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FUNDAMENTAL CONCEPTS REQUIRED BY ELECTROMECHANICAL TECHNOLOGY GRADUATES FOR ENTRY-LEVEL EMPLOYMENT IN RELATED INDUSTRY

A Dissertation

Submitted

In Partial Fulfillment

of the Requirements for the Degree of

Doctor of Industrial Technology

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ABSTRACT

The objective of this study was to determine the fundamental electromechanical concepts needed by electromechanical technology graduates to perform efficiently at the entry-level employment in related industry. An extensive review of the literature indicated that it was necessary to prepare electromechanical technologists with emphasis given to the area of electrical/electronics technology, mechanical technology, fluids, and fiber optics. Thusly prepared, these graduates would be able to service modern industrial equipment and would have greater opportunities in the job market than at present.

A Likert format questionnaire was developed to gather the necessary data. The survey instrument consisted of 91 concept statements grouped under four area headings: electrical/electronics, mechanical, fluids, and fiber optics. Each concept statement was followed by a scale section in order to ascertain the degree of importance of each concept to the respondent's job.

The population targeted for this study consisted of all the affiliates of the Instrument Society of America (ISA) working in the fields of computer, instrumentation, automation, and robotics, in the United States. The randomly selected sample was made up of 589 members with the majority (479 or 81.32%) coming from the states of Texas, Pennsylvania, Illinois, Ohio, New York, Michigan, Louisiana, Wisconsin,

and Indiana. Of the 589 questionnaires mailed, 329 (55.85%) were returned. Of these, 4 were incomplete and the remaining 325 (55.18%) questionnaires became the basis for this study.

The collected data were analyzed at the Academic Computing Services at the University of Northern Iowa, using the Statistical Package for Social Sciences (SPSSX). Mean values and standard deviations for each concept was determined as well as the grand mean value. The results of the study were presented in tabular form.

Forty-one concept statements were rated with a mean value equal to or greater than the grand mean value (2.80). The area of electrical/electronics technology had the highest number of important concept statements with 26 (63.41%) concepts, followed by the area of fluids with 10 (24.39%) concepts, next the area of mechanical technology with 4 (9.76%) concepts, and finally the area of fiber optics with 1 (2.44%) concept.

The results of this study were:

1. There is a need for electromechanical technologists to function effectively in the fields of computer, instrumentation, automation, and robotics.

2. Electromechanical technology programs should place most emphasis in the area of electrical/electronics technology followed by the area of fluids.

3. Contrary to the findings of the survey of literature, the area of fiber optics has been shown by this study to be of low importance for today's electromechanical technologists.

CHAPTER 1

INTRODUCTION

Almost everyone is aware that job and career changes result from technological advancements which eliminate existing jobs and create new ones (Anthony, 1984). Specialized employees might soon be outdated. Therefore to prevent massive unemployment it is necessary to prepare students for the changing world of work (Butler, 1984). Actually, many systems (computers, aircraft, robots, electric power plants, manufacturing processes, automobiles, etc.) apply and use concepts in the areas of electrical/electronics, mechanical, fluids, and fiber optics sciences. This study considered the areas of electrical/electronics technology, fiber optics, mechanical technology, and fluids as very closely related areas.

Statement of the Problem

The research problem that was investigated in this study was to determine the fundamental concepts needed by electromechanical technology graduates for entry-level employment in related industry.

Definition of Terms

For the purposes of this study the following definitions were used.

Duty is a large segment of work performed by an individual. It is one of the distinct major activities involved in the work performed and it is composed of several related tasks (Melching & Borcher, 1973, p. 4).

Electromechanical Technologist is a person whose experience has resulted from a cross-disciplinary education. These experiences are the result of a formal course of study and experience gained through on-the-job and continuing education. The electromechanical technologist is qualified to perform tasks which require electrical/electronics technology, fiber optics, mechanical technology, fluids, or a combination of these technologies.

Engineering is the art of directing the great sources of power in nature for the use and the convenience of humans. Engineering involves people, money, materials, machines, and energy. It is primarily concerned with how to direct to useful and economical ends the natural phenomena. Engineering seeks newer, less expensive, better means of using natural sources of energy and materials to improve the standard of living and to diminish labor (Encyclopedia of Science and Technology, 1987).

Expert is a person who has acquired special skill in or knowledge of a particular subject through professional training or practical experience (Webster's new international dictionary, 1981).

A Four-Year Technology Program is a university technology program leading to a baccalaureate degree, with an emphasis in mathematics, science, humanities, and social studies (Patterson, 1970, p. 43) and includes a technical area or main field of study. Mathematics and science are disciplines which support and strengthen the technical area.

Grand Mean is the value equivalent to the average of several means.

Industrial Technology is the application of significant knowledge of theories, concepts, and principles found in the humanities and the social and behavioral sciences, including a thorough grounding in communications skills; the understanding and ability to apply principles and concepts of mathematical and physical sciences; the application of concepts derived from and current skills developed in a variety of technical disciplines including--but not limited to--materials and production processes, industrial management and human relations, marketing, communications, electronics, and graphics; and may include a field of specialization, for example: electronic data processing, computer integrated design and manufacturing, construction, energy, polymers, printing, safety, and transportation (Keith, 1986, p. 22).

Science is a branch of study in which facts are observed and classified, and, usually, quantitative laws are formulated and verified. It involves the application of mathematical reasoning and data analysis to natural phenomena (Dictionary of Scientific and Technical Terms, 1984).

Task is a unit of work activity or operation that constitutes a logical and necessary step in the performance of a duty (United States Air Force, 1973, p. 3).

Technologist is a person qualified by training and experience to perform tasks and/or services which require judgment skills equal to or greater than manipulative skills, and which involve knowledge of science, mathematics, manufacturing and construction processes and human relations (Harris, 1970a, p. 22). The technologist also deals with other related areas such as electronics, communications, industrial management, and graphics.

Technology is a systematic knowledge and action, usually of industrial processes but applicable to any recurrent activity. Technology is closely related to science and to engineering. Science deals with humans' understanding of the real world about them--the inherent properties of space, matter, energy, and their interactions. Engineering is the application of objective knowledge to the creation of plans, designs, and means for achieving desired objectives. Technology deals with the tools and techniques for carrying out the plans (Encyclopedia of Science and Technology, 1987). Besides dealing with tools and techniques, technology also deals with processes.

Usable, for this study, means complete and ready for statistical analysis.

Conceptual Framework

In a study about task analysis for industrial robot maintenance mechanics, Minty (1985) recommended that educators consider electromechanical programs. The increased use of numerically controlled machinery, computer assisted design (CAD), and computer assisted manufacturing (CAM), demonstrate that robots are not the only machines developed with electrical and mechanical components. Minty believed a broader program thrust such as an electro-mechanical area could improve the marketability of the students' skills. Minty's recommendations are also supported by Brooking (1984) who stated that " . . . technicians need to be trained to design, produce, install, program and maintain modern computer controlled automated equipment. This training must come from a combination of electrical/electronics, mechanical, pneumatic, hydraulic, and thermal technician curricula" (p. 3).

This point was also stressed by a report of the Technical Education Research Center (1972):

> The answer is a curriculum built upon a series of unified concepts, which are common both to electrical and mechanical technology.

> Such concepts must be used in concurrent courses for mutual support and learning reinforcement through introduction, application, and repetition of application in electrical, mechanical, and electromechanical laboratories. If, through the use of integrating concepts, it is possible for the student to use common definitions and terminology--rather than learn an "electrical language" and a "mechanical language"--he will not only have less material to master but a better opportunity for a durable learning experience, because he will have seen more applications of the principles, in varying circumstances. (pp. 3-4)

Technological educational institutions and technology teachers must integrate the areas of electrical/electronics technology and mechanical technology into a single area to cope with industry's requirements according to high technology. As Glines (1986) pointed out, technology education needs more risk-takers, more visionaries. Research and development concepts must emerge. This requires that individuals and institutions of higher learning imagine, invent and create new techniques and philosophies.

Nagle (1987) stated that today's new employee will hold an average of seven different jobs over the course of a working lifetime. The Occupational Outlook Handbook (1986) estimated that the average worker will hold from four to six jobs in two or three different career areas. Students should know that they may be trained and find employment now, but in a few years they may need retraining or be unemployed. Technology educators have an obligation to be as certain as possible that graduating students are aware of the need to be flexible, adaptable, and change-oriented. It is necessary to provide students with education rather than training (Glines, 1986). The researcher agrees with this statement because an educated person is more flexible in shifting from one job to another, has a better chance of moving up in his/her career, and requires a relatively short period of time in being trained for a specific task.

There is an important distinction between education and training. Training is preparation for well defined future tasks, such as to operate a lathe, a typewriter, or a computer. Education is, in contrast, preparation for future events. A good educational curriculum includes the types of knowledge and skill that will be important in the future (Nagle, 1987). Four-year electromechanical technology programs should include preparation in communications, human relations, math, physics, chemistry, manufacturing, and management as well as specialized studies within the concentration. Butler (1984) stated that the future of an economy depends on productivity, and productivity depends in many complex ways on the quality of education. Therefore, the intent of this study was to provide input to four-year educational institutions with electrical/electronics technology and mechanical technology programs so they can adjust and update their curriculum to prepare employees for the world of tomorrow.

In the years to come, industrialized countries will face unemployment problems because of technology and the lack of redirecting human resources toward existing or new jobs. While jobs will disappear in certain areas, there will be persistent labor shortages in other technology areas. Osborne (1979) pointed out, for example, that the semiconductor industry will produce thousands of secondary companies that use microelectronics. For example, occupations in the microelectronics industry such as computers (hardware and software), robotics and industrial automation are expected to grow much faster than the average for all occupations through the mid 1990's (Occupational Outlook Handbook, 1986). Robots may replace blue collar production line workers, but someone must design, build, and service the robots. Universities will have to reorganize their curricula to increase the output of well prepared professionals, while simultaneously preparing to cope with lifelong learning (Cross, 1985; Barron & Curnow, 1979).

The advancement of technology creates a challenge for educational institutions to meet industry's needs. Institutions of higher education play a very important role in preparing employees for new technology occupations, and in upgrading workers as technological change occurs. Long and Warmbrod (1982) pointed out that the continual change and the rapid advance of technology provides a strong challenge to post secondary educational institutions to keep up to date and to make the adaptations this role requires.

A Report of the U.S. Department of Education Task Force on Learning and Electronic Technology (1984) pointed out that advanced technology--microprocessors, computers, video recording devices, etc--is creating a revolution and is changing the world as it is known. This revolution is making profound changes in business, industry, and education. This statement is an alert and it is better to pay attention to the way in which high technology is changing society and the world of work or we will be very sorry (Orme, 1980).

According to Kaapke (1976), "In our constantly changing society with its increasingly rapid advancement in technology, the curriculum that meets today's educational needs will not be satisfactory for those of tomorrow" (p. 28). Kaapke implied the need for constant communication between educational institutions and industrial representatives in order to have a flexible curriculum to meet industrial needs. Therefore, to prepare an individual for an entry-level job, the curriculum designer should know the entry-level requirements of industry. To reflect industrial entry needs and develop a sound educational curriculum, industrial representatives should assist in determining these entry-level requirements.

Need for the Study

As shown in the preceeding paragraphs, there was a need to determine the fundamental concepts needed by electromechanical technology graduates in view of the ever increasing sophisticated industrial systems which require more than one area of knowledge to maintain them. This need was also supported by the following researchers:

1. Minty (1985) recommended that a study should be done to determine industry's requirements for electromechanical technologists. He stated that new industrial systems use electrical and mechanical components; therefore, this new kind of technologist will have greater opportunities in the job market.

2. Brooking (1984) pointed out that in order to maintain modern industrial equipment it is necessary to prepare people with a content combination in electrical/electronics, mechanical, pneumatic, hydraulic, and thermal. He believed that to prepare such a 'super' technician may seem unlikely but not impossible.

Purposes of the Study

The purposes of this study were to:

1. Provide a list of fundamental electromechanical concepts which may contribute to the planning and development of the curriculum for electromechanical technology graduates in four-year educational institutions in the U.S. in general and, in particular, the School of Electromechanical technology at the National University of Education, in Lima, Peru. The researcher was aware that technology and cultural aspects differ from one country to another. However, the methodology used in this study will be valuable in conducting a similar study in Peru.

2. Establish the need that the areas of electrical/electronics technology and mechanical technology may be combined into a single new area with clear advantages for graduates to adapt to job changes due to advances in technology.

3. Provide a guide to high-school counselors, high school students, and teachers of electrical/electronics technology and mechanical technology so they can become aware of the fundamental concepts needed by electromechanical technology graduates for entry level employment in related industry.

4. Foster a spirit of cooperation between the electromechanical industry and higher education. Industry representatives were given the opportunity to rate the fundamental concepts needed by electromechanical technology graduates to meet industry's needs and make suggestions during the data gathering process.

Assumptions

The following assumptions were made in pursuit of this study:

1. That a need existed for identifying the fundamental concepts needed to prepare electromechanical technology graduates for entry-level employment in related industry.

2. The concepts used in this study provide a valid summation of the concepts which have been studied and/or identified in the areas of electrical/electronics, fiber optics, mechanical, and fluids technologies.

3. There existed a need for competent electromechanical technologists and this need will continue both in the near and distant future.

4. The results of this study would assist in the development of an electromechanical curriculum for four-year industrial technology programs.

5. Industry representatives surveyed were cognizant of the entry-level fundamental concepts related to the electromechanical area and were able to interpret the questionnaire.

6. The information collected from all participants in this study was provided honestly.

Limitations

1. The population for this study was limited to employees who work in the industry of computers, robotics, automation, and instrumentation in the United States as identified by the Instrument Society of America.

2. Even though the sample was randomly selected, a stratified random sampling would ensure that subgroups in the population of

employees would be represented in the sample in the same proportions as in the population (Cates, 1985).

3. Communication with the participants was primarily by mail.

4. The anticipated results of this study was based on the literature survey and the responses given by the participants in this sample, and the reader is cautioned that any judgements are to be made with this limitation in mind.

Delimitations

1. This study was intended to determining the fundamental technical concepts only. This study did not attempt to determine the concepts needed in other areas related to the electromechanical technologist such as communications, management, and marketing.

2. The term "electromechanical" in this study refers to electrical/electronics, fiber optics, mechanical, and fluids technologies.

3. Information obtained from the survey instrument was intended to determining what knowledge is required at the entry-level employment in the electromechanical industry and did not indicate how much knowledge is required in each area.

Research Questions

The research questions to be answered in this study were:

1. Which important fundamental concepts in the area of electrical/electronics technology were needed by electromechanical technology graduates for entry level employment in related industry?

2. Which important fundamental concepts in the area of mechanical technology were needed by electromechanical technology graduates for entry level employment in related industry?

3. Which important fundamental concepts in the area of fluids were needed by electromechanical technology graduates for entry level employment in related industry?

4. Which important fundamental concepts in the area of fiber optics were needed by electromechanical technology graduates for entry level employment in related industry?

5. What were the important fundamental technical concepts needed by electromechanical technology graduates for entry level employment in related industry?

Development of the Survey Instrument

A survey instrument was used to gather the necessary data to answer the five research questions. The procedure for developing the survey instrument was accomplished by:

1. Reviewing doctoral dissertations and textbooks related to electricity/electronics, mechanical, fluid, and fiber optics.

2. Compiling concept statements identified through the aforementioned materials.

3. Adding concept statements regarding computers, robotics, automation, and instrumentation identified as having components of the electromechanical area.

4. Consolidating the fundamental concept statements reviewed by selected experts from education and industry for additions, deletions, and comments. The panel of experts consisted of four persons from industry and two educators working in the electromechanical area.

