Energy and Engine Research through Undergraduate Research Program

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Abstract

The need for engineers to engage in research and development activities in engines and propulsion systems has been increasing. This is more so evident in automotive industry where there has been a push to increase overall efficiency of propulsion systems, make use alternative fuels to help reduce dependency on oil and reduce exhaust emissions, and to use environmentally friendly fuels. Most of the mechanical engineering students have very little research experience by the time they graduate and even less so in engines, fuels and engine exhaust emissions.

To address some of these problems an undergraduate research program was developed and implemented in the mechanical engineering department. Initially, the program catered to a very small number of students seeking to work on research projects in the subject area. However, in the last two years, the National Science Foundation has been funding the project under its Research Experience for Undergraduates (REU) program. The funding allows up to eight students from different institutions to work with the faculty and graduate students on experimental and analytical projects in combustion engines, fuel systems, exhaust emissions, fuel cells and energy systems.

This paper describes structure of research projects, expectations on the part of faculty advisors and students, preparation of student participants for subsequent research career or advanced degree and the extent to which project objectives have been met. Tracking of the past REU student participants has shown that several of them are pursuing advanced degree programs while a similar number is planning to pursue research and development career in industry.

Introduction

There has been an increased interest in providing research opportunities to undergraduates at many institutions. While major research universities and some well-known liberal arts colleges have provided opportunities to their undergraduates to conduct research in basic and applied sciences and mathematics[1-3] these programs have been somewhat limited. This is particularly so in the field of engineering where faculty and their graduate students tend to focus their efforts more on their research projects and funding than training undergraduates for research.

Research Program through REU

The Department of Mechanical Engineering at UM-D has been providing limited research opportunities in combustion engines and fuel systems to its undergraduates. The program was limited to a select few who had keen interest in the subject matter. The laboratory research facilities were recently expanded to cater to increased funding in the subject area and the award of the National Science Foundation REU site has allowed expansion of undergraduate research opportunities to students from academic institutions across the country. Up to eight undergraduate students have been involved in the project each year, receiving financial support during summer to conduct research in combustion engines, exhaust emissions, fuel systems and related areas. Undergraduate research programs provide a range of opportunities to students and benefit institutions and the nation, as has been pointed out in several studies [4-8].

Program Plan and Recruitment: Between three to four mechanical engineering faculty members were involved in advising student participants and directing their projects. The admissions guidelines, developed by the committee made up of project faculty, required applicants to be students majoring in any engineering discipline. The applicants were expected to have at least a basic knowledge and understanding of thermodynamics and some proficiency in using computer technology. Applications were solicited from over 200 engineering colleges and universities in the U.S. In keeping with the overall philosophy of the institution and the REU program the committee developed additional criteria in accepting students, such as:

- Providing equal opportunities to applicants from 4-year colleges and major research universities.
- Proactive efforts to include women and underrepresented minority students in the program.
- Genuine interest on the part of applicants to participate in research and investigative tasks as evaluated from applications, statement of career goals, and faculty recommendations.

In spite of the very pro-active initiatives to recruit women and minority students in the program the efforts were not as successful as envisioned by the committee. Table 1 shows participants' statistics over the last two years of the program.

Table 1

Ethnicity	Applications	Accepted	Participated
Caucasian	76	17	12
African Amer.	4	4	0
Hispanics/Latinos	5	4	1
Native Americans	0	0	0
Asians	6	2	3
Total	91	27	16

Of the 91 applicants over the two-year period, five were women. Although they were offered positions in the program (two in year 1 and three in year 2) only one female student ended up in the research program. The reasons for lack of participation ranged over a wide spectrum including better opportunities elsewhere, far away distance from the home institution to the host institution, lower financial benefits, etc.

Project Design and Implementation: Efforts were made to involve about 50% of the students in experimental research while the others in analytical and modeling type projects. While some of the students conducted their research on projects that were specifically designed for the REU students, others were involved in on-going research in the subject areas. The former projects were derivatives of on-going activities in the department but were tailored to REU students. This was necessary to ensure that students could complete their projects in time, arrive at appropriate conclusions, complete their project reports and present their findings before an audience.

