7917709

HERRING, HAROLD PRESTON
A MODEL CURRICULAR DESIGN NEEDED FOR THE PREPARATION OF ELECTRICAL ENGINEERING GRADUATES AS IDENTIFIED BY SELECTED ENGINEERS AND ELECTRICAL ENGINEERING FACULTY AT MICHIGAN STATE UNIVERSITY.

MICHIGAN STATE UNIVERSITY, PH.D., 1978

University Microfilms International 300 N. ZEEB ROAD, ANN ARBOR, MI 48106

A MODEL CURRICULAR DESIGN NEEDED FOR THE PREPARATION OF ELECTRICAL ENGINEERING GRADUATES AS IDENTIFIED BY SELECTED ENGINEERS AND ELECTRICAL ENGINEERING FACULTY AT MICHIGAN STATE UNIVERSITY

By

Harold Preston Herring

A DISSERTATION

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

Department of Administration and Higher Education

1978

ABSTRACT

A MODEL CURRICULAR DESIGN NEEDED FOR THE PREPARATION OF ELECTRICAL ENGINEERING GRADUATES AS IDENTIFIED BY SELECTED ENGINEERS AND ELECTRICAL ENGINEERING FACULTY AT MICHIGAN STATE UNIVERSITY

By

Harold Preston Herring

The consideration of viewpoints by those knowledgeable in the field of engineering education must be an essential ingredient in the formulation of a curricular design program. The purpose of this study was to construct a model curricular design for the preparation of undergraduate electrical engineering students. The research results were made available to institutions of higher education nationally for potential use in structuring and redefining programs and course planning.

The population to be studied in this research included two groups. All faculty members in the Department of Electrical Engineering and Systems Science at Michigan State University, with the rank of Assistant Professor, Associate Professor or Professor, and who have as a major focus the field of electrical engineering, comprised the first sample group. The second group included selected

engineers currently working in the field of electrical engineering and identified from organizations which have employed graduates from the Department of Electrical Engineering in the last ten years. A total of twenty faculty members and eighty selected engineers were included in the study.

Methodological considerations dictated that the survey instrument reflect the broadest range of course material related to the undergraduate electrical engineering program. As such, minimal ECPD course requirements were reflected in the survey questionnaire to which all participants responded. Six research hypotheses were offered, stipulating no significant differences between the two sample groups regarding the importance placed upon individual courses in the study. Data collection procedures in the research permitted a rank ordering of courses for the final model curricular design. To accomplish this goal, two separate questionnaires were prepared and responses obtained from participants. Response rates for both surveys resulted in a 90 percent return rate from faculty and selected engineers to the first survey and an 80 percent and 81.2 percent return rate to the second questionnaire for both groups, respectively.

Five statistical techniques were used to analyze the data in the present study. A multivariate analysis of variance was performed to analyze individual courses in the first study. A Pearson product moment correlation was calculated to compare the degree of similarity between groups and a Spearman correlation was used to analyze the similarity between the rank ordering of courses.

Conclusions

Mean and standard deviation scores from Study #1 revealed a limited range of responses to the importance placed upon individual courses by the two sample groups. Courses in engineering science generally were rated less similar by the two groups than were other course categories. The rank ordering of courses in Study #2 likewise revealed a high degree of similarity between the two groups. These results revealed that the six research hypotheses were not rejected at the .05 level of significance.

The research specifically supported the inclusion of ECPD minimal course requirements in an undergraduate engineering program. The model offered in the study suggests a greater emphasis on electromagnetics and physical electronics courses, and on digital electronics and systems courses. The model additionally suggests that nontechnical courses such as engineering safety standards and governmental policy and technology be included in an undergraduate electrical engineering program.

ACKNOWLEDGMENTS

The encouragement and advice of numerous individuals, interested both in professional and personal growth in those whom they advise, have assisted in making this study and my entire doctoral program possible:

To Dr. Richard Featherstone, Professor and major adviser, who has always had an open door and a sincere interest in the progress of this study.

To Dr. George VanDusen, Associate Professor and committee member, who greatly assisted in the early formulation of the research topic and who willingly offered his time amidst busy schedules to review the study during its later stages. His comments and encouragements were deeply appreciated.

To other committee members, Dr. Larry Foster and Dr. Donald Nickerson, for their valuable comments during final dissertation preparation, and to Dr. David Fisher, Professor of Electrical Engineering, for his comments on the technical aspects of electrical engineering curricular programs.

To the staff of the Office of Engineering Student Affairs for their encouragement and support, and their ability to add a realistic perspective to one's involvement in a doctoral program.

To my parents, Harold and Julia Herring, for their training on the merit of honesty and hard work.

And most importantly to my wife, Ginny, to whom this is dedicated and without whose sacrifice, constant support, and love this doctoral study would not have been possible.

TABLE OF CONTENTS

Page

APPENDICES

APPENDIX

LIST OF TABLES

CHAPTER I

INTRODUCTION

The challenge of offering the most current and meaningful subjects in all segments of education today is one of the foremost issues which must be dealt with by school leaders. As both technological and social changes continue to rapidly occur, the demand for schools to structure courses which will meet a variety of societal needs will increase. Probably in no other area have such demands created as dramatic a change as that experienced in the field of engineering. From the intense rush, following the launching of the Russian Sputnik, to increase our country's technological capability to the more recent push for more applied approaches to technology, engineering has indeed been a field pressured to stay current with these numerous changes.

This rapidly changing pace of technology, however, has created new and difficult problems for educational leaders in the field of engineering. First, there is a constant need to provide students with material which reflects the most up-to-date advances in technology. But there is also a fundamental principle which demands that engineers receive basic training in the traditional course areas, training which will enable them to adapt to a constantly changing technological society.

These two important yet often conflicting philosophies make the curricular design process in engineering education almost constantly at issue. Faculty members interested in research argue that an undergraduate program must prepare the future engineer for research and development activities and as such must be comprised mostly of theoretical approaches to basic science principles. Engineers in both the public and private sector counter that applied courses need to be offered at the undergraduate level which will prepare the student for a more functional position as a practicing engineer. This debate indicates that those individuals and groups with a vested interest in the training of engineering students may have significant opinions to offer which leaders in engineering education need to consider.

Statement of the Problem

The consideration of viewpoints by those knowledgeable in the field of engineering education must be an essential ingredient in the formulation of a curricular design program. In the present research the process of soliciting input from these two groups will result in the construction of a model four-year curricular design for the Department of Electrical Engineering at Michigan State University. Potential strengths and weaknesses of various aspects of the present curriculum in the Department of Electrical Engineering will be identified for the continuous improvement of the core curriculum by those in decision-making positions in the College of Engineering. This model curricular design will be based on the contrasting importance which industry professionals and faculty in the Department of Electrical Engineering at Michigan State University place on various courses. Reactions by the two sample groups to the six general categories of courses, commonly used by many institutions offering an accredited undergraduate program, may be useful in the future structuring of subject areas in the field of electrical engineering.

Purposes of the Study

While the views of numerous groups of individuals have been solicited regarding opinions on various aspects of an engineering program, few studies have been conducted which specifically gathered data from faculty and industry for the purpose of structuring a model curricular program for the preparation of electrical engineering students. The purpose of this study is to present the resulting model curricular design to the Department of Electrical Engineering at Michigan State University for possible future use in program and course planning. The opportunity to incorporate viewpoints from selected engineers who have an indirect affiliation with Michigan State University will both help in making the recommended curricular design more pertinent to the Department of Electrical Engineering. Faculty involvement in the research design will provide a standard against which comparisons can be made concerning opinions on electrical engineering courses.

In addition, a secondary purpose of the study is to make the research results available to institutions of higher education nationally for possible use in redefining their respective electrical engineering curricular programs. Most institutions offering the professional engineering baccalaureate degree require that certain minimal course standards be met. These basic requirements, stipulated by the national accrediting organization, are shared by many institutions and as a result the research findings in this study may be applicable to institutions other than Michigan State University. Basic required courses, however, are only one part of a total curricular program in electrical engineering. The need exists to present a design which is inclusive and which measures the specific degree of importance which knowledgeable individuals place upon both fundamental engineering courses and those which may broaden the student's educational experience.

Research Questions

The need to present a total curricular program in this study, based on reactions from the two sample groups mentioned earlier, necessitates that specific responses be solicited from survey participants. More specifically, courses based upon a priority order must be presented in this study to develop a model curricular program. It is necessary, therefore, for this study to answer specific questions from which certain assumptions may be tested to accomplish the goal of establishing a model curricular design. The following research questions will be tested in this study:

1. What do engineers in the electrical engineering industry suggest as the most important courses in the preparation of undergraduate students?
2. What do faculty in the Department of Electrical Engineering at Michigan State University suggest as the most important courses in the preparation of undergraduate students?
3. What model curricular design is suggested by both selected engineers and faculty in the Department of Electrical Engineering at Michigan State University in the preparation of undergraduate students?

Research Hypotheses

The review of the literature in engineering curriculum development in addition to the previous research questions assisted in the formulation of the research hypotheses. The purpose of these hypothesis is to explore the relationship between the views held by engineers and Electrical Engineering faculty and the six variables of course categorization. The following research hypotheses will be tested:

Hypothesis I:

There is no significant difference between mathematics courses suggested by practicing engineers and those suggested by faculty for a model curricular design in the Department of Electrical Engineering.

Hypothesis II:

There is no significant difference between basic science courses suggested by practicing engineers and those suggested by faculty for a model curricular design in the Department of Electrical Engineering.

Hypothesis III:

There is no significant difference between engineering design courses suggested by practicing engineers and those suggested by faculty for a model curricular design in the Department of Electrical Engineering.

Hypothesis IV:

There is no significant difference between engineering science courses suggested by practicing engineers and those suggested by faculty for a model curricular design in the Department of Electrical Engineering.

Hypothesis V:

There is no significant difference between technical elective courses suggested by practicing engineers and those suggested by faculty for a model curricular design in the Department of Electrical Engineering.

Hypothesis VI:

There is no significant difference between nontechnical courses suggested by practicing engineers and those suggested by faculty for a model curricular design in the Department of Electrical Engineering.

Limitations of the Study

As mentioned earlier, a noticeable advantage of the usefulness of this research is its applicability to the Department of Electrical Engineering at Michigan State University. Additionally, because other institutions have similar course categories and basic course requirements as those used in this study, the data generated have use to other institutions as well. However, a research study involving two different samples of respondents, that intends to apply those findings to one specific group, necessarily limits the conclusions which can appropriately be drawn. This limitation, and others as well, is part of this study and must be recognized as parameters in the data analysis. The following limitations are present in this research study:

1. Any research conducted using an original survey instrument is necessarily limited in the conclusions which may be drawn. This study will

be based on responses by participants to an original survey questionnaire and only appropriate conclusions may be drawn.

2. Responses by faculty members to the subject areas included in the questionnaire may be biased favorably towards those engineering courses currently offered at Michigan State University and unfavorably biased towards those subject areas not contained in the curricular program at the University.

3. Descriptions of subject areas listed in the questionnaire may be defined or interpreted differently by both faculty members and engineers in industry. Because only subject areas (calculus as an example) will be used in the research as opposed to competency areas (the ability to solve integration equations), varying definitions may be used by different respondents.

Delimitations of the Study

The need for a comprehensive approach in the establishment of a curricular design in electrical engineering education, as mentioned earlier, could necessarily make the scope of this study extremely broad. However, responsible research demands that certain controls be placed on the parameters of a study of this nature in order that conclusions which are applicable, and which can be implemented, result. The following delimitations, therefore, are placed upon this study:

1. Participants in the study from industry are representative of organizations which have employed graduates of the Department of Electrical Engineering at Michigan State University during the last ten years. While respondents from this group are located in various regions of the United States, conclusions from the study can only be drawn relative to their relationship with the electrical engineering program at Michigan State University.

2. Participants in the study from industry are employed in both engineering and managerial positions and, therefore, conclusions about the curricular model suggested in the study are representative of both groups.

Definition of Terms

The curriculum development process in engineering education involves structuring courses in various categories, some of which are applicable only to the field of engineering. This particular research study, in addition, involves particular sample groups which, in the interest of clarity, must be commonly understood by those analyzing the research data. The following definitions, therefore, will assist the reader in reviewing this study.

Curriculum.--A group of formal courses and laboratory experiences used by a school to provide opportunities for student learning leading to desired outcomes. In the present study the term pertains to all courses and laboratories available for formal training of engineering students.

Model Curricular Design.--A preferred set of courses and laboratory experiences structured in such a way that optimum learning occurs.

Selected Engineers.--For purposes of this study, electrical engineers in industry or other organizations working in a managerial or technical capacity.

Faculty.--Full-time teaching or research personnel in the Department of Electrical Engineering, excluding administrative-professional, clerical, and instructor/specialist employees, at the rank of Assistant Professor, Associate Professor, and Professor.

Nontechnical Courses.--Courses offered at Michigan State University which are available to Electrical Engineering students but not required by the College of Engineering. In the present study nontechnical courses include those required for graduation from Michigan State University as general (university) college credits such as social science, humanities, and English.

Basic Science Courses.--Science-related courses offered by nonengineering departments at Michigan State University such as chemistry, anatomy, or biological science.

Engineering Science Courses.--Courses offered in the College of Engineering which have their roots in mathematics and basic sciences, but carry knowledge further toward creative application. Courses which offer a bridge between basic science and engineering practice (20).

Engineering Design Courses.--Courses which involve the process of devising a system, component, or process to meet desired needs. Courses which offer skills in the decision-making process in which the basic sciences, mathematics, and engineering sciences are applied to convert resources optimally to meet a stated objective (20).

Organization of the Study

This study includes a review of the relevant literature in Chapter II pertinent to engineering education and curriculum design. Chapter III, a description of the research design, includes an overview of the population and samples tested in the study, the development of the survey instrument and pretesting procedures, and the data collection and data analysis procedures undertaken in the research. An analysis of the data is included in Chapter IV. And finally, Chapter V contains the summary and conclusion of the study, as well as recommendations for future research in the area of engineering curriculum design.

CHAPTER II

REVIEW OF LITERATURE

Introduction

Professional schools in the United States have been confronted with demands for educational change and revitalization at rates with which the average university organization is not ready to cope. While the rate of technological change in this country has been increasing, the dynamics of our society and of our technology have created an even larger expectation that changes will continue.

While this rate of change has been rapid, curricular innovations in American universities have not evolved with equal consistency. Instead, changes are made in academic programs after long intervals and these changes are slow in developing. Equally frustrating has been the lack of methodology or techniques to effectively adjust to a dynamic educational environment. And just as evident as the slow process by which curricular changes are made, faculty and administrators who demand rigor in their own classrooms or work expect much less when confronting curricular innovations on their own campuses. The willingness to approach curricular progress in this manner can be understood when one realizes that data for curricular design and content is not readily available.

Within this broad context of curriculum development, engineering education has played a significant role in the last decade. The Final Report of the Goals of Engineering Education stated the case clearly:

> To a larger extent than most other academic disciplines, engineering education has been the subject of extensive study. . . . At the same time there is clear evidence that forward looking educators and employers alike are conscious of the need for continued development and growth in engineering education. The rapid accumulation of knowledge of all kinds in recent years, the accelerating pace of technological developments, and the growing complexity of social, economic and technical interrelationships in modern society demand a careful and continual appraisal of all educational practices in terms not only of their adequacy of meeting present needs but of their ability to satisfy the much more demanding requirements of the future. (21:1)

In this chapter, a review of the literature dealing with curriculum development and design will be presented. The historical development of curriculum theory--the early beginnings of the theoretical constructs of curriculum thought--will be reviewed in detail to lay the groundwork for more specific discussions of curriculum development pertaining to engineering education. An overview of the progression of engineering education, from the first attempts to examine degree programs in engineering, will be given. These early attempts, and those being made presently, by engineering educators to strengthen the quality of both undergraduate and graduate degree programs is vitally important for a total understanding of engineering education. One can readily see that both practicing engineers and engineering educators, through their involvement in the American Society for Engineering Education, have been deeply involved in the on-going improvement of training programs.

Finally, research studies pertaining to curriculum development in engineering education will be reviewed and the findings relevant to this study analyzed. Included in this section will be a discussion of both technical and nontechnical courses which have been incorporated in training programs at institutions offering an undergraduate degree in electrical engineering.

Historical Development of Curriculum Theory

While much attention has been given to different aspects of curriculum such as design and evaluation, less has been written about the concept of curriculum development, the theory upon which a concern for curriculum rests. Probably one of the most fundamental analysis of curriculum theory has been written by Dressel (16) who stresses that the purposes and goals of higher education are important to the concept of curriculum development. "Learning must be given direction, meaning and organization by objectives which relate each unit and course to other courses and to the curriculum" (16:19). From this Dressel saw the purposes of higher education as preserving the cultural heritage and utilizing that heritage for a better environment. The functions of higher education are the ways in which these purposes can be achieved, as in the instructional process and community service.

In tracing the historical development of curriculum theory, Owen (55:9) stresses the significance of certain early events in the progress of curriculum development. Initially, the administrative machinery of Britain's Education Department began to be evaluated in early 1858. People began to express concern that the department was spending large sums of money while schools drifted into the position of finding themselves under centralized but purposeless governmental control. As a result, the Newcastle Commission was established to investigate the department and resulted in one of the earliest attempts of citizens to express concern for school curriculum matters.

The Newcastle Commission found that the Education Department exerted excessive control of information in the schools and the Revised Code of Conduct for the schools of Britain resulted. Under this Code a standard of attainment was established for students and curriculum decisions were relegated to a citizens board. Other significant events in curriculum development identified by Owen included the Elementary Education Act of 1870, in which local school boards were made mandatory, and the Bryce Report of 1889 which recommended the best methods of establishing a well-organized system of education in England (55:11). This report also contained segments referring to the involvement, or lack of it, of teachers in curriculum matters. Finally, the Education Act of 1902 further identified the role of administrators in dealing with curriculum matters and established student evaluation as a part of the school's function.

While similar events occurred in the United States, research by Koopman indicates that with the Yale Report of 1828 a more conservative approach to curriculum development was taken (39:3). This report reaffirmed the need for the classical curriculum with a prescribed set of courses and memorization of facts by students. While a challenge to this report was made in 1842 with the Wayland Report, which advocated expanded programs and more useful training for farmers and merchants, basically this traditional approach to curriculum design continued through the 1880s.

In the post Civil War era, developments occurred which began to liberalize the thinking of educators on curriculum theory. The expanded growth of the cities, the demand for more specialized skills, and the opportunities for specialized graduate study had an influence on the movement away from more traditional curricular designs. In 1876, more than 50,000 students were enrolled in collegiate departments and in 1894 Charles Elliot abolished required subjects for seniors and juniors at Harvard and helped support the elective system (39:11). At Johns Hopkins in 1885 President Daniel Gilman introduced seven elective programs, with any student having an opportunity to eliminate a required course with a credit by examination program.

Beauchamp identifies some additional events which had a major impact on the development of curriculum theory prior to 1900. The major-minor system was established which furthered the specialized training which students received in undergraduate school. In 1881 David Stan Jordan introduced an elective system around major areas of study at Indiana University which added to a less traditional approach to curriculum development. Also, Beauchamp (3) notes that the introduction of professional and technical curriculums, along with the establishment of agricultural and technical colleges, gave the most impetus to a more liberalized outlook on curriculum development. Medical schools were first established in 1765 in Philadelphia and Law schools in 1779 at William and Mary College (3:13).