5. Developing a questionnaire, using concept statements to identify the importance of each concept as rated by employees working at different levels in computers, robotics, automation, and instrumentation.

The validation of the concept statements and questionnaire was done by four professors at the university level. Two were from the electrical/electronics technology area, and the other two were from the mechanical technology area. The researcher improved the questionnaire according to the comments made by the professors.

The next step was to do the pilot study. Its purpose was to find out how much time respondents needed to complete the survey instrument and to determine if they could understand the written directions without any assistance. A pilot study of the questionnaire was conducted through six employees working in the electromechanical area in the Waterloo-Cedar Falls, Iowa area.

Population and Sample

The population for this study consisted of employees at different levels working in computers, robotics, automation, and instrumentation in the United States as identified by the Instrument Society of America (ISA). From a population of 9211 members, 600 members were randomly selected. From this selection, 11 members were excluded because five of them live overseas, two live in Canada, and the other four are not ISA affiliates anymore. Therefore, the sample for this study was 589 members.

Instrumentation

The survey instrument used in this study was a questionnaire (Appendix G). This questionnaire contained a list of concept statements grouped under the areas of electrical/electronics, fiber optics, mechanical, and fluids. Respondents were asked to rate each concept statement according to the importance it represented to their job.

Data Collection

A copy of the questionnaire was mailed to each member of the sample along with a cover letter (Appendix H) explaining the objective of the study, a letter from the Director of Education Services at ISA (Appendix I), and a self-addressed envelope. After waiting three weeks from the mailing of the questionnaire a reminder was sent to each member of the sample. The time limit established during the data collection process was 35 days. The first mailing resulted in 259 responses (43.97%) and after mailing a reminder and waiting two weeks, the total number of responses was 325 (55.18%). According to Babbie (1973) a return rate of 50% is considered sufficient for valid data analysis.

Data Analysis

The data collected attempted to answer each of the following research questions:

1. Which important fundamental concepts in the area of electrical/electronics technology were needed by electromechanical technology graduates for entry level employment in related industry?

The concept statements pertinent to the answer of this question were the ones numbered 1 to 35 in the survey instrument. These concepts were listed in descending order from the highest to the lowest mean value. When two or more concepts had the same mean value, the concept whose standard deviation was lower had priority over the concept whose standard deviation was higher. For the purpose of this study, the important fundamental concepts in the area of electrical/electronics were identified as those statements whose mean values were equal to or greater than the grand mean value.

2. Which important fundamental concepts in the area of mechanical technology were needed by electromechanical technology graduates for entry level employment in related industry?

To answer this question concept statements 67 to 91 in the survey instrument were considered. The procedure was the same as that described for research question one.

3. Which important fundamental concepts in the area of fluids were needed by electromechanical technology graduates for entry level employment in related industry?

This question was answered through statements 52 to 66 in the survey instrument. The analysis procedure was the same as the first research question.

4. Which important fundamental concepts in the area of fiber optics were needed by electromechanical technology graduates for entry level employment in related industry?

The procedure was the same as for research question one. The concept statements 36 to 51 in the survey instrument were considered in this case.

5. What were the important fundamental concepts needed by electromechanical technology graduates for entry level employment in related industry?

To answer research question number five, all the important fundamental concepts in the areas of electrical/electronics technology, fiber optics, mechanical technology, and fluids previously identified were listed in descending order from the highest to the lowest mean value. If two or more concepts had the same mean value, the order was determined from the lowest to the highest standard deviation.

Organization of the Study

As already described, Chapter 1 dealt with the rationale for this study. A review of the literature related to the study is presented in Chapter 2. The review was grouped around five areas: history of four-year industrial technology programs, related research, research related to the task analysis methodology, electronics evolution, and fiber optics and fluids development.

The design of the study is the focus for Chapter 3. This chapter deals with selection of the method of analysis, population and sample description, identification and validation of fundamental concepts, development and validation of questionnaire, pilot study of questionnaire, data analysis, data collection, and procedure for answering the research questions.

The analysis and presentation of the data are presented in Chapter 4, as they relate to the five specific research questions. Chapter 5 is divided into four sections: summary, findings, conclusions, and recommendations.

CHAPTER 2

REVIEW OF LITERATURE

Review of related literature was concentrated on five major areas: first, history of four-year industrial technology programs; second, related research; third, research related to the task analysis methodology; fourth, electronics evolution; and fifth, fiber optics and fluids development. The review of literature supported the need to determine the fundamentals of electromechanical concepts to cope with advancing technology and lifelong learning.

History of Four-Year Industrial Technology Programs

Four-year industrial technology programs have experienced rapid growth in the past 35 years. In 1950 there were only six institutions of higher education that offered industrial technology programs (Moor & Will, 1975); however, presently, there are one hundred and fifty-five institutions offering a variety of industrial technology programs (Gore & Dufek, 1986). Industrial technology programs have grown in number and level of sophistication during the last three decades and have reached a point of recognition and acceptance as unique, distinct, and essential educational entities (Wamble, 1984).

Industrial technology education made little progress at four-year institutions before World War II. The six institutions prior to 1950 were: Alabama A & M College, Arizona State University, Bradley University, Kansas State College, Southern Illinois University, and West Virginia State College (Hauer, 1963; Cunningham, 1969).

After World War II, as technology became more complicated and new discoveries or inventions were available, the manufacturing process became more mechanized and more efficient. At the same time, the industrial organizational structure and management became more complex. Thus, these changes affected the educational requirements for employment in industry. The new employees needed a strong technical background, knowledge of human relations, and skill in coordinating the efforts of people (Cunningham, 1969; Foecke, 1968). "During recent years, four-year technology programs have developed and are being well received also by other academic disciplines as being a very rigorous curriculum and acceptable for the four-year degree-granting institution" (Dean & Hauer, 1969, p. 11).

To understand where the four-year technology program fits into the technological spectrum, one must show how the technology spectrum has changed from early in this century to the present. Lohman (1970) indicated the changes in the technological curriculum as depicted in Figure 1. Before World War II the spectrum was from craftsman, to engineer, to scientist. After World War II the field of science broadened with a more complete understanding of the laws of nature. As a result, there was an increase of scientists with doctorate degrees and a gap developed between the engineer and the scientist. To fill this gap, engineering schools included more mathematics and scientific courses in the curriculum, and deleted shop courses and other skill or craft courses. Besides, there were more engineering baccalaureate graduates seeking graduate degrees. This created a gap between the

Craftsman		Engineer	Scientist

a. Before World War II

Craftsman	Engineers	. . . Gap . . .	Scientist

b. Immediately After World War II

Craftsman	. . . Gap . . .	Engineer	Scientist

c. Early 1960s

Craftsman	Associate Degree Technician	B.S. Degree Technologist	Engineer-Scientist

d. 1970s

Figure 1. Changes in technology spectrum.

craftsman and the engineer. In closing this gap, the associate degree programs were sufficient at the beginning of the curriculum's implementation. However, as more engineering students enrolled in institutions with science and mathematics oriented curricula, it became necessary to establish the four-year technology programs (Patterson, 1970).

The reader will note in Figure 1 above that the engineer and the technologist do not occupy the same level. One might wonder if technologists and engineers should be at the same level. Even though the engineer has an in-depth emphasis on mathematics and science in his/her curriculum, the technologist's preparation covers, besides the main technical field, other areas such as industrial management, human relations, communications, and marketing.

Banister (1970) stated that four-year technology programs emerged from two principal sources: the technical (engineering) institutes and the industrial education (primarily Industrial Arts) departments within colleges and universities. Banister (1970) and Harris (1970b) pointed out that the most significant event in the evaluation of industrial technology was the formation of the National Association of Industrial Technology (NAIT) in 1967 as an entity separate from the American Industrial Arts Association. By elaborating a distinctive educational philosophy, identifying appropriate objectives, developing criteria for accreditation, seeking to establish an accrediting agency, providing data and encouraging research, this body has enabled the profession to realize its full potential.

Kleintjes (1969) described three factors which contributed to the emergence of four year industrial technology programs. The three factors were:

> 1. The change in engineering curricula. Increasing emphasis on mathematics and science in the engineering curricula to cope with the complex advancements in technology had eroded the course offerings in shop or skill subjects and left little room for managerial and personnel-related courses.
> 2. The increased enrollments in two-year technical programs of persons capable of continuing in four-year programs. Articulated two-plus-two programs emerged.
> 3. The continually increasing demand by industry for supervisory and management personnel and persons with a combination of technical and general education characteristics to take over areas no longer compatible with modern engineering preparation. (p. 115)

Weber (1962) proposed that industrial technology programs have the following characteristics: (a) management oriented rather than engineering oriented, (b) broad and general curricula, (c) a variety of courses in experimental laboratories, and (d) graduation requirements similar to other four-year programs.

The broadness of industrial technology was recognized since the first conference of the National Association of Industrial Technology (NAIT). Keith (1986) stated that Dr. Nelson Hauer, in his remarkable presentation titled Status Study and Objectives stressed the need for "an education sufficiently broad and sound to adapt to the changing needs of our dynamic society" (p. 1).

The field of industrial technology education provides an opportunity for post-high school education for individuals with unique characteristics and interests in a technical area (Patterson, 1970). Miller (1976) summarized characteristics of successful engineering technology students as "1. academic ability must be at least average, 2. average or better ability in mathematics and science, and 3. people oriented to make judgments and function effectively" (p. 33).

Miller (1976) added that in the post World War II era industrial technology programs have become increasingly important to industry and education. Today, industrial technology is part of the overall technological spectrum which serves the nation.

Related Research

A great deal of research has been directed toward the development of curricula for emerging technologies. This type of research, however, has been limited in the area of electromechanical technology but there have been a few studies.

One of these studies was reported by Schill and Arnold (1965). Employing a modified Q-sort research technique, course descriptions of post-high school technical courses were placed on cards and respondents were asked to sort the cards on the basis of the course's applicability to their technology. The analysis of these data was "sufficient to conclude that there was a common knowledge required of the various technologies and the level of function within the technologies" (p. 50). The researchers found that the three areas of electronic, mechanical, and chemical technology overlapped so that a cross-disciplinary technology existed for each of the three possible pairs of technologies.

Lescarbeau (1968) reported on the development of a consortium in which seven educational institutions formed a nonprofit corporation to develop and implement a curriculum to educate technicians for the business machine and computer industries. These institutions were joined by industrial experts from several business machine and computer manufacturing companies in the development of the suggested curriculum. Lescarbeau reported that:

> Highly skilled technicians must be capable of working closely with engineers and scientists and of supervising and coordinating the efforts of skilled craftsmen and maintenance men . . . the adequately trained electromechanical technician must have attained certain abilities, scientific knowledge, and technical skills. These have been broadly defined as follows:
> 1. Facility [sic] with mathematics . . .
> 2. Proficiency in the application of physical scientific principles . . .
> 3. An understanding of the materials and processes commonly used in the technology.
> 4. An extensive knowledge of a field of specialization . . .
> 5. Communication skills that include the ability to interpret, analyze, and transmitt facts and ideas graphically, orally, and in writing.
> 6. The ability to get along with people. (p. 4)

Roney (1970a) performed a two-part research project in the area of electromechanical technology. The first part surveyed the need for electromechanical technicians, the second part presented a two year post-high-school technical curriculum. Data for the first phase were obtained through personal interviews of responsible individuals in 26 industrial concerns throughout the United States. The interviews sought information pertinent to the present and projected needs for electromechanical technicians and the educational requirements for such a person. The results of these interviews pointed to "a very real immediate need for the electromechanical technician" (p. 8).

The second phase of the research involved the distribution of a two-page questionnaire to 146 organizations that were thought to employ technicians. The returns from this mailing indicated "a high percentage of their technicians have pre-employment training in electronics" (Roney, 1970b, p. 11). Further comments of respondents were favorably disposed toward the development of the proposed electro-mechanical technology curriculum. The curriculum that was developed was based on:

> 1. . . . electrical and mechanical principles rather than on specific applications of these principles.
> 2. Communication skills . . .
> 3. . . . the interrelationship of electrical and mechanical elements of system and devices . . .
> 4. Principles of electrical and mechanical physics . . . (p. 7).

Skouby (1973) analyzed the electromechanical technician occupations and presented findings pertinent to curriculum development. He developed a questionnaire that was completed by technicians and their supervisors throughout the United States. The questionnaire asked for information concerning the technical areas that were a part of electromechanical technology. Respondents were asked to indicate how frequently they used specific skills, and the primary technical area in which they were used. Spearman rank order correlation coefficients were developed from these data. The areas of testing, troubleshooting, and analyzing were found to be the activities most commonly indicated by all respondents.

Stone (1975) identified the common core of tasks in the following electromechanical clustered occupations: residential appliance, commercial appliance and equipment, business and office machines, industrial machinery, and automated agri-business systems. The data for the study were obtained throught the administration of a complex questionnaire. The questionnaire was distributed to workers in the state of Iowa in the five occupations aforementioned. Respondents were asked to provide data in three areas: (a) biographical, (b) type of equipment used and how frequently work was performed on each equipment item, and (c) tasks performed. Analysis of Variance (ANOVA), and the Scheffe test were used to separate tasks into primary, secondary, and tertiary core areas. The separation was based on the mean performance frequency of each task for each of the five occupational areas.

Even though the research in the electromechanical area was limited, there was a need for the electromechanical technologist. For example, in order to maintain today's modern agricultural equipment a service technician needs a great deal of knowledge and skill. To assure high machine productivity, advanced and complex electronic and hydraulic subsystems are necessary. These subsystems so far have been designed for warning or monitoring purposes (Conrads, 1983). However, experts predict the development of "active" systems where the information would enter a "closed loop," bypassing the operator. The monitors would signal a microprocessor, and it in turn would make the necessary adjustments by sending commands to the various control systems of a tractor or combine (Reichenberger & Guebert, 1984; Conrads, 1983). Failure of any of these complex subsystems would mean down time for the farmer, which translates into financial loss due to repair costs and decreased productivity.

Studies (Owens, 1979; Long, 1976) indicated that the major reason for farmers' dissatisfaction with the service received through the dealer and also one of the major reasons for service departments' lack of profitability was the shortage of qualified workers who possess adequate knowledge and skills. Conrads (1983) found a high rate of incorrect diagnosis by American mechanics. He found replacement of non-failed components had a cost anywhere from 20 to 60 percent and in certain areas as high as 80 percent. In the area of electrical systems, which has advanced rapidly, the complexity of the systems has yielded equipment problems which are intricate to diagnose and repair. In fact, it was estimated that of the total time required for repair of an electrical system, 15 to 50 percent would be devoted to diagnosing and locating the cause of the problem. The importance of the problem would be obvious when it is compared to transmission and engine problems, which require about 15 to 35 percent and 10 to 25 percent respectively of the total repair needed to locate the problem (Long, 1976). Conrads (1983) believed that at this time North American technicians generally had a low level of knowledge concerning basic electrical systems.

Hathaway (1983) believed that it was not important that students know the difference between a particular system used in a John Deere and in an International Harvester tractor. The important point was that the student understands the principle of the system inside-out.

Research Related to the Task Analysis Methodology

An objective of any technology program is the successful employment of a student upon graduation from a specialized field of study. Successful employment implies industrial recognition of knowledge and skills which the graduate brings with him to the job. The success or failure of a technology program is directly related to the performance of the graduates in industry's jobs (Solomon, 1984).

The Rockefeller Report (1981) stresses the point that the technology education system must no longer prepare people in only the traditional skills, but also must prepare individuals in new and sophisticated skills in order to raise the standard of living.

Allen (1981) stated that "As citizens . . . we want students to leave our schools with the ability to perform well without retraining on the part of the employers" (p. 39). To measure the quality of the schools' products, citizens must look at whether or not students can find jobs and succeed in them. For this to be possible, instructors must be aware of what is happening in business and industry.

