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MULTIDISCIPLINARY PROJECTS:

A MODERN TECHNIQUE IN ENGINEERING EDUCATION

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ABSTRACT

The multidisciplinary project laboratory course has been developed for the purpose of preparing young engineers to deal successfully with the complex practical problems associated with today's technology. Students undertake a realistic engineering project which they pursue from inception to completion. Such a program fosters logical planning, ingenuity and creativity, constructive cooperation with related disciplines, technical responsibility, and a systematic approach to problem solving. The multidisciplinary project technique used in the Mechanical and Aerospace Engineering Department at Rutgers University is discussed in terms of a project example and benefits derived from the course.

INTRODUCTION

Recent revisions of engineering curricula have been characterized by two major trends: (1) a continually increasing emphasis on courses concerned with teaching theoretical techniques or concepts and (2) an overall reduction of total number of courses required for graduation. Partially as a result of these changes, a very important aspect of basic engineering has been slighted, namely that part of the curriculum integrating theory and experiment through engineering projects. Undoubtedly, these new curricula effectively prepare young engineers for analytical work. However, graduates of such programs often lack the techniques necessary for dealing successfully with complex practical problems which characterize both research and performance analyses.

Industrial managers indicate that many of today's graduating engineers, although well qualified as far as theoretical understanding is concerned, do not appear to be prepared for planning and implementing engineering projects involving the prediction of the performance of complex systems. Such projects require a familiarity with engineering hardware and experimental measurement techniques, as

well as the ability to contribute to group problem solutions. These managers further indicate that many industries must provide training programs for young engineers covering material which they feel should have been offered as part of their undergraduate education.

The majority of engineering problems of today are complex and may involve such diverse disciplines as psychology, economics, biology, chemistry, and physics, as well as the many fields of engineering. How can an engineer adequately study air pollution problems, for example, without concerning himself with chemical processes, atmospheric properties, weather phenomena, financial limitations and perhaps even politics? In order to analyze such problems adequately, the young engineer should be prepared to interact effectively with other disciplines, in addition to engineering, which may be associated with the project. Most important engineering projects of today are multidisciplinary in nature and require a multidisciplinary group approach.

In an attempt to provide a meaningful education in engineering, within the framework of present day curricula, an increasing number of colleges and universities have evolved some type of project course. These courses range in length from part of a semester to one academic year, with some extending over a longer period of time. The structures of the courses range from individual study and basic research to group projects, and may involve engineering design, feasibility, and applications studies. Course supervision varies from weekly meetings to periodic reviews of the students' work. This paper describes multidisciplinary projects as a modern technique in engineering education and discusses a typical multidisciplinary project course. The paper also points out the need for improved industry-university relations to foster this type of education for future engineering graduates.

MULTIDISCIPLINARY PROJECT OBJECTIVES

The overall objective of the multidisciplinary project course is to expose students to a realistic engineering problem which, upon satisfactory completion, should enhance their ability to assume responsibilities and to optimize their decisions. This type of laboratory experience is increasingly important because practicing engineers continually need to find, accept, and apply new ideas, methods, and materials. Such experience will provide the young engineer with a background in engineering hardware and experimental measurement techniques, and better prepare him for a career in engineering.

Benefits of the multidisciplinary projects type of course are many. These projects foster a logical and orderly approach to group problem solving. In order to achieve the problem solution, the students must analyze the project in its entirety prior to its initiation. This requires the definition of important parts of the project and compromises between ideal and practical approaches.

The projects encourage planning and efficiency, since the project must be completed in a finite amount of time. Of concern to the investigators are both the economics of the project and the time to be allotted to each phase of the program. It emphasizes the need for application of critical path techniques.

The projects foster ingenuity and creativity as the students apply their basic engineering knowledge to practical projects. Students are encouraged to use the equipment available in the laboratory with modifications as necessary, since financial resources for the projects are generally limited.

The projects also promote technical responsibility and professional ethics. The students are obliged to defend the technical recommendations which they have derived on completion of their project.

The projects help to broaden the students' outlook and capabilities. Discussions with faculty and industry personnel, library research using the various sources of scientific information, and discussions with peers, all become useful and valuable resources as a student analyzes and conducts his project.

