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Electronic Instrumentation and Saftey: Education for Medical Technologies

Scott Anderson

ELECTRONIC INSTRUMENTATION AND SAFETY: EDUCATION FOR MEDICAL TECHNOLOGISTS

Scott D. Anderson, M.S.

The University of North Dakota, 1975

Faculty Advisor: Dr. Myron Bender

The purpose of this investigation was to determine: (1) the possible need for an electronic instrumentation and safety course designed for medical technologists, (2) the type of medical electronics program practicing medical technologists would like to see implemented in their curricula, (3) concepts which would be included in an electronics course to provide for an effective learning experience for medical technologists in the area of electro-medical instrumentation and safety, (4) whether medical technologists believe a course in medical electronics and electrical safety should be a requirement or an elective for a major (BS-MT) in medical technology, (5) what qualifications and/or proficiency an instructor must command to implement such a program.

Methods

Research of the descriptive type was employed throughout the study: a questionnaire was used to collect the desired information and a computer was used to synthesize the data. The data were collected from 165 universities, university hospitals, and institutes of technology offering programs in medical technology in the United States. Data were presented in tabular form accompanied by narrative summaries.

Conclusions

Conclusions drawn from the findings were: (1) a definite need exists for electronic education for medical technology students, (2) the study and operation of instrumentation systems is an integral part of electronic education for medical technology students, (3) of the institutions surveyed who offer electronic education, the majority of them are taught in the medical technology department in conjunction with physics, engineering, and chemistry, (4) electrical safety is extremely important when working with electronic instrumentation, (5) emphasis of electronic concepts be general rather than in-depth, (6) the study and operation of instrumentation systems in an integral part of electronic education for medical technology students, (7) college level physics should be a requirement in the medical technology curricula and a prerequisite to an electronic course, (8) a course in electro-medical instrumentation and electrical safety should be a requirement for a major (BS-MT) in medical technology.

Recommendations

It is recommended that: (1) an electronics course for medical technology students should emphasize the application of principles, not a detailed analysis of components and circuits; be pragmatic in nature; be minimal in theory and mathematics, (2) instruction involves mechanical workings of the instrument, with enough theoretical background so that the students understand how the appropriate signal is generated from the sensor and translated into a visible signal, (3) investigation be continued by the medical technology and industrial technology departments to continually update, further develop, and implement content to keep abreast of technology.

ELECTRONIC INSTRUMENTATION AND SAFETY: EDUCATION FOR MEDICAL TECHNOLOGISTS

by
Scott D. Anderson

Bachelor of Science, University of North Dakota, 1973

A Thesis

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This Thesis submitted by Scott B. Anderson in partial fulfillment of the requirements for the Degree of Master of Science from the University of North Dakota is hereby approved by the Faculty Advisory Committee under whom the work has been done.

(Chairman)

Dean of the Graduate School

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(Chairman)

Dean of the Graduate School

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Title Electronic Instrumentation and Safety: Education for Medical Technologists

Department Industrial Technology

Degree Master of Science

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ABSTRACT

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It is recommended that: (1) an electronics course for medical technology students should emphasize the application of principles, not a detailed analysis of components and circuits; be pragmatic in nature; be minimal in theory and mathematics, (2) instruction involves mechanical workings of the instrument, with enough theoretical background so that the students understand how the appropriate signal is generated from the sensor and translated into a visible signal, (3) investigation be continued by the medical technology and industrial technology departments to continually update, further develop, and implement content to keep abreast of technology.

CHAPTER I

INTRODUCTION

In recent years, increased use of electronic instrumentation in the medical field has created weaknesses in some areas of medical technology curricula. These deficiencies have activated further course development for the purpose of broadening the technological backgrounds of medical technology students. (3,4)

The National Council of Medical Technology Education prepared a report sighting weak areas of instruction, ". . . inadequate clinical instruction in instrumentation, mathematics, clinical application of laboratory test results, and application of theory to practical aspects of laboratory work." (1, p. 7)

Medical technology is expanding at the same rate as all technology of medicine. This technological expansion has promped an urgent need for the integration and/or consolidation of new disciplines into the medical technology curricula. Through change, it is hoped that more confident and competent medical technologists will emerge, capable of understanding complex instrumentation systems.

Statement of the Problem

This research was concerned with criteria and content for medical technology education at the undergraduate level in the area of electro-medical instrumentation and safety.

The objectives of this research were to: (1) determine the possible need for an electronics instrumentation and safety course designed for medical technologists, (2) determine the type of medical electronics program practicing medical technologists would like to see implemented in their curricula, (3) determine concepts which should be included in an electronics course to provide an effective learning experience for medical technologists in the area of electro-medical instrumentation and safety, (4) determine whether medical technologists believe a course in medical electronics and electrical safety should be a requirement or an elective for a major (BS-MT) in medical technology, (5) determine what qualifications and/or proficiency an instructor must command to implement such a program.

Need for the Study

Professional educators of medical technology and practicing medical technologists are seeing the large influx of electronic instrumentation in their laboratories.

Instrumentation systems today are a major tool in the laboratory environment. What was once a primitive basement operation is now a highly sophisticated, automated instrumentation system. With the broad variety of instruments and scientific methods available to the medical technologists, it is feasible to perform with ease large numbers of accurate analytical laboratory tests in a relatively short time.

In most clinical laboratories, many of the simple analytical tests are performed with electronic instruments. These instruments, with continuous daily use, are susceptible to mechanical failure. In most cases it is the responsibility of the medical technologist supervising the laboratory operations to perform the necessary maintenance and to correct minor malfunctions. At present, very few medical technologists possess the technical electronic background to deal with such assignments.

When electronic failure is the cause of instrument breakdown, there is usually a delay until the manufacturer's representative arrives, alleviates the problem, and returns the instrument to proper use. This process could possibly be accelerated if the medical technologist had an electronic and/or mechanical education and could intelligently communicate with the manufacturer, pointing out the operational defect before the latter sent out his representative.

Along with the operation of any electronic device, safety should be a major concern. Safety is probably the most important element when working with electronic apparatus. All electronic instruments require electrical power to function and are potential hazards when used incorrectly. It is the responsibility of the medical technologist to know both his or her limitations and the limitations of the instrument. Instruments that are misused and/or abused by unqualified personnel are subject to shorter lives and become possible safety hazards. Equally important, proper grounding and calibration are directly related to accurate analytical output of electronic instruments.

With the large overlapping of electronic instrumentation in our society today and all manufacturers continually offering improvements, electronic education would aid in consumer or user knowledge. Electronic education may also aid the medical technologist in advising on the design of a more efficient instrumentation system. It is proposed that electronic instrumentation and safety education for medical technology students would result in more confident and more competent medical personnel.

