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Science Education as It Relates to Technical Education.

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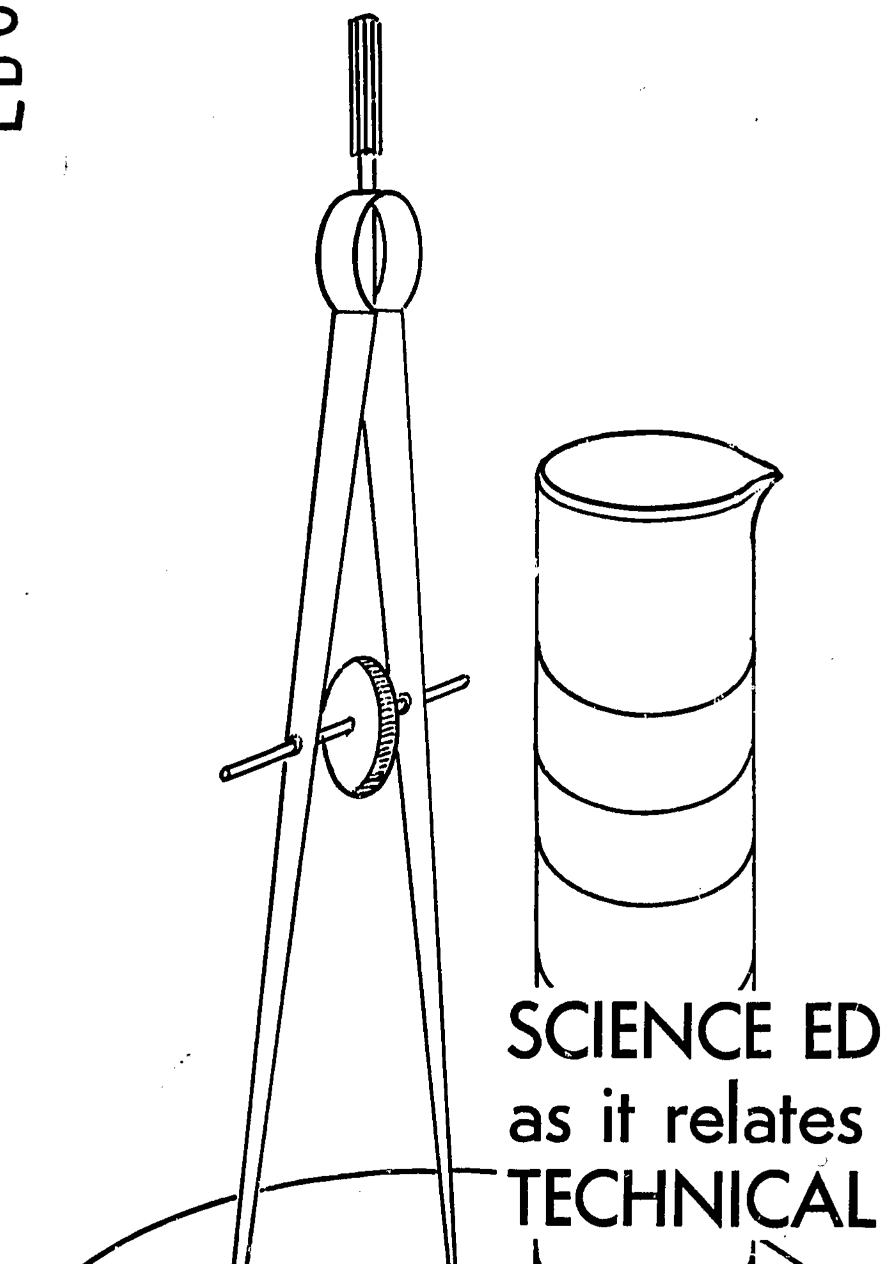
The purpose of the symposium was to bring to the attention of the scientist, the industrialist, and the educator some of the critical problems facing the implementation of program offerings for technicians. Presentations were "The Science and Mathematics Base of A Technical Curriculum" by Maurice W. Roney, "Science-Based Technical Education in the American Educational System" by Jerry S. Dobrovolny, "Problems of Student Motivation and Identification with Science in Technical Education," by Stanley M. Brodsky, "Science Requirements for a Technical Teacher" by Arnold A. Strassenburg, "Technicians and Industry" by Joseph A. Patterson, "Utilization of Technicians in Engineering Laboratories at Bell Helicopter Company" by George H. Linnabery, and "Training and Utilization of Engineering-Scientific Technicians in the Petroleum Industry" by Harold S. Kelly. Because of the shortage of competently trained paraprofessional employees in all of the professional fields, science educators are urged to become involved in the development of new approaches in science education to help eliminate some of the problems confronting science educators in technical education programs. (CH)



SCIENCE EDUCATION as it relates to TECHNICAL EDUCATION

AAAS

SCIENCE EDUCATION as it relates to TECHNICAL EDUCATION.

Papers from a Symposium
sponsored by

AMERICAN TECHNICAL EDUCATION ASSOCIATION,

AMERICAN ASSOCIATION OF JUNIOR COLLEGES,

AAAS COMMISSION ON SCIENCE EDUCATION.

1968 Annual Meeting of the
American Association for the Advancement of Science
Dallas, Texas, December 29, 1968

Foreword

The shortage of competently trained para-professional employees in all of the professional fields has brought into sharp focus the need for the establishment of a large number of post-high school educational programs designed to prepare technicians. Education beyond the high school is today a recognized social and economic necessity. The concept of technical education as being a part of higher education has emerged during the past decade as the job functions of the technician have been delineated to require a significant mathematics and science base.

Many problems remain to be resolved from the standpoint of curriculum content, manpower needs, semantic differentials, teacher preparation, student identification and motivations, and the public image of technical education. Several professional organizations have been actively involved in working on some of these problems. Included among these are the American Technical Education Association, American Association of Junior Colleges, American Society for Engineering Education, and, more recently, the Commission on Science Education of the American Association for the Advancement of Science.

The purpose of the symposium is to bring to the attention of the scientist, the industrialist, and the educator some of the critical problems facing the implementation of program offerings for technicians. Since these programs are post-high school and are considered a part of higher education, the roles of the junior college and of the comprehensive community college must be considered as having the greatest potential for providing the vehicle for program implementation. There is a need for the science educator to understand the succinct differences between technical education and trade preparatory training on the one hand, and preprofessional science and mathematics education at the lower division on the other hand. He must also recognize his responsibility in becoming involved in the development of new approaches in science education to help solve some of the problems confronting science educators in technical education programs.

JERRY S. DOBROVOLNY
Symposium Organizer

Preface

In the report of the AAAS Conference on Science in Technical Education, *Technical Education: A Growing Challenge in American Higher Education,* the Commission on Science Education of the American Association for the Advancement of Science stated that: "The need for educating larger numbers of highly trained technicians is reaching the critical stage, and there is as much reason now for national concern about technical education as there was for concern about the education of scientists and engineers two decades ago." The Commission agreed that it should continue its active interest in technical education with particular emphasis on enlisting additional participation by the scientific community in the improvement of the science and mathematics content of technical education programs.

As one step toward accomplishing this objective, the Task Force on Technical Education of the Commission on Science Education invited Jerry S. Dobrovolny, Professor and Head, Department of General Engineering, University of Illinois, and President of the American Technical Education Association, to organize a symposium on some of the basic problems of technical education to be held on December 29, 1968, at the annual meeting of the AAAS in Dallas, Texas. The symposium was sponsored jointly by the AAAS Commission on Science Education, the American Association of Junior Colleges, and the American Technical Education Association. The sponsors also provided support for publication of the conference papers.

The sponsors of the symposium wish to express appreciation to Miss Molly Moffett of the Publications Office of the American Association of Junior Colleges and to Miss Orin McCarley of the Education staff of the Commission on Science Education for their work in editing the symposium papers and preparing them for publication.

May, 1969

HOWARD F. FONCANNON
Coordinator, Technical Education Project
Commission on Science Education

Single copies of this report can be obtained without cost by writing to Education, American Association for the Advancement of Science, 1515 Massachusetts Avenue, N. W., Washington, D. C. 20005.

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Contents

Introduction

Increased sophistication in research and development in industry has brought into focus the need for competently trained technicians. In the judgment of many, the predominant locus for such training will be at the post-high school level. Such education and training now exists extensively in junior and community colleges, technical institutes, branches of four-year colleges, and area vocational schools. However, the supply of graduates of these technician training programs has not been adequate for the needs of industry. Technical education is a legitimate part of the higher education program. In recent years the need for a significant mathematics and science component in the training of technicians, particularly as aides to engineers and physical scientists, has become apparent.

This symposium has as its objective to bring to the attention of the science community some of the critical problems and some proposed solutions in the field of technical education. Advances in technical education are dependent on an understanding by the science community of these problems and require the cooperation of this community and those in technical education.

Hopefully, the presentations made in this publication will stimulate discussion and lead to significant cooperative activity.

LEWIS R. FIBEL
Symposium Chairman

Part I

Science and Mathematics in the Technical Curriculum

The Science and Mathematics Base of a Technical Curriculum

MAURICE W. RONEY
Director, School of Occupational and Adult Education
Oklahoma State University

Mathematics and science requirements in the two-year, post-high school technology curriculum are sufficiently different from the courses normally offered for transfer credit to merit special consideration. The post-high school program is a unique educational package. It borrows heavily from higher education for its content and from vocational education for its objectives. But its curriculum and its instructional processes are strictly its own. Neither the traditional college nor the traditional vocational school provides a pattern for the technical curriculum.

The conventional mathematics and science courses of a multi-purpose university, college, or junior college do not provide the flexibility required in a technical curriculum. Colleges frequently operate on the "goods-by-the-yard" system. Standardized mathematics and science courses are pulled from the shelf, supermarket style. While this kind of curriculum design may be satisfactory for the four-year college curriculum, it is highly unsatisfactory for technical programs. For one thing, the structure of a college curriculum is entirely different from that of a technical curriculum. In engineering, for example, mathematics and science courses make up the first half of the study plan. The student is given an extensive program of mathematics, physics, chemistry, and general education before he enters upon any study of a specialized nature. A two-year technology curriculum cannot afford this luxury. It is necessary, for a number of reasons, to introduce the technical study in the first term of a technical program. Courses in mathematics and science must be concurrent with and coordinated with the technical study. For this reason mathematics and science courses designed for an engineering curriculum are inefficient in a technical curriculum.

Neither do the traditional methods of vocational trade training provide the answer. Trade training normally requries a person-to-person relationship, with a single instructor responsible for most, if not all, of the training program. Skills and knowledge are integrated by the trade instructor who relates mathematics and science directly to the needs of the trade.

Technical training requires an entirely different approach. First of all, the subject matter in any technology is far too broad to be taught by any one person. Secondly, the mathematics and sciences of the technical curriculum are not job skills; they are learning skills. The specific content of mathematics and science courses is determined by the specific needs of technical courses. The mathematics needed in a materials testing course, for example, may be well beyond the mathematics used by the graduate technician on the job. These three factors—the separation of mathematics and science into discrete courses, the coordination of course work required in the tight vertical structure of the two-year curriculum, and the emphasis on principles rather than job skills—put special requirements on the mathematics and science program in technical curricula.

In order to understand these special requirements, it is necessary to study the special needs of students. Just as the curriculum differs from the more traditional form of higher education and vocational education, so also do the students. Unless these differences are recognized and given consideration, the program will not attract and hold capable students.

The typical technical student is intensely interested in a specialized field of study. He comes to the technical program because of its positive values—not because he cannot study in some other field. He is, in a sense, a fugitive from general education; tired of taking "subjects" and anxious to get his teeth into something interesting. He comes to learn electronics, or metallurgy, or industrial chemistry, not more of the same things he studied in high school. Indeed, he is quite likely to be conditioned to dislike general education by years of unhappy experience in secondary school. Furthermore, the typical student in a technical program is likely to be more mature than the usual high school graduate. He may very well have worked for a year or two since leaving high school. It is not unusual for individuals with one or more years of college credit to enter these special purpose programs.