In keeping in touch with industry, task analyses must be conducted in order to develop an appropriate curriculum. As will be demonstrated in this section, task analysis was considered the modern method of determining industrial standards.

Analyzing work in terms of what people do and can do on the job has been called occupational analysis, job analysis, task analysis, trade analysis, and position analysis (Minty, 1985). Some writers saw little or no difference in many of these terms while others saw differences which have major implications for how the analysis should be conducted.

Christal (1969), in a speech to the American Personnel and Guidance Association, described a system of task analysis being used by the USAF. The system involved a task inventory being sent to airmen and the development of a data bank which classified job descriptions into occupational clusters. He also discussed a retrieval system to be used with computers, and how this retrieval system could provide information on training needs. Christal (1969) discussed the accuracy and reliability of the system:

> We have conducted many studies to determine the quality of information collected with job inventories. We know that when a worker fills out an inventory on two occasions, he gives essentially the same information both times. Split-sample correlations for information concerning the percent of employees in an occupational area performing tasks in an inventory run in the neighborhood of .95 to .99, even for sample sizes of 50 to 100 cases. Supervisors agree with the information provided by their subordinates. Information collected with daily work records is consistent with information collected with inventories. Workers do not inflate their job descriptions in terms of the number or difficulty levels of tasks reported. There is a high probability that significant tasks missing from the inventory will be written in by workers who perform them. In summary, we know that we get good information using job inventories. (p. 6)

Melching and Borcher (1973) identified five advantages in using the task inventory analysis technique:

> 1. The technique is economical. Data can be collected from hundreds of workers in an occupational field for less than it would cost to collect data from a few cases using professional job analysis.

> 2. The information collected is quantifiable. The number of people performing any given task can be counted and their characteristics described.
> 3. Since the data collected by task inventory techniques are quantifiable, they can be sorted, manipulated, analyzed, and reported by computer.
> 4. The results of the task inventory can be validated and checked for stability using conventional statistical techniques.
> 5. The technique yields information that is accurate. Workers do not inflate their job descriptions in terms of the number or difficult levels of tasks reported. There is a high probability that significant tasks missing from the inventory will be written in by workers who perform them. (p. 3)

According to Melching and Borcher (1973), the development and use of task inventory involved three main phases. These phases along with some of the goals and activities of each were:

> 1. Construction of Initial Inventory of Tasks. Here the goal is to generate a comprehensive inventory of fundamental tasks for a given occupational area, using various standard sources of information. With the aid of experts, statements are refined and grouped and made ready for administration to job incumbents.
> 2. Acquisition of Information about Each Task. In this phase, the inventory of tasks is submitted in questionnaire form to a large group of job incumbents. After each incumbent provides certain background information about himself, he checks each task in the inventory that he actually performs. Following this, he indicates the relative amount of time he spends performing this task compared with other tasks that he does on his job. On occasion, incumbents may be asked to provide other information about the tasks they perform.
> 3. Analysis of Task Data. Once questionnaires are returned and checked for completeness, responses are tabulated and summary statistics derived. The results can then be used to guide the development or revision of training programs. (p. 4)

Mager and Beach (1967) published a book about task analysis. They directed the analysis exclusively to instruction. The tasks were to be rated in terms of frequency of performance, importance, and learning difficulty. The steps were rated by type of performance (recall, manipulative, problem solving); and learning difficulty. However, they said " . . . there are probably as many techniques for performing a task analysis as there are people doing it . . . The only large error you can make is not to use any task analysis technique at all" (Mager & Beach, 1967).

Sherman and Wildman (1981) came to the same conclusion as Mager and Beach. They said: "There is agreement among all the theorists on at least one point: Task analysis, at a minimum, assists the instructor or designer to understand the content to be taught. This alone is sufficient reason for recommending task analysis" (p. 1).

Electronics Evolution

Electronics has been identified as a rapidly changing field in which new devices emerge frequently. Electronics components have been reduced in size over the last three decades "from the bulky vacuum tube to slivers of silicon the size of a contact lens" (Markoff, 1981, p. 13). These rapid technological advances have resulted from phenomenal advances in microelectronics technology (Norman, 1981). The so-called "high technology" employers of today would not exist without microelectronics devices such as integrated circuits (IC), metal oxide semiconductors (MOS), and microprocessors (MPU) (Solomon, 1984). According to Norman (1981), "a microprocessor is essentially a device for processing information that is fed to it through a keyboard" (p. 11). Larsen, Rony, and Titus (1975) referred to the microprocessor as "an extremely small data processor" (p. 13). Data processor was identified as a broader term, but generally implies a computer. Thus, the microprocessor was used in minicomputers and microcomputers. In such cases, the microprocessor represents the control and processing portion of the minicomputer or microcomputer. Unlike the computer, the microprocessor has no memory but can handle both arithmetic and logic operations under program control.

> Modern electronics uses few discrete components. In today's electronics devices, IC assemblies perform most operations. The shift toward ICs has changed the way we understand the operation of electronic devices. It may no longer be necessary to investigate the detailed operation of many components in order to understand stereos, television sets, calculators, and computers. If such devices are constructed from modern ICs, then only the function of the individual ICs must be detailed. Thus our understanding of electronics today is focused on function (what it does) rather than theory (how it does it). (Boyce, 1982, p. 8)

Norman (1981) referred to the overwhelming use of the microprocessor as "The New Industrial Revolution" (p. 30) because of the dominant use of the microprocessor in industrial control and robotics. In the consumer market the microprocessor has been utilized in microwave ovens, cars, robots, electronic doorbells, thermostats, and automatic processes in general. It was identified as being used in home video recorders, stereo receivers, audio cassette tape decks, home security alarm systems, and video games. Solomon (1984) stated that the technology has advanced so fast that a ten year old computer was nearly an antique. Manufacturers of electronics test equipment use microprocessors within the test instruments for control and self-testing of the test instruments. The present day automobile uses a microprocessor to control ignition timing, ignition, fuel mixture, and anti-skid controls and to detect operating deficiencies while signaling the driver of the operational malfunction.

> Microelectronics controls are more reliable and flexible than their mechanical counterparts, they can be used to regulate complex cycles lasting from a few seconds to several hours, and they can quickly be reprogramed to enable the machine they control to perform different tasks. The reduction in the number of moving parts that results from the replacement of mechanical components with electronics controls can, moreover, be significant: a sewing

> machine . . . uses a single integrated circuit to control the sequence and pattern of stitches, in place of some 350 cams, gears, and other parts. (Norman, 1981, p. 14)

According to Reichenberger and Guebert (1984) we are on the threshold of an electronics revolution in the farm machinery industry. A typical farm tractor of the 1940's had only six controls and two gauges and could draw a three-share plow. Today, a four-wheel drive tractor has 300 horsepower, 14 gauges, 17 buttons, nine levers, four pedals, 13 switches and was capable of pulling a 16-share plow. By the end of the decade, electronic components used in farm machinery will be even more complex, both in quality and in quantity. While today's sensors and gauges only display information for the operator to study and use for decision making, future microprocessors will sense, detect and automatically adjust equipment settings without the operator's help or interference. Also, electronic components used in a tractor will increase from $100 for today's tractor to $1,100 by the year 1990 (Reichenberger & Guebert, 1984). Conrads (1983) stated that the result will be more efficient farm equipment which will also be easier to repair. In fact, it will be as easy to repair as replacing a faulty circuit board or component with a new one. This will be true, of course, if the repairman or the mechanic is familiar with electronics and electrical systems. To assure quality service and repair, major farm equipment manufacturers offer training programs aimed at diagnosis and trouble-shooting for technicians and mechanics employed by their respective dealerships. These programs, however, may not be as effective as they could be, due to a fundamental problem. To understand the sophisticated diagnostic procedures, the mechanics need to be familiar with the basic electrical systems and electronics in theory and practice. Unfortunately, experts believe that technicians in U.S. have very little knowledge about basic electrical systems (Conrads, 1983).

Fluids constitutes an important technology within the electromechanical technology area. The special properties of fluids play an important role in any electromechanical system.

Fiber Optics and Fluids Development

Besides electronics, fiber optics and fluids also have an important impact in industrial processes and manufacturing. Therefore, the electromechanical technologist should also have the fundamental concepts in these two areas because of their applications and importance in the electromechanical area.

The fiber optic systems has been identified as the fastest growing market in the electro-optics industry. The major fiber optic applications include telephones, cable TV, industrial automation, and computers. In the twenty-first century, electronic communications and components will be based heavily on electro-optics. It will be expected that all new telephones, computers, and television systems will be linked by fiber optics cables (in conjunction with space satellites) using laser light operating with integrated optical circuits. Computer plotters and recording devices of today will largely be replaced by the instantaneous fiber optic plotters and display systems of tomorrow. Industrial automation and control will use many fiber optic systems bringing dramatic changes in required equipment standards (Culshaw, 1984; Daly, 1984).

In the area of fluids, hydraulics and pneumatics technology are not new developments. Ancient civilizations used hydraulics extensively for irrigation systems, and pneumatics were used by primitive man in the form of blow guns. Not until the latter half of the twentieth century have hydraulics and pneumatics become a major method of transmitting power (McCloy & Martin, 1980).

Fluids power means using pressurized fluids in a confined system to accomplish work. Liquids and gases are both fluids. Hydraulic systems circulate liquids, usually petroleum oils, but often synthetic oils and water base fluids have been used for safety reasons. Pneumatic systems use air which is exhausted to use atmosphere after it has accomplished the assigned task (Gruen & Garrett, 1985).

When confined, the fluids used in hydraulic systems exhibit the characteristics of a solid and provide a very positive and rigid medium to transfer power through the system. Conversely, air used in pneumatic systems exhibits spongy characteristics, and provisions must be made in its control to effect smooth operation of actuators. Air and oil are frequently combined in one system to provide the advantages of both in accomplishing the work specified (McCloy & Martin, 1980).

The ongoing refinement and development of motors, cylinders, pumps, and fluids control components have served to make hydraulic and pneumatic power transmission viable in instances that previously used mechanical or electrical control. Today fluids power finds application in a myriad of industries including manufacturing, construction, and agriculture, as well as aerospace, marine, and land transportation (Bennett, 1982).

Summary

The review of the literature has revealed that there is a need for determining the fundamental electromechanical technology concepts. A study regarding the electromechanical tasks, somewhat related to this topic, that the researcher was able to find was the one made by Stone (1975). Stone identified the skills needed in electromechanical occupational clusters while the study to be conducted will identify the fundamental concepts needed by electromechanical technology graduates for entry-level employment in fields such as computers, robotics, automation, and instrumentation. These fields will demand more qualified personnel because of advancing technology. Of these four fields, instrumentation will be a clear megatrend in science and technology (Hirschfeld, 1985). Instrumentation requires concepts related to computer, robotics, and automation (Gillum, 1985; Guterl, 1984).

Because electricity and electronics are an integral part of the lives of all Americans, and because rapid technological advancements are being made in the industries that manufacture and utilize electronic components, there is a need for continued research in this area.

Also, there appears to be sufficient information to indicate the importance of the use of survey instruments as appropriate tools to establish lines of communication between industry and education to use as the basis for curriculum design and revision of the fundamental concepts needed by electromechanical technologists. Feirer (1965) stated, "if the content of social studies should come from society, then it stands to reason that the content of industrial education should come from industry" (p. 23).

Analysis of occupations has long been used as a basis for curriculum by industrial educators. Several types of analysis have been used: job analysis, occupational analysis, trade analysis, and task analysis are the more common types. The most common analysis since 1974 for educators has been task analysis. Herschbach (1976) believed task analysis lends greater validity to the analysis process.

CHAPTER 3

DESIGN OF THE STUDY

The research method used in this study is referred to as descriptive. Koul (1986) described this method:

> Descriptive research studies are designed to obtain pertinent and precise information concerning the current status of phenomena and, whenever possible, to draw valid conclusions from the facts discovered. Descriptive studies . . . involve measurement, classification, analysis, comparison, and interpretation of the data collected. (pp. 393-394)

Koul stressed that descriptive research explores how to achieve goals by suggesting possible ways and means on the basis of the experience of others or the opinion of experts; investigates phenomena in their natural setting; does not allow the researcher to manipulate the variables or arrange for events to happen; and allows the researcher to describe, analyze, and interpret his data in clear and precise terms.

The specific research questions of this study to be answered through the data gathered by the survey instrument were:

1. Which important fundamental concepts in the area of electrical/electronics technology were needed by electromechanical technology graduates for entry level employment in related industry?

2. Which important fundamental concepts in the area of mechanical technology were needed by electromechanical technology graduates for entry level employment in related industry?

3. Which important fundamental concepts in the area of fluids were needed by electromechanical technology graduates for entry level employment in related industry?

4. Which important fundamental concepts in the area of fiber optics were needed by electromechanical technology graduates for entry level employment in related industry?

5. What were the important fundamental technical concepts needed by electromechanical technology graduates for entry level employment in related industry?

Selection of the Method of Gathering Data

The problem investigated in this study was determining the fundamental concepts needed by electromechanical technology graduates to perform efficiently in entry-level employment in related industry. The objective was to identify and validate the fundamental electromechanical concepts and prioritize them for educational purposes.

Morsh and Archer (1967) delineated eight methods of gathering task analysis data: questionnaire, checklist, individual interview, observation and interview, technical conference, daily diary, work participation, and critical incident. Melching and Borcher (1973) pointed out that the questionnaire is the most economical method to gather data from a large group of people. Therefore, the questionnaire was the survey instrument used in this study to collect the necessary data.

Population And Sample Description

The review of literature has shown that people working in computers, robotics, automation, and instrumentation must have knowledge in areas such as electrical/electronics technology, mechanical technology, fluids, and fiber optics. According to the Thomas Register of American Manufacturers (1987) the U.S. states having the most companies involved in computers, robotics, automation, and instrumentation are California, New York, Ohio, Illinois, and Massachusetts. According to Marlow (1987) the organization suitable for this study was the Instrument Society of America (ISA). This organization has affiliates in the fields aforementioned.

In order to determine the members of the population, the researcher sent a letter (Appendix A) to the General Manager of ISA requesting a list of names and addresses of its members in the fields of computers, robotics, automation, and instrumentation working in the states of California, New York, Ohio, Illinois, and Massachusetts. The researcher received a letter (Appendix B) from the General Manager of ISA. In that letter the General Manager stated that ISA was interested in the study but they would not release the names and addresses of its affiliates. The only way to overcome this situation was to conduct the study in conjunction with ISA. In that letter the General Manager of ISA expressed that if the researcher was interested in the proposition, the researcher should contact Dr. Douglas J. Kolb, Director of Education Services at ISA. The researcher and his advisor made several phone calls to Dr. Kolb. A summmary of Chapter 1 of the dissertation proposal, a copy of the questionnaire, and a letter (Appendix C) were sent to him explaining the objective of the study and requesting his support. After several contacts by phone, Dr. Kolb, the researcher, and his advisor agreed:

1. ISA would randomly select the sample of 600 members among its affiliates in instrumentation, computers, robotics, and automation.

2. Most ISA affiliates in the areas of computers, robotics, automation, and instrumentation were in the states of Texas, Pennsylvania, Illinois, Ohio, New York, Michigan, Louisiana, Wisconsin, and Indiana. Therefore, most members of the sample came from these states instead of the five states selected by the researcher, based on the sources available at the library at the University of Northern Iowa.

3. The printing of the questionnaire would be done by ISA.

4. ISA would pay the postage in mailing the questionnaire, the cover letter explaining the objective of the study, a letter from Dr. Kolb supporting the study, and a self-addressed stamped envelope.