This research attempted to develop and structure its findings into an electronic instrumentation and safety program for medical technologists. However, this course could be helpful to other medical personnel, such as chemists and nurses.

Since a phase of industrial technology is concerned with the study of electronics and instrumentation systems, it is apparent that both medical technology and industrial technology might benefit from the expertise, equipment and facilities available in each department. A descriptive electronics course emphasizing electro-medical instrumentation and safety, pragmatic in nature, applications oriented, but with a minimum of mathematics, is suggested. Therefore, the purpose of this study is to develop criteria and content for medical technologists' education in the area of electro-medical instrumentation and safety.

Definition of Terms

The following are a list of terms used throughout the description of the research material.

Medical technology--the area of medicine concerned with the application of principles of natural, physical, and biological sciences to the performance of laboratory procedures which aid in the diagnosis and treatment of diseases and the maintenance of health. (10)

Instrumentation system--a set of instruments and equipment utilized in the measurement of one or more characteristics or phenomena, plus the presentation of information obtained from those measurements in a form that can be read and interpreted by man. (9)

Electro-medical instrumentation--the measurement and recording of electronic, chemical, and physiological variables.

Safety hazards--potentially dangerous situations of instruments which are caused by abuse, lack of preventive maintenance, or natural routine use.

Electronic concepts--cognitive areas within the scope of electronic education.

Limitations

The scope of this study was to identify basic criteria and content that would serve as guides for medical technologists' education in the area of electro-medical instrumentation and safety. The data of this study were obtained by the use of a survey instrument. The electronic concepts were developed through the use of reference material and existing electronic, instrumentation, and safety programs.

The mailing of the survey instrument was limited to universities, university hospitals, and institutes of technology in the United States currently offering accredited medical technology programs. The reference used for the selection was "Allied Medical Education Directory." (2)

The data in this study were limited to the survey instruments received between the dates of November 6, 1974 and February 14, 1975. By the latter date, it was felt that all potential participating personnel had returned the survey instrument.

CHAPTER II

REVIEW OF LITERATURE

Introduction

Analysis of the literature revealed that very few studies have been undertaken to determine the extent of electronic instrumentation and safety offerings in the profession of medical technology. However, a relatively large number of medical technology programs across the nation make courses in basic electronics and/or instrumentation available to their students.

In many cases, other disciplines such as physics, chemistry, or engineering offer their facilities and expertise to help in the education of medical technology students.

Review of the literature discusses: (1) the function and role of the medical technologist in our society, (2) the rationale as to why electronic education may be desirable in light of the rapid expansion of medical instrumentation, (3) the future of instrumentation, and (4) the content of existing electronic and/or instrumentation programs within the medical technology curricula, and (5) electronic instrumentation and electrical safety texts.

Function and Role of the Medical Technologist in Our Society

The medical technologist is an indispensable member of the health team. Departments within the clinical laboratory where medical technologists work are hematology, immunohematology, chemistry, and microbiology. Medical technologists, who are occasionally referred to as a medical or laboratory technicians, concentrate their skill toward laboratory diagnosis, management, and research.

Laboratory diagnosis refers to the performing of chemical, microscopic, and bacteriological tests to provide data for use in diagnosing diseases. The medical technologist receives specimens or obtains body fluids such as urine, blood, and sputum or other secretions from the patient and makes qualitative and quantitative medical analyses with the use of instrumentation systems. From these anlyses the medical technologists, along with other members of the medical team, contributes toward proper diagnosis and treatment.

The medical technologist is also a manager. He or she may supervise and coordinate the activities of workers performing in the laboratory. The medical technologist may be an educator who develops, organizes, and directs medical technology educational programs, formulates and outlines course material and establishes criteria for the enrichment of the medical technology curricula.

Medical research is a very important area of medical technology. It is through research with other medical research divisions, cooperating together as a team, that many of the "incurable" diseases have been controlled or cured.

Rationale of Electronic Education for Medical Technologists

Owing to the rapid pace of technology, weaknesses in many educational programs in hospitals, clinics, and colleges have been created. These weaknesses have come about because of the rapid expansion in instrumentation in the medical field.

In the center of the medical community are the medical technologists who have probably been hit hardest by the increase in instrumentation. Therefore, in an attempt to keep abreast of the rapid pace of instrumentation technology, directors of medical technology programs must reassess their undergraduate programs.

Terence C. Karselis (4, p.134), BS, MT (ASCP), assistant professor of medical technology at the University of New York at Buffalo recognized this problem and observed:

> In recent years the need for a broader technological background in medical technology education has made itself obvious. This is essentially true in the areas of chemistry and hematology where automation made its first impression. The rapid expansion of instrumentation has produced weaknesses in some areas of medical technology education. This has stimulated a reassessment of undergraduate curriculum in many schools.

Also, with the rapid growth in the world's population, the need for health care has increased and hospitals and clinics have become crowded, thus causing an increase in the number of medical personnel and the size of their facilities.

These facts have created a need for more medical technologists to handle the large amount of laboratory testing necessary to make accurate analyses. The resulting heavy work load makes one aware of the need for more personnel educated in the use of electronic instrumentation in medical technology.

In a pamphlet prepared by the Director of Curriculum for Medical Technology at the University of North Dakota (5, p. 2), opportunity and need for a broader technological education were expressed.

> The need for medical technologists has grown with the physician's dependence upon laboratory tests for accurate diagnosis and progress of treatment. The advent of many drugs, treatments and antibiotics demands that careful laboratory checks be used to monitor effectiveness for the patient. Developments in chemistry and instrumentation has led to a need for personnel trained in operational techniques.

Many diagnostic, therapeutic, and analytical instruments may be found in a medical laboratory. A large majority of these instruments are electronic in nature and require electrical power for operation.

Medical technologists must not only master the operation of these instrumentation systems, but must also be responsible for their routine maintenance, in order to forestall lengthy down time. (3,5,7)

Medical technologists, like other hospital personnel, depend heavily on accurate analytical results from the instrumentation at their disposal. With day-to-day routine tests, the possibility of electronic and/or mechanical failure is inevitable. The supervising laboratory medical technologist has the responsibility of maintaining a satisfactory level of performance of all equipment, making minor electronic repairs and/or seeing to it that a factory representative is called upon.

Education in routine maintenance is usually provided by the instrument manufacturer. In the past, few technologists have been instructed to go beyond the performance of routine tasks to make these corrections. These minor problems inevitably result in long delays of instrument down time. (3, 5,6)

This situation need not exist. Just as medical technologists can be taught to operate instruments, they can also be taught to test and perform minor electronic and mechanical failures. Schroeder (6) pointed out that educators in colleges and hospitals are aware of this problem and have begun to offer courses in electronics and instrumentation to their students and staff.