Since 1900 the disorder created by the major-minor system has effectively been halted. Although more order had been restored in the 1900s, radical experiments in curriculum design had been attempted at Antioch, The University of Chicago, Bennington, and Swarthmore. During the era of World War II, the approach was to emphasize the development of broad interdisciplinary courses designed to give the students in a particular field an overview of major principles in addition to a specialization (3:15).

One of the more complete analysis of the development of curriculum theory has been written by Mullen (52) in 1976. He studied the entire spectrum of curriculum development from 1940 to 1975 and focused his study on the emergence of curriculum design, curriculum planning, and curriculum theory. The period of the 1940s, according to Mullen, witnessed an era of progressivism in curriculum design with ideas on curricular content and organization being primary and those on subjects being secondary (52:39). More concern surfaced in the 1950s for an academic emphasis in curriculum design and a blending of these two philosophies--concern for ideas and for academics--was evidenced in the 1960s. A renewed emphasis on humanism has been evident in the 1970s in curriculum design.

Another recent study contributing to the analysis of curriculum theory was by Bullough (8) in 1976. He studied the work of Harold Alberty, a noted educational leader at Ohio State University, and concluded that his work provides a case study through which to view the rise of curriculum as a separate field of inquiry within education. Alberty developed a macro design for curriculum organization based on philosophical and psychological foundations and because of these foundations his work added credibility to the field of curriculum theory.

A theoretical approach to the study of curriculum development was undertaken by Forbes in 1975 (22). She attempted to develop a curriculum framework that could be applied to program development in nursing without embarking upon empirical testing procedures. She developed an approach to program development in nursing through the establishment of a code of ethics for specifying the rules that govern program development in nursing. Another highly theoretical study of curriculum theory was conducted by Swensen (66). He maintained that epistemological considerations (those considerations which provide a theory of the nature and grounds of knowledge) are significant in curricular deliberations and that any epistemology selected for curricular purposes should conform to certain conditions. Since no curriculum escapes some epistemological preconceptions, any evaluation effort or original curriculum design study should be comprehensive, leading to a potential integration of the disciplines.

As indicated earlier, the period of the 1950s in curriculum development witnessed significant events which have had and will continue to have an impact on curriculum theory. Among these are an increase in the number of students attending colleges, an increase in the heterogeneity of students, the expansion of scientific research and the presence of international tension and its impact on American democracy. These developments have resulted in a reemphasis on the humanities and social sciences, moral training, and values in our nation's schools.

An Overview of Engineering Education

Few fields have engaged in such thorough self-analysis as engineering education during the last half-century. While basic course requirements have remained relatively stable for engineering students during this time, the changing technological scene has dictated that engineering education change accordingly in order to offer current training to students. An investigation of the growth of engineering education will reveal that it has indeed kept abreast of developments in the field.

Broadly considered, two prominent trends have influenced the history of engineering education in the United States. Initially, a strong desire for uniform standards and practices in engineering education prompted the field to take a dominant role in directing academic priorities for colleges and universities. These priorities were generally considered to be a provision for fundamentals in engineering curricula, educating the engineer to perform a variety of jobs (21:21). Wickenden recognized the need for such fundamental training and Hammond placed even greater emphasis on a broad education and suggested that a large part of the student's specialized training should be postponed until the senior year or even later (21:2). The general result of these two movements has been to indeed diversify engineering education, to create a program which has attempted to offer specialized education as well as a broad, fundamental orientation to the field.

The two movements referred to earlier were both influenced by and chronicled in several different studies in engineering education. The first study of noticeable impact was the Mann Report (44:31). Officially entitled The Report of the Joint Committee on Engineering Education, this report was the first major attempt to examine programs in engineering education. This significant report was predicated on a survey questionnaire of 3,246 engineers in industry and governmental agencies to determine what should be taught in undergraduate engineering schools. The report favored a five-year degree program in engineering, although the fifth year would be for a Masters Degree in a specific engineering field. It additionally stipulated the basic responsibilities of engineering education, namely a commitment to the individual, to society, and to the engineering profession. The basic objectives of engineering education were said to be the preparation of students for participation in a profit motive economy, the preparation of students for technological change, and for changes needed in mankind. Additional goals were the development in students of a conviction that education is both a self-discipline and a continuous process. The report also stressed that the first three years of undergraduate work should be general studies, including both theoretical and laboratory instruction. It also emphasized that engineers must be exposed to the humanistic side of engineering, to the questions of costs and values in the field of engineering.

The second major effort at laying the foundation for engineering education was the Report of the Investigation of Engineering Education, 1923-29. Known as the Wickenden Report, this study stressed that three areas should be emphasized in curriculum planning; the exact or pure sciences, foundations of the economy, and training in both written and spoken English (70:1067). This report agreed with the Mann Report that general and humanistic training were essential in an engineering curricular program. Wickenden expressed in his report more of a concern for the kind of continuing education which an engineering student would undertake upon completion of his degree than for the subject matter taught during the undergraduate training period.

The third study, written in 1940 and called the Hammond Report, addressed itself mainly to the need of an engineering program being extended for five to six years instead of the normal four-year period (26:563). Hammond also stressed a humanistic approach to engineering education and said that technical work should be done in the fifth or sixth years as opposed to the third or fourth years of undergraduate work. A second Hammond Report issued in 1944, entitled the <u>Report of the Committee on Engineering After the War</u>, essentially reaffirmed the content and conclusions of the first Hammond Report (26:564). The primary thrust of both reports was in the development of a method of approach in engineering.

The Grinter Report of 1955 was a response to the need for engineering education to ensure that it was keeping pace with the technological developments of the 1950s. While lengthy recommendations were made in the report, only three were considered of real importance to engineering curriculum development:

(1) A strengthening of work in the basic sciences, including mathematics, chemistry and physics.
(2) The identification and inclusion of six engineering sciences, taught with the full use of the basic sciences, as a common core of engineering curricula, although not necessarily composed on common courses.
(3) An integrated study of engineering analysis, design and engineering systems for professional background, planned and carried out to stimulate creative and imaginative thinking, and making full use of the basic and engineering sciences. (24:25)

The Grinter Report recommended that one-quarter of an engineering curricular program be composed of basic sciences (chemistry, physics, and mathematics) while another one-quarter consist of engineering sciences (thermodynamics, electrical theory, and field mechanics) (24:37). This was the first report of national significance to stress a greater emphasis on basic sciences and more emphasis on engineering sciences in an engineering curricular program.

The final, and most significant, major review of engineering education pertaining to curriculum was the Final Report of the Goals Committee, more commonly called the Goals Report, written in 1968. The Goals Report endorsed the five-year program as being the basic professional degree in engineering (21:17). It endorsed the basic tenants of the Grinter Report, including placing an emphasis on math, physical sciences, engineering sciences, engineering analysis, design and engineering systems. It also recommended a renewed emphasis on the humanities and recognized a need for better communication skills by engineers. The Goals Report stressed that engineering education should enhance general education, advanced study, and immediate productivity by engineering graduates (21:18). The report also categorized into three areas the subject matter which an engineering curriculum must stress. This delineation, important for the purposes of this study, is the last major attempt to define course content in this manner:

"MATH	PHYSICAL SCIENCES	ENGINEERING SCIENCE
Algebra	Physics	Electric Circuits
Trigonometry	Geology	Electronics
Calculus	Biology	Thermodynamics" (21:23)
Analytic Geometry	Astronomy	
Differential Equations		
Vector Analysis		

In addition to the studies mentioned earlier, several early authors expressed concerns for the future direction of engineering education and changes which needed to be made in curricular designs. Jewett (37:272) emphasized the need for engineering education to become more flexible, to change and adapt itself to the expanding and changing fundamental science. He thought that basic science courses needed to be strengthened, especially physics, chemistry, and math. Hollister likewise recognized the wealth of knowledge upon which engineers based their skill and called for innovative curricular programs to meet the demands for improved training for engineers (32:503). Other writers spoke about specific curricular course content in engineering education, notably John Ide, who foresaw a need in the future for problem-oriented research in an engineering program, primarily because support from the federal government had been decreasing (34:95). He recognized that much of what had been taught in education had emphasized engineering sciences rather than pure engineering. He additionally saw a need to direct attention towards practical research in transportation, energy, etc. Writing about steps which need to be taken in the future, Ide saw the following:

> (1) Science policy planning involving the relationship between states and municipalities.
> (2) Technology assessment.
> (3) Establishment of national goals, such as that established by the National Aeronautics and Space Administration. (34)

Probably one of the strongest areas of disagreement in engineering education circles deals with the question of whether theory or practice should play a dominate role in curricular content. This question will have a major influence upon this study and needs to be discussed here for that reason. A conference held at the University of Michigan dealt with this issue. The

Eight Ann Arbor Symposium in 1963 generally concluded that the need for theory in engineering education was essential, that it lays the groundwork for further specialized course work (19:77). Saying that "the engineering student should have enough practice mixed in with the theory so that the fundamentals can be thoroughly appreciated and really understood," the Symposium held that practice without theory in engineering education was useless, that one must have the basic theory presented in the first three to four years of undergraduate work and then begin to put it to use in a professional setting.

Curriculum Development in Engineering Education

A careful analysis of the literature in curriculum development and design reveals that little research has been conducted pertaining to the development of new or alternative curricular designs in academic institutions. Most related research, both current and more dated studies, have focused on the establishment of competencies in an area of study, with a series of courses then being matched to those competencies to better train college students. Also, studies have focused on the establishment of goals of a particular academic program and subsequently structuring courses to meet those goals. But rarely has a study been attempted which specifically compares the opinions of faculty and industry professionals to the courses which should be offered in an undergraduate program in an attempt to construct a curricular design.

Additionally, numerous studies have been conducted on two areas of curriculum which have received much attention during the last ten years. Secondary school administrators have been greatly concerned with curriculum change and evaluation, concerns which have in large part emanated from increased societal pressures for accountability in primary and secondary schools. While these two areas have a related bearing on the major focus of this research, they do not directly parallel this study and as such will not receive attention in the literature review.

However, professionals from the secondary school arena, and to a lesser extent those concerned with higher education, have been very active in the study of curriculum development and design. Studies centering on this topic have focused on areas related to this research, such as the study of opinions of faculty and students pertaining to undergraduate courses and using case study approaches to structure a model for curriculum development.

Two recent studies which surveyed faculty members in higher education concerning curriculum design have a close relationship to this research. Handleman (29) studied the opinions of faculty members using both an interview and survey research technique and objective and open-ended questions. He found that the rate of innovation of curricular development, as viewed by faculty members, should be reduced. In his sample group faculty members felt that the urgency to change, while an important concern, had become primary to the orderly development of an undergraduate degree program at several community colleges in Florida.

Hatch (30) studied medical school faculty through a survey questionnaire in developing a systems analysis approach to medical school curriculum. This study has a bearing on the present research because it involved an analysis of a professional school curricular design and it incorporated a survey of the faculty of a professional school. Hatch found that a systems analysis approach had potential for identifying objectives in medical education and that objectives of medical education had not basically changed in the past several years.

Monack (48) sought to determine whether new and advanced technological changes affected engineering education and if so to what extent curricular changes were made necessary. He sampled 158 faculty members, administrators of 154 institutions and a random sample of engineers to determine to what extent these three groups were similar in their views on curricular matters. He specifically focused on whether broader or more specialized training was needed as a result of suspected changes in technology in the United States. Monack concluded that there exists a strong feeling that specialization in an undergraduate engineering curriculum should be kept to a minimum. More emphasis should be placed in engineering curriculum on business courses such as economics, and psychology, personnel relations and engineering law. The essential ingredients which Monack recommended in an engineering curricular design based on his study included differential equations, vector analysis, modern physics, shop practice, basic electronics, and instrumentation (48:174). As in the Mann and Hammond Reports referred to earlier, Monack recommended a five-year engineering curriculum. His findings may be summarized as concluding that new technologies, which are constantly changing, have not greatly altered engineering curriculum. The changes which have occurred indicate a new approach in engineering education, with more emphasis on functional categories in engineering education.

Another major effort which investigated engineering curricula was a study commissioned by the American Society of Engineering Education in 1952. The Report of the Committee on Evaluation of Engineering Education surveyed accredited schools and in a final report in 1953 made four primary recommendations:

(1) Basic science courses should be increased
(2) Engineering science courses were important in an engineering curriculum but based on responses from 122 institutions they should not be increased in number
(3) Engineering design, analysis and systems courses are needed in a curricular program
(4) Technical elective courses should be increased (57:26)

A more recent investigation of engineering curriculum content was undertaken by Rader in 1970. He proposed that today's engineering graduate is undereducated in engineering synthesis and a counter to this trend would be to place less emphasis on theory and devote more time to practical items in the curriculum (56:972). Rader forecasted that engineering should be taught as it involves the many factors found in the business world, not as an analytical science. The curriculum must prepare the engineer for an early management position and an early introduction to the prolific world of materials. He indicated that new advancements in the field meant that the engineer must become more knowledgeable with respect to producibility.

John Dixon wrote about approaching the education of engineering students from a different viewpoint--that of preparing what he called a "design scientist" (14:33). While the engineering scientist is primarily theoretical and the engineering technologist more practical, the design scientist would be one in the middle, both theoretical and practical and in a position to affect public life. He must, because of this, be required to expose himself to social issues and humanistic challenges. Dixon proposed a model curriculum to train design scientists, including the following:

Basic Sciences	Physics, biology, chemistry
Math	Calculus, differential equations
Engineering Science	Circuits, thermodynamics, mechanics
Engineering Analysis	Dynamics, fluid mechanics
Humanistic Science	History, literature, economics

(14:35)

Other studies have used a research procedure similar to that being used in the present study--that of a rank ordering technique. Eure (20) in 1975 identified and arranged the goals of a core curriculum using a rank ordering technique and a scale of importance to which participants in the study could respond. Also using a Delphi technique, he used goal statements representing academic areas to present to a panel of experts. Howard (33) established a curricular design for the preparation of instructional paraprofessionals based on competencies needed by these personnel. The design established was based on the curricular planning process developed by Galen Saylor and William Alexander and was also conceptually evaluated by a panel of experts.

In a related approach to curriculum design, Roberts in 1975 attempted to construct a design for developing a multicultural curriculum (59). He concluded that there were several assumptions one makes about the establishment of a curriculum and that on the basis of these assumptions several other elements of a design for developing a multicultural curriculum could be advanced.

Other related studies in curriculum development and design have been primarily conducted for use at the secondary school level. Hall (25) studied the curriculum planning process and the products or outcomes of that process. This study looked at the quality of the courses being initiated from the curriculum planning process by surveying both teachers and administrators in a secondary school in suburban Chicago. Hall found that a high relationship exists between the quality of the planning process and the outcomes, or the curricular design, of that process.

In addition, Loret (42) focused on developing a curriculum model for a secondary school interdisciplinary program by interviewing selected schools interested in environmental education. He developed a five-phase model for developing a curricular design for environmental education. Stoutmire (64) generated a curriculum design studying a general education program in a community college through use of the Delphi technique. Conducting his study in three phases, he focused on the aims, objectives, and learning experiences of those students in the general education program and developed a curricular design more suitable to their future educational needs.

A number of studies have focused on the process which needs to occur before a curricular design can be proposed. Callison (11) used a conceptual framework to study curriculum design for the purpose of identifying which curricular elements in a program should be analyzed. Her study is useful because she found that the curricular analysis process does have utility, that it is applicable to use and as such can in other research be used to identify curricular elements and sources of data collection in curriculum research. Massey (45) used a case study approach to analyze and structure a model for curriculum development. He studied both personnel in a secondary school and those in the surrounding community to develop a curricular design for a school system in North Carolina.

Gaevert (23) conducted one of the more pertinent studies to the present research in 1975. She developed and validated a conceptual model for a curricular design which would better serve to train talented students in a professional program at a state university. Using an interviewing technique, she included faculty and students in an honors seminar to conceptually analyze the curricular process. She concluded that faculty and administrators responsible for developing curricular designs work from a broad conceptual perspective and always remain ready to adapt the curricular design appropriately. Domanico (15) studied the curricular reform movement within a given secondary school district to determine the options which existed for developing a model curricular design. He used a mailed questionnaire sent to 157 chief school administrators, concluding that the curricular reform movement in fact had an impact on the options which administrators used in developing their school curricular designs.

Four related studies have recently been conducted concerning curriculum development and design. Dukes (17) developed a model for the design of a community college curriculum through surveying faculty to determine the characteristics of community college students. He surveyed numerous administrative officers of thirty-nine community colleges in Illinois, including faculty, student personnel, and academic administrators. Using a mailed questionnaire and a rank ordering technique of student characteristics, Dukes found data on student characteristics as having a significant bearing on decisions which were made on curriculum development. Rowe (61) also studied the need for student-based data in reaching curriculum decisions. He developed and conducted a broad research project, gathering data from several sources in the United States, which identified need statements and were reacted to by both students and educators. He concluded, like Dukes in the earlier study, that student-based data were capable of affecting decisions made for a program's curricular design.

In addition, Moore (49) surveyed selected educators involved in the curriculum development process to determine the essential elements of that process. He found that data supported a systematic curriculum development procedure and that educators agree on the important elements which should go into that procedure. There is, however, much more knowledge of the procedures than there is a commitment to implement them. Bentson (5) surveyed a selected population in a school district in Virginia to assess whether institutional levels for curriculum decision-making were created during the evaluation of an existing curricular program. He found that during the process of curriculum studies organizations tended to create institutional structures to guide ways to implement potential changes in the curriculum. This study has a parallel to the present research because of the effects which an analysis of curricular designs can have on the eventual implementation--or lack of it--of results of such a study.

Edenborough (18) analyzed a current curricular program at a major state university by surveying graduates using the Delphi technique. He identified both strong and weak aspects of the undergraduate business program and found that many areas currently offered at the university were perceived as important to the graduate's occupation. He subsequently made recommendations for curricular revision based on the findings of the study.

Several additional contributions have been made in engineering curricular design. Wright (74) analyzed the role of research in undergraduate engineering education by informally surveying the engineering department at the University of Illinois. While limited opportunities were available to undergraduate students, they did have an opportunity to engage in a one-hour class to prepare themselves for research. Wright indicates that the advantages of such a program are that average students can become involved in research if some direction is offered and part-time employment is available to students under this arrangement. Waina (67) attempted to study engineering curriculum design by specifying objectives (stated goals) instead of looking at courses as in the present study. He wanted to specify objectives in such a way that their attainment could be measured on a binary. He proposed a procedure for eventually specifying an engineering curricular design to a high degree of detail.

Murphy (53) evaluated a typical engineering curriculum to determine how well it was designed with respect to the criteria of structure, content, and the laws of effective learning. He subsequently attempted to re-design the curriculum and offered recommendations on how the re-design could be implemented.