If the technical curriculum is to attract and hold the type of students that have been described—and these will be some of the very best—a substantial introduction to the specialized field of study must be included in the first term. If the first term consists only of general education subjects—mathematics, English, and social studies—it will hold very little interest for some of the most capable students. In many technical curricula, courses in the field of specialization make up from one-third to one-half of the first term. Mathematics and communication skills, being tool subjects, are also introduced in the first term, which means that social sciences, humanities, and physical sciences must be deferred to the subsequent terms.

Another important advantage is obtained by introducing technical courses in the first term. It is possible, by this design, to obtain significant depth in the specialized field of study in the final stages of the program. In the four-semester program, for example, if the introduction to the specialized field is deferred, even for one term, it is not possible to cover both the range of basic principles and the more advanced concepts needed for success as a technician.

A second major consideration in the design of technical curricula is the correlation of course work in mathematics, science, and technology. A number of studies have been made to determine the relative emphasis on mathematics in technical institute curricula. This emphasis is usually measured by the credit-hour requirements in mathematics. But the amount of mathematics shown in formal courses is not a true measure of the mathematical ability needed for the curriculum. True, the content of courses in mathematics should identify the concepts, formulas, and constructs that are needed. But the technical courses must provide the applications. This means that the content of technical courses must be tailored to parallel the student's progress in mathematics. With this arrangement the student has the advantage of formal mathematics instruction plus the reinforcement of learning that comes from interesting applications of mathematics in technical courses.

Science principles can be treated in somewhat the same manner, although it is not always possible to coordinate science courses with technical courses. In general, science courses should be scheduled during the second and third terms of a four-term curriculum. With this plan, the student has one full term of mathematics preceding the study in science and takes at least one course concurrently. The choice of which science topics to schedule first in the curriculum can be made on the basis of the need for principles of electricity, mechanics, chemistry, and so on, in the technical study.

To illustrate the two factors of curriculum design that have been discussed a graphic illustration may be helpful.

THE DISTRIBUTION OF SUBJECT MATTER IN TWO TYPES OF TWO-YEAR POST-HIGH SCHOOL CURRICULA

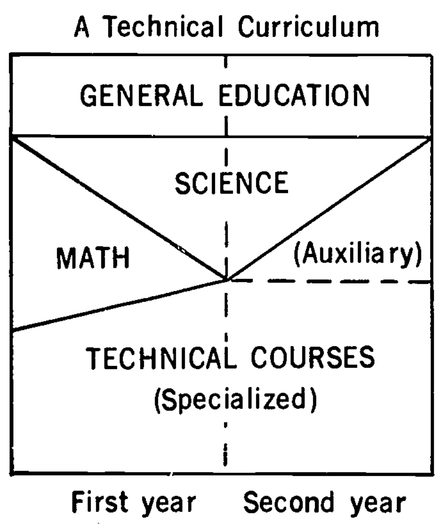

Figure 1

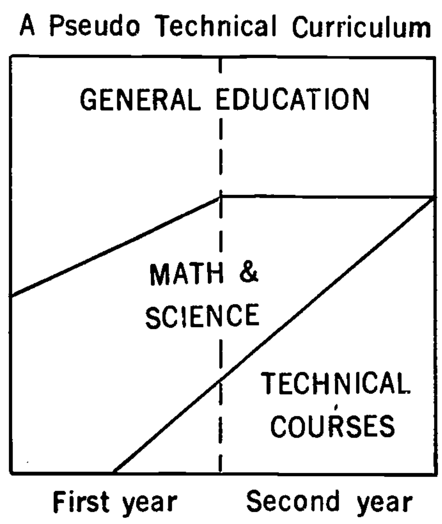

Figure 2

Figures 1 and 2 illustrate a basic difference that exists between technical curricula and what I have chosen to call pseudotechnical curricula. In these diagrams the areas shown represent subject-matter emphasis, starting at the left with the first term and moving to the right through the two-year program. The technical curriculum, represented by Figure 1, is a fair representation of the course organization in an engineering technology curriculum. It contains the two basic elements of strength that have been discussed. Specialized technical course work is introduced in the first term and constitutes roughly 50 percent of the curriculum with mathematics and science courses carefully coordinated. The slanting lines indicate the change in emphasis on subjects in scheduled classes. Mathematics, for example, begins in the first term as a discrete subject, but it is also an integral part of the technical courses.

Figure 2 represents a compromise between the objectives of a technical curriculum and the forces that impinge on the institution to design all curricula alike as nearly as possible. Approximately two-thirds of the course work is in mathematics, science, and general education. Technical courses are concentrated in the second year. This type of curriculum has neither the appeal to students nor the effectiveness of an integrated curriculum. Its primary appeal is to administrators, since roughly two-thirds of the course work can be "taken from stock" in most institutions. A curriculum of the type represented by Figure 2 lacks the positive approach that is necessary to attract the really able student interested in a specialized field of study. It may, and very probably will, suffer from a lack of unity, cohesion, and direction. By contrast, the integrated curriculum shown in Figure 1 has a strong sense of direction. Students are normally under the guidance of technical specialists throughout the program and the interrelationship of all subjects and courses can be made apparent.

As a means of presenting the significant points of conclusion, I will describe the mathematics and science program in a typical school. This hypothetical school offers two-year, post-high school, programs in electronic, mechanical, and civil engineering technology, or in construction. It has an enrollment large enough to provide flexibility of schedules. Entering students are average in ability based on national norms for college freshmen. Entrance requirements include two years of high school mathematics.

The mathematics and science program in this school might have the following characteristics:

> The mathematics program consists of two courses: a first term course in algebra and trigonometry, and a second term course which includes algebra, trigonometry, and selected topics in analytic geometry and calculus.

Algebra and trigonometry are functional in nature. Instruction is aimed at developing practical problem-solving skills. Emphasis is on the use of mathematics as a tool skill—not the mechanics of formula derivation.

Analytic geometry and calculus are introduced by special applications. Problem-solving, using these concepts, is limited to applications that are meaningful to the student.

Because the needs of individual curricula differ, separate sections in mathematics are set up for students in each curriculum. The topics covered in algebra and trigonometry courses are much the same as those included in any college-level courses in these subjects, but the order in which topics are taught and the emphasis given to each topic are determined by the needs of each technology.

Coordination of mathematics instruction with technical courses is accomplished in two ways: (1) Mathematics courses give special emphasis to the topics being used in technical courses. Technical courses provide the applications of mathematics being taught in mathematics courses. (2) Instructors in technical courses review or reteach the mathematics needed in these courses. Up to 20 percent of the class time is used for this purpose.

The physical science part of the technical program consists of selected topics in physics and one general chemistry course. Physics-mechanics and physics-electricity are required in all technical curricula. Physics courses have a base of mathematics which include algebra and plane trigonometry. Higher mathematics is not required.

The order of priority for physics courses varies by curriculum. For example, physics-mechanics is the prerequisite for technical courses in mechanical technology and civil or construction technology. Physics-electricity is an auxiliary science in these curricula and is scheduled without particular reference to technical courses.

Mechanics and electricity are given special emphasis by a liberal use of applications. Auxiliary topics such as heat, sound, and light are introduced but are given less emphasis.

All instructors of mathematics and science have education and/or experience in technology.

The foregoing description is necessarily oversimplified. Many philosophical and practical problems arise in the process of developing a program in such broad and comprehensive fields as mathematics and science. There are areas of disagreement, for example, between advocates of pure mathematics and proponents of applied mathematics. Some schools will require a "common core" of mathematics and physical sciences for several technology curricula. Nevertheless, the program I have described is representative of ongoing programs in successful schools.

This is not to say that what is being done now will be entirely adequate for the future. However, the experiences of technical educators have shown that some of the traditional methods of teaching mathematics and science are not satisfactory for technical education. Technical education has a form and character of its own. It is a mixture of college and vocational education. If this kind of a mixture is necessary, so be it. It is infinitely better than failure to provide good educational services by refusing to change from our traditional ways of doing things.

Science-Based Technical Education in the American Educational System

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Introduction

The concept of post-secondary, science-based, two-year, associate-degree programs in technical education has received considerable attention during the past decade, and particularly during the last five years; however, technician preparatory programs date back to the nineteenth century. During the building of the Erie Canal, a shortage of trained personnel resulted in a number of "Mechanics Institutes" being organized to train technicians. As the nation was being spanned by railroads, the need for trained personnel was again brought into sharp focus.

To help solve technical manpower needs, the Morrill Act was passed in 1862 for the purpose of organizing the land grant colleges "to teach such branches of learning as are related to agriculture and the mechanic arts." In the beginning, these colleges offered programs dealing with the practical side of agriculture and engineering. Today they are science-oriented universities offering a wide spectrum of curricula including agriculture and engineering.

By 1890 the land grant colleges, as well as the private schools, were established in the four-year curriculum pattern. The need for technicians, however, continued and in 1895 the Frederick Pratt Technical Institute, patterned after the technikum of Germany, was established. By 1922 there were thirteen technical institutes in the United States.

In 1954 the Smith Report[1] indicated that there were sixty-nine technical institutes in existence. The G. Ross Henninger study[2] for the American Society for Engineering Education in 1959 reported surveying 144 technical institute programs, 92 public and 52 private. Today it is estimated that over 500 institutions are offering some type of technical education program.

Manpower Team Concept

For a better understanding of the need for a science-based program to prepare technicians, a brief discussion of the manpower team concept as it relates to the world of work is in order. As advances in science and technology have occurred, the fragmentation of job functions has increased proportionately. In the time of the Industrial Revolution in England in the late eighteenth century, the early industrial innovators, such as James Watt, worked as individuals. They designed their own machinery, built it, and then operated it. This procedure was followed into the middle of the nineteenth century when the two-man teams of inventor-engineer and craftsman-builder began to evolve.

The inadequacy of the two-man team became apparent during World War I; however, not much was done about it even though the Wickendon-Spahr report[3] of 1931 urged the training of technicians to assist the engineer. It is interesting to note that at the time of the preparation of the report (1930) the characteristics of the technical institute were described as:

> . . . a school of post-secondary character, but distinct in character from a college or university . . . to train men and women for callings and functions which occupy an area between the skilled crafts and the highly scientific professions. . . . Industry must, therefore, look increasingly to technical schools rather than to its rank and file for its technical and supervisory personnel.

The report goes on to state that in the manufacturing industry the desirable ratio of technicians to engineers should be about three to one depending upon the particular industry and the particular job function. The report further states:

> The technical institute needs a director and staff who are in intimate touch with industry and specially proficient in blending scientific and practical instruction rather than leadership of the "educationist" type.

When we consider the fact that this was written thirty-nine years ago, it is sometimes difficult to rationalize the lack of implementation and identification of this important segment of our technical manpower for all these years.

The great depression of the thirties undoubtedly influenced the implementation of training and educating a significant number of technicians. However, with the coming of World War II, the great shortage of technicians again became apparent. Many of you, I am certain, remember the ESMWT (Engineers, Science, Management War Training) programs. The manpower needs of industry during World War II brought into sharp focus the need for the three-man manpower team, namely the engineer, the technician, and the craftsman.

In 1956 the President appointed a Committee on Scientists and Engineers to investigate the shortage of scientific manpower. This committee devoted a considerable amount of time to the discussion of the importance of technicians in the engineering manpower team. In its final report to the President dated December 1958,[4] the report states:

> The members of the President's Committee are unanimous in the belief that the manpower problems of technicians are at least as severe as the problems of scientists and engineers.

The information developed by the President's Committee on Scientists and Engineers along with the Henninger Study provided the groundwork for the passage of Title VIII of the National Defense Education Act of 1958. This Act provided for the specific responsibility for training of technicians for the defense industries as outlined in the report by the President's Committee on Scientists and Engineers.

To further demonstrate the importance of preparing technicians, the President's Panel of Consultants on Vocational Education reported in November 1962, in its Appendix I entitled, *Technical Education in the United States*,[5] on the great need for training technicians at the post-secondary level. Based on these data, the Vocational Education Act of 1963 was passed by Congress and signed into law by the President. Further testimony to the importance of this activity has been the rewriting of all of the past legislation pertaining to vocational and technical education resulting in Public Law 90-576, Vocational Education Amendments of 1968.

Today the fragmentation of the manpower team has resulted in the need for several levels of competency to be operative in any successful utilization of trained manpower. The three principal levels of competence on any manpower team are normally identified as professional, technical, and vocational.