Karselis (4, p. 134), who has developed an electronics course for medical technology students, concluded that electronic and instrumentation education are necessary to develop more confident and competent medical technologists.

> The acute need for instruction in instrumentation is acknowledged by a majority of medical technology educators. In an effort to provide confident, competent technologists capable of mastering complex instrumentation, instruction in basic electricity, electronics and even computers is now being proposed. An electronics course that would help to build such confidence in a technologist is needed.

Future of Instrumentation

In man's quest to conquer the unknown, he finds solutions to many of his problems and answers to many of his questions only to discover he has more unsolved mysteries ahead of him and a greater possibility for error.

As instrumentation becomes increasingly complex in the future, the possibility for electronic failure becomes greater. The result, of course, will be more frequent periods of down time. Unless major changes are made in the design and production of the new instrumentation systems, such problems are likely to continue. (7)

Simplicity of operation, together with smaller sample sizes and amounts of reagents, will facilitate a larger number of tests to be run more economically. (7,8)

It is difficult to predict what the future of electronic instrumentation will be. Whatever the answer, instrumentation will have to keep abreast of the current medical trends.

Instrumentation systems in use today may be out of date and of little use in the medical laboratory in a few years. Patton (7) predicted that in the near future, much of our present automated equipment may be obsolete because of the large size of the sample, the large volume of reagents, and the questionable accuracy of the readout devices.

The future of any laboratory lies in the current choice of laboratory instrumentation. Instruments in the very near future will be more accurate, smaller, and easier to manipulate.

In conclusion, it can be said that the future of the clinical laboratory lies in the hands of the instrument manufacturers. (7,8)

Content of Existing Electronic and/or Instrumentation Programs Within the Medical Technology Curricula

A very limited amount of research, course development, and content has been published in electronics and/or instrumentation for medical technology. The three programs displayed below aided in the development of the philosophy and partial content of this research.

Three of the existing electronic programs were found in publication form and were developed by:

1) Terence C. Karselis, BS, MT(ASCP)
   Assistant Professor, Department of Medical Technology
   State University of New York
   Buffalo, New York

2) Thomas D. Schroeder, Ph.D.
   Department of Chemistry
   Shippensburg State College
   Shippensburg, Pennsylvania

3) Physiology Department
   University of the Pacific
   Stockton, California

The following compilation shows which of the major concepts identified by the author are included in each of the three existing programs.

EXISTING PROGRAMS			MAJOR CONCEPT HEADINGS AS IDENTIFIED BY THE AUTHOR
1	2	3	
X	X	X	Basic Theory of Electricity
X	X	X	Direct Current Concepts

EXISTING PROGRAMS 1	2	3	MAJOR CONCEPT HEADINGS AS IDENTIFIED BY THE AUTHOR
X	X	X	Fundamentals of Electromagnetism
X	X	X	Meter Movements
X	X	X	Alternating Current Concepts
X	X	X	Amplification
X	X	X	Special Purpose Devices
X	X	X	Semiconductor Fundamentals
X	X	X	Transistor Amplifiers
X	X	X	Signal Generator Applications
X	X	X	Semiconductor Control Devices
X			Electrical Safety
X		X	Introduction to Instrumentation
X		X	Phase I Signal Sensing and Conversion (Transducers)
X		X	Phase II Signal Processing (Amplification)
X		X	Phase III Signal Processing (Special Circuits)
X		X	Phase IV Signal Readout (Display Systems)
X	X	X	Instrumentation Systems
X	X	X	Laboratory Activities

The following major concepts which were covered by the University of the Pacific which were not considered necessary by Karselis and Schroeder:

		X	Physiological Stimulation Techniques
		X	Recording and Stimulating Electrodes Design, Theory, and Applications to Living Tissues
		X	Telemetry for Biological Systems

EXISTING PROGRAMS 1	2	3	MAJOR CONCEPT HEADINGS AS IDENTIFIED BY THE AUTHOR
		X	General Electrophysiology of Cells and Tissue
		X	Electrophysiology of Isolated Excitable Tissue *In Vitro*
		X	Electrophysiology of Receptors
		X	Electrophysiology of the Vertebrate Spinal Cord
		X	Electrophysiology of the Cerebral Cortex in the Cat and Rat Preparation

The major concepts of Electrical Safety, Introduction to Instrumentation, Phase I, Phase II, Phase III, and Phase IV, that were not checked above, are possibly part of the content of the existing programs but were not cited in the publications.

Electronic Instrumentation and Electrical Safety Texts

An increasing number of texts are becoming available on Electronic Instrumentation and Electrical Safety. A few of these books are listed in Appendix D.

CHAPTER III

METHOD AND PROCEDURE

Type of Research

The purpose of this chapter is to present the method and procedure followed in the design and administration of the survey instrument used in this study.

Research of the descriptive type was employed throughout the study: a questionnaire was used to collect the desired information. This approach was considered to be the most feasible, economically and physically, in surveying a large, widespread population.

Participant Selection and Compilation

The 1973 Allied Medical Education Directory was used as the source to identify institutions that currently have a medical technology education program. Institutions selected to participate in this research were from universities, university hospitals, and institutes of technology in the United States. Two hundred and seventy-five addresses were compiled and the survey instrument mailed.

Questionnaire Design

The questionnaire is widely used by educators to obtain facts about past, present, and anticipated events, conditions and practices and to make inquiries concerning attitudes and opinions. (11)

This questionnaire was not designed to prove or disprove anything. It was designed to verify and compile educational information which could be used as a guide in structuring an electronic instrumentation and safety course for medical technologists.

The questionnaire was possibly too long. Each question included in the questionnaire, however, was felt to be necessary to fulfill the objectives of the study. It should be noted that some recipients may not have supplied accurate answers, others may have felt unqualified to divulge information, or others may have been discouraged by the length or subject matter of the questionnaire.

A closed-form questionnaire was designed for, and used in, this study. The questionnaire consisted of four sheets of paper, printed on both sides. Objectives of the survey were identified on the first page of the questionnaire followed by three major groups of inquiry: (1) ascertainment of need, (2) instructor proficiency and competency, and (3) educational concepts. Space was provided on the last page of the questionnaire for comments, suggestions and/or criticisms. The questionnaire is featured in Appendix A.

Cover Letter

Enclosed with the questionnaire were a stamped, self-addressed, return envelope and a cover letter. The cover letter, addressed to the Program Coordinator of Medical Technology, introduced the questionnaire and stated the purpose of the study, the major topics, and what was hoped to be learned from the information. Suggestions and recommendations were strongly encouraged and a summary of the results of this study would be available to those interested and/or involved in further development of medical technology curricula. The cover letter was approved and signed by the chairman of the advisory committee from the Department of Industrial Technology, a member of the advisory committee from Medical Technology, and the author. This was to demonstrate to the recipients that there was an inter-departmental interest as well as a personal interest in their responses. (See Appendix B)

The initial mailing of the survey instrument was November 6, 1974.