5. ISA would address each envelope to each member of the sample and mail the envelopes.

6. The researcher would pay for the printing of the questionnaire and send the original form of the questionnaire, the original form of the cover letter, 600 manila envelopes with the researcher's return address, and 600 self-addressed stamped white envelopes to ISA.

After mailing all the materials, the researcher requested by phone a list of all the names and addresses of the members of the sample for the purpose of follow-up. The researcher received the list requested, but he was told that this list be destroyed immediately upon completion of the study. The researcher agreed.

From the list, the researcher excluded eleven members because five lived overseas, two were from Canada, and four were not affiliated with ISA anymore. The final sample, then, consisted of 589 members.

The population for this study consisted of 9,211 members; 4,852 (52.68%) grouped under the field of automation and control; 3,319

(30.03%) involved in computers; and 1,040 (11.29%) in robotics. Table 1 depicts the distribution of the members of the population by field.

Table 1

Number and Percentage of Population by Field

FIELD	N	%
Automation and Control (Instrumentation - Automation)	4,852	52.68
Computers	3,319	36.03
Robotics	1,040	11.29
TOTAL	9,211	100.00

Members in the fields of instrumentation and automation were grouped under automation and control. For this study, 8,171 (88.71%) members of the population belonged to the fields of automation and control (instrumentation and automation) and computers.

From the list, the researcher counted the number of members selected from each state. Most members of the sample, 479 (81.32%), were from the states of Texas, Pennsylvania, Illinois, Ohio, New York, Michigan, Louisiana, Wisconsin, and Indiana. Table 2 shows the number and percentage of the members of the sample by state. The composition of the members of the initial sample by field is shown in Table 3.

Table 2

Number and Percentage of Members of the Sample by States

STATE	N	%
Texas	137	23.26
Pennsylvania	75	12.73
Illinois	69	11.72
Ohio	58	9.86
New York	38	6.45
Michigan	28	4.75
Louisiana	26	4.41
Wisconsin	25	4.24
Indiana	23	3.90
Others	110	18.68
TOTAL	589	100.00

From Table 3 it is shown that 275 members (45.83%) were from automation and control, 225 members (37.50%) were from computers, and 100 members (16.67%) were from robotics. There was no way for the researcher to find out the fields where the 11 excluded members belonged.

Identification of Fundamental Concepts

Identification of fundamental electromechanical concepts was done by the researcher. To accomplish this objective the researcher:

Table 3

Number and Percentage of Members of the Initial Sample by Field

FIELD	N	%
Automation and Control (Automation and Instrumentation)	275	45.83
Computer	225	37.50
Robotics	100	16.67
TOTAL	600	100.00

1. Reviewed doctoral dissertations and textbooks related to electricity/electronics technology, mechanical technology, fluids, and fiber optics. The sources considered in the electricity/electronics area were Azar (1985), Osborne (1985), Wamble (1984), and Nathan (1982); in the mechanical technology area, Adams (1985) and Rothbart (1985); in fluids, Bennett (1982) and Sullivan (1982); and in fiber optics, Senior (1985), Cancellieri (1984), Culshaw (1984), Daly (1984), Jeunhomme (1983), and Barnoski (1981).

2. Compiled concept statements identified through the materials previously mentioned.

3. Added concept statements regarding computers, robotics, automation, and instrumentation identified as having components of the electromechanical area. The following publications were reviewed:

McDonald (1986), Borer (1985), Gillum (1985), Guterl (1984), Minty (1985), Morrison (1984), Beakley and Lovell (1983), and Cassell (1983).

4. Listed the fundamental concept statements related to the electromechanical area. Figure 2 shows the procedure used in identifying the fundamental concept statements.

Validation of Fundamental Concepts

To validate the fundamental concepts that resulted from the study of several sources, the researcher sought the advice of "experts," which Wamble (1984) defined as a process of discussion and interviews with knowledgeable individuals in a technical field. For this study, people were selected who had at least the following qualifications:

1. They should be working in industries related to computers, robotics, automation, instrumentation, or industrial equipment.

2. They should be educators, supervisors or engineering consultants.

3. They should have 10 years of experience within the electromechanical technology area.

Six persons (Appendix D) working in the electromechanical area in the state of Iowa were asked to review the fundamental concepts previously identified. Three of the six people were supervisors, one at the Viking Pump company, located in Cedar Falls, and two were supervisors at the John Deere company, located in Waterloo. A fourth person was an engineering consultant in Cedar Falls. Two people were educators in the area of computers or robotics at the Hawkeye Institute of Technology in Waterloo.

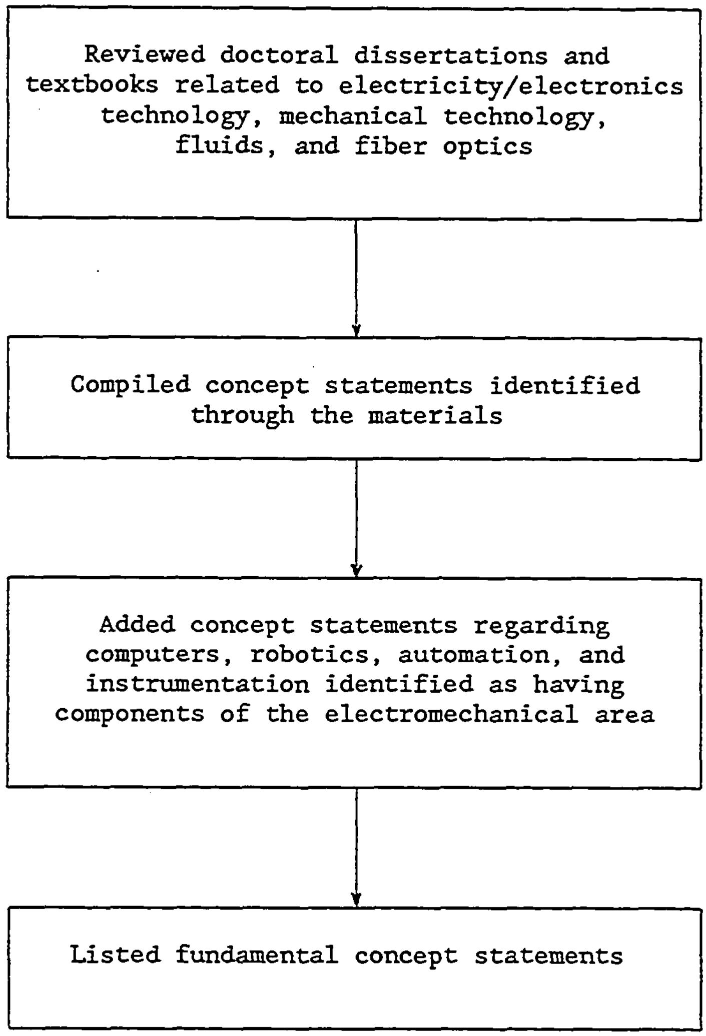

Figure 2. Procedure used in identifying the fundamental concept statements.

Supervisors in the electromechanical area were selected because they have had more experience with the entry-level requirements in the electromechanical area. The engineering consultant was selected because of his experience with electromechanical systems other than the specific fields of computers, robotics, automation, and instrumentation. Educators have had experience in the selection of fundamental concepts needed by electromechanical technology graduates for entry-level employment in related industry. These six experts were asked to review the concept statements and make additions and deletions of the survey instrument. After receiving the comments from the six experts, the survey instrument was reconstructed taking into consideration the suggestions that had been made.

Two professors (Appendix E) with three years or more of teaching experience at the university level in their respective areas were asked to review the survey instrument, remove duplications, include additional concepts, and consolidate the concept statements. One of the professors in the field of electrical/electronics technology reviewed the concept statements related to electrical/electronics and fiber optics. The other professor in the field of mechanical technology reviewed the concept statements related to mechanical and fluids. Again, the survey instrument was redone according to the comments made by the two university professors. The procedure that was followed in validating the fundamental concepts is illustrated in Figure 3.

Development and Validation of Questionnaire

The objective of the study was to determine the fundamental concepts needed by electromechanical technology graduates for entry level employment in related industry. A Likert format questionnaire was used as the instrument for this study. In a Likert scale, respondents could indicate personal agreement or disagreement while weighing the

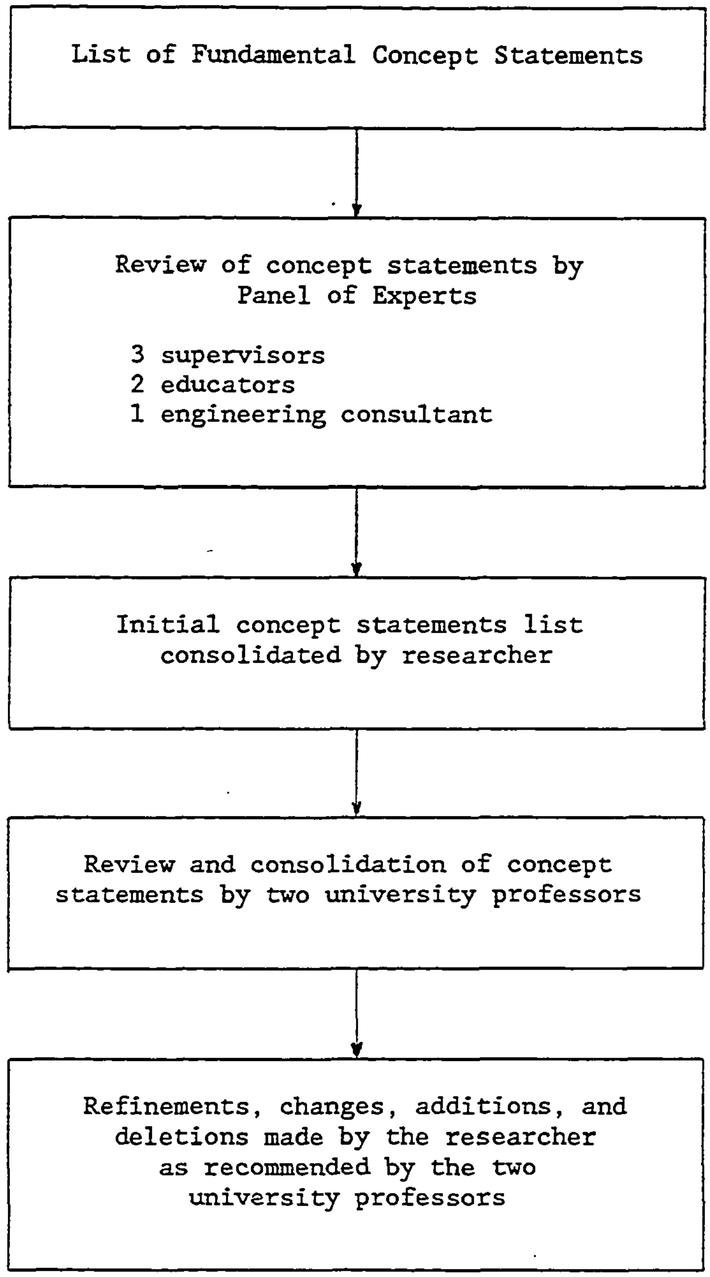

Figure 3. Procedure used in validating the fundamental concepts.

response by marking a point on the scale. The importance scale contained the following descriptors:

5. This concept is the most important
4. This concept is very important
3. This concept is important
2. This concept is the least important
1. This concept is not important

To prevent bias, two different professors (Appendix F) with similar qualifications of the first two who validated the fundamental concepts were asked to repeat the process. Necessary changes were made before the survey instrument was prepared in the final form.

<u>Pilot Test of Questionnaire</u>

The survey questionnaire was piloted with six persons working in the electromechanical area in the state of Iowa, specifically in the Waterloo-Cedar Falls area. Of the six persons, three were employed at the following companies: John Deere, Microtech Consulting Company, and Viking Pump. The remaining three were employees in computer repair, industrial control, and electrical/mechanical in addition to studying at Hawkeye Institute of Technology in Waterloo.

The pilot study was administered and monitored to determine the time needed for each respondent to complete the questionnaire. The respondents were able to accomplish this without any assistance due to the fact that the written directions were clear and concise. The time needed to complete the questionnaire was between six and ten minutes. After the pilot study, the questionnaire was prepared in its final form. The researcher worked with his advisor regarding the format, content, and presentation of the survey instrument before it was sent to the members of the sample. A copy of the questionnaire is shown in Appendix G.

Data Collection

Following the pilot test, a cover letter (Appendix H) explaining the objective of the study, a letter (Appendix I) from the Director of Education of the Instrument Society of America (ISA), a self-addressed stamped envelope, and the instrument were mailed to each member of the sample by the ISA. At the end of three weeks, a reminder (Appendix J) was mailed to each member of the sample. After waiting another two weeks from the mailing of the reminder, the sample was closed because the percentage of returns were greater than 50%.

Data Analysis

The data gathered were used to determine:

1. mean response value and standard deviation for each concept statement in the area of electrical/electronics technology.

2. mean response value and standard deviation for each concept statement in the area of mechanical technology.

3. mean response value and standard deviation for each concept statement in the area of fluids.

4. mean response value and standard deviation for each concept statement in the area of fiber optics.

5. grand mean value.

Data gathered were analyzed using the Statistical Package for Social Sciences (SPSSX) and facilities at the Academic Computing Services at the University of Northern Iowa, Cedar Falls, Iowa.

Research Question One

Which important fundamental concepts in the area of electrical/electronics technology were needed by electromechanical technology graduates for entry-level employment in related industry?

To answer this question, a ranking scale was employed. Rank was calculated by considering the mean values. When two or more concept statements had the same mean value, rank was determined by considering the standard deviation. Hopkins (1980) pointed out that an ordering by rank provides opportunity for the researcher to give serial numbers to the element being studied. A rank order assigns a position number in a distribution of values so that all of the values greater than a specified value are on one side of the specified value and all small values are on the other side. This ranking was done by using the mean value of each concept statement as rated by respondents. Hopkins (1980) stated that ranking meets two criteria: (a) it allows the researcher to differentiate within groups when observation takes place in a limited range of continuum; and (b) it permits handling data quantitatively that cannot be more exactly discriminated.

First of all, the fundamental concepts in the area of electrical/electronics (1 through 35) were listed in the same order as they appeared in the survey instrument along with their mean values as shown in Table 4. $\bar{X}1$ represents the mean value for concept number 1. Likewise, $\bar{X}2$ represents the mean value for concept number 2 and so on. The equation that was used for the mean value is:

Table 4

Method for Reporting the Results of the Questionnaire Regarding the Fundamental Concepts in the Area of Electrical/Electronics Technology With Their Mean Values

CONCEPT	MEAN
1	$\bar{X}1$
2	$\bar{X}2$
3	$\bar{X}3$
.	.
.	.
.	.
n	$\bar{X}n$

$$\bar{X}1 = \frac{\sum_{i=1}^{N} Xi1}{N}$$

where:

$\bar{X}1$ = mean value for concept number 1

$\sum_{i=1}^{N} Xi1$ = sum of the points obtained for concept number 1 from all respondents

N = number of respondents

By the same token,

$$\bar{X}2 = \frac{\sum_{i=1}^{N} Xi2}{N} \quad , \quad \bar{X}3 = \frac{\sum_{i=1}^{N} Xi3}{N} \quad , \text{ etc.}$$

All of the calculations were done at the Academic Computing Services at the University of Northern Iowa. The next step was to list the fundamental concepts in the area of electrical/electronics technology needed by electromechanical technology graduates for entry level employment ranked in descending order from the highest to the lowest mean value. When two or more concepts had the same mean value, the order was established from the lowest to the highest standard deviation. This means that the concept whose standard deviation was lower had priority over the concept whose standard deviation was higher.