A professional person is identified as being competent by virtue of his fundamental education and training to apply the scientific methods and outlook to the analysis and solution of problems. He is able to assume personal responsibility for the development and application of science and knowledge, notably in research, designing, superintending, construction, manufacturing, managing, and the education of other professionals. The work is predominantly intellectual and not of a routine character. It requires the exercise of original thought and judgment and the ability to supervise the technical and administrative work of others.

The technician can be found to be working in a wide range of job classifications. In the *Characteristics of Excellence in Engineering Technology Education*[6] (1962), an engineering technician is defined as:

> . . . one whose education and experience qualify him to work in the field of engineering technology. He differs from a craftsman in his knowledge of scientific and engineering theory and methods, and from an engineer in his more specialized background and his use of technical skills in support of engineering activities.

The technician works closely in support of the professional person. He assists in developing the project that the team is working on and becomes involved with calculations, prototype development, liaison work with the craftsman, and a wide range of support activities. Similar identifications of technician activities can be developed for the other professional fields, such as health, business, agriculture, architecture, etc.

To assist in the development of an identity for the technician, the National Society of Professional Engineers has worked closely with representatives of the American Society for Engineering Education developing a philosophy that encourages the engineering technician to relate to the engineering profession. The Society has established the Institute for the Certification of Engineering Technicians and, since 1961, has been accepting applications and processing them to certify the individual technicians into the following three grades:

Junior Engineering Technician: The applicant must have either two years of experience in work requiring elementary technical ability as evidenced by the endorsement of a professional engineer or equivalent or be a graduate of an Engineers' Council for Professional Development accredited program in some field of engineering technology.

Engineering Technician: The applicant must meet one of the requirements for the grade of junior engineering technician and must have five additional years of applicable experience as evidenced by the endorsement of two professional engineers or equivalent. He must be at least twenty-five years of age and may be required to pass an examination.

Senior Engineering Technician: The applicant must meet the requirements for the grade of engineering technician and must have at least ten additional years of experience of a high-level detailed technical nature as evidenced by the endorsement of three professional engineers or equivalent. He must be at least thirty-five years of age.

It is obvious that it is difficult to define the engineering technician in specific terms. It is a matter of developing a philosophy and understanding of the kind and level of work that the technician becomes involved in.

The third major category of the three-man team concept is, of course, the craftsman. The craftsman is involved with manufacture, construction, and maintenance in our industrial complex. The skills are primarily manipulative as they apply to the operation of specific machines and the fabrication of buildings and equipment. The maintenance component of the craft is a significant one in our complex society today.

Identification of Technical Education Programs

The identification of the technical institute as an institution to provide post-secondary education for the purpose of training technicians to function between the craftsman and the professional was discussed above when reference was made to the Wickendon-Spahr report. Perhaps the first organized movement to correlate the activities of technical institute education was the formation of the Technical Institute Division within the American

Society for Engineering Education in 1941. As a result of the activities of this group, the accreditation of two-year associate degree programs was started in 1944 by the Engineers' Council for Professional Development. After a decade or so, it became apparent that there was a need for a national study to determine the status of technical education in the United States. This resulted in the Henninger study mentioned above. The important finding of the Henninger study was the recommendation for developing objective criteria that could be used by the accreditation teams when looking at technical institute programs.

In the spring of 1959, a Steering Committee was appointed to plan and oversee an evaluation of technical institute education. This was organized through the Technical Institute Division of the American Society for Engineering Education in a project that was funded by a grant from the National Science Foundation. The project officially began on December 1, 1961. The report of the study was published in 1962 and was entitled *Characteristics of Excellence in Engineering Technology Education.*[6]

At about the same time that this activity was taking place, the U.S. Office of Education was vitally concerned with the problem of evaluation in terms of the implementation of program development under Title VIII of the National Defense Education Act of 1958. Specifically, the Act provided for educational programs to train youths and adults for "useful employment as highly skilled technicians in recognized occupations requiring scientific knowledge." The Office of Education study resulted in the publication printed in March 1962, entitled *Occupational Criteria and Preparatory Curriculum Patterns in Technical Education Programs.*[7] It is interesting that the conclusions and recommendations of these two independent studies are essentially the same in terms of identifying the curriculum content, level of program, student identification, faculty selection, and the general philosophy relating to post-secondary technical education.

The report *Occupational Criteria and Preparatory Curriculum Patterns in Technical Education Programs*[7] sets forth some general requirements for technical occupations. The general abilities for a technician are listed as follows:

> Facility with mathematics; ability to use algebra and trigonometry as tools in the development of ideas that make use of scientific and engineering principles; an understanding of, though not necessarily facility with, higher mathematics through analytical geometry, calculus, and differential equations, according to the requirements of the technology.
>
> Proficiency in the application of physical science principles including the basic concepts and laws of physics and chemistry that are pertinent to the individual's field of technology.
>
> An understanding of the materials and processes commonly used in the technology.
>
> An extensive knowledge of a field of specialization with an understanding of the engineering and scientific activities that distinguish the technology of the field. The degree

of competency and the depth of understanding should be sufficient to enable the individual to do such work as detail design using established design procedures.

Communication skills that include the ability to interpret, analyze, and transmit facts and ideas graphically, orally, and in writing.

One of the significant aspects of the ASEE report, *Characteristics of Excellence in Engineering Technology Education*, is the identification of programs of engineering technology where engineering is used as an adjective modifying the noun "technology." The report defines engineering technology as follows:

> Engineering technology is that part of the engineering field which requires the application of scientific and engineering knowledge and methods combined with technical skills in support of engineering activities; it lies in the occupational area between the craftsman and the engineer at the end of the area closest to the engineer.

The Data Compatibility Group of the National Center for Educational Statistics of the U.S. Office of Education has developed (1966) the following definition of technical education.[8]

> Technical education is concerned with that body of knowledge organized in a planned sequence of classroom and laboratory experiences, usually at the post secondary level, to prepare pupils for a cluster of job opportunities in a specialized field of technology. The program of instruction normally includes the study of the underlying sciences and supporting mathematics inherent in a technology, as well as methods, skills, materials, and processes commonly used and services performed in the technology. A planned sequence of study and extensive knowledge in a field of specialization is required in technical education, including competency in the basic communication skills and related general education. Technical education prepares for the occupational area between the skilled craftsman and the professional person such as the doctor, the engineer, and the scientist.

Technical Education Curriculum

A technical curriculum is normally a minimum of two years made up of four semesters or six quarters of a planned sequence of college-level courses, which usually leads to an associate degree. It differs significantly from the first two years of lower-division work in an engineering curriculum or any other professional curriculum. The first two years of a professional baccalaureate curriculum are primarily devoted to mathematics, science, and general education with very few specialized technical courses. On the other hand, a technology program must initiate specialized technical courses early in the program if the desired objectives are to be accomplished within the time available. The sequencing of courses and topics must be carefully organized to permit the student to develop to the desired levels of competence. A technology curriculum must require the rigor of effort on the part of the student that is equivalent to the rigor of effort required in a college program.

A technology curriculum must be structured to prepare a graduate to enter a job and be immediately productive with a minimum of on-the-job training. It must also prepare the graduate to keep abreast of the developments in the technology throughout his career and also to enable him with a reasonable amount of industrial experience, to advance into positions of increased responsibility. In addition, it must include sufficient work in the nontechnical area to prepare the individual to participate fully in the society of which he is a part.

The breakdown of a typical two-year associate degree program in technical education, as described in the *Characteristics of Excellence in Engineering Technology Education*,[6] is as follows:

	Semester Credit Hours
Basic Science Courses	
Mathematics	10
Physics	8
	18
Non-Technical Courses	
Communications	6
Humanistic-Social Studies	9
	15
Technology Courses	
Technical Skills	6
Technical Specialty	33
	39
Total	72

The mathematics and science base of a technical curriculum must be structured to reflect the relevance of the topical coverage in the various courses as they relate to the specific subject matter of the technology being studied. These courses should be uniquely designed courses to meet the above objectives.

The technical specialty courses must be structured to meet the demands peculiar to a technical curriculum. They should be applicatory in nature and at the same time should be used to develop within the student the conscious appreciation of the scientific principles involved in the particular topic being developed. There is a great need for new and innovative curriculum development projects to prepare new instructional material to properly present the required subject matter.

Some of the other problems that relate to the implementation of a well-structured technical education curriculum have to do with student selection, motivation, and identification, as well as faculty requirements.

Future of Technical Education

The potential for the development of a well-structured comprehensive technical education program in the United States is perhaps greater today than it has been at any time in the past. One of the most significant developments has been the activities undertaken by the Commission on Science Education of the American Association for the Advancement of Science, which appointed a Task Force on Technical Education for the express purpose of studying science in technical education. The culmination of the first phase of this study was the AAAS Conference on Science in Technical Education held in Washington, D.C., on July 22 and 23, 1968, which brought together fifty leaders in technical education from universities, junior and community colleges, federal and state governmental agencies, industries, and professional associations. The conference addressed itself to the critical problems facing technical education today and were grouped within the following nine categories:

1. Technical Education in the American Educational System
2. Technicians in the Labor Force
3. Measurement of Supply and Demand
4. Institutions
5. Students
6. Teachers
7. Curricula
8. Science and Mathematics Courses
9. Methods

Position papers were prepared in advance of the conference by the staff of the Task Force and were used as a basis for discussions in each of the groups listed above. A detailed report of the conference has been prepared by the Commission to bring to the attention of the people working in the area of technical education the important findings of this conference.[9] One of the most important items discussed was that of the status of technical education. In the AAAS *Bulletin,* September 1968, the following statement appears:

> It is generally agreed that technical training programs should be at the college level, and they are being conducted largely by community and junior colleges along patterns and at levels of rigor established by the private technical institutes.

The identification of technical education as a part of higher education should provide a considerable impetus in attracting additional students into these programs. Two of the other problems that were identified as major areas of concern were science and mathematics instruction in technical curricula and teacher education. Both of these will be discussed at other times in this symposium.

Another important activity that is being carried on at this moment is the organization of a national advertising campaign to assist in the identification of technical education. The National Industrial Conference Board, the U.S. Office of Education, the National Advertising Council, and the American Technical Education Association, have undertaken the development of a multi-media advertising campaign to bring to the attention of high school students, parents, industry representatives, and counselors the importance of the role of the technician in modern industry. The campaign is scheduled to provide material to go to the major trade magazines, newspapers, radio, television, and other communication media on or about April 1, 1969.

It has been estimated by the U.S. Department of Labor that between 1963 and 1975 there will be a need for 74,000 to 100,000 new technicians per year in all fields. Additional data indicate that the number of available graduates from technical education programs will range from 16,000 in 1963 to approximately 57,000 in 1975. For the year 1975, the new demand will exceed the new supply by 73,000 or 56 percent of the requirements.

In the light of the projected shortage of qualified technicians entering the labor force the paradox that faces us is the fact that two-year technical schools in the United States are filled only to about 60 percent of their capacity.

Many of the larger corporations in the United States are so concerned about the effective utilization of their manpower that they have identified a vice president at the corporate level to deal with this critical problem. Evidence supports the premise that if we do not solve the problem of a critical shortage of technical manpower the advancements in our society may well have to be slowed down because of lack of competently trained personnel. The future of technical education is bright; however, it will require the joint efforts of the entire educational spectrum to insure complete success.

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Problems of Student Motivation and Identification with Science in Technical Education

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After agreeing to give a paper with this title, I quickly discovered that so precise a focus is premature. No major body of research has been directed at this target, although peripherally related areas are being investigated. Furthermore, the title is presumptuous in its implication that such problems are researchable and significant, and that under the light of research it will be possible to improve technical education by reinforcing the science orientation of students.

The difficulty, as I see it, is that we cannot assume that "science," at either the secondary or post-secondary level, is synonymous or even related to technology in the student's perception, nor can we assume that the role of "science" in developing interest in technology education, is a positive one. Similarly, interest and orientation to mathematics may not correspond to interest and orientation to technology at the associate degree level.

Therefore, a preferable area of discussion at this stage of development would be "Problems of Student Motivation Toward Semiprofessional Higher Education in Technology and the Factors Which Influence It."