<u>Follow-up</u>

On January 8, 1975, thirty-eight percent of the surveyed institutions had responded to the initial mailing of the instrument. On January 10, 1975, a follow-up letter was mailed to the remaining sixty-two percent, explaining the importance of their professional opinion in the success of the study. If they had not received a questionnaire or misplaced it, another one would be sent urging them to consult a fellow colleague who was more knowledgeable about the questionnaire subject matter. They were asked to complete and return the questionnaire, using the self-addressed stamped envelope provided. (See Appendix C)

The survey ended February 28, 1975. At that time, one hundred and sixty-five of the original two hundred and seventy-five institutions had responded. This represents sixty percent of the total population questioned.

Treatment of Data

After completion of the survey, the data from the questionnaires were recorded on Fortran Coding Forms. One hundred and forty-seven items were obtained from each questionnaire. Information from the coding form were transferred to computer job cards and a computer program entitled "Tally" was processed by the computer center at the University of North Dakota.

Information derived from the computer print out were used in the construction of tables. A descriptive analysis of the tabular information was analyzed and each topic discussed in a narrative summary.

CHAPTER IV

PRESENTATION AND ANALYSIS OF DATA

Intent of Study

The intent of this research was to provide information about electronic instrumentation and safety and to develop a positive attitude toward the integration of such a discipline with medical technology.

This research was an attempt to: (1) determine the possible need for an electronic instrumentation and safety course designed for medical technologists, (2) determine what type of medical electronics program practicing medical technologists would like to see implemented in their curricula, if such a program were offered, (3) determine what concepts should be included in an electronics course to provide an effective learning experience for medical technologists in the area of electro-medical instrumentation and safety, (4) determine whether medical technologists believe a course in medical electronics and electrical safety should be a requirement or an elective for a major (BS-MT) in medical technology, (5) determine what qualifications and/or proficiency an instructor must command to implement such a program.

Type of Analysis

Analysis of the data was conducted with the use of the computer. It was programmed to synthesize the data and print out the following for each item on the questionnaire:

1) The mean score.

2) The frequency of each rating.

3) The percent of each rating.

The information were separated into three groups:

1) Institutions who have an electronics course.

2) Institutions who do not have an electronics course.

3) A combination or total over-all response of the above two groups.

The numbers used in the following tables are mean scores unless otherwise indicated. A sum of the means of the institutions having a course and institutions not having a course will not and is not intended to equal the combination mean score.

Population

One hundred and sixty-five of the two hundred seventy-five questionnaires were returned. This represents a return of sixty percent.

One hundred and twenty of the one hundred and sixty-five questionnaires were fully completed and used in the computer analysis. This represents a completed return of 72.73 percent. Forty-nine institutions, 29.70 percent, offer an electronics course for their students and seventy-one institutions, 43.03 percent, do not. The remaining forty-five institutions, 27.27 percent, returned partially answered or unanswered questionnaires which were not used in the computer analysis.

From this point on. throughout the study, institutions offering a course in electronics to their students are labeled "Do Have Course," those institutions not offering a course are labeled "Don't Have Course," and the total number of institutions returning the completed questionnaire are labeled "Combination."

<u>Analysis of the Possible Need for Electro-medical Instrumentation Instruction</u>

In Table 1 data are presented indicating the need for electronic education in the medical technology curricula. Of the forty-nine institutions offering electronic education, twenty-four institutions (49.98 percent) rated it "essential," seventeen institutions (34.69 percent) valued it "highly desirable," and no institutions in this group rated it "of little value" or "of no value." This yielded a mean of 4.327, indicating "highly desirable."

Seventy-one institutions not having an electronics course as a part of their program had a mean of 3.648, still within the range of "highly desirable."

The combination of the two groups shows that thirty-four institutions (28.33 percent) indicated an electronics course for medical technology students to be "essential," forty-nine institutions (43.83 percent) "highly desirable,"

TABLE 1

AN ELECTRICITY ELECTRONICS COURSE FOR MEDICAL TECHNOLOGY STUDENTS IN ELECTRO-MEDICAL INSTRUMENTATION AND SAFETY SHOULD BE INCLUDED IN THE CURRICULUM FOR A MEDICAL TECHNOLOGY DEGREE

	Don't Have Course No.	Don't Have Course %	Do Have Course No.	Do Have Course %	Combination No.	Combination %
Essential	24	48.98	10	14.08	34	23.33
Highly Desirable	17	34.69	32	45.07	49	40.83
Desirable	8	16.33	25	35.21	33	27.50
Of Little Value	0	0.00	3	4.23	3	2.50
Of No Value	0	0.00	0	0.00	0	0.00
No Answer	0	0.00	1	1.41	1	0.83
	49	100.00	71	100.00	120	100.00
Mean Value		4.327		3.648		3.925

Value Scale: (0.00 - 5.00)

4.51 - 5.00 Essential
3.51 - 4.50 Highly Desirable
2.51 - 3.50 Desirable
1.51 - 2.50 Of Little Value
0.51 - 1.50 Of No Value
0 No Answer

thirty-three institutions (27.50 percent) "desirable," three institutions (2.50 percent) "of a little value," and one institution (0.83 percent) eliciting "no response." This yielded a mean of 3.925 indicating a value of "highly desirable."

Analysis of Instructor Proficiency and Competency

Table 2 indicates the rank order and the mean rating of the cognitive areas an instructor should command to implement such a course. The values given in this table are mean scores. Electronics was considered by the respondents to be "absolutely essential" in all groups, with physics, mathematics, and chemistry of "considerable importance." Although the rank order varies slightly in the "Do Have Course," where chemistry is ranked before mathematics and biology before computer programming, the general rank order is slightly changed.

Table 3 displays departments which teach electronic education to medical technology students. The data for this table were taken from the forty-nine institutions including electronic education in their medical technology program.

Electronic education is taught by medical technology personnel in 46.94 percent of the forty-nine institutions surveyed. Physics, Chemistry, Clinical Facility, School of Pharmacy, Engineering, Biochemistry and Microbiology are departments offering their facilities and expertise for electronic education for medical technology students.