The equation that was used for the standard deviation is:

$$s1 = \sqrt{\frac{\sum_{i=1}^{N} (Xi1 - \bar{X}1)^2}{N - 1}}$$

where:

s1 = standard deviation for concept number 1

Xi1 = points obtained for concept number 1 from respondent 1 when i = 1. When i = 2, Xi1 becomes X21. This means that X21 represents the points obtained for concept number 1 from respondent 2, and so on.

$\bar{X}1$ = mean value for concept number 1

N = number of respondents

$$\sum_{i=1}^{N} (Xi1 - \bar{X}1)^2 = \text{sum of all squared deviations from the mean}$$

By the same token,

$$s2 = \sqrt{\frac{\sum_{i=1}^{N} (Xi2 - \bar{X}2)^2}{N - 1}}, \quad s3 = \sqrt{\frac{\sum_{i=1}^{N} (Xi3 - \bar{X}3)^2}{N - 1}}, \text{ etc.}$$

Table 5 shows the fundamental concepts in the area of electrical/electronics technology needed by electromechanical technology graduates for entry-level employment in related industry ranked in descending order from the highest to the lowest mean value as rated by all respondents. EE1 represents the concept in the area of electrical/electronics with the highest mean value. EE2 represents the second highest value, and so on. $\bar{X}EE1$ and $\bar{X}EE2$ represent the mean value for the highest and second highest ranked value.

Finally, a summary of the important fundamental concepts in the area of electrical/electronics needed by electromechanical technology graduates for entry-level employment in related industries is indicated in Table 6. Wamble (1984) used the grand mean value as a cutoff point in separating important items from lesser important ones. For the purpose of this study, the important fundamental concepts in the area of electrical/electronics technology were identified as those having mean values equal to or greater than the grand mean value.

The grand mean value indicates the average of means of all concepts from all respondents. The equation that was used to find the grand mean value is:

Table 5

Method for Reporting the Results of the Questionnaire Regarding the Fundamental Concepts in the Area of Electrical/Electronics Technology in Descending Order According to the Mean Value

RANK	CONCEPT	MEAN
1	EE1	$\bar{X}$EE1
2	EE2	$\bar{X}$EE2
3	EE3	$\bar{X}$EE3
.	.	.
.	.	.
n	EEn	$\bar{X}$EEn

$$\text{Grand mean} = \frac{\sum_{i=1}^{N} \bar{X}i}{N}$$

where:

$\sum_{i=1}^{N} \bar{X}i$ = sum of the mean values of all concepts (electrical, mechanical, fluids, and fiber optics)

N = total number of concepts

Table 6

Method for Reporting the Results of the Questionnaire Regarding the Important Fundamental Concepts in the Area of Electrical/Electronics Technology in Descending Order According to the Mean Value

RANK	CONCEPT	MEAN
1	EE1	$\bar{X}$EE1
2	EE2	$\bar{X}$EE2
3	EE3	$\bar{X}$EE3
.	.	.
.	.	.
x	EEx	$\bar{X}$EEx

$\bar{X}$EEx represents the lowest mean value equal to or greater than the grand mean value. EEx represents the concept whose mean is $\bar{X}$EEx.

Research Question Two

Which important fundamental concepts in the area of mechanical technology were needed by electromechanical technology graduates for entry level employment in related industry?

The procedure that was followed to answer this research question was the same as the one described for the first research question. In this case the concepts considered were the mechanical ones (67 through 91) in the survey instrument.

Research Question Three

Which important fundamental concepts in the area of fluids were needed by electromechanical technology graduates for entry level employment in related industry?

The procedure for answering this research question was the same as for the first research question. Only the concept statements 52 through 66 in the survey instrument were considered.

Research Question Four

Which important fundamental concepts in the area of fiber optics were needed by electromechanical technology graduates for entry level employment in related industry?

The procedure to be used was the same as the one described for research question one. The concepts relating to the area of fiber optics (36 through 51) were the only ones considered to answer the fourth research question.

Research Question Five

What were the important fundamental technical concepts needed by electromechanical technology graduates for entry level employment in related industry?

This question was answered by considering all the important fundamental concepts obtained through the previous four research questions. These important fundamental concepts were listed in descending order from the highest to the lowest mean value as depicted in Table 7. In case that two or more concepts had the same mean value,

Table 7

Method for Reporting the Results of the Important Fundamental Concepts in the Electromechanical Field in Descending Order According to the Mean Value

RANK	CONCEPT	MEAN	AREA
1	EM1	$\bar{X}$EM1	
2	EM2	$\bar{X}$EM2	
3	EM3	$\bar{X}$EM3	
.	.	.	
.	.	.	
N	EMN	$\bar{X}$EMN	

the order was determined from the lowest to the highest standard deviation.

EM1 represents the concept with the highest mean value of the four areas: electrical/electronics technology, fiber optics, mechanical technology, and fluids. $\bar{X}$EM1 represents the mean value for concept EM1. Likewise, EM2 represents the concept with the second highest mean value. $\bar{X}$EM2 represents the mean value for concept EM2, etc. The area to which each concept belonged (electrical/electronics technology, fiber optics, mechanical technology, and fluids) was indicated in the column AREA.

The conclusions to be determined from Table 7 were:

1. Number and percentage of important concepts belonging to each of the four areas considered in this study.

2. The area that predominates in the upper 25%.

3. The area that predominates in the lower 25%.

CHAPTER 4

PRESENTATION AND ANALYSIS OF DATA

Return Rate

A survey instrument was sent to each member of the sample. It consisted of 589 members working in the fields of instrumentation, computers, robotics, and automation in the United States. All members of the sample were affiliates of the Instrument Society of America (ISA). Most members, 479 (81.32%) were from the states of Texas, Pennsylvania, Illinois, Ohio, New York, Michigan, Louisiana, Wisconsin, and Indiana.

The number of responses was 329 (55.85%). A return of 50% is considered meaningful for statistical purposes (Babbie, 1973). Of the 329 questionnaires, one questionnaire was returned because of an insufficient address, one questionnaire was returned blank because the member was not an employee and did not have job experience, and two questionnaires were partially answered. Therefore, 325 (55.18%) questionnaires were usable. The number of respondents and percentage by field is shown in Table 8. It shows that 235 members (72.31%) specified their main field of activity; 90 (27.69%) indicated more than one main field of activity, citing Instrumentation as the most common one; 94 (28.92%) were from the field of instrumentation; 62 (19.08%) were from the field of automation; 52 (16.00%) were from the field of computer; and 27 (8.31%) were from the field of robotics.

Table 8

Number and Percentage of Respondents by Field

FIELD	N	Cumulative N	%	Cumulative %
Instrumentation	94	94	28.92	28.92
Automation	62	156	19.08	48.00
Computer	52	208	16.00	64.00
Robotics	27	235	8.31	72.31
Comp-Inst-Autom	33	268	10.15	82.46
Comp-Automation	22	290	6.76	89.22
Inst-Automation	19	309	5.85	95.07
Inst-Computer	9	318	2.77	97.84
Inst-Comp-Autom-Robot	5	323	1.54	99.38
Inst-Robotics	1	324	0.31	99.69
Inst-Autom-Robotics	1	325	0.31	100.00
TOTAL	325		100.00	

Treatment of Data

Mean response values and standard deviations were calculated for each of the 91 concept statements. Concept statements were analyzed separately by area (electrical/electronics technology, mechanical technology, fluids, and fiber optics) and ranked in descending order from the highest to the lowest mean value. When two or more concepts had the same mean values, the rank was established from the lowest to the highest standard deviation.

Important concept statements by area were determined by taking into consideration the grand mean value of 2.80 (on a scale of 1 to 5). Therefore, concepts were considered important when their mean values were equal to or greater than 2.80.

Research Question One

Which important fundamental concepts in the area of electrical/electronics technology were needed by electromechanical technology graduates for entry-level employment in related industry?

Table 9 shows the fundamental concepts in the area of electrical/electronics technology (1 through 35) in the same order as they appeared in the survey instrument along with their mean values.

Table 10 depicts the fundamental concepts in the area of electrical/electronics technology needed by electromechanical technology graduates for entry-level employment in related industry ranked in descending order from the highest to the lowest mean value as rated by all respondents. When two or more concepts had the same mean value the rank order was established from the lowest to the highest standard deviation (s).

The concept "process control and feedback" was rated highest with a mean value of 4.25. On the other hand, the concept "microwave energy and radiation" was rated lowest with a mean value of 2.06.

Three concepts were rated with a mean value greater than 4.00, 16 concepts were rated with a mean value greater than 3.00 and less than

Table 9

Fundamental Concepts in the Area of Electrical/Electronics Technology With Their Mean Values

ORDER	CONCEPT	MEAN
1	Sources of electricity	3.17
2	Electric conductor materials and properties	2.94
3	Electric insulator materials and properties	2.90
4	Printed circuitry (manufacturing, losses, efficiency, etc.)	2.54
5	Electro-thermal losses	2.53
6	Electronic symbols on diagrams	3.79
7	Electrical quantities (voltage, current, resistance, power)	4.12
8	Ohm's law in AC and DC circuits	3.97
9	Kirchhoff's laws in AC and DC circuits	3.60
10	Magnetism and electromagnetism	3.14
11	Effect of capacitance and inductance in AC and DC circuits	3.45
12	Impedance and its effect on power in AC circuitry	3.37
13	Negative and positive feedback	3.49
14	Characteristics and operation of semiconductors (diode, transistor, SCR, etc.)	3.36
15	Efficiency of electric motors	2.86
16	Operation of electric machines (motors, alternators, and generators)	3.18
17	Process control and feedback	4.25

Table 9 (continued)

ORDER	CONCEPT	MEAN
18	Displays (e.g., seven segment, multiplexing LED's, matrix LED, and LCD's)	3.36
19	Electrical generation/transmission systems	2.69
20	Electrical transducers (e.g., photoelectric detector, temperature probe, microphone, thermistor)	3.73
21	Radio frequency transmission	2.48
22	Measurements of RF energy and its use in sensors, diesel engine, timing, etc.	2.17
23	Microwave energy and radiation	2.06
24	Analysis and design of basic transistor amplifiers	2.37
25	Microchips (properties, manufacturing, uses)	2.76
26	Linear IC's (op amps, timer, voltage regulator)	2.95
27	Digital IC's (TTL, CMOS, HTL, memories)	2.94
28	Operation of multivibrators and oscillators	2.50
29	Operation of timing circuits	2.99
30	Programmable controllers	4.09
31	Operation of microprocessors, memory circuits, and CPU's	3.75
32	Principles of Boolean algebra for digital circuits	3.29
33	Machine and assembly language	2.89
34	Writing, running, and debugging microcomputer programs (BASIC, PASCAL, etc.)	3.39
35	Microprocessor interfacing	3.55

Table 10

Fundamental Concepts in the Area of Electrical/Electronics Technology in Descending Order According to the Mean Value

RANK	CONCEPT	MEAN
1	Process control and feedback	4.25
2	Electrical quantities (voltage, current, resistance, power)	4.12
3	Programmable controllers	4.09
4	Ohm's law in AC and DC circuits	3.97
5	Electronic symbols on diagrams	3.79
6	Operation of microprocessors, memory circuits, and CPU's	3.75
7	Electrical transducers (e.g., photoelectric detector, temperature probe, microphone, thermistor)	3.73
8	Kirchhoff's laws in AC and DC circuits	3.60
9	Microprocessor interfacing	3.55
10	Negative and positive feedback	3.49
11	Effect of capacitance and inductance in AC and DC circuits	3.45
12	Writing, running, and debugging microcomputer programs (BASIC, PASCAL, etc.)	3.39
13	Impedance and its effect on power in AC circuitry	3.37
14	Displays (e.g., seven segment, multiplexing LED's, matrix LED, and LCD's)	3.36[a]
15	Characteristics and operation of semiconductors (diode, transistor, SCR, etc.)	3.36[b]
16	Principles of Boolean algebra for digital circuits	3.29

Table 10 (continued)

RANK	CONCEPT	MEAN
17	Operation of electric machines (motors, alternators, and generators)	3.18
18	Sources of electricity	3.17
19	Magnetism and electromagnetism	3.14
20	Operation of timing circuits	2.99
21	Linear IC's (op amps, timer, voltage regulator)	2.95
22	Electric conductor materials and properties	2.94[c]
23	Digital IC's (TTL, CMOS, HTL, memories)	2.94[d]
24	Electric insulator materials and properties	2.90
25	Machine and assembly language	2.89
26	Efficiency of electric motors	2.86
27	Microchips (properties, manufacturing, uses)	2.76
28	Electrical generation/transmission systems	2.69
29	Printed circuitry (manufacturing, losses, efficiency, etc.)	2.54
30	Electro-thermal losses	2.53
31	Operation of multivibrators and oscillators	2.50
32	Radio frequency transmission	2.48
33	Analysis and design of basic transistor amplifiers	2.37
34	Measurements of RF energy and its use in sensors, diesel engine, timing, etc.	2.17
35	Microwave energy and radiation	2.06

<u>Note</u>. $^{a}s = 1.07$. $^{b}s = 1.23$. $^{c}s = 1.13$. $^{d}s = 1.26$.

4.00, and 16 concepts were rated with a mean value equal to or greater than 2.00 but less than 3.00. The concepts with a mean value greater than 4.00 are process control and feedback, programmable controllers, and electrical quantities (voltage, current, resistance, power).

The important fundamental concepts in the area of electrical/electronics technology needed by electromechanical technology graduates for entry-level employment in related industries are indicated in Table 11. Only the concept statements whose mean values are equal to or greater than the grand mean value (2.80) are shown. Twenty-six out of 35 fundamental concepts in the area of electrical/electronics technology were rated equal to or greater than the grand mean value by all respondents.

Research Question Two

Which important fundamental concepts in the area of mechanical technology were needed by electromechanical technology graduates for entry level employment in related industry?

To answer this research question the concepts considered were the mechanical ones (67 through 91) in the survey instrument. Table 12 depicts the fundamental concepts in the area of mechanical technology with their mean values.

Table 13 indicates the fundamental concepts in the area of mechanical technology needed by electromechanical technology graduates for entry level employment ranked in descending order from the highest to the lowest mean value. When two or more concepts had the same mean

Table 11

Important Fundamental Concepts in the Area of Electrical/Electronics Technology in Descending Order According to the Mean Value

RANK	CONCEPT	MEAN
1	Process control and feedback	4.25
2	Electrical quantities (voltage, current, resistance, power)	4.12
3	Programmable controllers	4.09
4	Ohm's law in AC and DC circuits	3.97
5	Electronic symbols on diagrams	3.79
6	Operation of microprocessors, memory circuits, and CPU's	3.75
7	Electrical transducers (e.g., photoelectric detector, temperature probe, microphone, thermistor)	3.73
8	Kirchhoff's laws in AC and DC circuits	3.60
9	Microprocessor interfacing	3.55
10	Negative and positive feedback	3.49
11	Effect of capacitance and inductance in AC and DC circuits	3.45
12	Writing, running, and debugging microcomputer programs (BASIC, PASCAL, etc.)	3.39
13	Impedance and its effect on power in AC circuitry	3.37
14	Displays (e.g., seven segment, multiplexing LED's, matrix LED, and LCD's)	3.36
15	Characteristics and operation of semiconductors (diode, transistor, SCR, etc.)	3.36

Table 11 (continued)

RANK	CONCEPT	MEAN
16	Principles of Boolean algebra for digital circuits	3.29
17	Operation of electric machines (motors, alternators, and generators)	3.18
18	Sources of electricity	3.17
19	Magnetism and electromagnetism	3.14
20	Operation of timing circuits	2.99
21	Linear IC's (op amps, timer, voltage regulator)	2.95
22	Electric conductor materials and properties	2.94
23	Digital IC's (TTL, CMOS, HTL, memories)	2.94
24	Electric insulator materials and properties	2.90
25	Machine and assembly language	2.89
26	Efficiency of electric motors	2.86

value, the rank order was established from the lowest to the highest standard deviation (s).