Unfortunately, even this discussion cannot be treated directly in terms of research findings. The present situation is characterized by a large number of identified problems, a general lack of applied research activity of acceptable quality, a few generally accepted answers, and inadequate response in the form of programs. Rather than attempt a bibliographic attack on this topic, I prefer to specify a number of problems which I, along with other engineering educators, consider to be important. I will not offer an exhaustive taxonomy but will concentrate on those problems which most directly affect young people for whom two-year engineering technology curricula are appropriate.

A brief digression is necessary first to justify the need for your attention to the seemingly parochial interests of technical educators. Today, we face all of the "parochial" problems in a matrix of critical national need for adequate numbers of well-trained and well-educated middle technical manpower in the form of physical science and engineering technicians. The serious imbalance in supply and demand of these types is well documented elsewhere.[1] This is the unifying overall problem which makes urgent the more specific problems which this symposium is exploring. Extended delay or failure to solve them will inhibit scientific and engineering research efforts and seriously damage the effectiveness of our technically based industries and government agencies, all of which will have far-reaching effects on the economy and concomitant domestic and international problems.

The time for leisurely consideration has been used unproductively. This may sound a bit dramatic, but the problem is real. We are at the stage of either devising ways to make the existing systems of technical education work effectively to meet these needs, or finding realistic alternatives outside the existing systems, or both.

The present manpower dilemma, however, is more an effect than a cause. Let me now identify some of the elements related to the total problem, which involve student orientation, motivation, and decision-making. I will deal separately with the following four categories of young people:

Graduates of two-year technology programs
Matriculated students in two-year technology programs
Applicants to two-year technology programs
Potential technology students during precollege teenage years

Problems Associated with Graduates of Two-Year Technology Programs

1. *About one-third do not immediately enter technical occupations.*[1]

A. Most of these continue as full-time students in baccalaureate programs. (1) Most enroll in engineering or technical curricula to improve their occupational qualifications beyond the technician level. Most encounter severe loss of credit in transfer to conventional curricula. (2) Some enroll in nontechnical curricula (e.g., education, business, liberal arts) to satisfy a changed occupational objective, to complete an interdisciplinary objective, or to increase the number of transfer credits. Still, severe loss of credit in transfer to most traditional programs is typical. (3) Some enroll in baccalaureate programs to delay service obligations.

B. Some enter the armed forces.

C. Some enter nontechnical occupations.

2. *Continuing education opportunities for employed graduate technicians are limited.*

A. Most enroll in part-time baccalaureate programs similar to 1A(1) and 1A(2) above. Credit loss greatly extends the time required to complete a degree. Most medium- and large-sized employers encourage and subsidize further education. Accessibility to further higher education varies geographically.

B. Relatively few noncredit specialized courses or programs, designed for graduate technicians, are offered by colleges or universities. In-plant- and industry-sponsored programs for graduate technicians are offered by some large employers, and occasionally by professional or technical societies. Accessibility is restricted both geographically and according to organizational affiliation.

3. *Technicians tend to be upward mobile occupationally, usually into professional and managerial functions.*

This characteristic is a positive factor in occupational attractiveness but represents a problem in terms of the numbers of available technicians.

The Bachelor of Technology Degree

Although most graduate technicians experience rapid educational and occupational growth in spite of the problems cited, the general view of two-year technology programs as "terminal" deters consideration of many students and parents. As more baccalaureate technology programs develop, the "terminal" label for two-year technology programs will be displaced by the more socially acceptable "transfer" title. In my judgment, this move to accommodate status seeking is valid to the extent that more and better technicians are produced, although the justification for the four-year "technologist" is shaky. Industrial employers are confused, since the demand for four-year programs comes mainly from the educators. However, many employers say they would like to have baccalaureate technicians, but they may not recognize the dangers. The connection to a four-year degree will probably induce many more applicants, but those who earn the B.S. in Technology as full-time students will have held themselves out of the labor market for two additional years, will have lost some of their value as technicians by not using their associate-degree-level skills in employment, and will be less likely to accept positions as technicians after receiving their baccalaureate. Furthermore, institutions which offer the entire continuum of a four-year program are less likely to know how to educate technicians, since traditional baccalaureate patterns are inappropriate. Nearby competing associate degree technology programs, which may be producing excellent technicians, will be destroyed for lack of applicants.

I am convinced that with reasonable admission standards, highly qualified technicians *can* be educated in two years. Also, the visible goal of graduation in two years is a tremendously motivating advantage which should not be lightly discarded.

Therefore, while I welcome the advent of four-year baccalaureate in technology programs as a stimulant to public interest and to facilitate upward educational mobility for graduates of two-year technology programs, the results could be disastrous if two-year programs are killed off and the four-year program graduates are reluctant to work as technicians.

I see a workable solution only if senior institutions concentrate on the upper half of a four-year program which is capable of receiving graduates from a variety of two-year technology specialties. Admission to full-time upper division study should be limited to the most academically capable graduate technicians, while the great majority of technicians should be encouraged to attend on a part-time basis, with employer support, while working in their occupational fields. Both streams should be permitted to transfer all credits from legitimate associate degree programs. In this way, whatever increases in enrollments occur due to the transfer character of technology programs will serve societal (industrial, student, and institutional) needs best.

Other problems concerning graduate technicians do not strongly influence student motivation, so let us move on to the next category.

Problems Associated with Matriculated Students in Two-Year Technology Programs

1. *Two-year college students tend to be less academically oriented than senior college students*[2,3] (see Table 1).

A. Two-year college students tend to be more like noncollege youth in academic ability than like senior college students.[4]

B. Two-year college students nationally tend to be more like senior college students socioeconomically than like noncollege youth[4] (see Table 2).

C. Public two-year colleges in urban centers enroll larger proportions of students from lower socioeconomic backgrounds than national norms[5,6] (see

TABLE 1

ACADEMIC ACHIEVEMENT IN HIGH SCHOOL REPORTED BY MALE COLLEGE FRESHMEN, FALL 1967[2]

(Selected Items)

	4-year Colleges and Universities*	2-year Colleges
Approximate N	86,000	17,600
Average grade in high school (% of N)		
"A"	17.0	2.0
"B"	57.0	37.3
"C"	25.3	58.6
Scholastic honor society (% of N)	30.2	6.2
National merit recognition (% of N)	11.9	1.8

* Norms for approximately 31,700 4-year college and 54,200 university male freshmen were reported separately, but are combined here by simple weighting.

TABLE 2

SOCIOECONOMIC DATA REPORTED BY MALE COLLEGE FRESHMEN, FALL 1967[2]

(Selected Items)

	4-year Colleges and Universities*		2-year Colleges	
Approximate N	86,000		17,600	
Estimated Parental Income (% of N)				
Less than $4,000	3.7		5.8	
Less than $6,000	11.7		17.6	
Less than $8,000	24.4		35.5	
More than $15,000	24.2		11.4	
More than $20,000	14.0		5.0	
Have No Idea	12.4		14.9	
Father's Occupation (% of N)				
Professionals	19.0		10.8	
Skilled, semiskilled, and unskilled workers	21.4		34.7	
Parent's Education (% of N)	Father	Mother	Father	Mother
Grammar school or less	7.9	4.7	15.3	9.4
Some high school	13.1	10.9	24.1	20.9
High school graduate	28.2	42.7	33.0	46.3
Sub-Total	49.2	58.3	72.4	76.6
Some college	18.8	21.0	14.8	13.8
College degree	19.4	17.5	9.4	8.2
Postgraduate degree	12.6	3.5	3.3	1.4
Sub-Total	50.8	42.0	27.5	23.4

* Norms for approximately 31,700 4-year college and 54,200 university male freshmen were reported separately, but are combined here by simple weighting.

Table 3). (1) Engineering technology programs in junior and community colleges tend to have somewhat larger proportions of students from lower

socioeconomic backgrounds than the average for the institution.[7,8] (2) By 1970 one of every two public school pupils in large cities will be termed culturally disadvantaged.[9]

TABLE 3
ACADEMIC AND SOCIOECONOMIC DATA
REPORTED BY TWO-YEAR COLLEGE MALE FRESHMEN
COMPARED WITH MALE ENGINEERING TECHNOLOGY FRESHMEN
AT ONE URBAN COMMUNITY COLLEGE, FALL 1967[2,7]
(Selected Items)

	2-year Colleges		Engineering Technology Urban Community College*	
Approximate N	17,600		200	
Average grade in high school (% of N)				
"A"	2.0		0.5	
"B"	37.3		63.6	
"C"	58.6		35.3	
Scholastic honor society (% of N)	6.2		11.0	
National merit recognition (% of N)	1.8		4.2	
Estimated Parental Income (% of N)				
Less than $4,000	5.8		12.6	
Less than $6,000	17.6		31.8	
Less than $8,000	35.5		56.5	
More than $15,000	11.4		1.1	
More than $20,000	5.0		0.0	
Have no idea	14.9		19.8	
Father's Occupation (% of N)				
Professionals	10.8		4.4	
Skilled, semiskilled, and unskilled workers	34.7		50.0	
Parent's Education (% of N)	Father	Mother	Father	Mother
Grammar school or less	15.3	9.4	27.9	26.6
Some high school	24.1	20.9	34.7	28.2
High school graduate	33.0	46.3	23.7	36.7
Sub-Total	72.4	76.6	86.3	91.5
Some college	14.8	13.8	11.1	5.9
College degree	9.4	8.2	2.1	2.1
Postgraduate degree	3.3	1.4	0.5	0.5
Sub-Total	27.5	23.4	13.7	8.5
Racial Background (% of N)				
Caucasian	87.9		65.8	
Negro	2.7		14.4	
Oriental	0.7		5.3	
Other	8.6		14.4	

* These data represent that portion of the engineering technology freshmen who completed valid A.C.E. survey forms at one urban community college. No generalization to other institutions is intended, although large deviations from national norms suggest that researchable differences may exist.

2. *The academic demand of two-year technology programs is high.*

A. Total hours in class, laboratory, and outside preparation or problem-solving are reflected in curricula with 18 or more credits being carried simultaneously.

B. Students take a large number of simultaneous courses—6 to 9, depending upon whether labs are counted separately from related classroom courses. A student may need to cope with three to five "tough" courses at the same time, which entail many new concepts, design-oriented problem-solving, and rapid coverage of new subject matter.

C. Many students have weaknesses in reading, writing, and verbal skills which inhibit effective academic performance and further burden available study time.

D. Many students from lower socioeconomic backgrounds are not supported by family or peer-group encouragement toward academic achievement. Such students often have difficulty in adjusting to demanding technical programs.

E. Many students must hold part-time jobs. This may severely restrict available study time.

3. *Technology programs are almost entirely prescribed with interconnected pre- and co-requisite sequences.*

A. There are few elective courses, usually appearing in general education areas, if at all. Achievement is required in a great variety of subject-matter areas.

B. Patterns of specialized technical coursework are relatively inflexible, making intra-institutional transfer between curricula costly in terms of mutual applicability of credits.

4. *Science courses are frequently internal barriers to academic success in technology programs.*[10]

A. Technology students do not relate "traditional" science courses to their occupational goals. This seems to be associated with the degree of abstraction with which the course is presented.

B. Most two-year colleges have separate faculties for science courses. These faculties usually give courses to liberal arts and other "transfer" students, as well as to students in career-oriented technology programs. (1) Science faculties tend to prefer traditional courses. (2) Science faculties are not usually directly responsible for a group of students majoring in their discipline. In such cases, they tend to be less student-oriented than faculties which relate to a group of majors.

C. Where technology faculties teach science courses, less student difficulty with such courses is frequently reported. (1) This is attributed to closer identification between science and technology in an applied course. (2) A loss of generality in some applied courses may raise future difficulties in applying scientific laws and principles to new situations.

D. "Specialized" technical courses frequently include substantial science content which duplicates science course content. This is particularly true of physics in the areas of mechanics, heat, electricity and magnetism, and atomic theory, depending upon the specific technical curriculum. (1) Technical faculties often maintain that where the duplication exists, the science courses given by separate science faculties do not adequately prepare technology students for the technical applications. (2) Some technical educators have proposed that science courses should be restricted to subject matter that is not covered elsewhere in the technical courses.