TABLE 2

QUALIFICATIONS AND/OR PROFICIENCIES AN INSTRUCTOR SHOULD COMMAND TO IMPLEMENT AN ELECTRO-MEDICAL INSTRUMENTATION AND SAFETY PROGRAM. HE OR SHE MUST UNDERSTAND THE BASIC PRINCIPLES, A WORKING AND PRACTICAL KNOWLEDGE OF:

Value Area		Combination*	Do Have Course	Don't Have Course
Absolutely Essential	Electronics	4.85	4.78	4.90
Considerable Importance	Physics	4.39	4.29	4.46
	Mathematics	4.11	3.86	4.28
	Chemistry	3.88	4.06	3.76
	Physiology	3.11	2.83	3.27
Moderate	Computer Programming	2.90	2.60	3.10
Minor Importance	Biology	2.80	2.67	2.90
	Anatomy	1.80	1.73	2.00

Value Scale : (0.00 - 5.00)

4.51 - 5.00 Absolutely Essential
3.51 - 4.50 Consierable Importance
2.51 - 3.50 Moderate
1.51 - 2.50 Minor Importance
0.51 - 1.50 No Importance
0.00 No Answer

*Indicates the mean score which determined the rank order.

TABLE 3

DEPARTMENTS OFFERING ELECTRONIC EDUCATION TO MEDICAL TECHNOLOGY STUDENTS THROUGH INTER-DISCIPLINARY INSTRUCTION

Department	Number	Percent
Medical Technology	23	46.34
Physics	8	16.34
Chemistry	5	10.20
Clinical Facility	4	8.16
School of Pharmacy	3	6.12
Engineering	3	6.12
Biochemistry	2	4.08
Microbiology	1	2.04
Total	49	100.00

Analysis of Educational Concepts

Basic theory, components and circuits. On the basis of the data in Table 4, educational concepts found to be "essential" or "very helpful" by the participants were recommended for inclusion in an electro-medical instrumentation and safety course. These concepts are pragmatic in nature with a minimum amount of theory. Concepts labeled "helpful" might be considered last in the selection of content for such a course. Variance in means between institutions offering a course is minimal, thus indicating a high correlation. There were no concepts in which the mean score fell in the ranges of "somewhat helpful" and "has no value."

TABLE 4

EDUCATIONAL CONCEPTS
(BASIC THEORY, COMPONENTS AND CIRCUITS)

Value Scale	Concept	Combi-* nation	Do Have Course	Don't Have Course
Basic Theory of Electricity				
Essential	Electrical Safety Rules	4.63	4.73	4.56
	Terminology & Definitions	4.54	4.67	4.45
Very Helpful	Measuring Instrument Usage	4.47	4.40	4.51
	Types of Current Flow	4.35	4.22	4.44
Direct Current Concepts				
Essential	Ohm's Law	4.56	4.63	4.51
Very Helpful	Series/Parallel Circuit Concepts	4.49	4.63	4.39
	Circuit Loading	4.27	4.26	4.28
	The Wheatstone Bridge	4.12	3.94	4.24
Fundamentals of Electromagnetism				
Very Helpful	Basic Electromagnetic Induction	3.84	3.78	3.89
	Electric Motors	3.51	3.41	3.58
Helpful	Electric Generators	3.28	3.10	3.41

Table 4.--Continued

Value Scale	Concept	Combi-* nation	Do Have Course	Don't Have Course
Meter Movements				
Very Helpful	Calibration	4.46	4.31	4.56
	Sensitivity	4.35	4.26	4.41
	Ammeters and Voltmeters	4.32	4.26	4.37
	D'Arsonual Galvanometer	4.27	4.20	4.31
Alternating Current Concepts				
Very Helpful	Terminology	4.30	4.51	4.15
	Capacitors and Capacitance	3.99	4.10	3.91
	Inductors and Inductance	3.90	4.02	3.82
	Reactance/ Impedance	3.56	3.55	3.56
Helpful	Phase Relationships	3.48	3.45	3.51
	Resonance	3.17	2.98	3.30
	Integration/ Differentiation	3.16	2.90	3.34
	RL and RC Time Constants	3.15	3.04	3.22
Amplification				
Very Helpful	Theory of Operation	4.01	3.98	4.03
	Gain of Amplifiers	3.77	3.80	3.76

Table 4.--Continued

Value Scale	Concept	Combi-* nation	Do Have Course	Don't Have Course
	Thermionic Emission	3.52	3.10	3.80
Helpful	Characteristic Curves	3.41	3.18	3.56
	Bias, Types and Methods	3.38	3.16	3.53
	Amplifier Classification	3.37	3.04	3.61
	Distortion	3.39	3.18	3.53
	Coupling Methods	3.28	3.06	3.44
Special Purpose Devices				
Very Helpful	Photo Tubes	4.00	4.10	3.93
	Cathode Ray Tubes	3.75	3.71	3.77
Helpful	Vacuum Devices	3.42	3.51	3.37
	Triodes	3.27	3.29	3.27
	Pentodes	3.05	2.92	3.14
	Tetrodes	3.02	2.84	3.14
	Remote Cut-off	2.81	2.41	3.08
	Gas Filled	2.78	2.51	2.97
Semiconductor Fundamentals				
Helpful	Donors and Acceptors	3.42	3.51	3.35
	P-Types and N-Types	3.39	3.53	3.30

Table 4.--Continued

Value Scale	Concept	Combi-nation*	Do Have Course	Don't Have Course
	Forward, Reverse Bias	3.30	3.49	3.17
	<u>Transistor Amplifiers</u>			
Very Helpful	Basic Transistor Theory	3.84	3.82	3.86
	Three Common Types of Amplifiers	3.59	3.41	3.72
	<u>Signal Generator Applications</u>			
Helpful	Feedback Principles	3.45	3.45	3.45
	Low Frequency Sine Waves	2.82	2.53	3.01
	Square Wave Generation	2.81	2.73	2.86
	High Frequency Sine Waves	2.77	2.47	2.97
	Precision Frequency Oscillators	2.75	2.39	3.00
	Ramp Generators	2.58	2.41	2.70
	<u>Semiconductor Control Devices</u>			
Helpful	Zener Diodes	3.13	3.16	3.11
	Field Effect Transistors	3.02	2.94	3.07
	Specific Integrated Circuits	3.01	2.94*	3.06

TABLE 4.--Continued

Value Scale	Concept	Combi-* nation	Do Have Course	Don't Have Course
	Silicone Controlled Rectifiers	3.01	2.92	3.07

Value Scale: (0.00 - 5.00)

4.51 - 5.00 Essential
3.51 - 4.50 Very Helpful
2.51 - 3.50 Helpful
1.51 - 2.50 Somewhat Helpful
0.51 - 1.50 Has No Value
0.00 No Answer

*Indicates the mean score which determined the rank order.

Analysis of Educational Concepts

Electrical safety. The data in Table 5 indicate that electrical safety is a very important area of electronic education. All of the concepts sighted were considered by the participants to be very practical and pertinent to medical technologists' education. These concepts are general in nature and are applicable to anyone working with electronic instrumentation in any environment.