Related Research Studies in Electrical Engineering Curriculum Design

The nature of this study, focusing upon the curricular content of electrical engineering as viewed by both employers in industry and faculty at Michigan State University, necessitates not only a study of subject areas in general engineering courses but more specifically an analysis of research conducted on components of a curricular design in electrical engineering. Five authors were found to have addressed attention to this issue, and Kloeffler (38:400) offered the most thorough investigation of course content in electrical engineering. He analyzed the curriculum of one hundred schools in 1954 and found that the greatest percentage of time was spent with basic electrical subjects (14.5%). He also found physical sciences to consume 12.7 percent of classroom time, mathematics 14 percent, electric power or communications 10 percent, engineering fundamentals 7.0 percent, with engineering craftsmanship being 5.4 percent. He further noticed a reduction in time spent toward design, shop practice, and kinematics with increases in mathematics, physical sciences, and physics. In his study Kloeffler noticed that the institutions surveyed mentioned a continued pressure to increase the curricular content in their engineering programs. Various changes had been instituted to cope with these demands, namely by increasing the number of credit hours for graduation and replacing the credit hours originally specified for electives by credits from other areas within engineering. Kloeffler then suggested a five-year curriculum for electrical engineering students, with the average credit hour increase in various subject fields as follows:

Mathematics	3.3%
Physical Sciences	6.0%
Engineering Drawing	1.4%
Engineering Fundamentals	2.8%

He further suggested that a minimum of four years be required to complete an undergraduate degree, that more specialized training be offered to the undergraduate in business and research, and more exposure to humanistic subjects be included in curricular programs (38:584).

Ryder studied electrical engineering education between 1925-1951 and found that the teaching of circuits had greatly increased and instruction in electronics had been divided into three areas: physical background of the vacuum tube, characteristics of the tube itself and an analysis of the circuit in which the tube must operate (38:583). The major change which he discovered during the period of time of his study was entirely focused on the practicing engineer, whereas in the 1950s training focused on equipping the engineer with technical information and leaving the practical application to be gained on the job. Susskind (65:841), in a study of microwaves in engineering schools, found that of the 147 schools studied all had courses in microwaves. This subject area was increasingly being adopted as a field of study for undergraduate students, and in fact he reasoned that engineering schools frequently anticipate a demand and provide instruction in a new field such as microwaves before it is developed technologically.

Waina (68:99) conducted a study attempting to establish a model curriculum in electrical engineering based on the tasks engineers actually perform in professional practice. He examined the activities engineers engage in, structured a set of problems that engineering educators believe that graduates should be able to solve, and developed a set of objectives for courses which would equip students to perform such tasks. The courses for which objectives were established were taken from the ASEE Goals Report referred to earlier and included the following: Math, Computer Science, Synthesis and

Analysis, Design of Systems, Experimental Engineering, and Engineering Ethics. McEnamy (46) studied twenty-two accredited electrical engineering curricular programs and demonstrated the differing emphasis placed on subjects by the schools. He found that over 20 percent of classroom time was spent towards nontechnical subjects. And finally Belknap (4:181) conducted an extensive survey of industrial leaders' opinions of the need for certain subjects in an electrical engineering curriculum. He found that responses indicated more need for economics, applied and theoretical mechanics, advanced mathematics, advanced physics but no increased need for specialized design courses.

The previous studies have focused on the inclusion of technically related subjects in an engineering curriculum and the research which has been conducted by those interested in this area. The presence, however, of nontechnical subjects has been widely debated in engineering education circles and for purposes of this study this issue must be discussed. Several authors have written on this subject, most notably Charles Morrow. In looking at the preparation of engineering students Morrow identified several things industry would like to see incorporated in such a curricular program.

(1) A more positive attitude by engineering educators
(2) A diversified approach to training engineers
(3) A better orientation of the student to industrial procedures

(4) Establishment of special brief courses
(5) A course that teaches science as a process of discovery
(6) A course that teaches the application of scientific knowledge
(7) A course that interrelates subject matter of one area (ME) to another (EE) (50:73)

He felt that the preparation of engineers should focus on a case history approach and on preparing the student for a degree of independence in the classroom.

Bailey (2:336) thought that engineering education had become too specialized and that industry's own training programs had themselves become too specific. He also reasoned that education had adapted one of industry's tactics--that of mass education (an outgrowth of mass production). He recommended a need for schools to be engaged in human engineering, the preparation of engineers to become good citizens, aware of their place in society and of their ability to contribute. Osborne (54:200) studied industry's views of the need for humanistic education for the engineer. He indicated that the degree of success of a man or woman in an organization is more dependent on his character than on his technical knowledge, therefore, stressing the importance of humanistic education. And finally Wickenden (71), Davis (13), and Jackson (36) looked at nontechnical courses in an engineering education program and concluded that exposure to humanistic education must not be left to the colleges of liberal arts in universities. Both support required sequences of language and literature taught by faculty in engineering colleges throughout the country.

Summary

While the studies mentioned in this section have spaned nearly thirty-five years of debate on the needed content in an engineering education curriculum, it is clear that a similarity exists in what leading educators believe to be essential in an engineering program. The presence of technical training is essential, but the demand for nontechnical training has been called for just as vigorously. Courses in humanistic education, emphasizing economics, engineering law, psychology, and principles of business have been deemed important as has basic math, chemistry, physics, advanced math, and laboratory training. Any differences which have existed in the literature review have dealt more with when and in what degree these courses should be offered rather than if they are needed in a curricular program. However, just as noticeable is the lack of research conducted on local as opposed to national levels pertaining to views of faculty and leaders in industry on appropriate curricular content in an engineering program. The author found numerous studies conducted which surveyed these two groups to determine their views on two-year technology programs, but those applicable to four-year institutions are limited. Only Monack and Schweingruber investigated opinions on curricular design and the later primarily dealt with views of alumni.

The previous review has made clear that there is some agreement on the part of educators as to what should be included in an engineering program; however, it still remains necessary to determine if any agreement exists between faculty and employers in industry as to specific course content needed to adequately prepare engineers for positions of responsibility.

CHAPTER III

THE RESEARCH DESIGN

Introduction

The purpose of this study was to prepare a model four-year curricular design for the preparation of undergraduate electrical engineering students. As stated in Chapter I, the following questions were answered in the present research:

1. What do engineers in the electrical engineering industry suggest as the most important courses in the preparation of undergraduate students?

2. What do faculty in the Department of Electrical Engineering at Michigan State University suggest as the most important courses in the preparation of undergraduate students?

3. What model curricular design is suggested by both industry professionals and electrical engineering faculty at Michigan State University in the preparation of undergraduate students?

This chapter will include a description of the population and samples studied in the research, the methodological procedures used to develop the survey instrument, and the research design used to obtain and analyze the data collected in the study.

Population and Sample

As stated in Chapter I, the purpose of this study was to identify a model curricular design for undergraduate students by obtaining opinions from faculty and selected engineers regarding the relative importance of various courses. The population to be studied in this research included two groups.

Faculty Sample

All faculty members in the Department of Electrical Engineering and Systems Science, with the rank of Assistant Professor, Associate Professor or Professor, and who have as a major focus the field of electrical engineering, were included in the faculty sample group. Faculty in this Department concerned with Systems Science were not part of the group. A total of twenty faculty were included in the sample group.

The Department of Electrical Engineering and Systems Science was identified for the study because faculty members represent diverse areas of interest in the Department and, therefore, may be reasonably assumed to represent electrical engineering faculty in general.

Industry Sample

Because results from the present study were used as recommendations to the Department of Electrical Engineering at Michigan State University, participants in the research from industry were selected with a desire that they have some affiliation with the University. Selected engineers, therefore, were identified from those organizations which have employed graduates from the Department of Electrical Engineering in the last ten years.

Engineers in the firms to be included in the study were identified by random selection from the 1976 Institute of Electrical and Electronic Engineers (IEEE) Directory. This publication provided two advantages for use in the present research:

1. Because of membership in the IEEE, those engineers listed in the Directory have an expressed interest in the field of electrical engineering and most likely in the preparation of future engineers. Participants in the study from this group may provide information more indicative of the views of electrical engineers regarding academic preparation at the undergraduate level.

2. The IEEE Directory contains a current listing of electrical engineers in both line and managerial or staff positions who may respond to the survey.

> The opinions of engineers in both groups are needed to provide a balanced view from industry as to needed components in a curricular design.

Because of the desire to obtain results from both line and staff engineers from industry, respondents were asked to indicate the type of position held in industry prior to receiving the survey instrument. The categories of positions included in this inquiry are listed below:

Product	Production
Project	Plant
Research	Development
Sales	Management
Testing	Other
Design	

Final results from respondents are included with the research data in Chapter IV. A total of eighty electrical engineers from industry participated in the research study.

Methodological Procedures

The diverse nature of the two groups included in the research study, and the small number of participants in the faculty sample, dictated that several steps be taken by the researcher prior to data collection to encourage an extraordinarily high return rate of the survey instrument. Initially, discussions were held with the Acting Chairman of the Department of Electrical

Engineering, and with the Chairman of the Department Curriculum Committee to determine the relevance of the study to the field of electrical engineering education. These discussions focused on the potentially different viewpoints which faculty and industry professionals might have relative to the topic and the interest which the twenty faculty members might have in participating in the research.

In addition, because participants from industry represented a wide cross section of professionals both in position and geographical location, the Dean of the College of Engineering at Michigan State University was asked to assist in the correspondence with the industry sample. All correspondence with this group was initiated from the Dean's office and this procedure greatly assisted in the high return rate received from industry. Specifically, the first study yielded a 90 percent return rate from the faculty and selected engineers. In the second study 80 percent of the faculty and 81.2 percent of the industry sample returned the survey questionnaire.

Industry participants were sent a letter from the Dean of the College (Appendix E) along with the first curricular rating instrument (Appendix I). The second letter and rating form (Appendices H and J, respectively) were sent to the industry group at a later date. Faculty members were contacted via a personal letter from the researcher (Appendix G) and identical survey questionnaires were delivered to the faculty sample group through the use of on-campus mail services in the College of Engineering.

The need for a significant return rate from the industry sample prompted one additional step prior to the collection of data. To ensure that selected engineers would maintain their interest in participating in the study, preliminary contact was made with 150 electrical engineers also selected at random from the IEEE Directory. A letter introducing the study and the intent of the participation request was sent from the Dean of the College of Engineering (Appendix C) along with a post card (Appendix D) which if returned would indicate a willingness to participate. Eighty post cards were received from this initial group which were coded for follow-up mailings of the actual survey instrument. The eleven categories which identified the type of position held by the respondents were included on the acceptance post card.

The Survey Instrument

Several steps were involved in the development of the survey instrument. In discussions with the Chairman of the Curriculum Committee various theories were explored dealing with the need for theoretical as opposed to practical courses in the training of electrical engineers.

Specific courses were discussed and catalogues from numerous institutions offering an undergraduate degree in electrical engineering were studied to potentially incorporate a wide variety of courses in the research design. Although one goal of the study was to offer recommendations pertaining to the Department of Electrical Engineering at Michigan State University, institutions with programs different both in size and scope to that of Michigan State University were studied to ensure that a representative sample of courses was included in the study. After additional contact was made with several other faculty members and previous research was reviewed, the survey instrument was developed.

Additionally, another important step was taken in the preparation of the survey instrument with respect to the courses which were offered to participants for a response. The Engineering Council for Professional Development establishes very clear requirements to which institutions seeking to obtain or retain accreditation must adhere. These requirements identified by the Council are not in the form of actual courses but rather in length of semesters or terms according to broad subject areas. As an example, the Council stipulates that institutions must require one-half year of basic science courses to be taken from a list of courses which the individual institution may then specify.

Because of these very direct minimal requirements identified by the ECPD, the researcher developed the survey questionnaire recognizing these standards. Rather than present all possible courses in an undergraduate electrical engineering program to participants for response, those basic requirements were offered as a group to respondents. Respondents were then asked to either agree that these minimally required courses should be required in an undergraduate program or to agree that they should not be so required. This step was taken fully expecting the survey participants to indicate that those courses stipulated by ECPD should in fact be required in an undergraduate electrical engineering program. Total responses to this question in four of the six categories are reported in Chapter IV of this study.

The final format of the questionnaire used in the study was the product of a review of other similar studies on engineering curriculum design and the current literature in survey research on questionnaire construction. While several rating scales were considered, the format used in the present research permitted respondents to express views directly related to the importance of various courses in an undergraduate program. The rating scale proved to be easy to use and made it possible to compare responses to the first questionnaire with those of the second survey.

The Pretest

After development of the questionnaire, six electrical engineers not included in the final sample and two faculty members were asked to complete the pretest questionnaire. The selected engineers were identified at random from the A.C. Spark Plug Division Plant in Flint, Michigan and prior to administering the pretest a preliminary letter of introduction (Appendix A) was mailed to the participants. The instrument was then mailed to the respondents and a personal interview was arranged in order to solicit direct feedback about the questionnaire. All representatives from the industry and faculty groups completed the questionnaire and were interviewed. Based on the responses and the comments from the pretest, and suggestions from others solicited, the format of the questionnaire was revised and various items were either eliminated or added. The final questionnaire was then prepared for mailing.

The Research Design

This study will offer for consideration a model curriculum for an undergraduate program in electrical engineering. In order to achieve this, not only were the mean scores of each course important to consider, but the importance of the courses relative to one another was of equal value in analyzing a total undergraduate program. The research design was, therefore, structured to permit both an analysis of individual course mean scores and a rank ordering of the courses in each of the six categories used in the research.

Data Collection Procedures

To accomplish the goal of a rank ordering of courses, it was necessary to obtain two separate sets of responses from participants in the study. The first survey attempted to determine if both faculty and selected engineers were responding similarly to courses included in the questionnaire. Courses which received opposite ratings from the two groups (important and not important ratings) were eliminated after the first survey analysis was completed.

A second survey, including only those courses upon which agreement was received from the two groups, was distributed. Having ensured that there was similarity between faculty and selected engineers with the courses from the first survey, responses to this second questionnaire allowed both an analysis of mean scores and a rank ordering of the courses.

The response rates for both surveys in the data collection procedures were extremely high and are presented in Tables 3.1 and 3.2. Participants who did not return the first survey were included in the sample for the second questionnaire. However, no responses to the second survey were received from any individual who did

TABLE 3.1

SUMMARY OF FACULTY - INDUSTRY RESPONSES
SURVEY #1

	Faculty		Industry	
	Number	% of Sample	Number	% of Sample
Total Sample	20	100.0	80	100.0
Total Responses Received	18	90.0	72	90.0
Total Nonrespondents	2	10.0	8	10.0
Nonparticipating Respondents	0	0.0	0	0.0
Total Responses Used (N)	18	90.0	72	90.0

TABLE 3.2

SUMMARY OF FACULTY - INDUSTRY RESPONSES
SURVEY #2

	Faculty		Industry	
	Number	% of Sample	Number	% of Sample
Total Sample	20	100.0	80	100.0
Total Responses Received	16	80.0	65	81.2
Total Nonrespondents	4	20.0	15	18.7
Nonparticipating Respondents	0	0.0	0	0.0
Total Responses Used (N)	16	80.0	65	81.2

not participate in the first study. The 81.2 percent return rate from industry, therefore, encompasses all selected engineers who responded to the first survey.

Questionnaires were coded for each study and key punched by the researcher. After key punching was verified and a duplicate deck of cards made, data analysis procedures were begun.

Data Analysis Procedures

Five statistical techniques were used to analyze the data in the present study. For the results of the first survey, a multivariate analysis of variance was performed. Cell means and standard deviations were obtained, and an F score and the significance of F were computed to analyze each individual course in the six categories in the study. This test only determined the amount of agreement being expressed by the two groups but did not indicate in which direction agreement was being expressed. Conclusions, therefore, regarding whether specific courses are viewed as important or not important cannot be drawn from use of the MANOVA technique in the first step of the present research.

The four remaining techniques used in the analysis were applied in the second step of data collection. Initially, mean scores and standard deviations were calculated for each course for both faculty and industry groups. Composite mean scores (faculty and industry groups combined) were then calculated and a rank ordering of all courses on the basis of these mean scores was performed. Next, using the actual mean values obtained in the previous procedure, a Pearson product moment correlation was calculated to compare the degree of similarity between the two groups of respondents. Borg and Gall (7:327) indicate that when two variables are expressed as continuous scores, as are the mean scores in this study, a product moment correlation is the most appropriate technique to use. It has the additional advantage of being subject to a smaller standard of error than other techniques and, therefore, offers a more stable measure of relationship. The Pearson formula used in the data analysis is as follows:

$$r = \frac{\Sigma\ (X-\bar{X})\ (Y-\bar{Y})}{\sqrt{\Sigma\ (X-\bar{X})^2}\ \sqrt{\Sigma\ (Y-\bar{Y})^2}}$$

It must be stressed that this technique assists in determining the relationship between the faculty and industry groups on each of the course mean scores and not on the rank ordering. Borg and Gall (7:328) also stress that when continuous scores can be converted to ranks, categories or artificial dichotomies, other correlational techniques may be appropriate. The Spearman technique, therefore, was used to analyze the similarity between the rank ordering of the courses in each of the six categories used in the study. This rank difference correlation, rho, is a special form of the product moment correlation and is used when continuous mean scores are listed in order of magnitude and then merely assigned ranks. For purposes of data analysis for this research study, it is important to note that rank scores do not reflect the differences between subjects nearly as accurately as do continuous or mean scores. While the rank difference correlation reduces the precision of the data, this reduction is usually slight. The Spearmen formula used in the study is as follows:

$$r_s = 1 - \frac{6\Sigma\ (x-y)^2}{n\ (n^2-1)}$$

An alpha level of .05 was established to test all six hypotheses in the research study.

Summary

A brief description of the research design was included in this chapter. The two sample groups studied in this research, those of faculty members in the Department of Electrical Engineering at Michigan State University and selected engineers from a variety of organizations employing graduates of the Electrical Engineering Department at Michigan State, have been described. The development of the methodological procedures used in the study, including the design of the survey instrument and the pretest administered to a sample group, have been reviewed.

The researcher has also attempted to illustrate the need for a two-step approach in the collection of data for the present study. With the goal of itemizing various courses in terms of importance being a central theme in this study, a rank ordering of these courses became a prime method of depicting a model degree program in electrical engineering. The second survey conducted allowed such a ranking to occur. A review of the two correlational techniques used to analyze the research data has also been included in this chapter.

CHAPTER IV

ANALYSIS OF THE DATA

Introduction

The data presented in this chapter are the result of a survey of faculty in the Department of Electrical Engineering at Michigan State University and selected engineers in the field of electrical engineering. Participants in these two groups responded to six categories of courses in an undergraduate electrical engineering program according to the importance which they placed on various courses in the preparation of students for work in the field of engineering. The purpose of the research was to determine a model curricular design for an undergraduate program in electrical engineering. More specifically, the research structured a model four-year program from both technical and nontechnical course areas for possible use in the Department of Electrical Engineering at Michigan State University. The six categories of courses, and the various course titles, were selected from an analysis of undergraduate electrical engineering programs across the United States which both were similar to and different from the program at Michigan State University. All faculty with the rank of Assistant Professor and above, and who had as a major concentration electrical engineering, were included in the faculty sample. Electrical engineers, selected randomly from the 1975 IEEE Directory, were identified based on their affiliation with organizations or companies which have employed graduates from the Department of Electrical Engineering at Michigan State University during the last ten years. The research was conducted in two phases, enabling the investigator to initially determine whether participants were responding similarly, and then through a second survey questionnaire determining the amount of agreement between the two groups regarding the importance of the courses listed.

