who actually did the work?

Who was behind the funding and expenditure of funds?

Who was leading and who was following?

Did anyone just go along for the ride?

How many publications did he/she produce and what role did he/she play?

Is this work really credible?

For instance, if one faculty member receives a grant to support ten graduate students in a government sponsored fellowship program, but does not advise all ten (he/she should not) then who receives ‘credit’ for supporting each fellow? Is it the originator of the grant or is it the principal advisor? While some may dismiss such a dilemma as mere pettiness, there is no question that these situations do exist and do play a role in the success or failure of working together, especially across departmental and college lines. The problem arises when we try to quantify what should really be qualified. Inevitably, some merit algorithm exists where (like good engineers) we assign numbers to all of that which we do, add up the numbers, and decide who is promoted, who receives the largest salary raise, and who does not achieve tenure. This paper does not attempt to address these difficult and seemingly perennial problems. There seems to be enough difficulty with assigning merit even within a department.

Cultural perspectives, too, also play an important role in success and failure of interdisciplinary teams, that is, how colleagues view their fellow workers who may be engaged in interdisciplinary activities (Allen, Allen and Meyer). There is something mysterious and vague about someone who is ‘working with another department’. There is unquestionably an underlying current, which is more than misperception, that guides faculty to certain avenues of productivity. When these avenues are crossed, confusion and mistrust can surface. Clearly though, many agree that this is where scientific advancement is the most fertile. Think of example after example, in historical context, have not most major achievements been reached because someone or some team thought ‘out of the box’? As faculty become more established, change can become more difficult because of the security offered by more traditional approaches (Gottman).

An interesting perspective (Sinnott and Johnson) places the university as a system of teams. These teams of both students and faculty research solutions to societal problems —such as environmental pollution and violent crime. Students and professors on an 'engineering and architecture' team would design energy-efficient homes and offices while those on a 'marketing and psychology' team would devise a public education campaign that gets people to walk instead of drive. A business expert and researcher/teacher would manage each team.

While this model may seem far-fetched to the average academic, its real-world orientation is an answer to law-makers' accusations that universities have lost touch with society's needs. In addition, the model offers a way to meld research and undergraduate teaching. After selecting a problem to focus on, this new university would trade its academic departments for expert teams of university professors, administrators and students, each charged with studying aspects of the problem. For example, one university might focus on care for elderly adults. The 'economics' team would explore ways to reduce the costs of elder-care, the 'anthropology' team would explore effective models of family and community care and the 'psychology' team would look for ways to improve elderly adults' mental health. The model would help bridge the separation between faculty members' roles as teachers and researchers. In addition, it would better prepare students for jobs by giving them experience at working on teams and solving real-world problems.

Radical ideas are always fun to think about. But the real world is today. So to speak of success in today's environment, a special team is required for success. This special team must be supported in some fashion by the managers (dean, director, chair, etc.) and recognized in an entrepreneurial light. Team approaches and team teaching do work (Beggs, Chamberlin, Roth). Unfortunately, some administrators still count. At a recent Industrial Advisory Committee meeting of the department, fashionable and collegial argument ensued after a presentation of 'the most productive' faculty which had been displayed in the traditional mode of simple counting.

II. The Interdisciplinary Engines Curriculum

Faculty in the Department of Mechanical Engineering - Engineering Mechanics at Michigan Technological University have been involved with teaching and research in engines for many years. As a consequence of this long and successful track record, a rich course offering in engines has evolved. This course sequence has been entirely within the department however. There had been no attempt at broadening the course to bring in subjects outside of the realm of mechanical engineering. This course sequence also focussed on the energy aspects of engine operation and analysis rather than the mechanical design (noise, structure, vibration, balance, etc.) Student interest in these courses has always been very good. Typically, approximately one hundred students are enrolled in the first engines course each year. (The department enrollment is approximately 1200-1400 students.) Interaction with industries in the automotive and diesel engine arena has been and continues to be strong. The quality of the engineering program at both the undergraduate and graduate level is clearly reflected in the students which graduate from the university. The Department of Mechanical Engineering - Engineering Mechanics at Michigan Technological University is well noted for national ranking, student balance, and research. The mission of the university is technological in character Over 60% of the student body of approximately 6500 students are enrolled in the College of Engineering. The ME-EM department is one of the largest mechanical engineering programs in the country. Employment opportunities have remained strong over the years. Most of these students become professionals at Caterpillar, Cummins, John Deere, General Motors, Ford, Chrysler, Chevron, Detroit Diesel and other automotive related industries.

Having this track record, faculty in the department established the Interdisciplinary Center for Advanced Propulsion. This Center is steered toward advanced study in both gasoline and diesel engines including emission control technology. This Center focuses on both undergraduate and graduate education.

III. Description of Developing Interdisciplinary Courses

The ME-EM Department has offered a rich spectrum of professional engine-related courses at the senior and graduate level. This has been partly due to close ties with industry and partly due to a strong egalitarian drive to fulfill the mission as a technological university. The department has maintained a reasonable undergraduate and graduate balance both at the research and teaching level.

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One of the underlying goals of the curriculum revision was to make this rich sequence

interdisciplinary. One of the hurdles had to be overcome is that of traditional departmental boundaries. As stated earlier, team teaching across departmental and college boundaries can be very cumbersome. Blending these departments together into an effective interdisciplinary teaching and research Center, recognized internally by the University Administration and externally to industry, was a primary objective.

Although still under development, the course sequence structure is shown in Figure 1. Most courses are interdisciplinary in some fashion although the degree of cross fertilization varies. On a cautionary note, advanced study courses are quite involved and contain sufficient fundamental theory with the necessary mathematics to ensure that a quality advance-degree graduate is produced. Other additions to the existing structure include two more laboratories, one steered toward combustion/emissions and the other focussed on diesel engines. These laboratory courses have a significant design component to them.