Two concepts were rated with a mean value greater than 3.00. Twenty-two concepts were rated with a mean value greater than 2.00 but less than 3.00. One concept was rated with a mean value less than 2.00. The concepts with a mean value greater than 3.00 are (a) work, torque, and power in mechanical systems and (b) displacement, velocity, and acceleration. The concept with a mean value less than 2.00 is "flywheels."

Table 12

Fundamental Concepts in the Area of Mechanical Technology With Their Mean Values

ORDER	CONCEPT	MEAN
1	Sources of mechanical energy	2.67
2	General physical properties of materials (aluminum, mica, iron, rubber, etc.)	2.58
3	Work, torque, and power in mechanical systems	3.02
4	Displacement, velocity, and acceleration	3.00
5	Friction and associated losses	2.68
6	Thermal, vibrational and stress failures	2.72
7	Statics	2.47
8	Dynamics and kinematics	2.58
9	Simple harmonic motion and applications	2.32
10	Flywheels	1.94
11	Springs and spring loaded designing	2.21
12	Mechanical metallurgy concepts	2.20
13	Elasticity and plasticity concepts	2.20
14	Simple machines	2.50
15	Linkages and lever mechanisms	2.64
16	Pulleys and belt drives	2.38
17	Chain and sprocket drives	2.26
18	Gears and gear trains	2.41
19	Cams and cam actuation	2.47

Table 12 (continued)

ORDER	CONCEPT	MEAN
20	Universal joints	2.10
21	Continuous and intermittent motion mechanisms	2.25
22	Mechanical transducers	2.83
23	Clutches and clutch systems	2.20
24	Bearings	2.47
25	Computer applications in mechanical design of mechanical energy	2.82

Table 13

Fundamental Concepts in the Area of Mechanical Technology in Descending Order According to the Mean Value

RANK	CONCEPT	MEAN
1	Work, torque, and power in mechanical systems	3.02
2	Displacement, velocity, and acceleration	3.00
3	Mechanical transducers	2.83
4	Computer applications in mechanical design of mechanical energy	2.82
5	Thermal, vibrational and stress failures	2.72
6	Friction and associated losses	2.68
7	Sources of mechanical energy	2.67

Table 13 (continued)

RANK	CONCEPT	MEAN
8	Linkages and lever mechanisms	2.64
9	Dynamics and kinematics	2.58[a]
10	General physical properties of materials (aluminum, mica, iron, rubber, etc.)	2.58[b]
11	Simple machines	2.50
12	Statics	2.47[c]
13	Cams and cam actuation	2.47[d]
14	Bearings	2.47[e]
15	Gears and gear trains	2.41
16	Pulleys and belt drives	2.36
17	Simple harmonic motion and applications	2.32
18	Chain and sprocket drives	2.26
19	Continuous and intermittent motion mechanisms	2.25
20	Springs and spring loaded designing	2.21
21	Mechanical metallurgy concepts	2.20[f]
22	Clutches and clutch systems	2.20[g]
23	Elasticity and plasticity concepts	2.20[h]
24	Universal joints	2.10
25	Flywheels	1.94

Note. [a]s = 1.14. [b]s = 1.19. [c]s = 1.08. [d]s = 1.15. [e]s = 1.16. [f]
[g]s = 1.11. [h]s = 1.13.

In the area of mechanical technology, the highest rated concept was "work, torque, and power in mechanical systems" with a mean value of 3.02. The lowest rated concept was "flywheels" with a mean value of 1.89.

The important fundamental concepts in the area of mechanical technology needed by electromechanical technology graduates for entry-level employment in related industry are shown in Table 14. Four out of 25 concepts were rated equal to or greater than the grand mean value by all respondents.

Table 14

Important Fundamental Concepts in the Area of Mechanical Technology in Descending Order According to the Mean Value

RANK	CONCEPT	MEAN
1	Work, torque, and power in mechanical systems	3.02
2	Displacement, velocity, and acceleration	3.00
3	Mechanical transducers	2.83
4	Computer applications in mechanical design of mechanical energy	2.82

Research Question Three

Which important fundamental concepts in the area of fluids are needed by electromechanical technology graduates for entry level employment in related industry?

To answer this research question concept statements 52 through 66 in the survey instrument were considered. Table 15 shows the fundamental concepts in the area of fluids with their mean values.

The fundamental concepts in the area of fluids needed by electromechanical technology graduates for entry level employment ranked in descending order from the highest to the lowest mean value are depicted in Table 16. Eight concepts were rated with a mean value greater than 3.00 but less than 4.00. Seven concepts were rated with a mean value greater than 2.00 but less than 3.00.

Modulating devices (flow, pressure, and directional control valves; nozzels; venturies) was the concept rated with the highest mean value (3.68) in the area of fluids. The lowest rated concept was "fluid lubrication characteristics," with a mean value of 2.28.

The important fundamental concepts in the area of fluids needed by electromechanical technology graduates for entry-level employment in related industry are shown in Table 17. Ten out of 15 fundamental concepts were rated equal to or greater than the grand mean value by all respondents.

Research Question Four

Which important fundamental concepts in the area of fiber optics were needed by electromechanical technology graduates for entry level employment in related industry?

Table 15

Fundamental Concepts in the Area of Fluids With Their Mean Values

ORDER	CONCEPT	MEAN
1	Fluids and their physical properties (friction, viscosity, turbulence, toxicity)	3.17
2	Relationships of force, displacement and pressure in fluids	3.24
3	Potential and kinetic energy in fluid systems	2.90
4	Fluid lubrication characteristics	2.28
5	Fluid reservoirs, strainers and filters	2.50
6	Pumps/compressors	3.06
7	Fluid logic control systems	2.67
8	Modulating devices (flow, pressure, and directional control valves; nozzels; venturies)	3.68
9	Proportionating valves	3.43
10	Fluid flow, velocity, and pressure drop in pipes	3.39
11	Seals and sealing materials	2.76
12	Fluid actuators (cylinders, motors)	3.04
13	Fluid transducers (pressure transducer, electronic flow meter, etc.)	3.65
14	Hydrostatic transmissions	2.33
15	Constant flow and pressure systems	2.92

Table 16

Fundamental Concepts in the Area of Fluids in Descending Order According to the Mean Value

RANK	CONCEPT	MEAN
1	Modulating devices (flow, pressure, and directional control valves; nozzels; venturies)	3.68
2	Fluid transducers (pressure transducer, electronic flow meter, etc.)	3.65
3	Proportionating valves	3.43
4	Fluid flow, velocity, and pressure drop in pipes	3.39
5	Relationships of force, displacement and pressure in fluids	3.24
6	Fluids and their physical properties (friction, viscosity, turbulence, toxicity)	3.17
7	Pumps/compressors	3.06
8	Fluid actuators (cylinders, motors)	3.04
9	Constant flow and pressure systems	2.92
10	Potential and kinetic energy in fluid systems	2.90
11	Seals and sealing materials	2.76
12	Fluid logic control systems	2.67
13	Fluid reservoirs, strainers and filters	2.50
14	Hydrostatic transmissions	2.33
15	Fluid lubrication characteristics	2.28

Table 17

Important Fundamental Concepts in the Area of Fluids in Descending Order According to the Mean Value

RANK	CONCEPT	MEAN
1	Modulating devices (flow, pressure, and directional control valves; nozzels; venturies)	3.68
2	Fluid transducers (pressure transducer, electronic flow meter, etc.)	3.65
3	Proportionating valves	3.43
4	Fluid flow, velocity, and pressure drop in pipes	3.39
5	Relationships of force, displacement and pressure in fluids	3.24
6	Fluids and their physical properties (friction, viscosity, turbulence, toxicity)	3.17
7	Pumps/compressors	3.06
8	Fluid actuators (cylinders, motors)	3.04
9	Constant flow and pressure systems	2.92
10	Potential and kinetic energy in fluid systems	2.90

Concept statements 36 through 51 in the survey instrument were considered to answer the fourth research question. Table 18 lists the fundamental concepts in the area of fiber optics with their mean values as rated by respondents.

Table 19 shows the fundamental concepts in the area of fiber optics needed by electromechanical technology graduates for entry level employment ranked in descending order from the highest to the lowest mean value. Thirteen concepts were rated with a mean value equal to or greater than 2.00 but less than 3.00. Three concepts were rated with a mean value less than 2.00 but greater than 1.00.

The concept "multiplexing" was rated with the highest mean value (2.84) in the area of fiber optics. The lowest rated concept was "optical fiber connection" with a mean value of 1.87.

The important fundamental concepts in the area of fiber optics needed by electromechanical technology graduates for entry-level employment in related industry are shown in Table 20. One out of 16 concepts in the area of fiber optics was rated equal to or greater than the grand mean value by all respondents. This concept is "multiplexing."

Research Question Five

What were the important fundamental technical concepts needed by electromechanical technology graduates for entry level employment in related industry?

To answer this research question only the important fundamental concepts of the four areas previously studied were considered. Table 21 shows the number and percentage of important fundamental concepts by area.

Forty-one out of 91 fundamental concepts were considered important by respondents. Of these, 26 concepts (63.41%) belong to the area of electrical/electronics technology, 10 concepts (24.39%) belong to the

Table 18

Fundamental Concepts in the Area of Fiber Optics With Their Mean Values

ORDER	CONCEPT	MEAN
1	Materials for optical fibers	2.17
2	Fabrication of optical fibers	1.87
3	Cladding materials and refraction of light	2.00
4	Fiber losses (absorption, scattering, etc.)	2.20
5	Glassy materials (properties and fabrication)	1.93
6	Physical properties in optical materials	2.06
7	Optical communication systems	2.77
8	Methods of light propagation in optical fibers	2.12
9	Light emission and laser operation	2.18
10	Optical transmission and reception	2.41
11	Operation of optoisolators	2.59
12	Photodiodes with and without internal gain	2.24
13	Optical fiber transmission lines	2.41
14	Modulation, demodulation, and optical integrated circuits	2.35
15	Multiplexing	2.84
16	Optical fiber connection	2.72

Table 19

Fundamental Concepts in the Area of Fiber Optics in Descending Order According to the Mean Value

ORDER	CONCEPT	MEAN
1	Multiplexing	2.84
2	Optical communication systems	2.77
3	Optical fiber connection	2.72
4	Operation of optoisolators	2.59
5	Optical fiber transmission lines	2.41
6	Optical transmission and reception	2.41
7	Modulation, demodulation, and optical integrated circuits	2.35
8	Photodiodes with and without internal gain	2.24
9	Materials for optical fibers	2.17
10	Light emission and laser operation	2.18
11	Fiber losses (absorption, scattering, etc.)	2.20
12	Methods of light propagation in optical fibers	2.12
13	Physical properties in optical materials	2.06
14	Cladding materials and refraction of light	2.00
15	Glassy materials (properties and fabrication)	1.93
16	Fabrication of optical fibers	1.87

Table 20

Important Fundamental Concepts in the Area of Fiber Optics in Descending Order According to the Mean Value

ORDER	CONCEPT	MEAN
1	Multiplexing	2.84

Table 21

Important Electromechanical Concepts by Area, Number and Percentage

AREA	N	%
ELECTRICAL/ELECTRONICS	26	63.41
FLUIDS	10	24.39
MECHANICAL	4	9.76
FIBER OPTICS	1	2.44
TOTAL	41	100.00

area of fluids, 4 concepts (9.76%) belong to the area of mechanical technology, and 1 concept (2.44%) belongs to the area of fiber optics.

Table 22 shows the important fundamental concepts listed in descending order from the highest to the lowest mean value. When two or more concepts had the same mean value, the order was established from the lowest to the highest standard deviation. The area to which each concept belongs (electrical/electronics technology, fiber optics, mechanical technology, and fluid) is also indicated.

Three concepts were rated with a mean value equal to or greater than 4.00. Twenty-six concepts were rated with a mean value greater than 3.00 but less than 4.00. Thirteen concepts were rated with a mean value greater than the grand mean value (2.80) but less than 3.00.

In the upper 25 percent, or the first 10 important concepts, 8 belong to the area of electrical/electronics technology, and 2 belong to the area of fluids. The eight important concepts in the area of electrical/electronics technology are: process control and feedback; programmable controllers; electrical quantities (voltage, current, resistance, power); Ohm's law in AC and DC circuits; operation of microprocessors, memory circuits, and CPU's; electronic symbols in diagrams; electrical transducers (e.g., thermistor, temperature probe, microphone, photoelectric detector); and Kirchhoff's laws in AC and DC circuits. The two concepts in the area of fluids are modulating devices (flow, pressure, and directional control valves; nozzels; venturies) and fluid transducers (pressure transducer, electrical flow meter, etc.).

In the lower 25 percent, or the last 10 concepts, six belong to the area of electrical/electronics technology, two belong to the area of mechanical technology, one belongs to the area of fluids, and one belongs to the area of fiber optics. The six concepts in the area of electrical/electronics technology are: electric conductor materials and properties, linear IC's (op amps, timer, voltage regulator), digital IC's (TTL, CMOS, HTL, memories), machine and assembly language, electric

Table 22

Important Fundamental Concepts in the Electromechanical Field in Descending Order According to the Mean Value

RANK	CONCEPT	MEAN	AREA
1	Process control and feedback	4.25	ELECT
2	Electrical quantities (voltage, current, resistance, power)	4.12	ELECT
3	Programmable controllers	4.09	ELECT
4	Ohm's law in AC and DC circuits	3.97	ELECT
5	Operation of microprocessors, memory circuits, and CPU's	3.75	ELECT
6	Electronic symbols on diagrams	3.79	ELECT
7	Electrical transducers (e.g., thermistor, temperature probe, microphone, photoelectric detector))	3.73	ELECT
8	Modulating devices (flow, pressure, and directional control valves; nozzels; venturies)	3.68	FLUID
9	Fluid transducers (pressure transducer, electronic flow meter, etc.)	3.65	FLUID
10	Kirchhoff's laws in AC and DC circuits	3.60	ELECT
11	Microprocessor interfacing	3.55	ELECT
12	Negative and positive feedback	3.49	ELECT
13	Effect of capacitance and inductance in AC and DC circuits	3.45	ELECT
14	Proportionating valves	3.43	FLUID
15	Fluid flow, velocity, and pressure drop in pipes	3.39	FLUID

Table 22 (continued)

RANK	CONCEPT	MEAN	AREA
16	Writing, running, and debugging microcomputer programs (BASIC, PASCAL)	3.39	ELECT
17	Impedance and its effect on power in AC circuitry	3.37	ELECT
18	Displays (e.g., seven segment, LCD's multiplexing LED's, matrix LED)	3.36[a]	ELECT
19	Characteristics and operation of semiconductors (diode, transistor, SCR, etc.)	3.36[b]	ELECT
20	Principles of Boolean algebra for digital circuits	3.29	ELECT
21	Relationships of force, displacement and pressure in fluids	3.24	FLUID
22	Operation of electric machines (motors, alternators, and generators)	3.18	ELECT
23	Sources of electricity	3.17[c]	ELECT
24	Fluids and their physical properties (friction, viscosity, turbulence, toxicity)	3.17[d]	FLUID
25	Magnetism and electromagnetism	3.14	ELECT
26	Pumps/compressors	3.06	FLUID
27	Fluid actuators (cylinders, motors)	3.04	FLUID
28	Work, torque, and power in mechanical systems	3.02	MECH
29	Displacement, velocity, and acceleration	3.00	MECH
30	Operation of timing circuits	2.99	ELECT

Table 22 (continued)

RANK	CONCEPT	MEAN	AREA
31	Linear IC's (op amps, timer, voltage regulator)	2.95	ELECT
32	Electric conductor materials and properties	2.94	ELECT
33	Digital IC's (TTL, CMOS, HTL, memories)	2.94	ELECT
34	Constant flow and pressure systems	2.92	FLUID
35	Potential and kinetic energy in fluid systems	2.90[e]	FLUID
36	Electric insulator materials and properties	2.90[f]	ELECT
37	Machine and assembly language	2.89	ELECT
38	Efficiency of electric motors	2.86	ELECT
39	Multiplexing	2.84	FIBER
40	Mechanical transducers	2.83	MECH
41	Computer applications in mechanical design of mechanical energy	2.82	MECH

Note. [a]s = 1.07. [b]s = 1.23. [c]s = 1.16. [d]s = 1.20. [e]s = 1.14. [f]

insulator materials and properties, and efficiency of electric motors. The two concepts in the area of mechanical technology are computer applications in mechanical design of mechanical energy and mechanical transducers. The concept in the area of fluids is "potential and kinetic energy in fluid systems." The concept in fiber optics is "multiplexing."