A total of eighteen faculty and seventy-two selected engineers completed the questionnaire in the first study phase for a 90 percent response rate for both groups. Sixteen faculty and sixty-five selected engineers responded to study #2 for an 80 percent and an 81.2 percent response rate respectively. Responses were transposed to data processing cards for analysis on the CDC 6500 computer at Michigan State University

Statement of Objectives

The six categories of courses were structured to enable respondents to indicate the degree of importance on a five-point scale of the various courses listed in the questionnaire. The subsequent analysis of the data was intended to achieve the following objectives:

1. To determine a model curricular design which is needed to adequately prepare electrical engineers for jobs in industry

2. To contrast the importance which selected engineers place on various courses in an electrical engineering program with the importance on such courses by faculty in the Department of Electrical Engineering at Michigan State University

3. To prepare a model curriculum, using six categories of courses, for potential implementation in the Department of Electrical Engineering at Michigan State University

Hypotheses

For purposes of this research project, a series of null hypotheses representing the six course categories was established for each of the objectives stated above. These hypotheses are as follows:

Hypothesis I:

There is no significant difference between mathematics courses suggested by practicing engineers and those suggested by faculty for a model curricular design in the Department of Electrical Engineering.

Hypothesis II:

There is no significant difference between basic science courses suggested by practicing engineers and those suggested by faculty for a model curricular design in the Department of Electrical Engineering.

Hypothesis III:

There is no significant difference between engineering design courses suggested by practicing engineers and those suggested by faculty for a model curricular design in the Department of Electrical Engineering.

Hypothesis IV:

There is no significant difference between engineering science courses suggested by practicing engineers and those suggested by faculty for a model curricular design in the Department of Electrical Engineering.

Hypothesis V:

There is no significant difference between technical elective courses suggested by practicing engineers and those suggested by faculty for a model curricular design in the Department of Electrical Engineering.

Hypothesis VI:

There is no significant difference between non-technical courses suggested by practicing engineers and those suggested by faculty for a model curricular design in the Department of Electrical Engineering.

Treatment of the Data

Subsequent to responses to the questionnaire being transposed to data processing cards, the Statistical Package for Social Sciences (SPSS) technique was used to test the research hypotheses. Basic descriptive data were accumulated by using the condescriptive technique within the SPSS procedures. For the results of the first study, a multivariate analysis of variance was employed. Within this test, an F score and the statistical significance of F were computed to analyze individual courses grouped according to the six general categories of courses. As stated in Chapter III, this test will assist in determining the extent to which faculty and selected engineers agree upon the importance of the courses. In addition, certain assumptions were made with respect to courses which should or should not be required in an undergraduate electrical engineering program. As mentioned in Chapter III, the Engineering Council for Professional Development stipulates various minimal standards for purposes of program accreditation, and these minimum requirements were offered as givens within the context of the survey questionnaire. As a result, F scores and the significance of F scores were tabulated from respondents in the form of a forced-choice from two options. Respondents either indicated that the ECPD stipulated minimal requirements within each of the six course categories should be required or should not be required. Pending a significant degree of similarity between the two sample groups on this variable for each of the six categories, this agreement was assumed for the second study and not included in that survey questionnaire.

In addition to the six course categories included in the questionnaire, two additional questions were asked of respondents concerning an undergraduate degree in electrical engineering. A Chi Square test of significance was employed to determine whether respondents thought the undergraduate program for electrical engineers should be maintained at four years, increased to five, or increased to more than five years. The same test was used to determine whether the Bachelor of Science or Master of Science degree should be the first professional degree granted to electrical engineers. A .05 level of significance was also used in the Chi Square test of significance. In study #2, mean scores and standard deviations were calculated for each individual course for the two groups of respondents. Composite mean scores were determined from which a rank ordering of all courses was arrived. In addition, a Pearson Product Moment Correlation using actual mean values was performed to compare the extent of group similarity. The Spearman Correlation technique was employed to test the similarity between the two sample groups of the rank ordering of courses.

In the first study, individual courses included in the survey questionnaire were rejected as not receiving significant agreement at the .05 level. More specifically, courses which received a score of .05 or below were rejected, indicating that no significant agreement was detected between the two sample groups. In the second study, the null hypotheses were rejected if the r scores from the Pearson Product Moment Correlation were also significant at the .05 level. A Spearman rank-order coefficient (r_s) of .7 or higher is usually the determining point for deciding significance in a rank-order technique. A score of .7 or higher in this research study was used to indicate high agreement between faculty and selected engineers in each of the six categories of courses.

The researcher selected the .05 level of significance for a variety of reasons. One assumption underlying the F test is that samples being compared are approximately the same size. Since the two sample groups in the present study were not of similar size, this assumption was not met. The .05 level of significance will, as a result, prohibit rejecting a true null hypothesis and at the same time allow for the identification of differences between the sample groups. The .05 level established in this case is, therefore, small enough to prevent a Type I error from being made yet flexible enough to allow for the identification of differences between sample groups.

Summary of Responses to Occupational Categories

Included on the jury response post card sent to selected engineers was information pertaining to the type of work in which the electrical engineers were involved. The goal in soliciting these data was to ensure that a balanced distribution of respondents was obtained from both managers and practitioners in the field of electrical engineering. While these data reveal that the highest percentage of engineers were from the managerial category, an almost equal distribution of line engineers participated from the functional areas of design, development, and project engineering. These data are summarized in Table 4.1.

TABLE 4.1

SUMMARY OF RESPONSES TO OCCUPATIONAL CATEGORIES

Variable	Absolute Frequency	Adjusted Frequency (%)
Project	5	6.9
Project	18	25.0
Research	7	9.4
Sales	3	4.2
Testing	7	9.7
Design	21	29.2
Production	5	6.9
Plant	5	6.9
Development	24	33.3
Management	26	36.1
Other	14	19.4

Summary of Responses to Individual Courses

Responses by the two sample groups to courses included in the survey questionnaire gave an indication of the level of importance placed upon individual subject areas. These responses were recorded on a five-point scale of importance and the results are given in Table 4.2. Both faculty and industry means and standard deviations are included, revealing a consistency of responses between 2.0 and 4.0 to most courses.

Results from this questionnaire also revealed a high degree of significance between the two groups of respondents. An F score and the significance of F were calculated, and the implication for each course list is given in Table 4.3. This table includes all courses in each of the six major categories incorporated in the survey instrument.

An important factor in the first study of this research dealt with the statistical basis upon which courses would either be retained or deleted from the second survey questionnaire. More specifically, based on mean scores and standard deviations, certain courses which received a high mean rating by both groups were deleted from the second study because of the relatively small variance between the two groups. Technical writing, as an example, received ratings of 1.35 and 1.98, respectively. However, in spite of the high

TABLE 4.2

SUMMARY OF MEANS - STANDARD DEVIATIONS FOR FACULTY - INDUSTRY STUDY #1

Variable	Faculty Mean	Faculty SD	Industry Mean	Industry SD
Mathematics				
a. Probability and Statistics	2.64	1.11	2.70	1.16
b. Complex Variables	2.76	1.43	2.94	1.39
c. Matrices	2.11	.85	2.80	1.28
d. Theory of Numbers	5.82	1.13	4.17	1.44
e. Advanced Calculus	3.11	1.26	2.92	1.50
f. Foundations of Analysis	5.35	1.16	3.79	1.38
g. Boundary Value Problems	2.94	1.19	4.07	1.32
h. Numerical Analysis	2.82	1.13	3.47	1.29
i. Applied Mathematics for Engineers	2.58	1.22	2.32	1.41
j. Partial Differential Equations	2.94	1.14	2.67	1.18
k. General Topology	5.64	1.22	4.73	1.21
Basic Science				
a. Quantitative Chemical Analysis	5.11	1.49	4.78	1.37
b. Solid State Physics	2.47	.79	2.77	1.40
c. Modern Physics	2.41	1.12	2.70	1.31
d. Statistical Physics	4.00	1.11	3.98	1.18
e. General Biology	5.23	1.14	5.63	1.11
f. Anatomy	6.00	.86	6.00	1.08
g. Engineering Thermodynamics	2.05	1.02	2.78	1.28
h. Optics	3.47	1.12	3.38	1.04
Engineering Science				
a. Electrodynamics	2.64	1.41	3.10	1.25
b. Electromechanics	3.17	1.33	3.07	1.27
c. Guided Wave Theory	2.82	1.18	3.77	1.43
d. Electric Machinery	2.94	1.29	3.14	1.39
e. Systems Science: Modeling and Analysis	2.58	1.27	2.61	1.31
f. Network Theory	2.47	1.50	2.00	1.00
g. Physical Principles of Electronic Devices	2.05	1.08	2.62	1.10
h. Introduction to Plasma Theory	4.29	1.49	4.42	1.42
i. Lasers	3.82	1.42	3.94	1.39
j. Statics	3.52	1.06	3.32	1.52
k. Dynamics	3.35	1.27	3.31	1.40

TABLE 4.2 (Continued)

Variable	Faculty Mean	Faculty SD	Industry Mean	Industry SD
l. Mechanics of Materials	4.11	1.05	3.81	1.27
m. Strength of Materials	4.29	1.31	3.62	1.40
n. Engineering Thermodynamics	2.64	1.11	2.90	1.26
<u>Engineering Design</u>				
a. Transmission and Radiation Laboratory	2.70	1.10	3.52	1.23
b. Communication Laboratory	2.64	1.32	3.29	1.27
c. Physical Electronics Laboratory	2.70	1.10	2.77	1.29
d. Introduction to Computer-aided Circuit Design	3.17	1.01	3.60	1.22
e. Microwave Networks and Antennas	2.76	1.09	3.19	1.12
f. Communication System Design	2.05	.74	2.73	1.05
g. Electronic Devices	2.29	.77	2.52	.96
h. Linear Integrated Circuits and Systems	3.00	1.50	3.47	1.21
i. Process Optimization Methods	2.58	1.27	3.08	1.25
j. Energy Conversion	4.05	1.24	4.35	1.15
k. Electronic Instrumentation in Biology-Medicine	4.05	1.24	4.35	1.15
l. Acoustics	4.64	.99	4.29	1.22
m. Digital Integrated Circuits and Systems	2.00	.86	2.32	1.01
<u>Technical Electives</u>				
a. Organic Chemistry	4.00	1.32	5.01	1.25
b. Physical Chemistry	3.76	1.43	4.54	1.33
c. Computer Assembly Language	3.41	1.50	3.16	1.49
d. Combinational Circuits	3.76	1.67	3.44	1.25
e. Technology and Utilization of Energy	3.00	1.54	3.12	1.42
f. Metals and Alloys	4.00	1.69	4.22	1.31
g. Physiological Ecology	5.00	1.54	4.77	1.25
h. Technical Drawing	3.94	1.51	3.40	1.46
<u>Nontechnical Electives</u>				
a. Philosophy	4.11	1.90	4.50	1.44
b. Economics	1.94	1.08	2.34	1.19
c. Sociology	4.41	1.58	4.55	1.41
d. Political Science	4.11	1.57	4.58	1.32
e. Labor Relations	3.35	1.83	3.97	1.41

TABLE 4.2 (Continued)

Variable	Faculty Mean	Faculty SD	Industry Mean	Industry SD
f. English Composition	1.47	1.00	2.20	1.37
g. Technology and Governmental Policy	3.52	1.46	3.91	1.18
h. Technical Writing for Engineers	1.35	.86	1.98	1.13
i. Inventions and Patents	4.00	1.54	4.01	1.42
j. Engineering Safety Standards	3.41	1.62	3.20	1.14

TABLE 4.3

MULTIVARIATE ANALYSIS - ALL ITEMS
STUDY #1

Category	F	Significance of F	Implication
<u>Mathematics</u>			
a. Probability and Statistics	.029	.862	No Significance
b. Complex Variables	.213	.645	No Significance
c. Matrices	4.38	.039	Significance
d. Theory of Numbers	18.99	.00004	Significance
e. Advanced Calculus	.235	.628	No Significance
f. Foundations of Analysis	18.209	.00005	Significance
g. Boundary Value Problems	10.234	.0019	Significance
h. Numerical Analysis	3.62	.060	No Significance
i. Applied Mathematics for Engineers	.478	.491	No Significance
j. Partial Differential Equations	.710	.401	No Significance
k. General Topology	7.70	.0068	Significance
Mathematics Total	5.95	.00001	
<u>Basic Science</u>			
a. Quantitative Chemical Analysis	.761	.385	No Significance
b. Solid State Physics	.733	.394	No Significance
c. Modern Physics	.716	.399	No Significance
d. Statistical Physics	.001	.964	No Significance
e. General Biology	1.741	.190	No Significance
f. Anatomy	.000	1.00	No Significance
g. Engineering Thermodynamics	4.73	.032	Significance
h. Optics	.060	.806	No Significance
Basic Science Total	1.66	.121	
<u>Engineering Science</u>			
a. Electrodynamics	1.70	.195	No Significance
b. Electromechanics	.090	.763	No Significance
c. Guided Wave Theory	6.33	.013	Significance
d. Electric Machinery	.292	.589	No Significance
e. Systems Science: Modeling and Analysis	.005	.941	No Significance
f. Network Theory	2.42	.123	No Significance
g. Physical Principles of Electronic Devices	3.65	.059	No Significance

TABLE 4.3 (Continued)

Category	F	Significance of F	Implication
h. Introduction to Plasma Theory	.120	.729	No Significance
i. Lasers	.099	.753	No Significance
j. Statics	.263	.608	No Significance
k. Dynamics	.010	.918	No Significance
l. Mechanics of Materials	.820	.367	No Significance
m. Strength of Materials	3.14	.079	No Significance
n. Engineering Thermodynamics	.571	.451	No Significance
Engineering Science Total	2.98	.001	
<u>Engineering Design</u>			
a. Transmission and Radiation Laboratory	6.25	.014	Significance
b. Communication Laboratory	4.81	.021	Significance
c. Physical Electronics Laboratory	3.47	.065	No Significance
d. Introduction to Computer-aided Circuit Design	.046	.829	No Significance
e. Microwave Networks and Antennas	1.75	.188	No Significance
f. Communication System Design	1.98	.162	No Significance
g. Electronic Devices	6.13	.015	Significance
h. Linear Integrated Circuits and Systems	.862	.355	No Significance
i. Process Optimization Methods	1.85	.177	No Significance
j. Energy Conversion	2.14	.146	No Significance
k. Electronic Instrumentation in Biology-Medicine	.853	.358	No Significance
l. Acoustics	1.21	.274	No Significance
m. Digital Integrated Circuits and Systems	1.46	.230	No Significance
Engineering Design Total	1.35	.201	
<u>Technical Electives</u>			
a. Organic Chemistry	8.84	.003	Significance
b. Physical Chemistry	4.54	.035	Significance
c. Computer Assembly Language	.370	.544	No Significance
d. Combinational Circuits	.782	.378	No Significance
e. Technology and Utilization of Energy	.102	.749	No Significance

TABLE 4.3 (Continued)

Category	F	Significance of F	Implication
f. Metals and Alloys	.350	.555	No Significance
g. Physiological Ecology	.392	.532	No Significance
h. Technical Drawing	1.82	.180	No Significance
Technical Elective Total	2.63	.012	No Significance
Nontechnical Electives			
a. Philosophy	.844	.360	No Significance
b. Economics	1.60	.208	No Significance
c. Sociology	.138	.710	No Significance
d. Political Science	1.58	.211	No Significance
e. Labor Relations	2.31	.131	No Significance
f. English Composition	4.19	.043	Significance
g. Technology and Governmental Policy	1.30	.256	No Significance
h. Technical Writing for Engineers	4.61	.034	Significance
i. Inventions and Patents	.001	.971	No Significance
j. Engineering Safety Standards	.290	.591	No Significance
Nontechnical Elective Total	1.16	.326	

individual course ratings, the small standard deviations of .86 and 1.13 reveal that there is little agreement about the importance of this course by faculty and selected engineers. This can be contrasted with another technical elective course, labor relations, which received ratings of 3.35 and 3.97. Although these ratings are lower in importance than those for technical writing, the high standard deviations of 1.83 and 2.31 reveal more overlap between the two groups and subsequently more agreement about the importance of this particular course.

With respect to the assumption of including the minimally required courses stipulated by ECPD in each of the six course categories, all respondents (100%) from both sample groups indicated that these courses should be required in an undergraduate electrical engineering program.

Seven of eight courses in the basic sciences category received similar responses from the two groups of participants. Only engineering thermodynamics received an F score significantly lower than the confidence level set for the study. In addition, all but one engineering science course--guided wave theory--received agreement between faculty and selected engineers. And three engineering science courses did not receive similar responses, those being transmission and radiation laboratory, communication laboratory, and electronic devices. Two courses each received no significant similarity in the elective course areas, those being organic and physical chemistry as technical electives and English composition and technical writing for engineers in the nontechnical elective categories.

Summary of Responses to the Nature of Undergraduate Programs

In the first survey questionnaire, two questions were asked of respondents pertaining to the nature of an undergraduate degree program in electrical engineering. The question of whether the undergraduate program for electrical engineers should be maintained at four years, increased to five or increased to more than five years was asked. In the faculty group, fifteen indicated that the current four-year program was desirable and none that a program of more than five years was acceptable. Forty-three industry professionals favored a four-year program, twenty-seven a five-year program, and only one a program of more than five years. With respect to the question of which degree should be the first professional degree granted to engineers, all seventeen faculty said the Bachelor of Science degree was the most appropriate while sixty-nine selected engineers had a similar response and two indicated the Master of Science degree as the preferable first professional degree. Results of these questions are included in Table 4.4.

TABLE 4.4

CROSSTABULATION OF RESPONSES TO THE NATURE OF AN UNDERGRADUATE PROGRAM STUDY #1

Variable	Chi Square	Significance	DF
Length of Program	4.70	.095	2
First Professional Degree	.042	.836	1

The responses to these questions indicated that there is no significant difference between the two groups in their views on the two questions. The Chi Square test of dependence indicated that answers to length of degree and first professional degree do not depend upon whether respondents are faculty or selected engineers.

Summary of Responses to Individual Courses Study #2

The second study conducted in this research was based upon findings gathered from responses received in the first survey questionnaire. Only courses which had no significant differences were included in this second study. Separate mean scores from the faculty and selected engineers revealed only slight differences in the importance placed upon individual courses.

Only six courses received a mean score lower than 2.0 and four courses a score higher than 5.0. Results of these data are presented in Table 4.5.

In addition, a rank-ordering of all courses was accomplished separately for the two groups. These data again reflect the similarity of ratings received from the two groups. In the mathematics category, as an example, both faculty and engineers rated applied mathematics for engineers and probability and statistics the highest of the six available courses, and the rank ordering of these two courses was the same (a rank ordering of 1 and 2 respectively). These data are illustrated in Table 4.6.

In addition, separate mean scores from each group were used to generate a composite mean score for all groups. The composite mean scores were very important in achieving the necessary rank ordering of all courses for the final model curricular design. Composite standard deviations, in addition to mean scores, are included in Table 4.7.