5. *Mathematics courses frequently involve difficulties very similar to those listed above for science courses.*

6. *Retention rates in engineering technology programs are lower than for most two-year occupational curricular areas, ranging from 30 to 60 percent, with most between 40 and 50 percent.*

Motivation is an important factor in avoiding attrition.[11, 12]

Student Attrition and Motivation

Low retention rates, which are characteristic of engineering technology programs, are the cumulative results of the problems listed above, and others not mentioned here. If we allow 15 percent over two years for an *unavoidable* component of attrition due to poor health, financial difficulties, nonacademic personal problems, selective service, change of residence, and so on, and another 5 to 10 percent for those who are completely misguided or mismatched to technology, there remains a substantial proportion of students (about 30 percent, on the average) who do not complete associate degrees, which I would term *avoidable attrition*. This magnitude of educational wastage adversely affects the national manpower situation, reduces institutional effectiveness, "turns off" many potential applicants, and leaves a bloody trail of battered student and family aspirations. The problem has been with us for many years and has been stubbornly unresponsive to individual treatments, to the point where many technical educators have developed a tolerance for low retention rates among technology students. The problem evidently consists of many interacting problems which urgently demand research attention.

I suspect that engineering technology curricula will always be challenging programs if acceptable quality is expected of graduates. It is likely that more technical and verbal competence will be expected of graduate engineering technicians rather than less, if trends in professional engineering education continue.[13,14] Increasingly, functions formerly performed by engineers will be delegated to technicians.

But technicians are not engineers, although a fair number eventually acquire engineering titles through experiential and educational growth. Nevertheless, as young college students, engineers and technicians are very different animals by almost any measure of academic ability and orientation. Furthermore, the lower socioeconomic groups are more likely to be attracted to two-year technology programs than to engineering—and this trend will probably accelerate in the future. Students from less-than-affluent backgrounds often bring additional sets of problems which complicate the prospects for satisfactory academic achievement.

We may view output requirements for technicians and actual student characteristics related to academics as two of the boundary conditions within which problems of avoidable attrition must be confronted. To me, the key is that mysterious state called student motivation. Of course, I do not suggest ignoring other ways into the many problems we face—but I am convinced that embryonic technician types *must be deliberately, externally motivated and reinforced* at a resonant frequency if any real impact on retention is expected. This may partially explain the resurgence of interest in cooperative work-study programs in technology, and the moves by some institutions to diversify their associate degree technology curricula to include academically softer industrial technician programs along with the tougher engineering technician curricula.

While curriculum reform, educational technology, better screening processes, and remediation programs may have positive influences, the strong effect which is needed must involve stimulating sustained student interest and performance. Given a student body with adequate intellectual equipment—that is, "capable average" high school graduates, who do not get their "kicks" from manipulating abstractions, who are not moved by the intrinsic beauty of mathematical structure, who are not committed to science for science's sake, who are earthy, pragmatic, and intellectually shallow at the time we meet them, but pressing to make a better life than their parents have—given this kind of student, we must take a hard look at all the positive and negative incentives in technical education which students perceive and respond to (positively and negatively). It is no surprise that a faculty composed of pure mathematicians is not especially successful in teaching mathematics to such students. Nor is it unexpected that a physics faculty with all of the conventional qualifications and disciplinary commitments fails to excite technology students.

We all know people who have been traumatized by early experiences with mathematics—who, even as adults, panic at the prospect of dealing with numbers. Evidently, entering technology students are neither fully traumatized by mathematics and science nor are they about to major in these disciplines. But we know, and they should feel, that applications of mathematics and scientific principles will be important parts of their occupational competence as technicians.

So we have an unacceptable paradox of occupationally motivated students being alienated in subject areas which have occupational importance. I hasten to add that technical faculties are not immune from this effect—formal study in any area cannot be assumed to be self-motivating. Nevertheless, the problem of meaningfully teaching fundamental material in areas which are not normally perceived by students as occupationally related is a major "hang-up" in educating technicians. If compartmentalized faculties organized along disciplinary lines cannot effectively motivate students (and there is some doubt that they are either willing or capable of attacking the problem), alternative structures and techniques will be necessary.

Problems Associated with Admission of Applicants to Two-Year Technology Programs

1. *Engineering technology programs usually require specific units of college preparatory mathematics and many require some science units to be presented by applicants.*

A. Applicants in college preparatory secondary school programs frequently "settle" for two-year technical programs rather than select them as a primary objective.

B. Applicants who present the required mathematics credit frequently cannot operate with the mathematics they have taken.

C. Applicants from secondary school programs other than college preparatory either do not qualify or require extensive noncredit coursework. (1) Some applicants from vocational programs may be more highly motivated toward technology and may be better equipped with hand skills than college preparatory students. (2) Many institutions offer "pre-tech" vestibule programs to improve the chances of success of marginally qualified technology applicants.

D. The proportion of college preparatory students is diminishing, while the numbers and proportions of noncollege preparatory nonvocational students are increasing. This latter category of students tends to run higher risks of failure in engineering technology programs than other groups. The "open door" philosophy of many two-year colleges does not appear to be compatible with the special requirements of engineering technology curricula.

E. Students from college preparatory technical high school programs tend to have the highest probability of success in two-year engineering technology curricula.

2. *Many two-year college technology applicants are not prepared for standard college freshman English courses due to weaknesses in reading, writing, and verbal skills.*

Most employers emphasize the need for graduate technicians to be able to communicate effectively.

3. *Larger institutions tend to emphasize objective measures of test scores and high school records with little or no personal contact with applicants.*

A. College Entrance Examination Board tests and other nationally popular admissions and placement tests do not seem to discriminate sufficiently for engineering technology applicants.

B. Some institutions rely on locally made tests for screening technology applicants. Levels of prediction precision are usually unacceptably low.

C. No satisfactory techniques have been developed for measuring a student's potential for motivation. (1) Interest inventories (which rarely include identifiable technician occupations), aptitude, and achievement measurements all have large error functions and none of these purport to be adequate measures of motivation. (2) It is unlikely that pencil and paper tests of motivation and motivation potential will be developed for admission screening in the near future. (3) Individual discussion and contact with students over a sufficient period of time by a trained observer may be one way of obtaining a first approximation of a student's potential motivation.

Admission Problems and Motivation

The existence of "pre-tech" programs reflects attempts to make engineering technology curricula accessible to a broader spectrum of high school graduates. It is also an indictment of the elementary and secondary schools for their apparently deficient results with significant numbers of students after twelve years of captivity. Those who operate "pre-tech" and other remediation activities are arrogant enough to think that they can show results in one semester or one year, which former educational custodians were not able to produce in twelve. Surprisingly, they do show results in many cases.

However, the students are older and more mature, they attend voluntarily, they are "in college," and they feel pressures from many sources to continue their education. Perhaps it isn't so surprising after all.

What really is surprising is that *any* students emerge from our secondary schools with appropriate preparation and a strong desire to attend two-year technology programs, but more about that later.

The business of predicting success of technology applicants from high school records and tests has its uses in conveniently solving competitive admissions problems, where they exist, but the measures are often of questionable validity. High school grade average, for example, which consistently has been the best predictor for college prep students into traditional baccalaureate programs, involves large prediction errors. Using this statistic for the more conglomerate groups applying for technology programs is hardly defensible—but still it is widely used. College Board scores are even less valid for these students.

If we are to test applicants, we need much better instruments than are presently available. Such instruments should be loaded with items appropriate to potential technicians rather than potential engineers, scientists, artists, or college professors.

Since paper and pencil measures of potential motivation seem unattainable, and in the absence of sufficient personal contact with applicants, we are left in the position of assuming that all entering students *can* be motivated to optimum performance. This may not be such a bad assumption, particularly if faculties accept it and attempt to demonstrate its validity. Given a reasonably operative screening and admission process, faculties should be held accountable for large-scale academic alienation of students or for inability to motivate them toward academic achievement.

Problems Associated with Potential Technology Students During Precollege Teenage Years

1. *Young people have little or no exposure to study materials or reliable information about technology as an occupational field.*

A. Secondary school curricula have no content which is directly related to technology. (1) Mathematics and science courses are usually presented without reference to technology. (2) General education courses do not deal with the role of "engineering" in society, although the contributions of "science" may be included. (3) Distinctions between science, engineering, and technology, as well as the occupational roles of their practitioners, are not clarified.

B. Teachers, supervisors, and guidance counselors are inadequately informed about technical education and the occupations to which it leads.

C. Parents in particular, and adults in general, are uninformed about technical education and technical occupations. Many are misinformed, identifying engineering technicians as blue-collar craftsmen and trade-level skilled workers.

D. Capable average students in ghetto communities have few, if any, role models in technology fields. Their educational attitudes and aspirations are often severely restricted by the ghetto environment.[15]

2. *Middle-class pressures toward baccalaureate programs prevent many students from considering two-year college technology programs.*

A. Parents and adult relatives have major influences on student educational and career decisions [3, 16, 17, 18] (see Table 4). Families with strong middle-class values, especially where one or both parents have attended college, usually direct their children to baccalaureate programs.

B. Teachers and counselors have an important influence on student decisions [16, 18] (see Table 4). Teachers and counselors tend to exhibit middle-class attitudes toward education and professional occupations.

TABLE 4
MAJOR INFLUENCES IN DECISION TO ATTEND THIS COLLEGE
REPORTED BY TWO-YEAR COLLEGE MALE FRESHMEN, FALL 1967[2]
(Selected Items)

Influence	2-year Colleges (% of 17,600)
Parent or other relative	46.5
High school teacher or counselor	23.3
Friends attending this college	14.2
Graduate or college representative	9.2
Counseling or placement service	5.4
Low cost	33.5
Academic reputation of this college	23.3

C. Some students have formulated their post-high school plans by the time they reach 8th grade.[19] Many others defer broad decisions concerning higher education and occupations until the last two years of high school. Some may not make such decisions at all, relying on fortuitous developments to determine their directions.

3. *Early negative attitudes toward certain subjects like arithmetic, mathematics, and science will limit later achievement and decision-making for many students [17, 20] including those who could be capable mathematics, science, engineering, or technology students.*

Secondary school students are more likely to have inadequately prepared science and mathematics teachers than in prior decades.[20]

4. *Environmental antecedents of science interest is a researchable* area.[21]

A. Science interest is not a homogeneous concept, but involves at least two dimensions.[21]

B. Breadth of interest in mathematics and science are independent of the amount of mathematics taken or the number of science courses completed.[22]

Public Information

The broadest problem of technical education is the inadequate and often inaccurate information which most people have about technical occupations. This is understandable, since technicians work out of view of the public, usually with another largely misunderstood group—engineers. Most groups that influence student educational and career decisions—parents, relatives, peers, teachers, counselors—do not know what technicians do, how they live, what they earn, or how they advance. Elementary and secondary schooling does nothing to inform students about relatively new occupational areas, particularly in technical fields. Therefore, free student choice is restricted by lack of information and lack of opportunity to conceive of themselves in these new roles. Much needs to be done before I would be satisfied that young people have as fair a chance to accept or reject technical careers as any other area.

Certainly, elementary and secondary schools should provide truthful information about professional and technical occupations in engineering-related fields and about their roles in society. The general public should be exposed to some of the same. These are massive needs which require correspondingly massive programs. Popular television shows have tremendous potential for inspiring occupational interest. Only recently has a technician been faithfully—if glamorously—portrayed on nationwide prime-time TV. A national effort is being planned by the National Advertising Council, the National Industrial Conference Board, the American Technical Education Association, and the U.S. Office of Education, which should stimulate interest (hopefully for legitimate reasons) in technical occupations. Still, the most useful component would be formal treatment of technical occupations in schools, based on accurate information and placed in the perspective of other semiprofessional occupations, together with comprehensive counseling materials.

Add to this an effort to blend some technological applications in mathematics and science courses, and I believe we would approach a fairer basis on which students could make better-informed decisions.