Introduction to Instrumentation. Table 6 afforded a comparison among the four phases of instrumentation and power supplies identified by the author. Concepts scored highest by the participants were Phase I (Signal Sensing and Conversion), Phase IV (Signal Readout), and Power Supplies. Since medical technologists are involved with transducers and display systems, it is evident that they would want reinforcement of these areas. Power Supplies are indicated "very helpful" and are an area which would be beneficial to expand upon.

Phase II (Signal Processing) is considered to be "very helpful" with possibly a small introduction of the types of amplifiers listed beneath it. The concept of amplification is evidently more important than the amplifiers themselves.

Phase III (Signal Processing) is less important to the medical technologist and could be used for students seeking advanced electronic understanding.

TABLE 5

EDUCATIONAL CONCEPTS
(ELECTRICAL SAFETY)

Value Scale	Concept	Combi-nation*	Do Have Course	Don't Have Course
Essential	Preventive Maintenance	4.62	4.65	4.61
	Care of Equipment	4.60	4.56	4.63
	Principles of Electrical Grounding	4.59	4.73	4.49
	Reporting of Faults	4.56	4.59	4.53
	Regular Testing and Calibration	4.56	4.51	4.59
	Electrical Shock	4.52	4.61	4.46
Very Helpful	Specific Situations Causing Electrical Shock	4.47	4.55	4.41
	Electrical Energy	4.41	4.47	4.37

Value Scale: (0.00 - 5.00)

4.51 - 5.00	Essential
3.51 - 4.50	Very Helpful
2.51 - 3.50	Helpful
1.51 - 2.50	Somewhat Helpful
0.51 - 1.50	Has No Value
0.00	No Answer

*Indicates the mean score which determined the rank order.

TABLE 6

EDUCATIONAL CONCEPTS
(INTRODUCTION TO INSTRUMENTATION)

Value Scale	Concept	Combi-nation*	Do Have Course	Don't Have Course
Phase I (Signal Sensing and Conversion)				
Very Helpful	Transducers	3.95	4.06	3.87
	Photo-electric	3.72	3.98	3.53
	Chemo-electric	3.59	3.59	3.59
	Electro-magnetic	3.58	3.39	3.72
	Thermo-electric	3.52	3.39	3.62
Helpful	Nucleo-electric	3.32	3.26	3.35
	Mechano-electric	3.29	3.06	3.45
	Acoustico-electric	2.90	2.59	3.11
Phase II (Signal Processing)				
Very Helpful	Amplification	3.54	3.36	3.48
Helpful	Operational Amplifiers	3.42	3.43	3.41
	Pre-amplifiers	3.38	3.37	3.39
	Differential Amplifiers	3.27	3.22	3.30
	Buffer Amplifiers	3.10	2.94	3.21

TABLE 6.--Continued

Value Scale	Concept	Combi-* nation	Do Have Course	Don't Have Course
Phase III (Signal Processing)				
Helpful	Filters, Shape as a Function of Frequency	2.78	2.63	2.89
	Integrators/ Differentiators	2.76	3.49	2.94
	Phase Difference Circuits	2.65	2.37	2.84
	Voltage Frequency Converters	2.64	2.37	2.83
	Trigger Circuits	2.62	2.41	2.76
	Function Generators	2.57	2.41	2.68
	Wave Shaping and Converters	2.55	2.39	2.66
Somewhat Helpful	Clipper and Limiter Circuits	2.46	2.22	2.62
Phase IV (Signal Readout)				
Very Helpful	Display Systems	3.82	3.73	3.89
	Recorders	4.14	4.04	4.21
	Visual	3.82	3.67	3.93
	Meters	4.04	4.02	4.06
	Digital Readouts	3.99	3.82	4.11
	Cathode Ray Tubes	3.87	3.73	3.96

TABLE 6.--Continued

Value Scale	Concept	Combi-nation*	Do Have Course	Don't Have Course
Helpful	Audio	3.02	2.47	3.41
	Triggered Alarms	2.97	2.51	3.30
	Tone Indicators	2.87	2.43	3.18
	Power Supplies			
Very Helpful	Transformers	3.89	4.02	3.08
	Regulators of Voltage	3.84	3.98	3.75
	Rectifiers	3.72	3.84	3.65
	Filters	3.72	3.73	3.70
	Batteries	3.69	3.88	3.56
	Voltage Dividers	3.58	3.69	3.51

Value Scale: (0.00 - 5.00)

4.51 - 5.00 Essential
3.51 - 4.50 Very Helpful
2.51 - 3.50 Helpful
1.51 - 2.50 Somewhat Helpful
0.51 - 1.50 Has No Value
0.00 No Answer

*Indicates the mean which determined the rank order.

Instrumentation systems. According to the data in Table 7, all of the instrumentation systems contained in the questionnaire were considered "essential" or "very helpful." Those receiving the higher ratings are possibly those instruments receiving the most laboratory use.

Laboratory Activities. Table 8 displays the rank order of laboratory activities as chosen by the participating institutions. The activities of Table 8 which were considered most important are pragmatic in nature and correspond to many of the concepts labeled "essential" or "very helpful" in Tables 4, 5, and 6.

An example of theory-activity relationships are meter usage, Ohm's law, and series/parallel circuits which were all valued "essential" or "very helpful" in Table 4, troubleshooting and preventive maintenance ranked "essential" in Table 5, and regulators of voltage, "very helpful" in Table 6.

From this comparison, it can be concluded that a direct relationship exists between basic theory and laboratory activities, thus the importance for supplying laboratory activities to reinforce theoretical material.

Analysis of Course Time and Credit Characteristics

Table 9 represented an attempt to identify the academic level when a course of this nature might be offered.

The majority of the institutions offering an electronics course as well as those institutions not offering an electronics course indicate the junior year to be the most

TABLE 7

EDUCATIONAL CONCEPTS
(INSTRUMENTATION SYSTEMS)

Value Scale	Concept	Combi-* nation	Do Have Course	Don't Have Course
Essential	Spectrophotometer	4.65	4.75	4.58
	pH Meter	4.52	4.61	4.45
Very Helpful	Flame Photometer	4.43	4.61	4.31
	Particle Counter	4.29	4.29	4.30
	Centrifuge	4.29	4.20	4.35
	Atomic Absorbtion Photometer	4.25	4.33	4.20
	Fluorometer	4.24	4.26	4.22
	Sequential Analyzer	4.21	4.24	4.18
	Gas Chromatograph	4.16	4.10	4.20
	Filter Photometer	4.13	4.26	4.04
	Electroencephalograph	3.05	2.49	3.44

Value Scale: (0.00 - 5.00)

4.51 - 5.00 Essential
3.51 - 4.50 Very Helpful
2.51 - 3.50 Helpful
1.51 - 2.50 Somewhat Helpful
0.51 - 1.50 Has No Value
0.00 No Answer

*Indicates the mean score which determined the rank order.