A composite rank ordering was then achieved based on the composite mean scores in the study (Table 4.8). These data will provide the real basis for the construction of a model curricular design to be proposed in Chapter V of this study. An important caution is necessary to note concerning the composite

TABLE 4.5

SUMMARY OF MEANS FOR FACULTY - INDUSTRY
STUDY #2

Variable	Faculty Mean	Industry Mean
Mathematics		
a. Probability and Statistics	2.41	2.72
b. Complex Variables	2.82	3.00
c. Advanced Calculus	3.58	2.83
d. Numerical Analysis	3.29	3.01
e. Applied Mathematics for Engineers	2.05	1.85
j. Partial Differential Equations	2.17	2.78
Basic Science		
a. Quantitative Chemical Analysis	5.17	4.91
b. Solid State Physics	2.00	2.34
c. Modern Physics	2.17	2.29
d. Statistical Physics	4.00	3.86
e. General Biology	5.35	5.68
f. Anatomy	6.05	6.14
g. Optics	3.47	3.55
Engineering Science		
a. Electrodynamics	2.11	2.67
b. Electromechanics	2.29	2.65
c. Electric Machinery	3.17	2.90
d. Network Theory	2.00	1.82
e. Introduction to Plasma Theory	3.70	4.09
f. Lasers	3.47	3.59
g. System Science: Modeling and Analysis	2.47	2.41
h. Physical Principles of Electronic Devices	1.52	2.41
i. Statics	3.52	3.09
j. Dynamics	3.52	3.08
k. Mechanics of Materials	4.11	3.73
l. Strength of Materials	4.29	3.72
m. Engineering Thermodynamics	2.58	3.23
Engineering Design		
a. Physical Electronics Laboratory	1.82	2.49
b. Introduction to Computer-aided Circuit Design	2.29	2.54
c. Microwave Networks and Antennas	2.88	3.19

TABLE 4.5 (Continued)

Variable	Faculty Mean	Industry Mean
d. Communication System Design	2.11	2.75
e. Linear Integrated Circuits and Systems	2.23	2.60
f. Process Optimization Methods	3.29	3.63
g. Energy Conversion	2.23	2.73
h. Electronic Instrumentation in Biology-Medicine	3.76	4.09
i. Acoustics	4.23	4.27
j. Digital Integrated Circuits and Systems	1.94	2.14
Technical Electives		
a. Computer Assembly Language	3.00	3.16
b. Combinational Circuits	3.17	2.98
c. Technology and Utilization of Energy	2.94	3.01
d. Metals and Alloys	4.35	4.39
e. Physiological Ecology	5.41	5.09
f. Technical Drawing	3.88	3.44
Nontechnical Electives		
a. Philosophy	4.17	4.39
b. Economics	1.76	2.18
c. Sociology	4.47	4.63
d. Political Science	4.11	4.45
e. Labor Relations	3.47	3.75
f. Technology and Governmental Policy	3.29	3.67
g. Inventions and Patents	2.70	3.85
h. Engineering Safety Standards	2.29	2.78

TABLE 4.6

COURSE RANK ORDERING - FACULTY AND INDUSTRY
STUDY #2

Variable	Faculty Rank Order	Industry Rank Order
Mathematics		
a. Probability and Statistics	2	2
b. Complex Variables	3	5
c. Advanced Calculus	6	4
d. Numerical Analysis	5	6
e. Applied Mathematics for Engineers	1	1
f. Partial Differential Equations	4	3
Basic Science		
a. Quantitative Chemical Analysis	5	5
b. Solid State Physics	1	2
c. Modern Physics	2	1
d. Statistical Physics	4	4
e. General Biology	6	6
f. Anatomy	7	7
g. Optics	3	3
Engineering Science		
a. Electrodynamics	3	5
b. Electromechanics	4	4
c. Electric Machinery	7	6
d. Network Theory	2	1
e. Introduction to Plasma Theory	11	13
f. Lasers	8	10
g. System Science: Modeling and Analysis	5	2
h. Physical Principles of Electronic Devices	1	3
i. Statics	9	8
j. Dynamics	10	7
k. Mechanics of Materials	12	12
l. Strength of Materials	13	11
m. Engineering Thermodynamics	6	9
Engineering Design		
a. Physical Electronics Laboratory	1	2
b. Introduction to Computer-aided Circuit Design	6	3

TABLE 4.6 (Continued)

Variable	Faculty Rank Order	Industry Rank Order
c. Microwave Networks and Antennas	7	7
d. Communication System Design	3	6
e. Linear Integrated Circuits and Systems	5	4
f. Process Optimization Methods	8	8
g. Energy Conversion	4	5
h. Electronic Instrumentation in Biology-Medicine	9	9
i. Acoustics	10	10
j. Digital Integrated Circuits and Systems	2	1
Technical Electives		
a. Computer Assembly Language	2	3
b. Combinational Circuits	3	1
c. Technology and Utilization of Energy	1	2
d. Metals and Alloys	5	5
e. Physiological Ecology	6	6
f. Technical Drawing	4	4
Nontechnical Electives		
a. Philosophy	7	6
b. Economics	1	1
c. Sociology	8	8
d. Political Science	6	7
e. Labor Relations	5	4
f. Technology and Governmental Policy	4	3
g. Inventions and Patents	3	5
h. Engineering Safety Standards	2	2

TABLE 4.7

SUMMARY OF COMPOSITE MEANS - BOTH GROUPS
STUDY #2

Variable	Composite Mean	Composite Standard Deviations
Mathematics		
a. Probability and Statistics	2.65	1.34
b. Complex Variables	2.96	1.39
c. Advanced Calculus	3.00	1.54
d. Numerical Analysis	3.07	1.18
e. Applied Mathematics for Engineers	1.89	1.16
f. Partial Differential Equations	2.87	1.48
Basic Science		
a. Quantitative Chemical Analysis	4.97	1.41
b. Solid State Physics	2.26	1.21
c. Modern Physics	2.26	1.05
d. Statistical Physics	3.89	1.21
e. General Biology	5.61	1.28
f. Anatomy	6.12	1.12
g. Optics	3.53	1.34
Engineering Science		
a. Electrodynamics	2.55	1.20
b. Electromechanics	2.57	1.08
c. Electric Machinery	2.96	1.39
d. Network Theory	1.85	1.10
e. Introduction to Plasma Theory	4.01	1.41
f. Lasers	3.56	1.32
g. System Science: Modeling and Analysis	2.42	1.11
h. Physical Principles of Electronic Devices	2.21	1.00
i. Statics	3.19	1.42
j. Dynamics	3.17	1.42
k. Mechanics of Materials	3.82	1.46
l. Strength of Materials	3.84	1.46
m. Engineering Thermodynamics	3.09	1.36
Engineering Design		
a. Physical Electronics Laboratory	2.34	1.20
b. Introduction to Computer-aided Circuit Design	2.48	1.24

TABLE 4.7 (Continued)

Variable	Composite Mean	Composite Standard Deviations
c. Microwave Networks and Antennas	3.12	1.30
d. Communication System Design	2.61	1.20
e. Linear Integrated Circuits and Systems	2.52	1.15
f. Process Optimization Methods	3.56	1.29
g. Energy Conversion	2.62	1.21
h. Electronic Instrumentation in Biology-Medicine	4.02	1.34
i. Acoustics	4.26	1.33
j. Digital Integrated Circuits and Systems	2.10	1.01
<u>Technical Electives</u>		
a. Computer Assembly Language	3.12	1.54
b. Combinational Circuits	3.02	1.24
c. Technology and Utilization of Energy	3.00	1.35
d. Metals and Alloys	4.38	1.36
e. Physiological Ecology	5.16	1.16
f. Technical Drawing	3.53	1.75
<u>Nontechnical Electives</u>		
a. Philosophy	4.34	1.59
b. Economics	2.09	1.17
c. Sociology	4.60	1.46
d. Political Science	4.38	1.53
e. Labor Relations	3.69	1.47
f. Technology and Governmental Policy	3.59	1.34
g. Inventions and Patents	3.60	1.57
h. Engineering Safety Standards	2.67	1.33

rank ordering provided in Table 4.8. One can readily determine, as mentioned earlier in this chapter, that there are slight differences between the composite mean scores provided in Table 4.6. Very definitive conclusions, therefore, will be made with respect to the ranking of all courses based on very close differences between mean scores. The difference between courses 4 and 5 in the mathematics category have a mean value difference of only .04. Yet in the construction of a model curricular design only four courses may be used from the mathematics category. Important distinctions will be made for purposes of meeting the goals of this study and must be noted with caution. Data concerning the rank ordering of courses are included in Table 4.8.

Summary of Pearson Product Moment Correlation Results

The first correlation results gathered from the Pearson Product Moment Correlation technique indicated generally a high degree of similarity between the two sample groups in all course categories. Borg and Gall (7) stipulate that an r score of .7 or higher indicates a high level of relationship between two variables, and results from this study reveal such a relationship between the faculty and industry groups (Table 4.9). The Pearson technique correlates the actual mean values gathered from study #2 of the research.

TABLE 4.8

COMPOSITE COURSE RANK - ORDERING
STUDY #2

Variable	Composite Ranking
Mathematics	
a. Probability and Statistics	2
b. Complex Variables	4
c. Advanced Calculus	5
d. Numerical Analysis	6
e. Applied Mathematics for Engineers	1
f. Partial Differential Equations	3
Basic Science	
a. Quantitative Chemical Analysis	5
b. Solid State Physics	1
c. Modern Physics	2
d. Statistical Physics	4
e. General Biology	6
f. Anatomy	7
g. Optics	3
Engineering Science	
a. Electrodynamics	4
b. Electromechanics	5
c. Electric Machinery	6
d. Network Theory	1
e. Introduction to Plasma Theory	13
f. Lasers	10
g. System Science: Modeling and Analysis	3
h. Physical Principles of Electronic Devices	2
i. Statics	9
j. Dynamics	8
k. Mechanics of Materials	11
l. Strength of Materials	12
m. Engineering Thermodynamics	7
Engineering Design	
a. Physical Electronics Laboratory	2
b. Introduction to Computer-aided Circuit Design	3
c. Microwave Networks and Antennas	7
d. Communication System Design	5

TABLE 4.8 (Continued)

Variable	Composite Ranking
e. Linear Integrated Circuits and Systems	4
f. Process Optimization Methods	8
g. Energy Conversion	6
h. Electronic Instrumentation in Biology-Medicine	9
i. Acoustics	10
j. Digital Integrated Circuits and Systems	1
Technical Electives	
a. Computer Assembly Language	3
b. Combinational Circuits	2
c. Technology and Utilization of Energy	1
d. Metals and Alloys	5
e. Physiological Ecology	6
f. Technical Drawing	4
Nontechnical Electives	
a. Philosophy	6
b. Economics	1
c. Sociology	8
d. Political Science	7
e. Labor Relations	5
f. Technology and Governmental Policy	3
g. Inventions and Patents	4
h. Engineering Safety Standards	2

TABLE 4.9

PEARSON PRODUCT MOMENT CORRELATION RESULTS BY CATEGORY

Variable	r Score	Significance of r	Implication
Mathematics	.74	.046	Similarity
Basic Science	.99	.001	High Similarity
Engineering Science	.84	.00	Similarity
Engineering Design	.83	.001	Similarity
Technical Electives	.96	.001	High Similarity
Nontechnical Electives	.94	.001	High Similarity

It is important to note that in the Pearson Product Moment Correlation the number of items, or courses, has been used as the n for the statistical procedure instead of the number of respondents from the two sample groups. Therefore, the lower number of items in the mathematics category--six--means that the significance of the r score (.046) computed for this category indicates the raw r has less validity as an indicator of similarity between the two groups. The higher the n value in this correlation technique, the more meaningful the r score is and conclusions arrived at in these categories are more statistically sound.

Summary of Spearman Rank Order Correlation Results

A similar approach may be taken in interpreting the results of the Spearman rank order correlation results. This technique correlates the actual rank order of courses between groups and also reveals a high degree of similarity. While engineering science received the least degree of similarity of responses, this technique actually indicates that there is less overlap, or correlation, between the ten courses rank-ordered in engineering science than there is between courses in any other category in the research. Courses suggested, therefore, for a model curricular design from this category would be offered with this caution in mind. Similarly, the mathematics category again was correlated low, with a high significance of r, and must be approached with equal caution. Results from the Spearman technique are included in Table 4.10. The summary conclusion from the analysis of data in the two correlation techniques revealed less similarity between the ranking of courses than between the mean values for the two sample groups studied. The rank ordering, therefore, while an important tool for this study has less validity in revealing the degree of importance placed upon all courses in the survey than does the correlation between mean values.

Summary

The purpose of this study was to propose a model curricular design for the preparation of undergraduate electrical engineers comparing responses of two sample groups to various technical and nontechnical courses.

To achieve this objective, six null hypotheses were offered each centering upon a specific category of courses commonly included in an undergraduate electrical engineering program at many institutions. Using the Pearson Product Moment Correlation technique, and a .05 level of significance, these six hypotheses were tested and the results are included in Table 4.11 (see page 92).

TABLE 4.10

SPEARMAN RANK ORDER CORRELATION RESULTS BY CATEGORY

Variable	r Score	Significance of r	Implication
Mathematics	.71	.056	Above Acceptable Level
Basic Science	.96	.001	Above Acceptable Level
Engineering Science	.87	.001	Above Acceptable Level
Engineering Design	.63	.025	Below Acceptable Level
Technical Electives	.82	.021	Above Acceptable Level
Nontechnical Electives	.90	.002	Above Acceptable Level

TABLE 4.11

SUMMARY OF RESEARCH HYPOTHESES RESULTS

Research Hypotheses	Decision
Hypothesis I There is no significant difference between mathematics courses suggested by practicing engineers and those suggested by faculty for a model curricular design in the Department of Electrical Engineering.	Not Rejected
Hypothesis II There is no significant difference between basic science courses suggested by practicing engineers and those suggested by faculty for a model curricular design in the Department of Electrical Engineering.	Not Rejected
Hypothesis III There is no significant difference between engineering design courses suggested by practicing engineers and those suggested by faculty for a model curricular design in the Department of Electrical Engineering.	Not Rejected
Hypothesis IV There is no significant difference between engineering science courses suggested by practicing engineers and those suggested by faculty for a model curricular design in the Department of Electrical Engineering.	Not Rejected
Hypothesis V There is no significant difference between technical elective courses suggested by practicing engineers and those suggested by faculty for a model curricular design in the Department of Electrical Engineering.	Not Rejected
Hypothesis VI There is no significant difference between nontechnical courses suggested by practicing engineers and those suggested by faculty for a model curricular design in the Department of Electrical Engineering.	Not Rejected

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Purpose and Need for the Study

The curricular planning process in higher education today is one of the more difficult and demanding tasks for educational leaders. Yet for institutions to stay attuned to serving the needs of the public, the curricular design process must be viewed as the central element around which the teaching, research, and service responsibilities of a university faculty revolve.

Implementing a process of planning courses which are to be offered in a college of university, however, is not a simple task. While several studies have been conducted which have focused on the views of students and alumni regarding an undergraduate engineering program, none has addressed the issue of what opinions are held by practicing engineers with respect to the courses needed to adequately prepare future students to solve the problems posed by a constantly changing technology. The following research effort, therefore, attempts to incorporate the viewpoints from selected engineers who have an indirect affiliation with Michigan State University for the purpose of constructing a model curricular design in the field of electrical engineering.

Chapter V presents a summary of the development of the study, the results of the research, and recommendations for future research in the area of engineering curriculum design.

Summary of the Study

The purpose of this study was to prepare a model four-year curricular design for possible future use in the Department of Electrical Engineering at Michigan State University. The study was also intended to be of use at other institutions in comparing the viewpoints of electrical engineering faculty and selected engineers working in various organizations throughout the United States. It was the intent, additionally, of this research effort to focus on both technical and nontechnical courses which would be part of an undergraduate program. In Chapter I of this study, the problem to be addressed was stated and the purposes of the research identified. Research questions to be addressed were presented which formed the basis for the six research hypotheses.

A review of related research was presented in Chapter II of the study. This review included a review of the historical development of curriculum theory and an overview of engineering education. The analysis of engineering education revealed that basic objectives of engineering education had been established early in the field and that both theoretical and practical courses should be offered to engineering students. Chapter II also reviewed the major developments in curriculum theory in both engineering education in general and electrical engineering specifically. The author concluded that little research had been attempted in the area of curriculum development in engineering education and that no study had been done specifying a model curricular design for the preparation of undergraduate electrical engineering students.

The research methodology and design of the study were presented in Chapter III of the research. The major basis for the design of the study was outlined, revealing that two separate survey questionnaires would be used in the study for the two sample groups included as respondents. This method of data collection enabled the researcher to determine whether similar responses were being received on specific courses in the initial survey effort, and from the second survey questionnaire what kind of similarity (agreement or disagreement) was being expressed.

An explanation of the data analysis procedures was also included in Chapter III. Five statistical techniques were used in analyzing the data and were discussed in Chapter III also. Initially, a multivariate analysis of variance was employed to test significance of each individual course with respect to responses received from the two sample groups. Additionally, mean and standard deviation scores were calculated which enabled composite mean scores to be obtained for each course. This procedure led to a rank ordering of all courses used in the second survey. The Pearson Product Moment Correlation technique and the Spearman Rank Order technique were employed to compare the degree of similarity between the two groups of respondents.

The data collected from the survey questionnaire was analyzed and presented in Chapter IV. The results of the multivariate analysis of variance in step #1 of the study were presented and courses which did not receive similar responses from the sample groups were deleted. Results of the rank ordering of courses were presented in this chapter and the correlational techniques to compare the two groups were given.

Conclusions

The following sections of this chapter will present for review the conclusions and implications of the study and recommendations for future research. Results from the data concerning occupational categories, results from the two studies conducted, and specific findings regarding each course category will also be reviewed in the following pages.

Information was initially collected concerning the type of occupational category in which selected engineers were involved at the time of the completion of the questionnaire. The goal in soliciting these data was to ensure that a balanced distribution of respondents from this group was obtained from both managers and practitioners in the field of electrical engineering. This goal was satisfied, as the largest number and percentage of respondents were from the management area of electrical engineering and a balanced proportion were from other practical areas of the profession. An important conclusion drawn from these data was that the number of trained electrical engineers currently in the area of sales engineering is predictably small. This fact is not surprising when one considers the increasingly large number of business graduates and interdisciplinary-trained engineering graduates who have been employed in the areas of technical and industrial sales and marketing. An additional result of these data not revealed in Chapter IV but gathered from the jury response post cards returned to the researcher was the widespread cross-mixture of occupational categories designated by many respondents. More specifically, individual respondents frequently identified more than one occupational category in which they had responsibility, revealing that for electrical engineers functional categories cannot be rigidly or narrowly defined, that more frequently an engineer involved in one area of practice will also have responsibility in another as well. It appears, however, that this does not pertain to those engineers in the management area. These individuals most often classify themselves as managers without accompanying involvement in a practicing area of engineering.

Study #1

Mean and standard deviation scores from Study #1 revealed a limited range of responses to the importance placed upon individual courses by the two sample groups. The two groups tended to rate courses included in the survey questionnaire toward the median of the scale, indicating that courses were viewed as important to moderately important. More specific results were obtained in each of the major course categories and are discussed below.