It is of course true that all projects do not meet all of these expectations for all students involved. However, experience to date indicates that students who have participated in such a multidisciplinary

project course are better able to meet the challenge of today's technology.

MULTIDISCIPLINARY PROJECT TECHNIQUE

The multidisciplinary project technique used in the Mechanical and Aerospace Engineering Department at Rutgers University has evolved over the past several years. Factors contributing to its evolution include a recent curriculum revision which reduced the amount of coursework required for a degree, the need for a terminal laboratory course, and the students' need for a chance to practice some of the principles they had learned in other more theoretically oriented classes. In addition, eight years of experience with the National Science Foundation Undergraduate Research Participation Program has emphasized the benefit students gain from pursuing a research topic from start to finish.

The multidisciplinary project course at Rutgers University extends over the two semester period of the senior year and is required of all students. The objectives of the course and project requirements are discussed at the beginning of the first semester. In addition, the students are asked to indicate their relative interests in the various subjects of mechanical engineering and associated outside disciplines.

Problems for projects are proposed by various faculty members within the Mechanical and Aerospace Engineering Department and are related to areas of faculty research and consulting interests. In addition, students are permitted to propose projects of their choice; however, they must find a faculty member who will serve as advisor to the project. Projects are then reviewed by the course directors and suitable projects are assigned to students, usually in groups of two. These project assignments are made on the basis of interest expressed by the students and are comparable to a job assignment given a young engineer working in industry. The students embark on the project under the guidance of a faculty member in an employer-employee relationship. The faculty member serves as a consultant to the project rather than a director, and provides advice as needed. He also acts as a liaison between the student investigators and other faculty members in engineering and in other disciplines.

The students' initial objective is to gain a working knowledge of the project area. They search the literature, consult with various faculty members, design an experimental apparatus, pursue analytical

approaches to the problem, and culminate this phase of their project with a formal proposal. The proposal is evaluated by the course director(s), as to completeness, cost, and understanding of the problem. The design of the experimental apparatus is checked to determine whether it will provide the desired data for the project and whether a machinist would be able to fabricate the facility from the working drawings. At the completion of this phase of the course, the students are permitted to proceed with their projects.

The components of the experimental facility which require machining are fabricated by the Engineering Machine Shop. The students follow the progress of their job in the shop and develop a working relationship with shop personnel. Discussion with the machinists concerning fabrication techniques, machining times, and realistic tolerances provides an invaluable experience for the students. In addition, the students accumulate and modify other laboratory equipment needed for their project. This may require selection of commercially available components and submission of purchase requests through the course director. (Each project has a preset small budget.) At such time as components for their experimental facility become available, the students assemble the facility and conduct some preliminary tests to evaluate its effectiveness. The students are made to realize that further improvements could delay the progress of the project. They must then weigh the value of improvements versus time delays in reaching their goal.

Following the completion of preliminary tests, a testing program is initiated to provide the desired experimental data. The experimental plans are reevaluated and revised as necessary. Care is taken in obtaining the experimental data, and uncertainties or errors and inconsistencies are noted. The resulting experimental data are analyzed, and the uncertainties in the final values are determined. These data are compared with existing experimental data and, where possible, with experimental and theoretical predictions, in order to verify their accuracy.

The final results are organized in such a manner as to demonstrate effectively the worth of the results. Comparisons with existing experimental and theoretical prediction techniques are noted and discrepancies are explained. These data and results are incorporated into a comprehensive written final report which reviews the entire project. The final report discusses the motivation for the project, the approach and experimental facilities

used, the experimental procedure and method of data analysis, and makes recommendations for future work in the area.

An oral final report is also presented to the other class members and faculty of the department. These oral reports cover the major points of the investigation and discuss the recommendations resulting from the work. These oral presentations are videotaped for future replay, to permit the students an opportunity to evaluate their own performance. The students' work is then evaluated by the course director and project advisors on the basis of creativity, reliability, and general usefulness.

In addition to the required work for the course, many students have entered the professional society (ASME, AIAA, ISA, etc.) student paper and speaking contests. Papers describing the results of their project work have won both regional and national awards.

MULTIDISCIPLINARY PROJECT EXAMPLE

In order to provide some insight into the type and scope of problems which are investigated in this course, a current project concerned with the chemical and thermal conditioning of biological sludge for vacuum filtration will be discussed briefly.