Additional Concepts and/or Areas Needed by Electromechanical Technologists

Respondents were asked to list additional concepts and or areas needed by electromechanical technologists. Appendix K lists all the statements provided by respondents in regard to this question. Appendix L shows the comments made by some respondents regarding the electromechanical area.

CHAPTER 5

SUMMARY, FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS

Summary

The review of literature indicated there was a need for electromechanical technology programs at four-year educational institutions. Minty (1985) and Brooking (1984) stated that new industrial systems use electrical and mechanical components which need to be serviced. Therefore, it is necessary to prepare electromechanical technologists to assure that modern industrial equipment will be serviced. This new kind of technologist will have greater opportunities in the job market than at present.

The purposes of this study were to:

1. Provide a list of fundamental electromechanical concepts which may contribute to the planning and development of the curriculum for electromechanical technology graduates in four-year educational institutions in the U.S. in general and, in particular, the School of Electromechanical Technology at the National University of Education, in Lima, Peru. The researcher was aware that technology and cultural aspects differ from one country to another. However, the methodology used in this study will be valuable in conducting a similar study in Peru.

2. Establish the need that the areas of electrical/electronics technology and mechanical technology may be combined into a single new area with clear advantages for graduates to adapt to job changes due to advances in technology.

3. Provide a guide to high-school counselors, high school students, and teachers of electrical/electronics technology and mechanical technology so they can become aware of the fundamental concepts needed by electromechanical technology graduates for entry level employment in related industry.

4. Foster a spirit of cooperation between the electromechanical industry and higher education. Industry representatives were given the opportunity to rate the fundamental concepts needed by electromechanical technology graduates to meet industry's needs and make suggestions during the data gathering process.

To accomplish these purposes the following research questions were answered:

1. Which important fundamental concepts in the area of electrical/electronics technology were needed by electromechanical technology graduates for entry level employment in related industry?

2. Which important fundamental concepts in the area of mechanical technology were needed by electromechanical technology graduates for entry level employment in related industry?

3. Which important fundamental concepts in the area of fluids were needed by electromechanical technology graduates for entry level employment in related industry?

4. Which important fundamental concepts in the area of fiber optics were needed by electromechanical technology graduates for entry level employment in related industry?

5. What were the important fundamental technical concepts needed by electromechanical technology graduates for entry level employment in related industry?

The population for this study was all the employees working in the fields of computer, instrumentation, automation, and robotics in the United States, as identified by the Instrument Society of America (ISA). The initial sample was made up of 600 members. Eleven members were excluded because five lived overseas, two were from Canada, and the other four were not affiliated with ISA anymore. Therefore, the final sample for this study was made up of 589 members. Most members of this sample (479 or 81.32%) were from the states of Texas, Pennsylvania, Illinois, Ohio, New York, Michigan, Louisiana, Wisconsin, and Indiana.

A survey instrument containing 91 concept statements was sent to each member of the sample. Three hundred and twenty-nine questionnaires (55.85%) were returned. Of these, one was returned because of an insufficient address, one was returned blank because the member was a student and had no job experience, and the other two were partially completed. Therefore, the number of usable questionnaires was 325 (55.18%). From the data collected the mean value and the standard deviation were calculated for each of the 91 concept statements. The grand mean value was also calculated. These calculations were done at the Academic Computing Services at the University of Northern Iowa, using the Statistical Package for Social Sciences (SPSSX). The data gathered were used to answer each of the five aforementioned research questions.

To answer research questions 1 through 4, a 3-step procedure was followed for each of them:

1. Concept statements were listed in the same order as they appeared in the survey instrument along with their mean values. Standard deviations were also calculated but not reported.

2. Concept statements were listed in descending order from the highest to the lowest mean value. When two or more concepts had the same mean value, the concept whose standard deviation was lower had priority over the concept whose standard deviation was higher.

3. For the purpose of this study, important fundamental concepts were identified as those statements having mean values equal to or greater than the grand mean value. The grand mean value for this study was 2.80.

Research question number five was answered by considering all the important fundamental concepts identified in the previous four research questions. These concept statements were listed in descending order from the highest to the lowest mean value.

Findings

The findings of this study were:

1. Twenty-six important fundamental concepts were identified in the area of electrical/electronics technology (see Table 11, p. 66).

2. Four important fundamental concepts were identified in the area of mechanical technology (see Table 14, p. 71).

3. Ten important fundamental concepts were identified in the area of fluids (see Table 17, p. 75).

4. One important fundamental concept was identified in the area of fiber optics (see Table 20, p. 79).

5. Combining the important concepts of the four individual areas above produced 41 important fundamental concepts to be included in the electromechanical area.

Conclusions

Based on the presentation and analysis of data presented in Chapter 4, the following conclusions have been reached:

1. Respondents from the fields of computer, instrumentation, automation, and robotics established, by rating concept statements in a survey instrument, that electromechanical technologists should have preparation in the areas of electrical/electronics technology, mechanical technology, and fluids. Therefore, there is a need for electromechanical technology graduates who can function effectively in the aforementioned fields.

2. Electromechanical technology programs must provide background in the areas of electrical/electronics technology, fluids, and mechanical technology in order that electromechanical technology graduates can perform efficiently in instrumentation, computers, robotics, and automation.

3. Electromechanical technology programs should place most emphasis in the area of electrical/electronics technology. This conclusion is in agreement with Conrads (1983).

4. Contrary to the findings of the survey of literature, the area of fiber optics has been shown by this study to be of low importance for today's electromechanical technologists. However, respondents reported that this area will become increasingly important in a few years from now.

Recommendations

The following recommendations are made in light of this study:

1. The areas of electrical/electronics technology, mechanical technology, and fluids should be combined into a single electromechanical area. This would ensure that graduates will perform effectively in fields such as computer, robotics, automation, and instrumentation.

2. All important electromechanical concepts identified in this study should be given emphasis in electromechanical technology programs.

3. The results of this study should be shared with curriculum planners for electromechanical technology programs at four-year educational institutions. By taking into account industry's requirements it will be possible to develop a sound curriculum for electromechanical technology programs. This will allow electromechanical technology graduates an opportunity to enter the job market and be adaptive to changes due to advances in technology.

4. Industrial expertise should be viewed as a potential resource by industrial technology educators. Efforts should be made to develop, maintain, and administer reciprocal modes of communication with industry.

Recommendations for Further Study

1. A study should be conducted to determine if there is a significant difference in perception among employees working in the fields of computer, robotics, instrumentation, and automation regarding the important electromechanical concepts identified in this study.

2. A study should be conducted to determine the difference in perception between electromechanical technology educators and electromechanical technology employees, regarding the fundamental concepts needed by electromechanical technology graduates for entry-level employment in related industry.

3. A study should be conducted to determine the appropriate stage within the college curriculum for teaching entry-level electromechanical technology concepts.

4. Research on the relationship of variables such as geographical location, size, and company activity to training needs for electromechanical technologists may provide useful data to curriculum planners.

5. A study should be conducted to determine the need for fiber optics and to what extent it will be used in the year 1995 and beyond.

6. A study should be conducted to assess the relationship between the field of instrumentation and the electromechanical area.

7. A study should be conducted to determine additional concepts and or areas needed by electromechanical technologists.

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APPENDIX A

LETTER SENT TO GENERAL MANAGER OF ISA

University of Northern Iowa
Department of Industrial Technology
Industrial Technology Center
Cedar Falls, Iowa 50614
Phone (319) 273-2561

October 9, 1987

Glenn F. Harvey
Instrument Society of America
Executive Director
P.O. Box 12277
67 Alexander Dr.
Research Triangle Park, NC 27709

Dear Mr. Harvey:

I am a doctoral student in the Department of Industrial Technology at the University of Northern Iowa, Cedar Falls, Iowa. I am presently working on my dissertation which deals with the identification of the concepts needed by electromechanical technology graduates for entry-level employment in related industry. According to Guterl (1984) the area of instrumentation is a field that encompasses a broad spectrum of engineering and scientific disciplines. Therefore, the population for my study will consist of workers in the area of instrumentation.

One of the purposes of my study is to contribute to the technological field by providing a list of fundamental concepts needed by electromechanical technology graduates so that students, the workers of tomorrow, will be able to cope with advancing technology and acquire a lifelong learning. To accomplish this goal it is necessary that a close cooperation exist between education and industry. I plan to request industry input through a questionnaire that is to be sent to workers in the instrumentation area.

Could you please send me a list of the ISA members working in the states of California, Texas, New York, Illinois, and Connecticut and those who belong to the following Technology Department Divisions: Analysis Instrumentation, Process Measurement and Control, Scientific Instrumentation and Research, and Test Measurement.

Your assistance and prompt response to my request will be greatly appreciated.

Sincerely,

Julio R. Garcia
Graduate Assistant

Dr. Rex W. Pershing
Advisor

APPENDIX B

LETTER SENT BY GENERAL MANAGER OF OF ISA

Instrument Society of America

October 22, 1987

Mr. Julio R. Garcia
Graduate Assistant
University of Northern Iowa
Industrial Technology Center
Cedar Falls, IA 50614

Dear Mr. Garcia:

REF: The Request Regarding Your Dissertation
H442-400-87

Your project is interesting and the results could be of interest to us. We can't release the names and addresses of ISA members for any use outside the Society, so I can't fulfill your request. The only way we could help you would be if the survey could be done by you in conjunction with ISA, on ISA stationery. If you feel this approach is a possibility for solving your need and you are interested in pursuing it, please call Dr. Douglas J. Kolb, our Director of Education Services.

Sincerely,

Glenn F. Harvey
Executive Director

GFH/dwe

cc: D.J. Kolb

INTERNATIONAL HEADQUARTERS
67 Alexander Dr., P.O. Box 12277, Research Triangle Park, NC 27709 (919) 549-8411 Telex 802-540 FAX 549-8288
Instrumentation • Systems • Automation — for the benefit of mankind

APPENDIX C

LETTER SENT TO DIRECTOR OF EDUCATION AT ISA

University of Northern Iowa
Department of Industrial Technology

Industrial Technology Center
Cedar Falls, Iowa 50614
Phone (319) 273-2561

January 18, 1988

Dr. Douglas J. Kolb
Director of Education Services
Instrument Society of America
67 Alexander Dr.
P.O. Box 12277
Research Triangle Park, NC 27709

Dear Dr. Kolb:

As per our telephone conversation I am sending a summary of Chapter I of my approved dissertation proposal and a copy of the questionnaire that will generate the survey data to be used in my doctoral dissertation. The objective of my study is to identify the fundamental concepts needed by electromechanical technology graduates to perform efficiently at the entry-level employment in related industry. The survey instrument has been reviewed by a panel of experts made up of four persons from industry and two educators from the electromechanical area, and validated by four university professors. Two professors were from the electrical/ electronics area, and the other two from the mechanical area. Through the pilot study with four employees it has been determined that the time needed to complete the questionnaire is approximately ten minutes at the most.

I would like to carry out this study in conjunction with the Instrument Society of America (ISA). In this regard I would appreciate it if you can send me the number of ISA affiliates in the fields of instrumentation, computers, robotics, and automation in the states of California, New York, Ohio, Illinois, and Massachusetts.

I would really appreciate if your organization could participate in this study and if so to what extent. I hope to get a positive and prompt response to my request. If you have any questions please call me at (319) 273-6426, or call Dr. Rex W. Pershing at (319) 273-2538.

Sincerely,

Julio R. Garcia
Graduate Assistant

Dr. Rex W. Pershing
Advisor

APPENDIX D

LIST OF EXPERTS

LIST OF EXPERTS

Mr. Andrew Redman
Division Manager Design Analysis Systems
(30 years of experience)
John Deere Company
Moline, IL 61265

Mr. Ross C. Lance
Production Engineering
(19 years of experience)
John Deere Company
Moline, IL 61265

Mr. James Meehan
Engineer Consultant
(24 years of experience)
James B. Meehan, P.E.
Cedar Falls, IA 50613

Mr. Bob Steward
Senior Lab Technician
(45 years of experience)
Viking Pump Company
Cedar Falls, IA 50613

Mr. John E. Carney
Instructor/Coordinator Electronics
(12 years of experience)
Hawkeye Institute of Technology
Waterloo, IA 50701

Mr. Robert Peterson
Department Head Electronics
(40 years of experience)
Hawkeye Institute of Technology
Waterloo, IA 50701

APPENDIX E

LIST OF PROFESSORS SELECTED TO VALIDATE THE FUNDAMENTAL CONCEPTS

LIST OF PROFESSORS SELECTED TO VALIDATE THE FUNDAMENTAL CONCEPTS

Dr. A. Tolu-Honary
Energy & Power (Mechanical)
University of Northern Iowa
Industrial Technology Center
Cedar Falls, IA 50613

Mr. Jere E. Wheatley
Energy & Power (Electrical/Electronics)
University of Northern Iowa
Industrial Technology Center
Cedar Falls, IA 50613

APPENDIX F

LIST OF PROFESSORS SELECTED TO VALIDATE THE QUESTIONNAIRE

LIST OF PROFESSORS SELECTED TO VALIDATE THE QUESTIONNAIRE

Dr. Mohammed F. Fahmy
Manufacturin Technology (Mechanical)
University of Northern Iowa
Industrial Technology Center
Cedar Falls, IA 50613

Dr. Rex W. Pershing
Energy & Power (Electrical/Electronics)
University of Northern Iowa
Industrial Technology Center
Cedar Falls, IA 50613

APPENDIX G

SURVEY INSTRUMENT

A SURVEY INSTRUMENT FOR DETERMINING THE FUNDAMENTAL ELECTROMECHANICAL CONCEPTS

Directions:

The concepts have been categorized under the areas of electrical/ electronics, fiber optics, fluids, and mechanical. Please respond to ALL of the concept statements in EACH area.

Please rate each of the following concept statements relative to its importance in your job according to the following scale:

5	4	3	2	1
Most	Very	Important	Least	Not

Each statement will begin with the question:

HOW IMPORTANT IS THIS CONCEPT TO YOUR JOB?