The tendency for both faculty and selected engineers to rate courses toward the median range was most clearly illustrated in the mathematics category. Only four courses were given a score other than in the 2.1-2.9 range, and only two courses were rated as low as 5.6-5.8. There was also a similar rating between the faculty and selected engineers. Both groups rated the same two courses (theory of numbers and general typology) as the lowest in importance in an undergraduate program. It may be concluded that both groups rated theoretical courses in mathematics as less important than applied courses. The high rating of probability and statistics and applied mathematics as opposed to theory of numbers is evidence of this difference in viewpoints.

Courses in the basic science category received less similar ratings than did mathematics courses. Clearly, courses which have a secondary relationship to electrical engineering (anatomy and general biology), as opposed to those which may be more directly related to physical and chemical systems in electrical engineering, were rated as lower in importance. Properties of physics and chemical analysis are more closely related to electrical engineering than are anatomy and biology.

Courses in engineering design also received very similar responses and only three were not incorporated in the second study. These were transmission and radiation laboratory, communication laboratory, and electronic devices.

Courses in the engineering science category generally were not rated similar by faculty and selected engineers. Only three courses were not rated in the important-to-moderately important range and only one course did not receive similar responses from the two groups.

Additionally, more than any other category technical elective courses were rated less similar than were those in the five other groups. Physiological ecology and organic chemistry were the two lowest rated subjects by the two sample groups. And courses in the nontechnical elective category received a somewhat wider range of responses than did courses in all categories except the technical elective group. Two courses were deleted from this category for the second study. English composition and technical writing for engineers received very high ratings by both faculty and selected engineers. While engineering is a highly technical and often theoretical field, the need exists for engineers to have an ability to write clearly and concisely. General reports and proposals for research and development projects require that engineers justify a proposal if it is to be accepted. The results of the first study would indicate, therefore, that generally both groups rated these two courses very high. The use of courses in this study which received high ratings, such as the two subjects discussed here, was dictated by methodological considerations. These considerations were discussed in Chapter IV and have a significant impact on the design of this study (see p. 76).

With these limits imposed, technical writing for engineers and English composition were highly rated by the two groups but they were not retained in the second study. Implications of these results are discussed later in this chapter.

Included in Chapter IV were data concerning two questions which were asked of respondents in the first survey questionnaire. Participants in the two sample groups were asked whether the length of an undergraduate degree program in electrical engineering should be maintained at four years, increased to five years, or increased to more than five years. This question was included in the survey because of its obvious connection with the question of what subject areas should be contained within an undergraduate electrical engineering program. This research study confined itself to an attempt at structuring an undergraduate program in electrical engineering specifically within a four-year model. The courses which were offered for response from participants were selected primarily because only a limited number could be identified to comprise a four-year degree program. It was the attempt of the researcher to allow respondents to indicate that, the limitation placed upon the survey design not withstanding, an undergraduate degree program may more appropriately be offered in a greater length of time than contained in this study. Respondents were also asked whether the Bachelor of Science or the Master of Science degree should be the first professional degree granted to engineering students. Results of these two questions could possibly be used as a basis for discussing future research needs in the area of engineering curriculum development.

Fifty-eight respondents, or 65.9 percent, indicated that the undergraduate degree program in electrical engineering should be maintained at four years. Twenty-nine, or 33.3 percent, preferred a five-year degree program, and one indicated a preference for a program of longer duration than five years. With respect to type of professional degree, eighty-six, or 97.7 percent, responded that the Bachelor of Science degree should be the first professional degree offered to engineering students. Two, or 2.3 percent, preferred that the Master of Science degree be the first degree offered. These results indicated that both faculty and selected engineers view the needed length of an undergraduate engineering program similarly and there were similar views regarding what professional degree should be the first offered to engineering students.

Study #2

Results obtained from the second study in general revealed a high degree of similarity in individual course ratings between faculty and selected engineers in all six categories. Mean scores between the two groups were similar and both faculty and engineers tended to rate courses towards the median range in terms of importance.

The rank ordering of courses by the two sample groups reflected this similarity. In the mathematics category, as an example, two courses were rated as the highest by both groups of respondents. Applied mathematics for engineers and probability and statistics were rated 1 and 2 by both groups. Solid state physics was rated #1 by faculty and #2 by selected engineers, while modern physics was rated #1 by engineers and #2 by faculty.

Results from the second survey revealed that the six research hypotheses should not be rejected at the .05 level of significance. There is no significant difference, therefore, between how faculty in the Department of Electrical Engineering and selected engineers from across the United States view the importance of major categories of courses within an undergraduate electrical engineering program. It was very evident that the two sample groups tended to view the importance of three course categories with an extreme degree of similarity. Basic science courses received a .99 r score, technical electives .96, and nontechnical electives .94. While these results are not surprising concerning the basic science courses, the scores in the technical and nontechnical elective areas were not expected. While the philosophy of a general education approach at the undergraduate level has been continually debated for a number of years, these results would indicate a significant level of acceptance of that philosophy by both faculty and selected engineers.

The rank ordering of course categories also supported the above conclusion. While basic science courses received the highest r score (.96), nontechnical electives received the second highest ranking (.90).

A Model Curricular Design

The purpose of this study was to propose a model four-year curricular design for the preparation of undergraduate electrical engineering students. To determine the parameters for this model, decisions were made with respect to the number of credit hours which would be included in each of the six categories of courses. These decisions were reached by surveying the electrical engineering programs of a variety of institutions of higher education to determine the average credit hours required in each of the six course categories. The programs surveyed were the same institutions referred to in Chapter I which were studied for purposes of determining the course titles to be used in the survey questionnaire used in this research study. In the interest of clarity, it was decided that quarter rather than semester hours would be used in this model and that the total credit hours would approximate 175 credits for a four-year program. Subsequent to this review, the following credit hours in each of the six course categories were used:

Mathematics	24 credit hours
Basic Science	23 credit hours
Engineering Science	46 credit hours
Engineering Design	24 credit hours
Technical Electives	17 credit hours
Nontechnical Electives	41 credit hours

An additional basis for the model presented here is that the minimally required courses stipulated by ECPD, and referred to earlier in Chapter III, will be used in this design. Both sample groups conclusively agreed that these courses should be included in an undergraduate electrical engineering program.

The following model curricular design, therefore, is proposed for the preparation of undergraduate electrical engineering students. Courses in the design are listed in priority order according to results of the research study.

Mathematics

Calculus with Analytic Geometry

Calculus with Vector Analysis

Ordinary Differential Equations

Applied Mathematics for Engineers

Probability and Statistics

Partial Differential Equations

<u>Basic Science</u>

General Chemistry - General Chemistry Laboratory

General Physics - General Physics Laboratory

Solid State Physics

Modern Physics

Optics

Statistical Physics

<u>Engineering Science</u>

Computer Programming for Engineers

Electric Circuit Theory - Electric Circuit Theory Laboratory

Signals and Information

Electromagnetics - Electromagnetics Laboratory

Control Theory

Network Theory

Physical Principles of Electronic Devices

Systems Science: Modeling and Analysis

Electrodynamics

Electromechanics

Electric Machinery

Engineering Thermodynamics

Dynamics

<u>Engineering Design</u>

Basic Electronic Circuit Design - Circuit Design Laboratory

Control Systems Design

Engineering Design (continued)

Digital Integrated Circuits and Systems

Physical Electronics Laboratory

Introduction to Computer-aided Circuit Design

Linear Integrated Circuits and Systems

Communication System Design

Energy Conversion

Technical Electives

Technology and Utilization of Energy

Combinational Circuits

Computer Assembly Language

Technical Drawing

Metals and Alloys

Nontechnical Electives

Economics

Engineering Safety Standards

Technology and Governmental Policy

Inventions and Patents

Labor Relations

Philosophy

Political Science

Sociology

Implications of the Study

The results of the research contained in this study, the samples used in the collection of data, and the accompanying model curricular design included earlier in this chapter present numerous implications for the overall conclusions to be drawn from this study. As an example, the cross section of participants selected from industry were chosen from a large geographical spectrum and selected engineers were identified from various functional areas within the field of engineering. And all faculty selected in the study held the rank of Assistant Professor or above in a Department of Electrical Engineering. The identification of these two sample groups, however, had certain delimitations. Selected engineers were identified based upon their employment with an organization previously employing graduates from the Department of Electrical Engineering at Michigan State University. And only certain functional areas of engineering were represented by the selected engineers participating in the study. Likewise, the faculty sample identified were all from the Department of Electrical Engineering at Michigan State University and, therefore, represented a more limited perspective on the importance of various courses to be included in a curricular program. Based upon these delimitations, the model curricular design suggested in this chapter is only one of numerous models which might be appropriate for the preparation of undergraduate electrical engineering students. While the design offered in this study reflects a broad range of both technical and nontechnical courses, this model may not be the best approach in structuring a four-year degree program but rather may merely be one of several alternatives to be considered by Departments of Electrical Engineering in the future.

Another implication of this study, resulting from the individual ranking of courses by both groups and referred to earlier in Chapter IV, pertains to courses which were excluded from the final model curricular design. Probably most surprising to the author was that the communication courses originally included in the survey questionnaire (English composition and technical writing for engineers) initially received high ratings by faculty and engineers but were not retained in the final model design. While English composition received ratings of 1.47 and 2.20, and technical writing for engineers received scores of 1.35 and 1.98 by faculty and selected engineers, respectively, the statistical procedures used in this research resulted in these two courses receiving a significant degree of difference by the two groups. Courses in communication skills which have received much attention in the technical areas by both practicing engineers and engineering educators were, therefore, not included in the model curricular design.

However, an interesting result of the data which was equally controlled by the statistical procedures used in this research was the handling of matrices in the mathematics category. While this course also received relatively high ratings from both sample groups, it also was not included in the final model. Being primarily a theory course, matrices has received increasingly unfavorable reaction as a course to be required of undergraduate students and is in fact to be dropped as a required course from the Electrical Engineering Department at Michigan State University. While statistical procedures permitted this course to be deleted from the model design, the absence of this course fails to carry the same impact as does the absence of the communication courses referred to earlier.

Finally, the model curricular design presented here, although developed in part from responses of electrical engineering faculty at Michigan State University, presents an interesting comparison with the four-year program currently offered by this Department. Most notably, the minimal requirements stipulated by the Engineering Council for Professional Development which forms the basis for the undergraduate program within the Department at Michigan State was also the foundation for the model program presented here. As indicated in Chapter IV, all respondents in the sample groups favored the inclusion of these basic mathematics, basic science, engineering science, and engineering design courses in the four-year model program making it at least fundamentally similar to the Michigan State program.

Other interesting comparisons may be made between the two undergraduate programs. Theory of matrices, mentioned earlier, is required by the existing program but excluded in the model design. In the basic science category, an unusually heavy emphasis is placed upon physics courses in the model design whereas additional chemistry is stressed in the Michigan State program. Modern physics is, however, offered as an elective basic science which Michigan State undergraduates may take to fulfill that requirement but it is included in the model design presented here.

In the engineering science category one immediately notices that the model suggested a greater emphasis on electromagnetics and physical electronics courses to the possible exclusion of systems and communication courses. This may not be surprising, nor may the fact that the Michigan State program likewise stresses these courses. The faculty participating in the study from Michigan State are indeed more representative of electromagnetics and physical electronics in the field of electrical engineering than they are of the system and communication fields. This background was, one may conclude, evident in the ratings which faculty offered in both the first and second study in the research. Additionally, an examination of specific courses in the engineering science category contained both in the model and the Michigan State program further illustrates this point. Six courses, generally placed in the areas of electromagnetics and/or physical electronics, were included in the model curricular design, including electromagnetics, electrodynamics, electric machinery, introduction to plasma theory, lasers, and physical principles of electronic devices. In the undergraduate electrical engineering program at Michigan State University at least ten credit hours of electromagnetic or physical electronics courses are required and two courses are optional to electrical engineering students. These results indicate a high degree of similarity within the engineering science category between the model design and the existing electrical engineering program at Michigan State University. A significant degree of similarity also exists between the two programs with respect to engineering design courses. The model reflects a greater emphasis on digital electronics and systems courses, represented by linear integrated circuits and systems, electronic instrumentation in biology and medicine, digital integrated circuits and systems, and process optimization methods. The Michigan State program is similar, with courses such as control systems, control systems laboratory, digital electronics (two courses), and process optimization methods.

And finally, very important differences exist between the technical and nontechnical electives in the model design and that of the Michigan State curriculum. Most noticeable is that the Michigan State program does not offer many of the courses included in the model design. Courses such as technology and the utilization of energy, engineering safety standards, inventions and patents, and technology and governmental policy are not available to Michigan State University electrical engineering students. Other courses in these two categories are available to Michigan State University students but are not frequently chosen by students. Examples of these courses would be labor relations, philosophy, and metals and alloys. Still other courses, such as technical drawing and economics, are both available to Michigan State students and are increasing in popularity and acceptance.

Recommendations for Further Research

The major purpose of this study has been accomplished. However, during the process of research additional questions frequently arise which may merit further investigation. This study has generated the following areas in need of further research in the field of engineering education.

1. While this study has focused on a specific faculty and a selected group of electrical engineers to respond to the importance of engineering courses, there is need to conduct a national survey of electrical engineers and electrical engineering faculty to obtain a larger base of information. Engineering faculty at smaller institutions, and engineers employed at a wider variety of organizations, may have different opinions on the needed areas to be offered in an undergraduate electrical engineering program.

2. Other studies in engineering curriculum design have solicited input from alumni and students regarding the nature of their undergraduate education. However, there is need for future research to focus on all constituencies in such a program of education to test the usefulness

of the educational process. Faculty, students, practicing engineers, and alumni who may not be active in the field should be surveyed and results published regarding their views of the engineering educational process.

3. While the present study directed attention to specific engineering courses and their importance in an undergraduate program, other research is needed which focuses on the goals and objectives of an engineering program and relates these findings to the courses which then need to be offered to undergraduate students. Such research which determines what faculty and selected engineers think <u>should be</u> the objectives of undergraduate education may conclude that very different courses are needed to attain these goals.

4. In relation to goals and objectives, the author found numerous research studies which have focused on engineering technology rather than four-year degree programs. There is a need for future research which compares the goals and objectives of these two different training programs and the subsequent changes which potentially need to be made in the subjects which are offered to engineering students. Engineering

educators may welcome any objective study which focuses on the overlap between these two programs.

5. The present study was concerned with engineering courses and reference has been made to the need for research relating specific courses to program goals and objectives. Additionally, research is needed which focuses on competencies or skills necessary for an engineer to perform successfully in a variety of capacities--whether it be teaching, research, or practical engineering positions. Such competencies may then lead to specific learning objectives for students, objectives which would be different from broader program goals and objectives.

6. Competency-based evaluation systems are needed in the field of engineering education and would be useful as future research material. Although much has been written concerning general evaluation programs in the field of education, little research has been concerned with engineering programs and the specific courses which are offered to undergraduate students.

7. An increasingly growing concern is mounting in engineering education with respect to criteria

used for purposes of accrediting professional engineering programs. Research is needed which analyzes this important activity and the effects which it has on the development of curricular programs. The question of how accreditation procedures should affect important educational decisions regarding curriculum is one which needs to be studied in the future.

8. Studies concerning the impact of related issues in engineering education upon curricular programs are also needed in the future. Responses received in this research indicated that, although there was little difference of opinion between faculty and selected engineers, the desired length of an undergraduate program in electrical engineering may be in question and may have a substantial impact on the total curricular program offered at an institution. Additionally, the role which cooperative education plays in the overall preparation of engineering students is a very important issue in the formulation of a curricular design. These issues and their impact on the total educational process are timely concerns to be dealt with in the future of engineering education.

APPENDICES

APPENDIX A

PRETEST LETTER OF INQUIRY

MICHIGAN STATE UNIVERSITY

COLLEGE OF OSTEOPATHIC MEDICINE
DEPARTMENT OF BIOMECHANICS

EAST LANSING · MICHIGAN · 48824

APPENDIX A

PRETEST LETTER OF INQUIRY

March 23, 1977

Mr. Randall Church
AC Spark Plug Division
1601 North Averill Avenue
Flint, Michigan

Dear Mr. Church:

May I express my appreciation for the opportunity of speaking with you concerning the curriculum evaluation study I am conducting at Michigan State University. Your responses will be very helpful as I prepare for the final research to be conducted later this Spring. The survey should hopefully take only 10 - 15 minutes to complete. Several items may be of interest as you complete this questionnaire:

1. This is a pilot study being conducted on electrical engineering curricular design. I am interested both in your responses to the survey and in your comments regarding the design of the questionnaire itself. It would be helpful to know, for example, if the survey is too long, too cumbersome to complete, too difficult to interpret or even possibly irrelevant to concerns dealing with an undergraduate curriculum.

2. You may detect difficulties with specific curricular items in the instrument. For example, the titles of the computer science courses may not be sufficiently specific to make a response possible. I am interested in your comments dealing with these areas of the survey.

3. The final research will involve both faculty and industry professionals like yourself. Twenty participants from each group will be included in the study.

Recognizing your busy schedule, I would like to take approximately one-half hour of your time to discuss your views on the contents of the rating scale and your reactions to the survey itself. I would hope your completing the survey would merely provide a basis for our discussing specific items which should be included in an Electrical Engineering program.

Mr. Randall Church
Page 2

I will be in contact with you by phone next week to arrange an appropriate meeting time.

May I express my appreciation again for your assistance.

Sincerely,

Mr. H. Preston Herring
College of Engineering

APPENDIX B

PRETEST PROFESSIONAL QUESTIONNAIRE

APPENDIX B

PRETEST PROFESSIONAL QUESTIONNAIRE

INDUSTRY PROFESSIONAL QUESTIONNAIRE

COLLEGE OF ENGINEERING

MICHIGAN STATE UNIVERSITY

PART I

1. NAME ____
   Last First Middle

2. NAME OF FIRM ______________________________________

3. BUSINESS ADDRESS __________________________________
   Street City

   ____
   State Zip Code

4. POSITION ____

5. EXPERIENCE (NUMBER OF YEARS IN EACH ACTIVITY)

   Design and Development (equipment, product, or process) ___________
   Production (manufacturing or maintenance) _________ yrs.
   Inspection or Testing ________ yrs.
   Time and Motion Study ________ yrs.
   Research ________ yrs.
   Teaching
     a. Academic _______ yrs.
     b. Industrial ______ yrs.
   Sales and Service ______ yrs.
   Supervisory ________ yrs.
   Other (please name) ______________________________yrs.___

PART II

BACKGROUND

The purpose of this survey is to establish a model curriculum in Electrical Engineering. Within each category of courses provided in this questionnaire, certain assumptions are made. The Engineering Council for Professional Development (ECPD) is a national policy-making body which oversees and guides the engineering profession. It "furthers the public welfare through the development of the better educated and qualified engineer, engineering technologist, and engineering technician." (ECPD 43rd Annual Report, 1975). The body also provides minimum standards for degree programs which are reflected in the survey. The IEEE additionally is concerned with standards for academic quality in engineering education in general and Electrical Engineering in particular.

INSTRUCTIONS

In order that the model curriculum can approximate a four year program, you are asked to rate the following engineering courses and to specify which courses in each category should be required for Electrical Engineering students.