TABLE 8

EDUCATIONAL CONCEPTS
(LABORATORY ACTIVITIES)

Value Scale	Concepts	Combi-nation*	Do Have Course	Don't Have Course
	Laboratory Activities			
Very Helpful	Meter Usage	4.42	4.61	4.30
	Trouble Shooting and Preventive Maintenance	4.38	4.61	4.22
	Ohm's Law as it Relates to Series/Parallel Circuits	4.21	4.43	4.06
	Oscilloscope Usage	3.94	3.88	3.99
	Voltage Regulators	3.66	3.82	3.55
	Amplifier Analysis, Gain and Frequency Response	3.61	3.55	3.65
Helpful	Sensing Transducers	3.50	3.43	3.55
	Power Supplies; Full and Half Wave Rectifiers	3.48	3.63	3.38
	Recording Transducers	3.47	3.22	3.65
	Dismantling and Reassembling of a Centrifuge	3.47	3.22	3.63
	Voltage Dividers	3.42	3.53	3.34

TABLE 8.--Continued

Value Scale	Concepts	Combi-* nation	Do Have Course	Don't Have Course
	Electric Motor Characteristics and Principles	3.34	3.06	3.53
	Operational Analysis of a Photosensitive Wheatstone Bridge	3.33	3.04	3.53
	Specific Integrated Circuits	3.32	3.08	3.49
	Operational Amplifiers	3.22	2.86	3.48
	Differential Amplifiers	3.18	3.00	3.31
	Frequency Counters	3.17	2.75	3.45
	Oscillator Analysis & Phase Measurements	3.07	2.71	3.32
	Function Generators	3.02	2.67	3.25
	Multivibrators	2.55	2.31	2.72
	Analog/Digital and Digital/Analog Conversion	2.52	2.37	2.62

Value Scale: (0.00 - 5.00)

4.51 - 5.00 Essential
3.51 - 4.50 Very Helpful
2.51 - 3.50 Helpful
1.51 - 2.50 Somewhat Helpful
0.51 - 1.50 Has No Value
0.00 No Answer

*Indicates the mean score which determined the rank order.

TABLE 9

POSSIBLE AVAILABILITY OF AN ELECTRONICS COURSE FOR MEDICAL TECHNOLOGY STUDENTS

Year	Combination No.	Combination %	Do Have Course No.	Do Have Course %	Don't Have Course No.	Don't Have Course %
Intern Period	11	9.17	3	6.12	8	11.27
Senior Year	26	21.67	11	22.45	15	21.13
Junior Year	79	65.83	31	63.27	48	67.61
No Answer	4	3.33	4	8.16	0	0.00
	120	100.00	49	100.00	71	100.00
Mean Score		1.367		1.265		1.437

Value Scale: (0.00 - 3.00)

2.51 - 3.00 Intern Period After Senior Year
1.51 - 2.50 Senior Year
0.51 - 1.50 Junior Year
0.00 No Answer

Note: No differentiation is made in the survey to identify 4-year and 5-year programs of medical technology. In the former the internship is the 4th year, in the latter the internship follows a bachelor's degree. In both structures the junior year is the favored year.

opportune time. The mean score of each group and the total population also indicates a trend toward the junior year.

According to the findings in Table 10, college level physics should be a requirement for a medical technology program. This was indicated by 66.33 percent of the total respondents.

From the data contained in Table 11, college level physics is highly recommended by the majority of the respondents as a prerequisite to the electronics course.

The data cited in Table 12 revealed that three semester hours or four quarter hours of credit should be awarded students who fulfill the requirements of the course.

Table 13 represents the general consensus of the respondents regarding laboratory and lecture time, without regard to a quarter or semester hour system. On the basis of these data, the class would meet for two hours of lecture and two hours of laboratory per week.

The data in Table 14 indicates that 71.43 percent of the medical technology programs that offer an electronics course for their students recommend it be a required course. Of the institutions surveyed who don't have an electronics course, 64.79 percent supported this recommendation.

Inspection of this data allows the generalization that a course in electro-medical instrumentation and electrical safety should be a requirement for a major (BS-MT) in medical technology.

TABLE 10

THE REQUIREMENT OF COLLEGE LEVEL PHYSICS IN THE MEDICAL TECHNOLOGY CURRICULA

Value Scale	Combination No.	%	Do Have Course No.	%	Don't Have Course No.	%
0.51-1.00 Yes	76	66.33	31	63.27	45	63.38
0.00-0.50 No	44	36.67	18	36.73	26	36.62
	120	100.00	49	100.00	71	100.00

TABLE 11

THE REQUIREMENT OF COLLEGE LEVEL PHYSICS AS A PREREQUISITE TO AN ELECTRONICS COURSE

Value Scale	Combination No.	%	Do Have Course No.	%	Don't Have Course No.	%
0.51-1.00 Yes	82	68.33	26	53.06	56	78.87
0.00-0.50 No	38	31.67	23	46.94	15	21.13
	120	100.00	49	100.00	71	100.00

TABLE 12

CREDIT HOURS AWARDED STUDENTS FULFILLING REQUIREMENTS OF THE ELECTRONICS COURSE (Mean of Responses)

System	Combination	Do Have Course	Don't Have Course
Semester Hours	3	3	3
Quarter Hours	4	4	4

TABLE 13

ELECTRONIC CLASS MEETINGS
(CLOCK HOURS PER WEEK)
(Mean Values)

	Combination	Do Have Course	Don't Have Course
Lecture Hours	2.1	2.3	2.3
Laboratory Hours	2.5	2.6	2.6

TABLE 14

SHOULD A COURSE IN ELECTRO-MEDICAL INSTRUMENTATION AND ELECTRICAL SAFETY BE A REQUIREMENT ON AN ELECTIVE FOR A MAJOR (BS-MT) IN MEDICAL TECHNOLOGY

	Combination		Do Have Course		Don't Have Course	
	No.	%	No.	%	No.	%
Requirement	81	67.51	35	71.43	46	64.79
Elective	31	25.83	8	16.33	23	32.39
Not Needed	1	0.83	0	0.00	1	1.41
No Answer	7	5.83	6	12.24	1	1.41
	120	100.00	49	100.00	71	100.00
Mean Score		2.55		2.47		2.61

Value Scale: (0.00 - 3.00)

2.51 - 3.00 Requirement
1.51 - 2.50 Elective
0.51 - 1.50 Course Not Needed at All
0.00 - 0.50 No Answer

Analysis of Comments

The following paraphrased responses are typical of those received regarding performance objectives for a medical technologists' electronic education course. The medical technology student:

1) Will be able to operate instruments confidently and competently.
2) Will be able to read and interpret instrument manuals and diagrams intelligently.
3) Will not put blind faith in an instrument just because it produces a "number."
4) Will learn the importance of and perform preventive maintenance, calibration, and proper grounding of the instrument.
5) Will be able to recognize trouble symptoms and be skeptical of results.
6) Will be able to report faults in instruments and keep an instrument log.
7) Will not be expected to repair most instruments.
8) Will be able to troubleshoot as prescribed in the manuals so as to rule out electrical failure versus mechanical failure.
9) Will be able to recognize jobs that are within the capabilities of the medical technologist and those that should be saved for qualified electronic technicians.