Educational Articulation

Another rather serious problem which influences much more than just technical education is the growing number of youths who are not stimulated to develop to their intellectual capacities during elementary and secondary education. At least part of the problem must be attributed to the conventional and unresponsive nature of much of our educational establishment. But this is too broad a problem to discuss usefully here. Let me focus on one piece of it which relates directly to technical education. To the extent that any intentional connection between secondary and higher education exists, the emphasis is on preparation for the baccalaureate—which is proper. What is disturbing is that "articulation for tradition" is the *only* articulation which is operative. For those who underachieve in this system, there are few alternatives available except continued underachievement. Yet many of these young people could have qualified and succeeded in junior college career programs if their secondary school curriculum prepared them for this step. Furthermore, if some of the pragmatic flavor of semiprofessional occupations was available in secondary curricula, student interest in the relevance of education might be renewed. Simply stated, preparation for associate degree occupational curricula is not synonymous with traditional college preparation. New kinds of articulation are needed.

Perspective

I have emphasized a large number of student-related troubles in technical education, some of which bear a relationship to science. Some of the problems were merely tabulated without discussion. Some are problems that others have studied, some are problems that are based on my own observations and those of colleagues.

Considering the variety and seriousness of the difficulties I have described, it might be concluded that technical education is about to sound its death rattle. Nothing could be further from the truth. This is a dynamic, literally exploding, area of higher education which is experiencing growing pains, largely due to its newness. Its leaders are educational heretics who are challenging the more dignified elements in American education for recognition, legitimacy, and cooperation, so that those young people who choose semiprofessional higher education will be more appropriately prepared, will be more likely to succeed in college, and will have well-established paths for further development.

The scientific community, as employers and supervisors of certain types of technicians, has a stake in assuring that adequate numbers of properly prepared graduate technicians are available. More important, your interests in people and society may coincide with a number of concerns expressed earlier. Finally, as individual adults, parents, relatives, and friends of youngsters, you should be knowledgeable about scientific and engineering semiprofessional occupations, as well as professional careers. An uninformed scientist is, after all, a logical absurdity.

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Science Requirements for a Technical Teacher

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Sources of Technical Teachers

From where do teachers of technicians come and how are they trained? I know of no completed studies which separate teachers of technical subjects from other teachers, but data have been collected which show generally the sources of community college teachers. Since the majority of technicians are trained at the rapidly growing number of two-year colleges, such data are probably relevant to our question.

One significant source of two-year college teachers—though not a source of the majority, as some believe—is the high school. It is not surprising that community college administrators, faced with extremely rapid growth, turn to well-qualified high school teachers to help solve staffing problems, and it also is not surprising that high school teachers regard the transition to a community college a promotion and an opportunity to exercise their creative talents. Despite the fact that science teachers who make this change are likely to be well prepared in their subject and experienced as classroom teachers, they are almost sure to be deficient in industrial experience and so may make poor teachers of technicians.

Another source of teachers for the two-year colleges is the four-year college. Science teachers at small four-year colleges frequently regret that they have so few students; physics and chemistry in particular are suffering from declining college enrollments. In contrast, the two-year colleges are places of bustling activity, and their heavy emphasis upon vocational and technical programs makes great demands upon the science and technology departments. The teachers who transfer from four-year colleges may also have little familiarity with technology and industrial processes, and in addition may be inclined toward presenting their specialty in a highly theoretical and abstract style. Both of these traits are serious defects in a teacher of technicians.

A third source of technical teachers is industry. It is becoming increasingly common that research scientists and engineers develop an interest in teaching at some point in their career, and the two-year colleges offer excellent opportunities without demanding advanced-degree credentials as other colleges do. Finally we have a group that will have proper appreciation for how the technician must perform on the job, but we may find the sacrifice in up-to-date theoretical knowledge of a generally applicable sort too great.

Probably the only ideal source of technical teachers is a graduate program designed explicitly for the purpose. Do these exist? Unfortunately not in any appreciable numbers. Many universities, to the extent they have considered the problem at all, assert that conventional advanced-degree programs provide appropriate preparation for college teaching. Most observers of the two-year colleges feel strongly that teaching at such institutions is greatly different from teaching at either the high school or four-year college level, and special preparation programs are needed. Even when these exist in significant numbers, there will still be the problem of determining what special courses and training experiences are useful in preparing teachers of technicians. This was to be the subject of this paper, but so little work has been done on this problem that I find I can do little better than to urge that universities take seriously the recommendation of the participants at the Conference on Technical Education sponsored by the Commission on Science Education of the American Association for the Advancement of Science in July, 1968:

> It is generally agreed that the traditional programs for the training of teachers, scientists, and engineers do not provide ideal preparation for teaching in technical education programs, including the teaching of science and mathematics. There is urgent need for experimentation with new kinds of preservice teacher education programs, designed expressly to meet the unique requirements of technical education.

To stop with the admonition that we should experiment with innovative preservice programs to prepare teachers of technicians for the community colleges would not be responsive to my assignment. Therefore, much of the remainder of this paper will make suggestions for teacher preparation that could be implemented quickly through existing administrative and curricular structures.

Possibilities for Teacher Preparation Under Existing Administrative and Curricular Structures

A. Needs of Science and Technology Instructors in the Two-Year Colleges

To begin, we might consider how many and what kinds of science courses, from among those regularly available at colleges and universities, are useful to teachers of technical students at the two-year colleges. To keep the discussion well-focused and within my range of experience, I will confine my remarks to teachers of the physical sciences and the technologies based on these sciences, specifically the mechanical and electrical technologies.

1. *Physics and Chemistry Teachers*

At present most two-year colleges which offer technology programs have physics and chemistry departments which are administratively and pedagogically separate from each other and from all technology departments. The physics departments typically offer four semesters of a physics course based on calculus for students who plan to transfer to upper division engineering programs. The course for technicians is usually only one year in length and the mathematics employed is less advanced than that used in the course for transfer students. The knowledge of physics required to teach either of these two courses is roughly the same. In my view it is equivalent to what is taught to an undergraduate physics major at a strong college. This should include a thorough treatment of the following topics: (1) Newton's Laws applied to the motion of objects subjected to position-dependent and velocity-dependent forces; (2) the concepts of energy, momentum, and angular momentum and the circumstances under which they are conserved; (3) Maxwell's Equations applied to static electric fields, electric circuits. magnets, and electromagnetic radiation; (4) the laws of thermodynamics applied to various kinds of systems and energy converters. The next higher level of courses, usually taken during the early years of graduate school, requires theoretical analysis at a level of sophistication which would be out of place at a two-year college and which contributes little to one's intuitive understanding of physical phenomena.

Thus, in my judgment, two-year college physics teachers need the equivalent of a strong undergraduate physics major; clearly this *can* be obtained by majoring in physics as an undergraduate. If this is not done, there is still time to enroll in the essential courses as a graduate student. Once these have been completed, the most profitable next step for a prospective two-year college physics teacher is not advanced work in physics. He should, in fact, be kept out of graduate science departments, for he will find there no help in preparing for his chosen career and no reinforcement of his view that teaching technicians will be a worthy and interesting challenge. This does not imply that a fresh baccalaureate degree holder in physics is ready for teaching at a two-year college. Such an individual should definitely go on to graduate work, but if he is to teach technology students, he needs engineering courses covering, for example, electric circuit behavior and strength of materials, more than he needs additional theoretical physics. An M.S. degree in engineering mechanics, electrical engineering, or materials science would be an appropriate goal.

If his curriculum permits, it would be helpful to the teacher candidate to elect courses in sciences related to his specialty, such as chemistry for physicists. In addition it would be useful if a prospective teacher of physics, whose early preparation concentrated on classical topics, could also find room in his program for modern topics such as solid state physics and nuclear physics.

I believe strongly that teachers can profit from learning something about the principles of teaching. However, I am not equally enthusiastic about all courses offered in schools of education. I recall taking a course called "Principles of Secondary School Education," which not only failed to prepare me in any way for my future as a college teacher, but seemed so general and idealized that I question its value for anyone. Hopefully modern courses of this kind come closer to telling it like it is. On the other hand, a course in learning theory should be useful to any teacher. And I see every day the unfortunate effects of an almost total lack of familiarity with available teaching materials on the part of most college teachers. Methods courses which focus on how and when to use teaching materials and technical devices should be required of all prospective teachers.

For a prospective chemistry teacher of two-year college technology students, the same general advice applies. An undergraduate major in chemistry, an M.S. degree in chemical engineering, and electives in the areas of basic physics, special topics in chemistry, and methods of teaching would provide the most suitable preparation which is presently available at most universities.

2. *Instructors of Mechanical or Electrical Technologies*

It seems obvious that instructors of technical subjects should major in the engineering departments related to their specialties. I will comment here only on what I regard as minimum suitable preparation in science and mathematics for these teachers. Most important is a problem-oriented course in basic, classical physics. The principles covered in such courses are, after all, the principles governing the behavior of the macroscopic systems with which all technicians deal. I do not see how this material can be treated in the required depth or with the needed rigor in less than three semesters. Many schools already have such a requirement for any engineering degree. I would, however, add to this a minimum of two more semesters dealing with atomic and nuclear structure and the concepts of quantum physics.

The sophistication of modern technology demands an understanding of systems on a microscopic level; this cannot be achieved by enrolling in the usual one-semester survey of modern physics.

It is not necessary that all of these physics courses fit into the teacher candidate's undergraduate curriculum; some could be postponed until his graduate years. It is also not necessary that all physics be learned in courses offered by physics departments. Achievement levels in physics should be established and met in any way possible. Much physics is now taught by engineers, and when this is done competently, I see no reason why anyone should object.

I believe one year of chemistry is an absolute minimum for any well-educated technology instructor; more is essential for some. Finally, mathematics covering differential equations, computer programming, statistics, and linear algebra is important. Here again, I believe the establishment of achievement levels makes more sense than semester hour requirements, but most students will need to take a mathematics course every semester during their undergraduate years to reach the desired level of mathematical competence to teach technology subjects.

B. University Programs

Few existing university programs have been designed with the needs of the two-year college teacher in mind. I wish to make it clear that the suggestions made above were restricted to conform to already available courses and curricula, and are not thought to be satisfactory in the long run. We must have experimentation with new types of teacher preparation programs. However, before this can begin, much must be done to improve relations between the two-year and four-year colleges. Articulation of upper-division programs with two-year college courses must be improved. Before the universities can deal intelligently with these problems, they must learn much more about the characteristics and goals of the two-year colleges.

I would like now to describe briefly the efforts of my university to improve articulation with nearby two-year colleges. These efforts have not, as yet, resulted in a teacher preparation program for the two-year colleges. They are relevant here primarily as an example of a kind of interaction that may provide the mutual trust and understanding that must be established before the design of a sensible teacher preparation program can begin.

One major feature of our program, which so far has involved only physics teachers, is a series of summer conferences. For one month during each of the past four summers, Stony Brook has provided facilities and staff for between twenty and thirty physics teachers from two-year colleges in New York to study topics in physics and to discuss teaching problems. The topics are selected from among those that are traditionally omitted from introductory physics courses but which are, nonetheless, assuming increasing importance in the discipline. Our staff tries not to present the subject as one we necessarily think every physics teacher should know, but rather to call attention to specific materials available to teach the topic, and to ask teachers to consider whether or not there should be a place in their own courses for these topics and materials.

Two other phases of our Program of Collaboration Between the New York Two-Year Colleges and the State University have been supported by a grant from the Esso Education Foundation. The first of these could be classified as "opportunities for professional development." For the past four semesters we have made it possible for three or four physics teachers from nearby two-year colleges to spend one-quarter of their time on the Stony Brook campus. Some have elected to participate in ongoing experimental research; others have undertaken the solution of a theoretical problem under the guidance of a theorist on our faculty; others have worked on the development of teaching materials, for example, computer-assisted instructional software; one even chose to pursue his interest in a historical physics topic using our staff and library, and this contributed directly to his work toward a Ph.D.

We have also been able to bring two individuals to our campus as faculty fellows for an entire academic year. These two enrolled in graduate courses (some for credit), participated in research projects, and joined in the planning and teaching of our large, introductory physics course. As a special project, one fellow systematically collected information about the physics and pre-engineering curricula, faculties, and students at both the two-year colleges in New York and the four-year colleges and universities to which they often transfer.