6. ECPD regulations stipulate a minimum of one-half year required mathematics beyond trigonometry for an undergraduate Bachelor of Science degree in engineering. Courses typically include:

   Calculus with analytic geometry
   Calculus with vector analysis
   Ordinary Differential Equations

   In your opinion, these courses: (Mark one of the following)

SHOULD BE REQUIRED	SHOULD NOT BE REQUIRED
[ ]	[ ]

7. Additional mathematics courses are available to Electrical Engineering students. Please rate the following courses according to their importance in an Electrical Engineering program.

	VERY IMPORTANT		RATING SCALE MODERATELY IMPORTANT			NOT IMPORTANT	
a. Probability and Statistics	1	2	3	4	5	6	7
b. Complex Variables	1	2	3	4	5	6	7
c. Matrices	1	2	3	4	5	6	7
d. Theory of Numbers	1	2	3	4	5	6	7
e. Advanced Calculus	1	2	3	4	5	6	7
f. Foundations of Analysis	1	2	3	4	5	6	7
g. Boundary Value Problems	1	2	3	4	5	6	7
h. Numerical Analysis	1	2	3	4	5	6	7
i. Applied Mathematics For Engineers	1	2	3	4	5	6	7
j. Partial Differential Equations	1	2	3	4	5	6	7
k. General Topology	1	2	3	4	5	6	7

8. Select three of the above courses which should be required in an undergraduate Electrical Engineering program. Identify by letter preceding course title:

_______ _______ _______

9. ECPD regulations stipulate a minimum of one year of basic science in an undergraduate degree program. Courses typically include:

   General Chemistry - General Chemistry Laboratory
   General Physics - General Physics Laboratory

   In your opinion, these courses:

   SHOULD BE REQUIRED [ ]   SHOULD NOT BE REQUIRED [ ]

10. Additional courses are available to Electrical Engineering students in the area of basic science. Please rate the following courses according to their importance in an Electrical Engineering program:

	VERY IMPORTANT		MODERATELY IMPORTANT			NOT IMPORTANT	
a. Quantitative Chemical Analysis	1	2	3	4	5	6	7
b. Solid State Physics	1	2	3	4	5	6	7
c. Modern Physics	1	2	3	4	5	6	7
d. Statistical Physics	1	2	3	4	5	6	7
e. Biological Science	1	2	3	4	5	6	7
f. Anatomy	1	2	3	4	5	6	7
g. Engineering Thermodynamics	1	2	3	4	5	6	7
h. Optics	1	2	3	4	5	6	7

11. Select three of the above courses which should be required in an undergraduate Electrical Engineering program. Identify by letter preceding course title.

________ __________ __________

12. ECPD regulations stipulate a minimum of one year of engineering sciences in an undergraduate program. Engineering science courses have their roots in mathematics and basic sciences, but carry knowledge further toward creative application and offer a bridge between the basic sciences and engineering practice. Courses typically include:

Computer Programming for Engineers
Electric Circuit Theory
Electric Circuits Laboratory
Signals and Information
Electromagnetics
Electromagnetics Laboratory
Control Theory

In your opinion, these courses:

SHOULD BE REQUIRED [ ]

SHOULD NOT BE REQUIRED [ ]

13. Additional courses are available to Electrical Engineering students in the area of engineering science. Please rate the following engineering science courses according to their importance in an Electrical Engineering program.

	VERY IMPORTANT		MODERATELY IMPORTANT			NOT IMPORTANT	
a. Electrodynamics	1	2	3	4	5	6	7
b. Electromechanics	1	2	3	4	5	6	7
c. Guided Wave Theory	1	2	3	4	5	6	7
d. Electric Machinery	1	2	3	4	5	6	7
e. Systems Science: Modeling and Analysis	1	2	3	4	5	6	7
f. Network Theory	1	2	3	4	5	6	7
g. Physical Principles of Electronic Devices	1	2	3	4	5	6	7
h. Introduction to Plasma Theory	1	2	3	4	5	6	7
i. Lasers	1	2	3	4	5	6	7
j. Statics	1	2	3	4	5	6	7
k. Dynamics	1	2	3	4	5	6	7
l. Mechanics of Materials	1	2	3	4	5	6	7
m. Strength of Materials	1	2	3	4	5	6	7
n. Engineering Thermodynamics	1	2	3	4	5	6	7

14. Select five courses from the above list which should be required in an undergraduate program. Identify by letter preceding course title.

______ ______ ______ ______ ______

15. Select two laboratories from the above list which should be required in an undergraduate program. Identify by letter preceding course title.

______ ______

16. Most Engineering Colleges provide for technical electives to be taken at the option of the individual student. Such courses are usually engineering science, design or basic science subjects, or other technical courses which supplement an engineering program. Please select six additional courses of a technical nature which, if taken, would better prepare a student for a position as an Electrical Engineer. Selections could be taken from those not chosen by you as required in the engineering science, design or basic science categories or any appropriate technical subject.

_____ a. _______________ _____ c. _______________ _____ e. _______________

_____ b. _______________ _____ d. _______________ _____ f. _______________

17. Please rank order your selections from the previous question by placing the appropriate number to the left of each subject. (1=most important; 6=least important)

18. ECPD guidelines suggest a minimum of one-half year of non-technical electives to broaden the student's engineering program. The following list contains possible objectives which non-technical courses may meet if included in an undergraduate program. Please rate each objective.

Non-technical elective courses should help the student:	VERY IMPORTANT		MODERATELY IMPORTANT			NOT IMPORTANT	
a. become more aware of his/her social responsibilities.	1	2	3	4	5	6	7
b. become better skilled in written communication.	1	2	3	4	5	6	7
c. become better able to consider related factors in the decision-making process.	1	2	3	4	5	6	7
d. become aware of the dynamics involved in human inter-action.	1	2	3	4	5	6	7
e. become better acquainted with laws and policies governing engineering practices.	1	2	3	4	5	6	7
f. become better acquainted with issues involved in labor-management encounters.	1	2	3	4	5	6	7
g. become aware of the American political process	1	2	3	4	5	6	7
h. become familiar with the American economic system.	1	2	3	4	5	6	7

19. Please rate the following non-technical courses according to their importance in an undergraduate Electrical Engineering program.

a. Philosophy	1	2	3	4	5	6	7
b. Economics	1	2	3	4	5	6	7
c. Sociology	1	2	3	4	5	6	7
d. Political Science	1	2	3	4	5	6	7
e. Labor Relations	1	2	3	4	5	6	7
f. English Composition	1	2	3	4	5	6	7
g. Technology and Governmental Policy	1	2	3	4	5	6	7
h. Technical Writing for Engineers	1	2	3	4	5	6	7
i. Inventions and Patents	1	2	3	4	5	6	7

20. Please list and rate other non-technical courses you feel are important in an undergraduate program.

a.______________________________	1	2	3	4	5	6	7
b.______________________________	1	2	3	4	5	6	7

20. cont.

	VERY IMPORTANT			MODERATELY IMPORTANT			NOT IMPORTANT
c.________________________	1	2	3	4	5	6	7
d.________________________	1	2	3	4	5	6	7

21. Please list the five most important non-technical courses which you feel should be included in an undergraduate program. (Such courses can be taken either from those in Questions 18 or 19.) List in order of preference.

a.________________________ d.________________________

b.________________________ e.________________________

c.________________________

22. Should the undergraduate program for Electrical Engineers:

a.______ Be maintained at four years

b.______ Be increased to five years

c.______ Be increased to more than five years

APPENDIX C

FIRST INQUIRY LETTER TO INDUSTRY

MICHIGAN STATE UNIVERSITY

COLLEGE OF ENGINEERING · OFFICE OF THE DEAN EAST LANSING · MICHIGAN · 48824

APPENDIX C

FIRST INQUIRY LETTER TO INDUSTRY

April 22, 1977

In the near future a survey will be conducted in our college focusing on various aspects of an undergraduate Electrical Engineering program. This study will use a curriculum rating instrument distributed to a panel of experts composed of faculty members and industry professionals to determine the relative importance of specific curricular items.

This is a project sponsored by a member of our staff to evaluate selected elements for designing improved curricula for the Bachelor of Science degree in Electrical Engineering. The research is being conducted as part of a doctoral study and the results will be given to the Electrical Engineering Department at Michigan State University for consideration and use. As a professional in the field of engineering your name has been selected by the writer for participation on the panel.

The enclosed post card is provided to identify the nature of your position and your willingness to be involved in the study. Participation will only involve completing a short questionnaire to be sent to you later this Spring. Just drop the card in the mail at your convenience.

Your acceptance of this invitation will be greatly appreciated.

Sincerely,

L.W. Von Tersch

L.W. Von Tersch, Dean
College of Engineering

Enclosure

APPENDIX D

JURY ACCEPTANCE POST CARD

APPENDIX D

JURY ACCEPTANCE POST CARD

SURVEY RESPONSE POST CARD

____

NAME   CITY   STATE

____

ADDRESS   ZIP CODE

PLEASE IDENTIFY THE NATURE OF YOUR PRESENT POSITION

_____ PRODUCT   _____ DEVELOPMENT
_____ PROJECT   _____ MANAGEMENT
_____ RESEARCH   _____ OTHER (PLEASE SPECIFY)
_____ SALES   ______________________________
_____ TESTING
_____ DESIGN
_____ PRODUCTION
_____ PLANT

____
TITLE OF PRESENT POSITION

APPENDIX E

FIRST LETTER WITH SURVEY

MICHIGAN STATE UNIVERSITY

COLLEGE OF ENGINEERING · OFFICE OF THE DEAN EAST LANSING · MICHIGAN · 48824

APPENDIX E

FIRST LETTER WITH SURVEY

May I express my appreciation for your response to participate in the Electrical Engineering curriculum study being conducted in our college. Your response has assisted us in gathering a significant number of industry professionals to be involved in the research.

Enclosed is a curriculum rating instrument. The form has been coded with a number for purposes of follow-up and to identify those who will be sent the results of the research. I would appreciate you completing the instrument and returning it in the enclosed self-addressed envelope. Postage has been paid for your convenience.

Thank you once again for your cooperation in the study. Final results will be sent to all participants approximately one month after it is completed.

Sincerely,

L.W. Von Tersch

L.W. Von Tersch, Dean
College of Engineering

APPENDIX F

SECOND LETTER WITH SURVEY

MICHIGAN STATE UNIVERSITY

COLLEGE OF ENGINEERING · OFFICE OF THE DEAN EAST LANSING · MICHIGAN · 48824

APPENDIX F

SECOND LETTER WITH SURVEY

September 8, 1977

Several months ago you assisted us in a study being conducted in our College pertaining to a model curriculum designed for undergraduate Electrical Engineering students. The preliminary results of that study indicated widespread agreement on specific courses between faculty and industry professionals.

In order to secure a final statistical analysis and to rank order the courses according to importance, it is necessary to obtain another rating of some of the courses included in the firrt survey.

We would appreciate, therefore, your taking an additional five minutes to complete the enclosed survey. Return postage has again been paid for your convenience.

Thank you again for your cooperation in the study.

Sincerely,

L.W. Von Tersch

L.W. Von Tersch, Dean
College of Engineering

APPENDIX G

FIRST LETTER TO FACULTY

MICHIGAN STATE UNIVERSITY

COLLEGE OF ENGINEERING • OFFICE OF STUDENT AFFAIRS
ENGINEERING BUILDING

EAST LANSING • MICHIGAN • 48824

APPENDIX G

FIRST LETTER TO FACULTY

April 30, 1977

I have been interested in issues relating to curricular development and specifically in the ways both faculty and those in industry view the necessary components in an undergraduate degree program. This interest has resulted in a doctoral study I am presently conducting related to an Electrical Engineering curricular model.

I have structured my research to focus on two groups of professionals - faculty in our Electrical Engineering Department and those who are employed in industries to which Electrical Engineering graduates have gone during the last fifteen years. Of particular interest in the study will be a determination of what courses the two groups hold as important for Electrical Engineering students during their four year degree program. Many courses which are currently offered in our department, and some which are not, are included in the rating instrument.

I would greatly appreciate your reaction to the importance of these courses in an undergraduate program. A rating scale is enclosed on which your responses may be recorded. Usually only five to ten minutes is needed to complete the form. Because of the limited size of our Electrical Engineering Department, responses from all faculty are essential to the validity of the research. I have included an envelope in which to return the survey to the Student Affairs Office.

Thank you for your assistance.

Sincerely,

H. Preston Herring, Academic Advisor
Engineering Student Affairs

APPENDIX H

SECOND LETTER TO FACULTY

MICHIGAN STATE UNIVERSITY

COLLEGE OF OSTEOPATHIC MEDICINE
DEPARTMENT OF BIOMECHANICS

EAST LANSING · MICHIGAN · 48824

APPENDIX H

SECOND LETTER TO FACULTY

September 25, 1977

Department of Electrical Engineering
Michigan State University
East Lansing, Michigan

Dear Dr.

Several months ago you completed a curriculum rating instrument concerning your reactions to the importance of various courses in an undergraduate Electrical Engineering program. Your response was greatly beneficial, and in comparing the Electrical Engineering faculty responses with those of a random sample of industry professionals some interesting results were found.

In order to complete the study and to enable me to rank order the courses according to importance, it is necessary to ask your assistance once again in completing this second survey. You will note that although this instrument closely resembles the first it is not identical. Based on earlier responses, several courses have been deleted.

I greatly appreciate your assistance in this sutdy. I feel that the research will yield some interesting results which I am anxious to share with you upon completion of the study. You may enclose the survey in the pre-addressed envelope and return it to the Student Affairs Office in Room 120.

Thank you again!

Sincerely,

H. Preston Herring
Student Affairs Office

APPENDIX I

FIRST CURRICULUM RATING INSTRUMENT

APPENDIX I

FIRST CURRICULUM RATING INSTRUMENT

MICHIGAN STATE UNIVERSITY

COLLEGE OF ENGINEERING

CURRICULUM RATING SCALE

BACKGROUND

The purpose of this survey is to establish a model curriculum in Electrical Engineering. Within each category of courses provided in this questionnaire, certain assumptions are made. The Engineering Council for Professional Development (ECPD) is a national policy making body which oversees and guides the engineering profession. The body also provides minimum standards for degree programs which are reflected in the survey. The IEEE additionally is concerned with standards for academic quality in engineering education in general and Electrical Engineering in particular.

INSTRUCTIONS

Please rate the following courses according to their importance in an undergraduate Electrical Engineering program.

1. ECPD regulations specify a minimum of one-half year required MATHEMATICS beyond trigonometry for an undergraduate Bachelor of Science degree in engineering. Courses typically include:

   Calculus with Analytic Geometry
   Calculus with Vector Analysis
   Ordinary Differential Equations

   In your opinion, these courses: (Mark one of the following)

SHOULD BE REQUIRED	SHOULD NOT BE REQUIRED
[ ]	[ ]

2. Additional MATHEMATICS courses are available to Electrical Engineering students. Please rate the following courses according to their importance in an Electrical Engineering program.

	VERY IMPORTANT		MODERATELY IMPORTANT			NOT IMPORTANT	
a. Probability and Statistics	1	2	3	4	5	6	7
b. Complex Variables	1	2	3	4	5	6	7
c. Matrices	1	2	3	4	5	6	7
d. Theory of Numbers	1	2	3	4	5	6	7
e. Advanced Calculus	1	2	3	4	5	6	7
f. Foundations of Analysis	1	2	3	4	5	6	7
g. Boundary Value Problems	1	2	3	4	5	6	7
h. Numerical Analysis	1	2	3	4	5	6	7
i. Applied Mathematics for Engineers	1	2	3	4	5	6	7
j. Partial Differential Equations	1	2	3	4	5	6	7
k. General Topology	1	2	3	4	5	6	7

3. ECPD regulations specify a minimum of one year of BASIC SCIENCE courses in an undergraduate degree program. Courses typically include:

General Chemistry - General Chemistry Laboratory
General Physics - General Physics Laboratory

In your opinion, these courses: (Mark one of the following)

SHOULD BE REQUIRED	SHOULD NOT BE REQUIRED
[ ]	[ ]

4. Additional courses are available to Electrical Engineering students in the area of BASIC SCIENCE. Please rate the following courses according to their importance in an engineering program.

	VERY IMPORTANT		MODERATELY IMPORTANT			NOT IMPORTANT	
a. Quantitative Chemical Analysis	1	2	3	4	5	6	7
b. Solid State Physics	1	2	3	4	5	6	7
c. Modern Physics	1	2	3	4	5	6	7
d. Statistical Physics	1	2	3	4	5	6	7
e. General Biology	1	2	3	4	5	6	7
f. Anatomy	1	2	3	4	5	6	7
g. Engineering Thermodynamics	1	2	3	4	5	6	7
h. Optics	1	2	3	4	5	6	7

5. ECPD regulations specify a minimum of one year of ENGINEERING SCIENCE courses in an undergraduate program. ENGINEERING SCIENCE courses have their roots in mathematics and basic sciences, but carry knowledge further toward creative application and offer a bridge between the basic sciences and engineering practice. Courses typically include:

Computer Programming for Engineers
Electric Circuit Theory
Electric Circuits Laboratory
Signals and Information
Electromagnetics
Electromagnetics Laboratory
Control Theory

In your opinion, these courses: (Mark one of the following)

SHOULD BE REQUIRED	SHOULD NOT BE REQUIRED
[ ]	[ ]

6. Additional courses are available to Electrical Engineering students in the area of ENGINEERING SCIENCE. Please rate the following engineering science courses according to their importance in an engineering program.

	VERY IMPORTANT		MODERATELY IMPORTANT			NOT IMPORTANT	
a. Electrodynamics	1	2	3	4	5	6	7
b. Electromechanics	1	2	3	4	5	6	7
c. Guided Wave Theory	1	2	3	4	5	6	7
d. Electric Machinery	1	2	3	4	5	6	7
e. Systems Science: Modeling and Analysis	1	2	3	4	5	6	7

	VERY IMPORTANT 1	2	3	MODERATELY IMPORTANT 4	5	NOT IMPORTNAT 6	7
f. Network Theory	1	2	3	4	5	6	7
g. Physical Principles of Electronic Devices	1	2	3	4	5	6	7
h. Introduction to Plasma Theory	1	2	3	4	5	6	7
i. Lasers	1	2	3	4	5	6	7
j. Statics	1	2	3	4	5	6	7
k. Dynamics	1	2	3	4	5	6	7
l. Mechanics of Materials	1	2	3	4	5	6	7
m. Strength of Materials	1	2	3	4	5	6	7
n. Engineering Thermodynamics	1	2	3	4	5	6	7

7. ECPD regulations specify a minimum of one-half year <u>ENGINEERING DESIGN</u> courses for an undergraduate degree. ENGINEERING DESIGN courses involve the process of devising a system, component, or process to meet desired needs and which offer skills in the decision-making process. Courses typically include:

Basic Electronic Circuit Design
Electronic Circuit Design Laboratory
Control Systems Design

In your opinion, these courses: (Mark one of the following)

SHOULD BE REQUIRED	SHOULD NOT BE REQUIRED
[ ]	[ ]

8. Additional courses are available to Electrical Engineering students in the area of ENGINEERING DESIGN. Please rate the following courses according to their importance in an engineering program.