Table 2
Student Research Projects

Project Title	Project Type
Optimization of an automotive catalyst geometry through CFD	Modeling
Investigation of combustion and exhaust emissions from gasoline-ethanol blends in a carbureted SI engine	Experimental
Performance analysis of catalytic converters	Modeling
A study of injection timing and HC emissions in a SFI spark ignition engine	Experimental
The effects of geometric parameters on regeneration characteristics of diesel particulate filters	Analytical/Modeling
A performance analysis of PEM fuel cells	Analytical
Engine performance and exhaust emissions from a biodiesel fueled DI diesel engine	Experimental
A comparison of traditional and hybrid powertrain architectures using PSAT	Modeling
CFD analysis of friction: effects of temperature, humidity and geometry on the airflow through a bipolar plate of a fuel cell	Analytical
Burn rates and exhaust emissions from ethanol-gasoline blends	Experimental

The first week of the 10-week program focused on participants' orientation where they were introduced to off-campus housing, library facilities, computer laboratories, participants' offices, machine shop facility, etc. They were also presented with a tentative schedule of activities, including seminars, field trips, weekly meetings and a list of projects available for them to work on. This was followed by faculty presentations on projects they were supervising that year. A no-

conflict process was implemented whereby the students had to self-select their projects after discussing their interests amongst themselves, the faculty supervisors and graduate students involved in the program. A team of two students worked on each of the experimental projects while the analytical or modeling projects were assigned to individuals. Table 2 shows some of the projects undertaken by students over the last two years. Some of the past project reports can be accessed at www.engin.umd.umich.edu/research/undergraduate/.

Group meetings between all student participants and faculty supervisors were held each week to evaluate progress of their research and to iron out any problems encountered in the conduct of their projects. Each student team was required to make a presentation on its research topic and progress made to-date. This was designed to expose the students to all projects in the program and provide them with an experience in oral and technical presentation skills. The ten-week program also included at least three seminars by experts from industry and academia and two field trips to local research laboratories involved in activities similar to those in the program.

Program Outcomes and Assessment

The faculty committee developed a series of outcomes, shown in Table 3, to evaluate the students' success in the research program. The outcomes were related to the program objectives and address common goals of all research projects.

Table 3
Program Outcomes

No	Outcome	Excellent	V. Good	Fair
1	The student's ability to plan the project work and handle it appropriately	69	25	6
2	The student's ability to use appropriate instrumentation and tools in the conduct of the research, including the use of library facilities.	88	12	0
3	The use of appropriate mathematics and science in the research project.	88	12	0
4	An interest in research or investigative type of work and quality of research.	81	19	0
5	The student's ability to evaluate data and make technically sound changes in data collection and/or assumptions, in consultation with the faculty advisor.	75	25	0
6	The quality of technical report detailing the investigation, its findings and conclusions, and the student's ability to communicate them to an audience.	75	25	0

Tools Used to Assess Outcomes and Project Assessment: The committee used several qualitative and quantitative tools to gauge outcomes and understand the extent to which the project has been successful. These are shown in Table 4 along with their use in assessing specific outcomes.

Table 4
Tools Used to Assess Outcomes

Tools	Used in outcomes
Report or presentation on past work related to the project	1, 2 and 3
Use of computer tools and/or laboratory equipment	1 and 2
Meetings with advisors & weekly group meetings	4 and 5
Use of mathematics and engineering relations	2 and 3
Final report	2, 3 and 6
Exit interview and exit survey	4
Final project presentation	2, 5 and 6

These tools and others were used to assess the extent to which the outcomes that were discussed earlier were satisfied. In assessing some of the outcomes, particularly those that could be judged collectively, the committee as a whole evaluated each of the students' performance related to that outcome. The others were evaluated by the faculty supervisor with assistance from the participating graduate student, as the case may be. The results of the study are shown in Table 3 (right column) in terms of percent of student participants' achievements. Generally, all students performed well and learned a great deal on conducting research and investigative work, ethical issues related to research, technical report writing, presentation of research problem before an audience of faculty and students, time management, and inquisitive evaluation of data and results and subsequent conclusions. Exit interviews and follow-up contacts indicate that over 40% of the REU students are continuing or plan to continue their education leading to advanced degrees in engineering. Most of the participants have stated that their participation in the REU program have motivated them to pursue advanced degree or a career in research and development field. The research project of one of the teams resulted in a technical publication; more can be expected in future.

Conclusions

The undergraduate research program in combustion engines and related areas at the University of Michigan-Dearborn has provided excellent research experience to undergraduates, both from research universities and 4-year colleges. Working closely with the supervising faculty and graduate research assistants the participants have excelled in acquiring knowledge, techniques, skills and inquisitive mind needed to be good researchers. The research program has resulted in

enhancing the students' analytical, experimental and computational skills as well as the use of library facilities for research. Project reports and presentations of their research before an audience have helped to improve participant's communication skills.

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Bibliographical Information

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