The final phase of our articulation program has consisted of a number of curriculum conferences. One series of five, held on Saturdays over a two-year period, focused on problems of teaching physics to potential transfer students at the two-year colleges. We learned what pre-engineering programs are like at both the two-year colleges and the universities, and we studied the reasons why transfer students experience difficulties. The other conference series dealt with physics as a component of technician education. Here interest seemed to focus on the physics topics which should be included in courses at the two-year colleges, and how they should be treated. After preliminary agreement was achieved, teachers of technology subjects were asked for their views, and the need for more articulation between these two groups was revealed. Finally, the need for better teaching materials received much attention, and the group devised a format for materials, which promises much in versatility, and sought mechanisms for getting the needed production under way.

Suggestions for New Programs

A. Reorganization of Faculty Groups at the Two-Year Colleges

1. *A Division of Technology Programs*

It is my observation that the instruction of technology students is a vastly different challenge from the presentation of science to academically oriented students. It would seem wise to me to create a Division of Technology Programs at two-year colleges which would hire to its faculty competent instructors of physics, chemistry, and mathematics as well as specialists in the technical subjects. All of these teachers would have experiences and interests in the way industry uses technicians. Theoretical scientists and mathematicians will never, I believe, bring to their courses the kind of emphasis on applications which would motivate technology students or satisfy technology instructors.

2. *A Division of Liberal Studies*

Once the burden of providing special courses for technicians is removed from the physical science departments, these could now merge to form a single unit of a Liberal Studies Division. This union would encourage the development of interdisciplinary science courses and courses in the social and political aspects of science. These would, in my opinion, be more suitable for general education purposes than the usual pattern of offering to liberal arts majors weak versions of introductory courses designed for future professional scientists.

Second-year science courses in the traditional disciplines to prepare transfer students for upper division science programs would also be offered by the faculty of this division. The physics course should be designed to accept students who have completed any one of the following: (1) a physics course taught in the Division of Technology Programs; (2) a general studies physics or physical science course taught in the Liberal Studies Division; (3) an adequately strong high school physics course. This plan has two great virtues which most programs now in effect lack. First, there are no dead ends; students who change their goals are not locked out by a premature decision. Second, this scheme provides a vertical structure which permits a student to profit from excellent high school preparation or self-study.

B. University Programs

My experience suggests that few university departments will spontaneously generate suitable programs to prepare two-year college science teachers. A combination of deep commitment to research and an understandable preoccupation with curricula designed to produce new scientists will deflect the resources needed to perform this task, the urgency of which—because of the low visibility of two-year colleges on university campuses—is little understood by university professors generally.

If the problem is to be dealt with effectively, university administrators must accept a responsibility to prepare more and better teachers—for all levels, but particularly for the two-year colleges. Once the commitment is made, specialists in curriculum development can be added to the faculty, or located among faculty already on hand, and assigned the task of designing and implementing effective programs. The home for these specialists could be a Center for Curriculum Development or a School of Education, provided these units have the respect of the faculty generally. The programs developed should draw on existing courses in the disciplines when these are appropriate. It will surely be necessary to add courses specially designed for the new teacher preparation programs, some of which could be given by scientists connected with the science departments, and some of which may be offered by scientists permanently assigned to the administrative unit responsible for the program.

I do not believe a program will succeed which is supported less strongly. The need is great, and there is evidence that the response to a well-organized program would justify the investment.

Let me close by describing one program which does address itself directly to the problem under discussion. I have selected this program, not because it provides a model to be emulated—it is too much a stop-gap measure for that—but because it emphasizes one essential feature of an acceptable program: supervised teaching experience relevant to the goals of the teacher-candidate. In this case, the relevant experience is a teaching internship in a two-year college.

We quote below from the May, 1968, issue of the Commission on College Physics *Newsletter:*

> Under a Ford Foundation grant, the St. Louis-St. Louis County Junior College District has begun a program designed to help overcome the shortage of teachers of technical subjects in the community colleges. The program includes the various technical disciplines, such as technical physics or general introductory physics. The physics program offers teachers two avenues of preparation: (1) a one-semester preservice internship program; and (2) a one-year master's degree program.
>
> The preservice internship program is under the direction of Dr. Charles R. Hill, Ford Internship Program, St. Louis-St. Louis County Junior College District, St. Louis, Missouri.

Its purpose is to meet urgent short-range needs and participants are trained to become either (1) teaching and laboratory assistants; (2) instructors of technical courses; or (3) instructors of academic subjects for technical students. Since candidates enter with varied backgrounds and levels of technical attainment, the entrance requirements—and the programs themselves—are flexible enough to accommodate these differences. Participants in the first group include graduates of two- and four-year schools and persons from industry, but for those with only a two-year degree some technical experience is required. Candidates in the second group, recruited from graduate schools and from industry, generally have a master's degree and some technical experience. Those in the third group, selected from among high school and/or college teachers, from recent college graduates, and from industry, are expected to have a master's degree in their subject area and, hopefully, some teaching experience. Exceptions, however, may be made in all three groups.

The internship program consists of course work (done in cooperation with Southern Illinois University), a short internship, a field experience, and seminars. Participants are paid a salary for one semester and are assigned to one of the three junior college campuses in the St. Louis area: Florissant Valley Community College, Meramec Community College, or Forest Park Community College. They are assisted in finding teaching jobs following their internship program.

The St. Louis program provides ideas on what might be done. We look forward to the next several years when many similarly imaginative programs will appear. Hopefully some of these will reflect the special demands made upon teachers of technicians.

Part II

The Technician's Relationship to Industry

Technicians and Industry

JOSEPH A. PATTERSON
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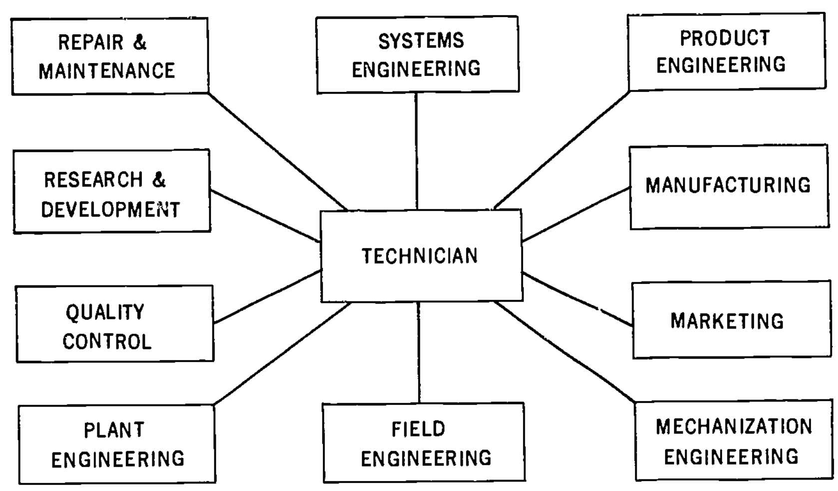
Technicians are making significant contributions to the technology advances that are being made in the industrial development of our nation. Industry has high regard for the technician, who plays a vital role in our overall operations and our plans for the future. Educators and the general public must recognize the important service the technician performs, the critical need for him, and the job satisfaction and rewards he receives. The idea that the work of technical institute graduates is second rate and nonprofessional should be corrected. The myth that technical training is for the below-average student who cannot qualify for the baccalaureate degree programs must be exposed. Education and industry can encourage more young people to enter the two-year technical programs being offered by junior colleges and technical institutes throughout the United States. If these problems are not solved, we cannot maintain the present rate of industrial growth that is so vital to the economic and social welfare of our country.

I represent a corporation that has been in operation for approximately forty years. The company rate of growth has been very rapid in the last twenty years. We are among the twenty most diversified companies in the United States and rank in the top 200 U.S. companies as far as gross income is concerned. Our goal is to become a three billion dollar company within the next ten years. The company is divided into four major divisions: research and development, components, equipment, and materials and services. We have facilities strategically located throughout the world producing electronic systems, missile systems, semiconductor products, electrical products, metal products, nuclear fuel, and providing geophysical service and scientific information concerning earth, sea, and space.

Technicians are used in all divisions of the company. They are recognized for their contributions to the success of the corporation and considered essential for our planned growth.

Chart A shows the different areas in the company where technically trained people work. It also identifies the challenge institutions face to provide education and training so that the technical graduate will be qualified to enter the many different areas of employment that exist within most large companies. This challenge is further complicated by the trend of the engineering schools to teach pure theory. This trend is widening the gap between the engineer and technician. Greater opportunity is offered the A.S. degree graduate, but a larger burden is placed on educational institutions to provide a quality graduate within the two-year program.

CHART A



The minimum educational requirements for entry-level technician jobs are a strong background in physics and mathematics. Physics is the basis for continued training in the student's major field. Mathematics is the tool used for understanding and learning the theory associated with the major field. An introductory course in calculus is recommended so the technician can communicate with the engineer and scientist, as well as be prepared to be creative and analytical as he becomes proficient on the job.

Technology advances are being made within shorter time intervals. As an example, we have seen the change from vacuum tube to transistor to integrated circuit and to large-scale integration in the last twenty years. The technician with the strong physics and mathematics background has made the transition with minor difficulty. The person weak in physics and mathematics has found it difficult to make the adjustment and faces becoming obsolete with a limited future. Another essential requirement is the ability to communicate orally and in technical reports, graphs, schematics, sketches, and so on. The rest of the curriculum should teach as much of the major field as possible within the program time limit.

Other characteristics that enhance the success of the technical graduate are:

1. A professional attitude. The technician is a professional and an important member of the team.
2. Versatility and ability to absorb new ideas and to attack and conquer new challenges.

3. Ambition, with a desire to master new processes and techniques.
4. Ability to get along well with superiors, co-workers, and subordinates.

When the technical graduate is on the job, the rewards are excellent. He can progress as far and as fast as his ability, determination, and personality warrants. He will work in an environment that will provide a responsible position and give a sense of achievement. Opportunities to work with engineers and scientists, expert in their field, allow a chance for additional education and new skills. With the variety of job areas the technician is qualified to fill, he can select the specialty that is best suited for his long-range personal goals. The starting pay for technicians ranges from $6,000 to $7,200 per year, and they can progress to salaries of $10,000 to $12,000 per year plus liberal fringe benefits. If the technician continues his education as he gains work experience, he can progress to engineering, supervisory, and administrative positions.

Education and industry must work together to get more of the total population enrolled in two-year technical programs. A concentrated effort must be made to define the critical need for the technician, what he does, and the rewards that he can receive. Junior and senior high school students and their parents, junior and senior high teachers and counselors, and the general public must be informed about technical education.

We must continue to research and develop new and improved curriculum and teaching techniques, such as the Electromechanical Technology Program being developed by Oklahoma State University. The U. S. Office of Education is doing an excellent job in identifying new areas of technology needs and supplying funds to develop curricula to meet these needs. It is time for technical education to throw off the shackles of the traditional methods and be creative and innovative.

Industry needs to take a more active role in developing technical education by: (1) sponsoring cooperative programs, (2) providing summer employment for students and teachers, (3) developing material for educating the general public about technician jobs and opportunities, (4) developing material to help institutions attract more students, (5) establishing scholarship funds for technical education students, and (6) donating surplus equipment and products as teaching aids.

The technician is a member of a sophisticated team that has the responsibility for solving complex technological problems. The ability of the technician to perform his part of the job and to be prepared to master technical advances as they occur is directly proportional to the quality and depth of technical training he has received. Industry and education must work together and separately to educate the general public concerning technical education and entice more young people to seek technical training. As technology races into the future, it will demand the services of larger numbers of well-trained technicians. Institutions that are creative and innovative will be best prepared to fill this need.

Utilization of Technicians in Engineering Laboratories at Bell Helicopter Company

GEORGE H. LINNABERY
Chief of Engineering Laboratories
Bell Helicopter Company

Bell Helicopter Engineering Laboratories consists of about 210 employees, of which 135 are classified as technicians. As technical assistants to engineers, they cover a wide range of skills in the individual laboratories. For the Mechanical Laboratory, which does static and fatigue testing of helicopter parts and components, we require mechanical or aeronautical training beyond secondary school. For the Metallurgical Laboratory, we prefer college work with some metallurgical and physics background. Our Process Control Laboratories technicians come generally from liberal arts colleges with chemistry as a major. For electronics and instrumentation, we are hiring technicians from the electrical engineering field. We prefer these employees to have a two-year associate degree or two years of college credit in one of the above fields.