ELECTRICAL/ELECTRONICS	MOST IMPORTANT	VERY IMPORTANT	IMPORTANT	LEAST IMPORTANT	NOT IMPORTANT
1. Sources of electricity	5	4	3	2	1
2. Electric conductor materials and properties	5	4	3	2	1
3. Electric insulator materials and properties	5	4	3	2	1
4. Printed circuitry (manufacturing, losses, efficiency, etc.)	5	4	3	2	1
5. Electro-thermal losses	5	4	3	2	1
6. Electronic symbols on diagrams	5	4	3	2	1
7. Electrical quantities (voltage, current, resistance, power)	5	4	3	2	1
8. Ohm's law in AC and DC circuits	5	4	3	2	1
9. Kirchoff's laws in AC and DC circuits	5	4	3	2	1
10. Magnetism and electromagnetism	5	4	3	2	1
11. Effect of capacitance and inductance in AC and DC circuits	5	4	3	2	1
12. Impedance and its effect on power in AC circuitry	5	4	3	2	1
13. Negative and positive feedback	5	4	3	2	1
14. Characteristics and operation of semiconductors (diode, transistor, SCR, etc.)	5	4	3	2	1
15. Efficiency of electric motors	5	4	3	2	1
16. Operation of electric machines (motors, alternators, and generators)	5	4	3	2	1

	MOST IMPORTANT	VERY IMPORTANT	IMPORTANT	LEAST IMPORTANT	NOT IMPORTANT
17. Process control and feedback	5	4	3	2	1
18. Displays (e.g., seven segment, multiplexing LED's, matrix LED, and LCD's)	5	4	3	2	1
19. Electrical generation/transmission systems	5	4	3	2	1
20. Electrical transducers (e.g., photoelectric detector, temperature probe, microphone, thermistor)	5	4	3	2	1
21. Radio frequency transmission	5	4	3	2	1
22. Measurements of RF energy and its use in sensors, diesel engine, timing, etc.	5	4	3	2	1
23. Microwave energy and radiation	5	4	3	2	1
24. Analysis and design of basic transistor amplifiers	5	4	3	2	1
25. Microchips (properties, manufacturing, uses)	5	4	3	2	1
26. Linear IC's (op-amps, timer, voltage regulator)	5	4	3	2	1
27. Digital IC's (TTL, CMOS, HTL, memories)	5	4	3	2	1
28. Operation of multivibrators and oscillators	5	4	3	2	1
29. Operation of timing circuits	5	4	3	2	1
30. Programmable controllers	5	4	3	2	1
31. Operation of microprocessors, memory circuits, and CPU's	5	4	3	2	1
32. Principles of boolean algebra for digital circuits	5	4	3	2	1
33. Machine and assembly language	5	4	3	2	1
34. Writing, running, and debuging microcomputer programs (BASIC, PASCAL, etc.)	5	4	3	2	1
35. Microprocessor interfacing	5	4	3	2	1
FIBER OPTICS					
36. Materials for optical fibers	5	4	3	2	1
37. Fabrication of optical fibers	5	4	3	2	1
38. Cladding materials and refraction of light	5	4	3	2	1
39. Fiber losses (absorption, scattering, etc.)	5	4	3	2	1
40. Glassy materials (properties and fabrication)	5	4	3	2	1
41. Physical properties in optical materials	5	4	3	2	1
42. Optical communication systems	5	4	3	2	1

	MOST IMPORTANT	VERY IMPORTANT	IMPORTANT	LEAST IMPORTANT	NOT IMPORTANT
43. Methods of light propagation in optical fibers	5	4	3	2	1
44. Light emission and laser operation	5	4	3	2	1
45. Optical transmission and reception	5	4	3	2	1
46. Operation of optoisolators	5	4	3	2	1
47. Photodiodes with and without internal gain	5	4	3	2	1
48. Optical fiber transmission lines	5	4	3	2	1
49. Modulation, demodulation, and optical integrated circuits	5	4	3	2	1
50. Multiplexing	5	4	3	2	1
51. Optical fiber connection	5	4	3	2	1
FLUIDS					
52. Fluids and their physical properties (friction, viscosity, turbulence, toxicity)	5	4	3	2	1
53. Relationships of force, displacement and pressure in fluids (fluid mechanics)	5	4	3	2	1
54. Potential and kinetic energy in fluid systems	5	4	3	2	1
55. Fluid lubrication characteristics	5	4	3	2	1
56. Fluid reservoirs, strainers and filters	5	4	3	2	1
57. Pumps/compressors	5	4	3	2	1
58. Fluid logic control systems	5	4	3	2	1
59. Modulating devices (flow, pressure, and control valves; nozzels; venturies)	5	4	3	2	1
60. Proportionating valves	5	4	3	2	1
61. Fluid flow, velocity, and pressure drop in pipes	5	4	3	2	1
62. Seals and sealing materials	5	4	3	2	1
63. Fluid actuators (cylinders, motors)	5	4	3	2	1
64. Fluid transducers (pressure transducer, electronic flow meter, etc.)	5	4	3	2	1
65. Hydrostatic transmissions	5	4	3	2	1
66. Constant flow and pressure systems	5	4	3	2	1
MECHANICAL					
67. Sources of mechanical energy	5	4	3	2	1
68. General physical properties of materials (aluminum, mica, iron, rubber, etc.)	5	4	3	2	1

	MOST IMPORTANT	VERY IMPORTANT	IMPORTANT	LEAST IMPORTANT	NOT IMPORTANT
69. Work, torque, and power in mechanical systems	5	4	3	2	1
70. Displacement, velocity, and acceleration	5	4	3	2	1
71. Friction and associated losses	5	4	3	2	1
72. Thermal, vibrational and stress failures	5	4	3	2	1
73. Statics	5	4	3	2	1
74. Dynamics and kinematics	5	4	3	2	1
75. Symple harmonic motion and applications	5	4	3	2	1
76. Flywheels	5	4	3	2	1
77. Springs and spring loaded designing	5	4	3	2	1
78. Mechanical metallurgy concepts	5	4	3	2	1
79. Elasticity and plasticity concepts	5	4	3	2	1
80. Simple machines	5	4	3	2	1
81. Linkages and lever mechanisms	5	4	3	2	1
82. Pulleys and belt drives	5	4	3	2	1
83. Chain and sprocket drives	5	4	3	2	1
84. Gears and gear trains	5	4	3	2	1
85. Cams and cam actuation	5	4	3	2	1
86. Universal joints	5	4	3	2	1
87. Continuous and intermittent motion mechanisms	5	4	3	2	1
88. Mechanical transducers	5	4	3	2	1
89. Clutches and clutch systems	5	4	3	2	1
90. Bearings	5	4	3	2	1
91. Computer applications in mechanical design	5	4	3	2	1

Your main activities are in the area of:

(1) Computers (2) Instrumentation (3) Automation (4) Robotics

Please indicate other concepts and/or areas important for the electromechanical technologist ______________________________

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THANK YOU FOR YOUR COOPERATION AND PROMPT RESPONSE!

APPENDIX H

COVER LETTER

University of Northern Iowa
Department of Industrial Technology

Industrial Technology Center
Cedar Falls, Iowa 50614
Phone (319) 273-2561

February 29, 1988

Sir:

I am in the process of writing my doctoral dissertation. The objective of my study is to identify the fundamental concepts needed by electromechanical technology graduates to perform efficiently in their entry-level employment positions. Fundamental concepts for this study refers to the essential ideas or notions from which others can be derived. In order to accomplish this objective I need the cooperation of experienced individuals like yourself who have been selected among others working in computers, robotics, automation, or instrumentation. I greatly appreciate the support received from the Instrument Society of America (ISA) through Dr. Douglas J. Kolb, Director of Education Services and wish to thank to its members for their cooperation in this research.

My study considers the areas of electrical/electronics, mechanical, fluids, and fiber optics. Hopefully, the results of this study will be used by Industrial Technology programs at four-year educational institutions to provide better education to students, the employees of tomorrow.

I would like to request approximately ten minutes from your busy schedule to complete the attached questionnaire. The questionnaire requires no personal identification. Would you please respond to the items included in the enclosed questionnaire form, place it in the self-addressed stamped envelope, and drop it in the outgoing mail today while you still have it at hand.

Thank you in advance for your time, effort and prompt response.

Sincerely,

Julio R. Garcia
Graduate Assistant

Dr. Rex W. Pershing
Advisor

APPENDIX I

LETTER SUPPORTING THE STUDY

Instrument Society of America

March, 1988

Dear ISA Member:

Ref: Research Study Survey

The Education Department is cooperating with Dr. Rex W. Pershing (Advisor) and Julio R. Garcia (Graduate Assistant) of the University of Northern Iowa in a research study. This study involves the major need for electro-mechanical concepts essential to success in entry level employment positions. The results of this study will be shared with ISA and could be important in guiding the direction and development of some of our industrial training courses.

Would you please read the enclosed information and respond to the survey questionnaire. A self-addressed stamped envelope is provided for your convenient and expedient reply.

Thank you for your time. Should you have an interest in the results, please contact me, and I'll be happy to share the summary with you.

Sincerely,

Douglas J. Kolb, Ed.D.
Director, Education Services

DJK:msg

Enclosures

cc: J. M. Bacon
L. D. Durbin
T. G. Fisher
P. L. Grady
G. F. Harvey
T. J. Picard, Jr.
G. R. White

INTERNATIONAL HEADQUARTERS
67 Alexander Dr., P.O. Box 12277, Research Triangle Park, NC 27709 (919) 549-8411 Telex 802-540 FAX 549-8288
Instrumentation • Systems • Automation – for the benefit of mankind

APPENDIX J

REMINDER

Julio R. Garcia
Ind. Tech. Center
Univ. of Northern Iowa
Cedar Falls, IA 50613

March 28, 1988

Dear ISA Member:

Approximately three weeks ago you received a letter from Dr. Douglas J. Kolb, Director of Education Services at ISA, requesting your cooperation in responding to a questionnaire entitled "A Survey Instrument For Determining the Fundamental Electromechanical Concepts". I urgently need your response in order to complete my doctoral dissertation.

If you have already filled out and returned the questionnaire please accept my sincere thanks.

Thank you very much for your cooperation.

Sincerely,

Julio R. Garcia
Graduate Assistant

Dr. Rex W. Pershing
Advisor

APPENDIX K

ADDITIONAL ELECTROMECHANICAL CONCEPTS PROVIDED BY RESPONDENTS

1. Engineering methodology
2. Troubleshooting methodology
3. Data communications operating system interfaces.
4. Interfacing
5. Differences/similarities between control system types/approaches: a. PLC based system, b. distributed control systems, and c. microcomputer based systems.
6. Theory and examples of interrelationship of various components, i.e., electric, mechanics, and fluid dynamics. Example: solid state pressure transducer/transmitter.
7. Control and analog logic circuits
8. Solenoid valves/ladder logic.
9. Principles of electrical noise, shielding.
10. Computer communications principles.
11. Information integration.
12. Structured programming techniques.
13. Digital data communications.
14. Servo systems.
15. Uninterruptable power supplies.
16. Composites
17. Heat transfer
18. Vibration is an important consideration when measuring/automating AC units.
19. Taguchi method, SPC, SQC.
20. Thermodynamic principles (i.e. refrigeration, boilers, energy management).

21. Combustion engineering.
22. Simple thermodynamics - heat flow, thermal resistance; TOLERANCING, how to set specifications, What is a good, manufacturable spec..
23. PID control
24. PID loops
25. An understanding of humidity and moisture concepts in process applications.
26. Pneumatic amplifiers (P/P transducers)
27. Selection/application of valves to control flow of fluids.
28. Distributed control systems
28. CAD/CAM systems
30. CAD/CIM
31. Thermodynamic properties of steam/water for electrical utility power plant work.
32. Electromechanical alignments.
33. Electro-pneumatics
34. Math
35. Geometric telerancing
36. Finite element analysis
37. Statistics
38. Fundamentals of data acquisition and analysis
39. Physics
40. Involved physics and electrostatics.
41. Chemical and biochemical concepts.
42. Chemical processes.
43. Manufacturing concepts

44. General manufacturing practices.
45. Process applications.
46. Manufacturing engineering.
47. Process control.
48. Quality control
49. Economics
50. Feasibility studies
51. Engineering economics.
52. Time management.
53. Project management.
54. Economic modeling.
55. Simple engineering economics
56. Writing skills.
57. Standard drafting practices.
58. State representation of systems.
59. Manual writing.
60. Technical writing.
61. Good verbal and writing skills.
62. Ability to communicate.
63. Ability to listen.
64. Verbal and written communication skills.
65. Learning to write concise procedures, troubleshooting aids, problem descriptions.
66. Interpersonal relationships.
67. Human interaction.
68. People.

69. Human relations within companies.

70. Interpersonal relationships are most important. Even the best technocrat is worthless without these skills.

71. Social aspects (liability, Gou't regulation, industry standards), reliability.

72. Ability to think (work with the mind).

73. Independent learning.

74. Ability to adapt or change or extend or extrapolate or integrate.

APPENDIX L

COMMENTS ABOUT THE ELECTROMECHANICAL AREA

1. Understanding the relationships between any or all of the concepts listed above.
2. Remember to express Not to impress. Keep it simple.
3. Please learn the students Mathematics!. The most applicants we see don't know the basics.
4. Understanding the application of standard software in several areas.
5. A foundation in general physics is essential to success in applying technology in all of these fields. In the age of specialization this is often overlooked.
6. The areas I've emphasized are the ones I use the most. I believe the entry-level person should seek to specialize in an area.
7. Attention to detail & common sense overview of system relationships and component function.
8. If I get one more resume that says: "I implemented a Z-80 microprocessor", I'll scream. In our business it has zero application.
9. Keep abreast of new technology.
10. Managing process control for major chemical company.
11. We don't design components or systems. We utilize existing systems where a lot of this work is already done.
12. Cooperative work programs, nothing beats exposure to the real world.
13. The component electronics, Electronics design, RF, Microwave and optical fiber communications seems to be more in a electronics technician's field of work rather than an electromechanical technician.

14. It is important to understand the concepts of the field in which the electromechanical technology is being applied.
15. Must be informed about various processes that they will be working on.
16. Should know a system as well as operation/operator.
17. Machine-human interface especially from systems perspective.
18. Process control system and maintenance of such system.
19. I work at boiling oil and chemical processes and not really in your technical area. However, "learned facts" are not very important compared to what can be done with facts and everything has some importance.
20. Knowledge of standard cabinet wiring practices (power segregation, N.E.C. standards, etc.)
21. Broad background necessary but not detailed.
22. Designing for producibility.
23. Chemical compatibility of materials and seals.
24. Working knowledge of specs - ASME, ISA, ANSI, etc.
25. Recent graduates lack the processing for the understanding of control logic ("relay logic") as it applies to controlling a process. Too often systems are over engineered, trying to let technology solve the process, rather than applying technology to the process problem.
26. Computers, instrumentation, and automation are about equally the same.
27. Hands on experience in working with instrumentation.

28. I have done "process engineering" in an automobile plant (includes ALL the engineering for a paint department as required by annual model change and production rate changes. Otherwise most of my career (30+ years) has been in product design: electromechanical, electronics and electrical power, computer systems. I have packaged electronics for space vehicles and designed equipment operated by computers, as well as performed pipe stress analysis for petrochemical plants. I have not done instrumentation for petrochemical plants or what most people think of as the process industries.
29. I am a senior process control engineer by description. I am equally involved with computers, instrumentation, and automation.
30. Knowledge of communication between devices from the instrumentation level to main frame computers will become increasingly valuable over the next five years.
31. Fiber optics: We don't use these concepts yet.
32. Fiber optics is not applicable in my job.
33. Fiber optics: Not yet, maybe in 2-3 years.
34. Fiber optics: I have not used any of these concepts YET, but I expect to before I retire.
35. Fiber optics: Not applicable in my work yet.
36. Fiber optics: Sorry I lack the technical ability to respond to this section.
37. Fiber optics: I do not use fiber optics - Had one project in 28 years of engineering.
38. Fluids: Not applicable in my work yet.

39. Fluids: In general not pertinent to my work as professor of Electrical Engineering

40. Fluids: Not used in my specialty but generally used by other ISA members.