The following were general comments received from the questionnaire respondents. They cover a variety of aspects regarding course content and approaches to implementation.

1) In designing a course in electronics for medical technologists, one should keep in mind that he is not training a technologist whose sole purpose is to keep laboratory instruments in repair, but to educate a technologist who will use the instrumentation.

2) Practical training in the use of instruments is much more valuable than a detailed electronics course for the following reasons:

a. Many advanced concepts will not be grasped by the average medical technologist.

b. Some would benefit from advanced training and could be a real asset to a clinical laboratory.

3) It has been suggested that a course in electronics is needed based on two levels of knowledge:

a. A required basic electronic course to be taught in conjunction with a practical course in instrumentation and electrical safety.

b. An advanced elective course with its own lecture and laboratory to be taught to medical technology students with an interest and aptitude for electronics.

4) Two problems exist in the instruction of electronics and instrumentation.

a. No good single text in this area is available and a limited amount of research has been conducted.

b. People who are able to teach electronics know little about medical instrumentation, and people who know about medical instrumentation know little about electronic theory.

5) Success of such a course requires an instructor with the ability to relate to medical technologists and do the work they do. Emphasis should be placed on the application of principles, not on the theory of components and detailed analysis of amplifiers and oscillators.

6) An instructor should have practical work experience in a clinical laboratory to relate to students the importance of the subject to the profession.

7) If electronic and mechanical equipment or facilities and expertise are limited, the instructor should seek interdisciplinary assistance.

8) Such a course should emphasize general knowledge of electronics and equipment: the remainder should include instrumentation, safety, and general maintenance. This necessitates knowledge of basic electricity, but does not require in-depth knowledge of electronic components.

9) Emphasis should be placed on block diagrams such as power supplies, pre-amps, and transducers, to allow a "systems" approach rather than the mathematical or in-depth approach.

10) The "Black Box" approach should be used when given an input to determine the output.

11) The laboratory should include routine electronic instrumentation of medical technology and electronics.

Content should emphasize the assembly of the instruments which makes them function correctly.

12) Basic electronics, electrical safety, and troubleshooting should be incorporated into all clinical courses any time the student is introduced to a new piece of electronic equipment. Inter-disciplinary assistance should be sought out in teaching this important subject.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

The foremost concern of this research was to determine a possible need for an electronic instrumentation and safety course for medical technologists, and the identification of pertinent electronic concepts for inclusion therein. Secondly, once the need and electronic concepts were identified, program coordinators elicited responses on the questionnaire regarding prerequisites to electronic and medical technology courses, possible inter-disciplinary assistance, instructor proficiency and competencies, and course time and credit characteristics. These responses were collected, synthesized, and analyzed.

Conclusions

The conclusions formulated as a result of this study were based on the responses of medical technologists or other related personnel who are directly or indirectly involved in the education of medical technology students.

In view of the limitations of the study, several conclusions have been derived.

1) A definite need exists for electronic education for medical technology students.

2) In the area of instructor proficiency and competency, a working and practical knowledge of electronics is "absolutely essential" followed by physics, mathematics, and chemistry which were rated of "considerable importance." Physiology, computer programming, and biology are of "moderate importance" with anatomy of "minor importance."

3) Of the institutions surveyed who offer electronic education, the majority of them are taught in the Medical Technology Department in conjunction with physics, engineering and chemistry. This is evidence that supports the success of interdisciplinary instruction in electronic instrumentation.

4) Little difference is apparent between the mean responses elicited by the institutions having an electronics course and institutions not having an electronics course, but most indicated a positive attitude.

5) The mean scores of Table 4 indicate that all of the educational concepts identified under "Basic Theory, Components, and Circuits" were considered "essential," "very helpful" or "helpful."

6) Electrical safety is extremely important when working with electronic instrumentation, as reflected by the mean scores of the groups identified.

7) Phase I (Signal Sensing and Conversion), Phase IV (Signal Readout) and Power Supplies or the input and output are considered to be the most important subsystems of instrumentation. Emphasis appears to be general rather than

in-depth. This is indicated by the high mean score in regard to the major topic of "Amplification" and the lower mean scores of its subdivisions.

8) The study and operation of instrumentation systems is an integral part of electronic education for medical technology students.

9) A direct relationship exists between basic theory and laboratory activities, thus indicating the importance of supplying laboratory activities to reinforce theoretical material.

10) The junior year is considered to be the most opportune time for a student of medical technology to receive electronic education.

11) College level physics should be a requirement in the medical technology curricula and a prerequisite to an electronics course.

12) Three semester hours and four quarter hours of credit should be awarded students fulfilling the requirements of the electronic course.

13) Class meetings consisting of two hours of lecture and two hours of laboratory should be held each week.

14) A course in electro-medical instrumentation and electrical safety should be a requirement for a major (BS-MT) in medical technology.

Recommendations

Based on the results of this investigation, it is recommended that:

1) An electronic instrumentation and safety course be made available to medical technology students at the University of North Dakota.

2) An inter-disciplinary effort be made between Medical Technology and the Department of Industrial Technology to implement such a course. This recommendation was based on the technology level, expertise, and facilities of both disciplines.

3) The resources for the course came from the facilities and expertise of both departments and that a cooperative effort be initiated through a team-teaching approach.

4) The educational concepts valued at "essential" and "very helpful" be included in the course content.

5) An electronics course for medical technology students should:

a. Emphasize the application of principles, not a detailed analysis of components and circuits.

b. Be pragmatic in nature.

c. Be minimal in theory and mathematics.

6) Instruction involves mechanical workings of the instrument, with enough theoretical background so that the students understand how the appropriate signal is generated from the sensor and translated into a visible signal. This would involve mechanical observations, flow patterns of external circuits, tubing, calibration, broken wires, and preventive maintenance.

7) This research be used in the design and implementation of an electro-medical instrumentation and electrical safety course for medical technology students.

8) Once a course has been established, its emphasis remains oriented toward the needs of the medical technology students and profession.

9) Investigation be continued by both departments, continually update, further develop and implement content to keep abreast of technology.