Many pollution experts agree that the limiting operation in a modern sewage disposal plant is getting rid of the solids that accumulate during various separation processes. Of particular concern is activated sludge, which is the solid residue resulting from aerobic digestion of soluble or nonsettleable solids in sewage. The primary difficulty is that this sludge is extremely difficult to filter.

The overriding problem in disposing of the sludge is that it retains a significant amount of water. Conventional drying methods leave a large quantity of water, eliminating the possibility of using the sludge as land fill. Furthermore, this sludge contains so much oxygen-consuming organic material that fish are destroyed if it is dumped into a waterway or an ocean.

The objective of the two students, who were assigned to this project, was to evaluate current chemical and heat conditioning procedures by searching the literature and by conducting a series of small scale experiments on activated sludge. A secondary objective, chosen by the students, was to explore the possibility of returning the filter cakes to the cycle.

A substantial portion of the first semester was spent in searching the literature, which included journals, reports and books in mechanical, civil, chemical, sanitary, and environmental engineering. Furthermore, records of congressional hearings were consulted to determine the direction of federal legislation governing the disposal of wastes. In order to supplement their engineering background, the students also spent some time studying basic biological concepts.

Based on this preliminary work, the students chose for actual investigation several chemical and heat conditioning techniques which showed some promise in terms of final filtration efficiencies and cost. They then developed test procedures and designed the required experimental apparatus. For the actual tests, the students are using the determination of surface charge as a measure of relative conditioning. It has been shown previously that the surface charge indicates the flocculative tendencies of the sludge; the more neutral the charge, the more effective the conditioning process. The results of this portion of the investigation will provide a measure of merit for each of the procedures. This information will be useful to municipal governments planning to invest money in secondary and tertiary treatment plants.

During the experimental phase, the students have also been actively pursuing the problem of closing the cycle, by finding a use for the final products of the vacuum filtration process. Two promising areas are the use of the filter cakes for fertilizer and as a nutrient supplement to animal feed. The heat conditioned sludge is particularly suited for these applications, since the material has already been sterilized.

As with most of these projects, other possible areas for exploration by future students have been outlined. Of particular importance is an economic feasibility study for a complete sewage treatment plant, which would take in raw sewage, process it, and be able to market the final products: water and filter residues.

GENERAL COMMENTS

The multidisciplinary project course, as developed in the Mechanical and Aerospace Engineering Department of Rutgers University has proved to be most satisfactory. Project-oriented investigation and experimentation has given the students a realistic contact with engineering design and development as they pursue a research

project from inception to completion.

It is generally assumed that students with high academic averages will perform well in independent programs such as the multidisciplinary project course. Results of the projects over the past few years have generally verified this assumption. Of special significance, however, has been the interest and success in such projects achieved by students with average or even poor academic records. These results indicate that a student's academic grade average, based primarily on performance in theoretically oriented courses, may not be an adequate measure of overall technical or professional competence.

The integration of these multidisciplinary projects with active research programs has worked quite well. Students have an opportunity to work closely with individual faculty members, thus sharing in their enthusiasm for experimentation. The student-faculty relationships fostered by these projects may help to alleviate some of the student alienation occurring in many educational disciplines. Further, the students feel that their work is important because it is contributing to the success of the ongoing departmental research programs.

There are many technical problems occurring in industrial research and development programs. Many of these problems would be appropriate for inclusion in a multidisciplinary project course. The lack of contact between such industries and universities, however, precludes the implementation of joint educational programs. It is hoped that the evolution of this type of program will stimulate a continuing dialogue between universities and industries.

CONCLUSIONS

Over the past several years, a multidisciplinary project course has been developed which appears to be a partial solution to some of the problems confronting most engineering schools. The integration of these projects with current research programs and engineering applications problems lends significance to the students' work. It provides them with what may be the only occasion in their educational career to demonstrate real creativity and personal motivation. The response of both students and faculty to this type of course has been encouraging.

The multidisciplinary project technique described herein appears to be a valuable addition to the engineering curriculum. It is hoped that as more engineering

colleges add these multidisciplinary projects courses, industry will be interested in this educational pattern and will assist these programs both with ideas and with funds supporting equipment.

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