Our first choice of educational background for a new technician would be a two-year program in a technical institute. When we employ a technician, his training is just starting and it takes at least five years of on-the-job training to become proficient in all phases of our operation. Thus, when adding a new technician, we prefer one that is going to make a career of being a good technician rather than one who uses his technician employment as a temporary means to finish his schooling and obtain an engineering degree.

Our second choice would be a partial engineering course interrupted because of financial problems or a growing family. We realize that this type of employee, who is capable of earning his degree, may only work as a technician until he can finish his degree. However, this is a long interim period (from five to ten years) requiring night school. During this interim we have a technician who is oriented toward the engineering aspects of laboratory skills. As a company policy, Bell Helicopter helps its employees to continue studying in local schools in subjects applicable to their job skills or to obtain a degree in a field of endeavor related to the needs of Bell.

Our third choice can be equivalent work experience to make up for the lack of schooling. Most often this man will be an instrumentation technician with training and work experience gained while serving in the military. This type of technician may have gained his experience in other laboratories. Bell Helicopter Engineering Laboratories does not consider factory production experience as equivalent for either educational or on-the-job training.

The interviewer with a job applicant tries to determine the man's attitude and future potential toward the kind of work he will be doing. We look for traits in an applicant that show that he can easily cooperate with others, has the ability to follow procedures and written instructions, is a self-starter, and doesn't need constant direct supervision and can plan his own work.

Bell Helicopter has the following technician classifications that a new technician can progress into if his skills and experience merit it.

Technician, Class I: Two years of college.

Technician, Class II: Two years of college plus two years' experience.

Technician, Class III: Two years' college plus four years' experience. (This is a lead man who directs other technicians).

Technician, Master: A very experienced man who has complied with the above requirements and has gained one or more very special skills. This classification is for the career technician.

Technician, Supervisor: General supervisor of technicians in a laboratory group.

The present pay scale ranges from $132.50 per week for a beginning Technician, Class I, to $243.50 per week for a Technician Supervisor, who oversees at least twenty employees.

As in every other company, many find advancement in other departments due to the broad training that a technician experiences in a laboratory job. Some of our technicians have been promoted to Detail Product Design or Liaison Engineering. For men who are pursuing, and are close to receiving their engineering degree, we classify as Engineering Assistants to give recognition and to encourage continuation of their studies. Opportunities in the Laboratory for better paying jobs are a strong motivating force among technicians to do a good job and to show initiative in their work.

Good technician applicants are in short supply and the work of the two-year technical institutes is a very welcome source of well-trained career technicians. There is no formal training in adhesive structural bonding, which is a large section of aircraft technology. We hope that some university or technical institute in the Fort Worth-Dallas area will accept this challenge.

Training and Utilization of Engineering-Scientific Technicians in the Petroleum Industry

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History

The shortage of technical people created by World War II stimulated the use of those with less formal technical training for supportive help to scientists and engineers. In the forties and early fifties, supportive people often had little formal training beyond high school. During the last fifteen years the need for scientists and engineers in research, development and operations has expanded more rapidly than the number acquiring baccalaureate and graduate degrees in science and engineering. This accelerated the trend toward the use of supportive people in more technical roles which require formal technical training after high school.

Accredited two-year engineering technician curricula, offered by some forty technical institutes and a considerable number of colleges, usually require the equivalent of 62 to 80 semester hours of college-level work. They include fundamental courses in mathematics, physics, chemistry, metallurgy, electricity, drafting, and applied courses which are designed with less depth in the theoretical aspects and with more time spent in applications than is the case for similar subjects of four-year engineering or science courses. The relative hours of theoretical versus practical, applied courses varies among the technician curricula. This variation is justified by the variation in the nature of the technician training required in the different industries and in the different specializations within a single industry.

Technician Curricula Needs of the Petroleum Industry

Curricula that place relatively more emphasis on fundamentals are favored by the petroleum industry because of the wide range of types of supportive work that exist in major oil companies, to which the engineer-scientist technicians can contribute. The greater the fundamental training, the greater the flexibility and adaptability to various supportive types of work within groups of scientists or engineers.

A professor consultant who studied the curriculum needs for an "in-house" technician training program of a major integrated oil company concluded: "One technician curriculum is not sufficient for all technicians in the company. A chemical technician will perform different functions than a chemical engineering technician and a mechanical engineering technician will also perform different functions than a chemical engineering technician. Therefore, somewhat different curricula are necessary for each type of work. However, certain things such as basic chemistry, English composition, mathematics (including elementary calculus and graphics) must be common to all technician curricula."

In California, and in other states, junior colleges now offer the two-year associate degree technician curricula. To meet future growing demands for engineer-scientific technicians, many other junior colleges are developing technician curricula. The two-year graduates of junior colleges whose curricula are in the first two years of a four-year engineering or science curriculum are found to be satisfactorily trained for engineering-scientific technicians in the petroleum industry, but most of these manage to go on and acquire the four-year baccalaureate degree in science or engineering.

My own view is that most engineering technician jobs in the petroleum industry are not too demanding as to formal specialized technical training and much of the know-how and specialization comes from learning while performing on-the-job duties. Engineering-scientific technician curricula that give more weight to fundamentals and that provide a limited number of applied courses for support of one of the specializations of chemical, petroleum, mechanical, metallurgical, electrical or civil engineering appear to be more suitable to the petroleum industry.

Utilization of Technicians in the Petroleum Industry

The recently released report by the National Petroleum Council, *Skills and Occupations of People in the United States Oil and Gas Industries*, based upon a broad and comprehensive survey in 1967, contains some significant statistics. The total number of scientists, engineers, and technicians in the oil and natural gas industries in the companies surveyed was as follows:

	Total Number	Percent of Total
Scientists	18,539	21.8
Engineers	37,642	44.2
Technicians	28,948	34.0
Total	85,129[a]	100.0

[a] Includes 2,596 scientists, 6,306 engineers, and 3,257 technicians employed by contractors for oil field services and refinery construction.

According to the report, "Engineers and scientists bear a 1:12 ratio to total oil company manpower," and "There is one person classified as a technician for every 2.2 persons working as engineers and scientists."

The NPC report also shows that among all functional divisions of the industry, there are 6,777 technicians supporting scientists, with 48 technicians per 100 scientists and 6,038 technicians supporting engineers, with 27 technicians per 100 engineers. The report also reveals that technicians are being used to a higher degree where engineers and scientists are concentrated, such as in producing, refining, and research and development.

Educational Backgrounds of Scientists and Engineers in the Petroleum Industry

Figure 1 shows distribution by discipline of degree holders in the petroleum industry. These are the disciplines that technicians support. Figures 2 and 3 show data on degree levels and disciplines for scientists and engineers in Research and Development in the industry.

The NPC report shows that R & D technical jobs are 62% of total jobs as compared with 12% for the total industry; that R & D uses 63 technicians per 100 scientists and engineers, compared with 40 per 100 for the industry; and that 75% of technical degree holders were engaged in engineering and scientific staff services, the remaining 25% being in operation, management, or other services.

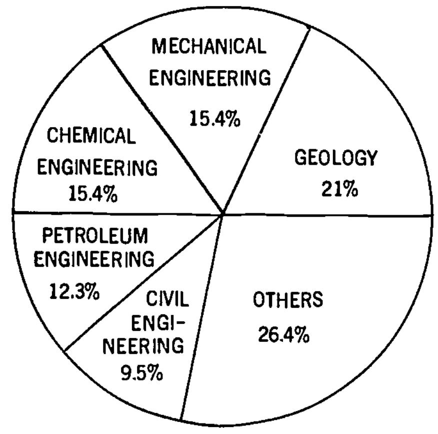

Fig. 1. Distribution of degree-holders by discipline. (Excludes R & D.)

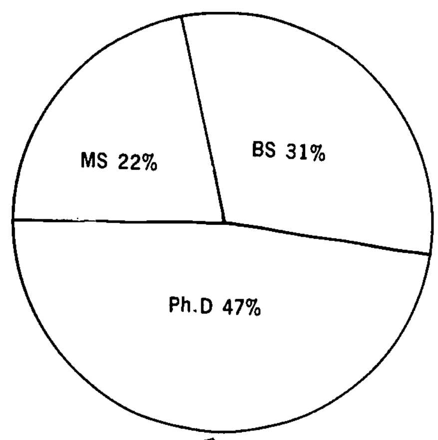

Fig. 2. Distribution of degree-holders in R & D, by level of degree.

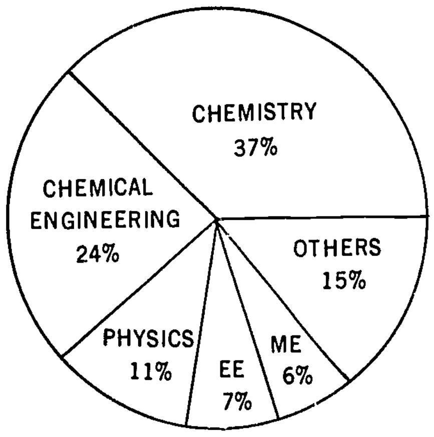

Fig. 3. Educational disciplines as a percent of all technical degree holders in R & D.

SOURCE: The National Petroleum Council, *Skills and Occupations of People in the United States Oil and Gas Industries.*

Upgrading of Nontechnical Hourly Employees

Trends in the petroleum industry toward automation and more complex instrumentation in operating departments increase the need for technically trained employees and diminish the need for nontechnical operating employees. In-house, extension, correspondence, and campus courses offer opportunities for the nonskilled to study and upgrade themselves into technician career programs. A technician program is being evaluated by Phillips Petroleum Company for present hourly nontechnical employees.

By meeting minimum requirements of course work off the job and by learning on the job, the technician has the opportunity to progress through four or five engineering-scientific technician job grades with gradually increasing technical duties until he is able to handle the lower levels of semiprofessional work now handled by staff engineers. The main requirement is the completion of the equivalent of 60 semester hours of engineering technician curricula with a minimum of 12 semester hours of basic courses in English, mathematics, chemistry, and physics. The other requirement is a minimum of two years of experience in some grades and three years in other grades. Thus, the on-the-job technician trainee has to complete the equivalent of 5 to 7.5 semester hours of the prescribed engineering curricula each year. This is a long, demanding program, requiring considerable personal discipline to complete. It is also difficult for the employer to offer enough additional salary above the existing high hourly rates for nontechnical operators and maintenance people to make the additional effort appear financially worthwhile to the employee.

If the time required in each job grade is waived and a high school graduate wants to acquire the equivalent of 60 semester hours at an accelerated pace, about the best he can do is complete 60 hours in 5 years. This requires 12 hours per year or 6 hours each semester. With 2 hours of study for each class hour, this amounts to 18 hours each week, which is an excessive load for a 40-hour employee with a family and family duties. It is possible that corporation managements may permit say 1 to 1.5 hours of class work on company time if the corporate needs for technicians become great enough to require increasing the number of technicians more rapidly than they can be recruited. The only alternative is to train and upgrade nontechnical operating and maintenance people already on the payroll who are needed in diminishing numbers in their present occupations, as automation advances in plants and fields.

The foregoing points up the fact that it is quite difficult for a high school graduate to acquire the formal training equivalent to 60 semester hours while working and taking care of a family. In fact, few will have the will and self-discipline required to do this. On the other hand, assimilation of this much formal education while attending college full-time on a two-year curriculum immediately after high school is much easier and one is more apt to complete the required work.

Multi-Level Job Description Charts

In addition to providing technician job and salary progression, Phillips is preparing a catalog of charts describing the scope, functions and material items for five levels of jobs for each engineering-scientist technician specialization. A single composite chart covering the job categories common to all such technician jobs serves to supplement the charts on each specialization. The composite chart covers general characterization, supervision received, responsibility and authority, and minimum qualifications as to education, experience, and knowledge common to all, and other skills and abilities. Thus, with the composite chart and the particular chart covering the unique job characteristics of a given specialization, a complete job description can be written for each specialization in five grade levels. This catalog of multi-level job description charts is intended to be a tool for the engineering supervisors or managers to refer to in recognizing job duties that are similar to the job duties of staff engineers under their supervision. Such duties can be transferred from the engineer jobs to technician jobs as fast as technicians can be recruited or trained, and thus upgrade the engineering and scientific jobs and provide a better-balanced, more efficient organization.

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