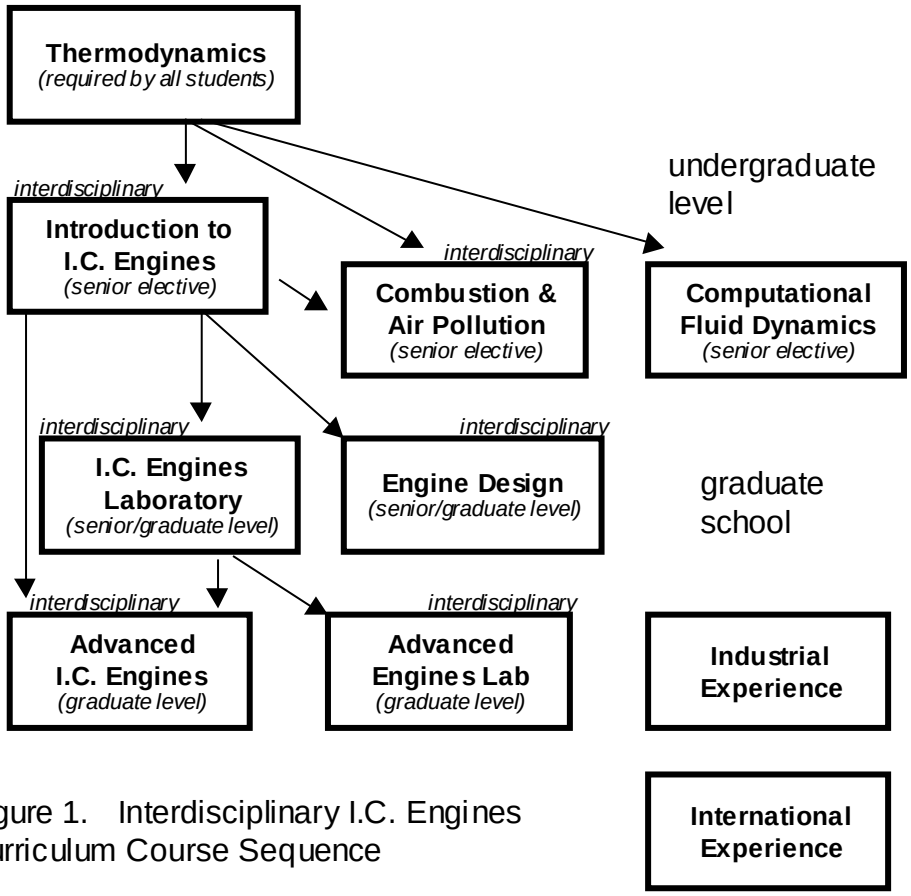

Figure 1. Interdisciplinary I.C. Engines Curriculum Course Sequence

The curriculum involves an Industrial Experience. Students have an option of visiting various engine and engine component manufacturers for extended periods for the purpose of gaining real time experience in the field. The Industrial Partners (an industrial advisory board) are encouraged to offer temporary positions for students, in a co-op (cooperative education) format. This experience is, out of practicality, optional but it is envisioned many of the ICAP students will elect this path.

IV. Current Status

The end result of ICAP is measure of the positive impact of the interdisciplinary experience, the overall academic achievement, and the career contributions ICAP students will make in the field of engines and advanced power plant concepts. While it is much too early to evaluate the program on these criteria, we can say there has been a surge of in interest by students and excitement amongst the faculty. The traditional introductory course was successfully team taught for the first time by faculty from mechanical, electrical, metallurgical, and chemical engineering. A new course in engine design has been developed and is being taught by two faculty from different colleges. The engines lab is being revitalized. More importantly, industry is recognizing the interdisciplinary effort and financially supporting the program. Amongst the faculty, new projects have surfaced that are interdisciplinary in nature and directly related to hybrid technology. In this regard, curriculum development through ICAP has been successful.
Interesting although not surprising to note, it appears much easier to assemble a team of faculty from outside the home department (in this case, mechanical engineering) than it does to solicit cooperation and team spirit *within* the department. There are several reasons for this but, for the most part, this can be explained by the following:

1. faculty outside of the department want to participate because of the broadening experience, the potential to pursue research and research funding in an area of interest outside of their traditional box, and the opportunity to talk to and instruct students in other departments (i.e., it's just plain fun), and,

2. faculty inside of the department are less willing to participate because of a perceived threat of territorial invasion and loss of competitive advantage (teaching favorite courses, laboratory space, graduate students, equipment, etc.).

In order to be successful, it is necessary for faculty to overcome the desire to be independently competitive if the university environment wishes to foster team efforts. When competitive spirit is rewarded yearly over a long period of time, then faculty become conditioned to argue to their advantage, and to their colleagues disadvantage. This is evident as faculty race against faculty for recognition, laboratory space, lighter teaching loads, departmental resources, and limited salary increases through 'objective' merit algorithms.

The ICAP curriculum development plan discussed in this paper is good exercise because the outcome will greatly benefit the students and faculty and is in line with the needs of industry and

society. Engines are no longer an assembly of nuts and bolts but well tuned systems that involve contributions and integration from electrical, mechanical, metallurgical, and chemical engineers. Any curriculum development involving an interdisciplinary approach is good exercise because such development allows faculty and administration the opportunity to examine their mode of operation and determine if teaming is possible and encouraged. Few will argue that interdisciplinary activity is frivolous; instead, interdisciplinary activity can and does lead to significant scientific achievement.

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