	VERY IMPORTANT 1	2	3	MODERATELY IMPORTANT 4	5	NOT IMPORTANT 6	7
a. Transmission and Radiation Laboratory	1	2	3	4	5	6	7
b. Communication Laboratory	1	2	3	4	5	6	7
c. Physical Electronics Laboratory	1	2	3	4	5	6	7
d. Introduction to Computer-aided Circuit Design	1	2	3	4	5	6	7
e. Microwave Networks and Antennas	1	2	3	4	5	6	7
f. Communication System Design	1	2	3	4	5	6	7
g. Electronic Devices	1	2	3	4	5	6	7
h. Linear Integrated Circuits and Systems	1	2	3	4	5	6	7
i. Process Optimization Methods	1	2	3	4	5	6	7
j. Energy Conversion	1	2	3	4	5	6	7
k. Electronic Instrumentation in Biology-Medicine	1	2	3	4	5	6	7
l. Acoustics	1	2	3	4	5	6	7
m. Digital Integrated Circuits and Systems	1	2	3	4	5	6	7

9. Most Engineering Colleges provide for <u>TECHNICAL ELECTIVES</u> to be taken at the option of the individual student. Such courses are usually engineering science, design or basic science subjects, or other technical courses which supplement an engineering program. Please rate the following technical courses.

	VERY IMPORTANT 1	2	3	MODERATELY IMPORTANT 4	5	6	NOT IMPORTANT 7
a. Organic Chemistry	1	2	3	4	5	6	7
b. Physical Chemistry	1	2	3	4	5	6	7
c. Computer Assembly Language	1	2	3	4	5	6	7
d. Combinational Circuits	1	2	3	4	5	6	7
e. Technology and Utilization of Energy	1	2	3	4	5	6	7
f. Metals and Alloys	1	2	3	4	5	6	7
g. Physiological Ecology	1	2	3	4	5	6	7
h. Technical Drawing	1	2	3	4	5	6	7

10. ECPD guidelines suggest a minimum of one-half year of NON-TECHNICAL courses to be taken to broaden the student's engineering program. Please rate the following NON-TECHNICAL courses according to their importance in an engineering program.

	VERY IMPORTANT 1	2	3	MODERATELY IMPORTANT 4	5	6	NOT IMPORTANT 7
a. Philosophy	1	2	3	4	5	6	7
b. Economics	1	2	3	4	5	6	7
c. Sociology	1	2	3	4	5	6	7
d. Political Science	1	2	3	4	5	6	7
e. Labor Relations	1	2	3	4	5	6	7
f. English Composition	1	2	3	4	5	6	7
g. Technology and Governmental Policy	1	2	3	4	5	6	7
h. Technical Writing for Engineers	1	2	3	4	5	6	7
i. Inventions and Patents	1	2	3	4	5	6	7
j. Engineering Safety Standards	1	2	3	4	5	6	7

11. Should the undergraduate program for Electrical Engineers:

a. ______ Be maintained at four years

b. ______ Be increased to five years

c. ______ Be increased to more than five years

12. Should the Bachelor of Science or Master of Science degree be the first professional degree granted to engineers?

a. ______ Bachelor of Science

b. ______ Master of Science

RATING CODE NO. ________

APPENDIX J

SECOND CURRICULUM RATING INSTRUMENT

APPENDIX J

SECOND CURRICULUM RATING INSTRUMENT

MICHIGAN STATE UNIVERSITY

CURRICULUM RATING SCALE

SECOND SURVEY

INSTRUCTIONS

This is the second of two rating instruments soliciting feedback from faculty and industry professionals regarding an undergraduate curriculum in Electrical Engineering. Please rate the following courses according to their importance in an undergraduate program.

1. Please rate the following MATHEMATICS courses according to their importance in an Electrical Engineering program.

	VERY IMPORTANT			MODERATELY IMPORTANT			NOT IMPORTANT
a. Probability and Statistics	1	2	3	4	5	6	7
b. Complex Variables	1	2	3	4	5	6	7
c. Advanced Calculus	1	2	3	4	5	6	7
d. Numerical Analysis	1	2	3	4	5	6	7
e. Applied Mathematics for Engineers	1	2	3	4	5	6	7
f. Partial Differential Equations	1	2	3	4	5	6	7

2. Please rate the following BASIC SCIENCE courses according to their importance in an Electrical Engineering program.

	VERY IMPORTANT			MODERATELY IMPORTANT			NOT IMPORTANT
a. Quantitative Chemical Analysis	1	2	3	4	5	6	7
b. Solid State Physics	1	2	3	4	5	6	7
c. Modern Physics	1	2	3	4	5	6	7
d. Statistical Physics	1	2	3	4	5	6	7
e. General Biology	1	2	3	4	5	6	7
f. Anatomy	1	2	3	4	5	6	7
g. Optics	1	2	3	4	5	6	7

3. Please rate the following ENGINEERING SCIENCE courses according to their importance in an Electrical Engineering program.

	VERY IMPORTANT			MODERATELY IMPORTANT			NOT IMPORTANT
a. Electrodynamics	1	2	3	4	5	6	7
b. Electromechanics	1	2	3	4	5	6	7
c. Electric Machinery	1	2	3	4	5	6	7
d. Network Theory	1	2	3	4	5	6	7
e. Introduction to Plasma Theory	1	2	3	4	5	6	7

	VERY IMPORTANT 1	2	3	MODERATELY IMPORTANT 4	5	6	NOT IMPORTANT 7
f. Lasers	1	2	3	4	5	6	7
g. Systems Science: Modeling and Analysis	1	2	3	4	5	6	7
h. Physical Principles of Electronic Devices	1	2	3	4	5	6	7
i. Statics	1	2	3	4	5	6	7
j. Dynamics	1	2	3	4	5	6	7
k. Mechanics of Materials	1	2	3	4	5	6	7
l. Strength of Materials	1	2	3	4	5	6	7
m. Engineering Thermodynamics	1	2	3	4	5	6	7

4. Please rate the following <u>Engineering Design</u> courses according to their importance in an Electrical Engineering program.

	VERY IMPORTANT 1	2	3	MODERATELY IMPORTANT 4	5	6	NOT IMPORTANT 7
a. Physical Electronics Laboratory	1	2	3	4	5	6	7
b. Introduction to Computer-aided Design	1	2	3	4	5	6	7
c. Microwave Networks and Antennas	1	2	3	4	5	6	7
d. Communication System Design	1	2	3	4	5	6	7
e. Linear Integrated Circuits	1	2	3	4	5	6	7
f. Process Optimization Methods	1	2	3	4	5	6	7
g. Energy Conversion	1	2	3	4	5	6	7
h. Electronic Instrumentation in Biology and Medicine	1	2	3	4	5	6	7
i. Acoustics	1	2	3	4	5	6	7
j. Digital Integrated Circuits and Systems	1	2	3	4	5	6	7

5. Please rate the following <u>Technical Elective</u> courses according to their importance in an Electrical Engineering program.

	VERY IMPORTANT 1	2	3	MODERATELY IMPORTANT 4	5	6	NOT IMPORTANT 7
a. Computer Assembly Language	1	2	3	4	5	6	7
b. Combinational Circuits	1	2	3	4	5	6	7
c. Technology and Utilization of Energy	1	2	3	4	5	6	7
d. Metals and Alloys	1	2	3	4	5	6	7
e. Physiological Ecology	1	2	3	4	5	6	7
f. Technical Drawing	1	2	3	4	5	6	7

6. Please rate the following <u>Non-Technical Elective</u> courses according to their importance in an Electrical Engineering program.

	VERY IMPORTANT 1	2	3	MODERATELY IMPORTANT 4	5	6	NOT IMPORTANT 7
a. Philosophy	1	2	3	4	5	6	7
b. Economics	1	2	3	4	5	6	7
c. Sociology	1	2	3	4	5	6	7
d. Political Science	1	2	3	4	5	6	7
e. Labor Relations	1	2	3	4	5	6	7
f. Technology and Governmental Policy	1	2	3	4	5	6	7
g. Inventions and Patents	1	2	3	4	5	6	7
h. Engineering Safety Standards	1	2	3	4	5	6	7

SELECTED BIBLIOGRAPHY

SELECTED BIBLIOGRAPHY

1. Ackerman, Adolph J. "A College Course in Construction Engineering." Journal of Engineering Education 34 (September 1944): 409-10.

2. Bailey, Alex D. "What Industry Expects of Engineering Education After the War." Journal of Engineering Education 34 (September 1943): 336-38.

3. Beauchamp, George A. Curriculum Theory. Wilmette, Ill.: The Kagg Press, 1969.

4. Belknap, J. H. "The Electrical Engineering Curriculum from an Industrial Viewpoint." Journal of Engineering Education 31 (June 1940): 181-84.

5. Bentson, Thomas Gentry. "The Institutional Level for Curriculum Decision Making: Existence and Characteristics in Selected School Divisions." Ed.D. dissertation, The University of Virginia, 1976.

6. Berger, Martin John. "What Industry Requires of the Graduate Engineer: A Case Study." Journal of Engineering Education 40 (September 1950): 378-91.

7. Borg, W. R., and Gall, M. D. Educational Research: An Introduction. New York: David McKay Company, Inc., 1973.

8. Bullough, Robert Vernon, Jr. "Harold B. Alberty and Boyd H. Bode: Pioneers in Curriculum Theory." Ph.D. dissertation, The Ohio State University, 1976.

9. Burdell, Edwin S. "The Philosophy of Humanistic-Social Studies in Engineering Education." Journal of Engineering Education 37 (September 1947): 344-46.

10. Burdell, Edwin S. "General Education in Engineering." _Journal of Engineering Education_ 46 (April 1956): 615-750.

11. Callison, Daren Brooks. "A Study of Curriculum Analysis through Application of a Conceptual Framework to Competency-Based Preparation Programs for Supervisors." Ed.D. dissertation, University of Georgia, 1976.

12. Crawford, Ivan C. "Are Recommendations of This Report Compatible with a Four-Year Curriculum?" _Journal of Engineering Education_ 31 (November 1940): 342-44.

13. Davis, Jess H. "An Administrator Takes a Look at General Studies." _Journal of Engineering Education_ 46 (October 1955): 112-16.

14. Dixon, John. "Training of the Design Scientist in Engineering Education." _Journal of Engineering Education_ 41 (September 1950): 33-35.

15. Domanico, Edward Martin. "An Examination of Procedural Options for Curriculum Development in Response to the Curriculum Reform Movement." Ed.D. dissertation, Temple University, 1976.

16. Dressel, Paul. _The Undergraduate Curriculum in Higher Education_. Washington, D.C.: The Center for Applied Research in Education, Inc., 1963.

17. Dukes, Lawrence Nelson. "The Use of Research on Student Characteristics in Curriculum Development: A Model for the Community College." Ed.D. dissertation, Northern Illinois University, 1976.

18. Edenbrough, Russell Spence. "An Analysis of the Curriculum by the Graduates of the Division of Business of Oklahoma Panhandle State University." Ed.D. dissertation, Oklahoma State University, 1975.

19. Eight Ann Arbor Industry-Education Symposium. _For Our Future Engineers--More Theory or More Practice?_ The University of Michigan Industry Program of the College of Engineering, May 1963.

20. Engineering Council for Professional Development. Annual Report. Engineering Education and Accreditation Report. Vol. 2. 1976.

21. Eure, Gerald Keith. "A Study to Identify and Arrange in Rank Order the Goals of a Core Curriculum by Utilization of the Delphi Technique." Ph.D. dissertation, The University of Alabama, 1975.

22. "Final Report: Goals of Engineering Education." Journal of Engineering Education 58 (January 1968): 373-446.

23. Forbes, Elizabeth Jane. "A Framework for Curriculum Development: An Approach to Program Development in Nursing." Ed.D. dissertation, Temple University, 1975.

24. Gaevert, Helen Sinclair. "An Exploration of a Curriculum Process: A Conceptual Model for Meeting the Educational Needs of Academically Talented Students in Professional Programs." Ed.D. dissertation, University of Houston, 1975.

25. Grinter, L. E. "Report on Evaluation of Engineering Education (1952-1955)." Journal of Engineering Education 46 (September 1955): 25-63.

26. Hall, Maud Christine Larson. "An Evaluation of Curricular Planning Processes and Products." Ph.D. dissertation, Northwestern University, 1976.

27. Hammond, H. P. "Aims and Scope of Engineering Curricula." Journal of Engineering Education 30 (March 1940): 555-56.

28. ________. "Report of Committee on Aims and Scope of Engineering." Journal of Engineering Education 30 (March 1940): 555-56.

29. ________. "Report of Committee on Engineering Education after the War." Journal of Engineering Education 34 (May 1944): 589-614.

30. Handleman, Chester. "Opinions of Selected Faculty Members on Curriculum and Instruction at Five South Florida Community Colleges." Ed.D. dissertation, Nova University, 1975.

31. Hatch, Loren Lorenzo. "Systems Analysis Approach to Medical School Curriculum: An Attitudinal Survey of Selected Medical Faculty Members." Ph.D. dissertation, Michigan State University, 1975.

32. Hess, Paul J. "Comments on Interim Report of Committee on Evaluation of Engineering Education." Journal of Engineering Education 45 (January 1955): 411-12.

33. Hollister, S. C. "The Need for the Appraisal of the Engineering Profession." Journal of Engineering Education 46 (January 1956): 503-05.

34. Howard, Alice L. Harrison. "A Curriculum Design for the Preparation of Instructional Paraprofessionals or Teacher Aides." Ed.D. dissertation, The University of Florida, 1975.

35. Ide, John M. "Engineering Education: Trends for the 70's." Journal of Engineering Education 6 (November 1970): 93-96.

36. Igrig, Harry K. "The Modern Engineer Should Be Educated as a Scientist for Industry." Journal of Engineering Education 43 (December 1952): 271-77.

37. Jackson, D. C. "Present Trends in Engineering Education." Electrical Engineering 59 (April 1940): 152-54.

38. Jewett, Frank B. "Engineering Education: Retrospect and Prospect." Journal of Engineering Education 35 (September 1944): 269-71.

39. Kloeffler, R. G. "100 Curricula in Electrical Engineering." Electrical Engineering 73 (May 1954): 398-401.

40. Koopman, George Robert. Curriculum Development. New York: Center for Applied Research in Education, 1966.

41. Kransberg, Melvin. "The Humanistic-Social Studies in an Engineering Education." Journal of Engineering Education 38 (September 1947): 230-34.

42. LeBold, William K. "Industry Views the Engineering Graduate and His Curriculum." Journal of Engineering Education 45 (June 1955): 808-17.

43. Loret, John Herman. "A Rationale and Model for a Comprehensive Interdisciplinary Curriculum in Environmental Education for Grades K-12." Ph.D. dissertation, The University of Connecticut, 1976.

44. Mann, Charles Riborg. "A Study of Engineering Education." The Carnegie Foundation for the Advancement of Teaching. Bulletin Number Eleven (1918).

45. Mann, Charles Riborg. "Report of the Joint Committee on Engineering Education." Journal of Engineering Education 9 (September 1918): 16-32.

46. Massey, Charles Edward. "Citizen Action Education for a Democratic Community: A Model for Curriculum Development." Ed.D. dissertation, University of North Carolina at Greensboro, 1976.

47. McEnany, Mike V. "Course Requirements in Humanistic-Social Studies." Journal of Engineering Education 37 (September 1947): 704-08.

48. McFarlan, Ronald L. "The Fledgling Engineer--Phusicist or Technician?" The Monitor 7 (March 1960): 18-22.

49. Monack, Albert James. "The Impact of New Technologies of Engineering Education: A Study of the Influence of Technological Needs on Engineering Curricula from the Viewpoints of Educators, Employers and Engineers." Ph.D. dissertation, New York University, 1962.

50. Moore, Walter Herbert. "A Study of the Essential Elements of a Curriculum Development Procedure." Ed.D. dissertation, University of Southern Mississippi, 1976.

51. Morrow, Charles T. "Goals of Engineering Education from an Industrial Viewpoint." Journal of Engineering Education 56 (November 1965): 73-76.

52. Muir, R. C. "An Industrial View of College and Post College Engineering Education." Journal of Engineering Education 31 (June 1940): 81-88.

53. Mullen, Gregory Joseph. "The Development of the Curriculum Field, 1940-1975." Ph.D. dissertation, Northwestern University, 1976.

54. Murphy, Jimmie. "Critical Path Scheduling of Fully Professional Engineering Curricula." Ph.D. dissertation, Texas A&M University, 1975.

55. Osborne, Harold S. "Engineering Education and the Requirements of Industry." Journal of Engineering Education 41 (September 1950): 200-05.

56. Owen, J. G. The Management of Curriculum Development. Cambridge: University Press, 1973.

57. Rader, Louis T. "The Future of Engineering Education and Industry." Journal of Engineering Education 60 (June 1970): 970-73.

58. Report on Evaluation of Engineering Education. Urbana, Ill.: American Society for Engineering Education, 1955.

59. "Report of the Committee on Engineering Education after the War." American Society for Engineering Education. Journal of Engineering Education 35 (September 1944): 36-58.

60. Roberts, Helen Randall. "A Design for Developing Multicultural Curriculum." Ed.D. dissertation, University of Massachusetts, 1975.

61. Rose, Leslie A. "Summary of Information Concerning Humanistic-Social Courses in Engineering Colleges." Journal of Engineering Education 37 (September 1946): 336-39.

62. Rowe, Fred Ares. "An Application for Inclusion of Student Based Data in Curriculum Decisions: A Needs Assessment." Ed.D. dissertation, Arizona State University, 1975.

63. Ryder, J. D. "The Renaissance in Electrical Education." Journal of Engineering Education 70 (July 1951): 581-84.

64. Schweingruber, Donald Lee. "A Comparative Study of Electrical Engineering Alumni Concerning Their Undergraduate Program." Ph.D. dissertation, Michigan State University, 1972.

65. Stoutamire, Virginia Lee. "A System for Generating Curriculum Design in Community Colleges." Ph.D. dissertation, The University of Texas at Austin, 1975.

66. Susskind, Charles. "Microwave Engineering: How a New Course Is Adopted." Journal of Engineering Education 46 (June 1956): 838-41.

67. Swensen, Charles Thomas. "An Epistemology and the Curriculum." Ed.D. dissertation, Arizona State University, 1975.

68. Waina, Richard Baird. "Specifying Objectives for an Engineering Curriculum." Ph.D. dissertation, Arizona State University, 1969.

69. Waina, Richard B. "System Design of Curriculum." Journal of Engineering Education 60 (October 1969): 97-100.

70. Wessman, Harold E. "Pendulum Swings Toward Broadening of Curricular in Engineering Education." Civil Engineering 19 (January 1949): 242-43.

71. Wickenden, W. E. "Report of the Investigation of Engineering Education, 1923-1929." Vol. 1. Pittsburgh: Society for the Promotion of Engineering Education, September 1930.

72. ________. "The Humanistic Band in the Engineering Curriculum." Journal of Engineering Education 30 (November 1939): 212-15.

73. Wickersham, R. O., and Younger, J. E. "Educational Requirements for the Analysis of Modern Aircraft Structures." Journal of Engineering Education 33 (September 1943): 853-62.

74. Wilkenson, Ford K. "A Case for the Five Year Curriculum." Journal of Engineering Education 35 (November 1945): 576-79.

75. Wright, F. D. "The Role of Research in Undergraduate Engineering Education." Journal of Engineering Education 57 (March 1967): 491-92.