MATH REQUIREMENTS TO PERFORM SELECTED OCCUPATIONS

by

James E. DeWitt

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APPROVED:

James L. Hoerner, Chair

Penny L. Burge

Jerald F. Robinson

Kusum Singh

Daisy Stewart

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James E. DeWitt

Committee Chairman: James L. Hoerner

(ABSTRACT)

The purpose of this study was to determine the mathematics levels commonly used in the performance of four selected occupations. This was compared to the mathematics levels generally required during the education and training for these selected occupations. The four occupations selected for this inquiry were: (1) family practice physician (2) finance officer (3) electronics technician and (4) machinist.

A survey instrument was created to ascertain formal mathematical preparation of those working in the selected occupations along with the frequency, importance and use of 60 progressive math topics from the secondary and postsecondary curriculum. A purposive sample of approximately sixty individuals from each of the four occupations participated by completing the questionnaire. Demographic information was collected from each of the participants in order to construct a descriptive profile. Along with the survey, two members of each occupation were interviewed to gain additional insight for the study.

A consistent use of basic math, such as adding, subtracting, multiplying, and dividing was being used in all four occupations. Both family practice physicians and finance officers reported using basic math as their primary application level of math on the job. The results of this investigation suggests that the two professional occupations, family practice physician and finance officer, did not use in their jobs the higher math levels they were required to study during their education and training. Conversely, the two technical occupations, electronics technician and machinist, did apply the higher level of mathematics they previously studied in the performance of their duties. Interviews with two members of each occupation supported these findings.

Our present educational system is not meeting the needs of a majority of the students it serves. As a result students are leaving school not prepared for future jobs; employers tell us many are not even prepared for today's jobs. This study examined the connection of the educational mathematics requirements of four selected occupations and the mathematics used to practice these occupations. The results of this study provide relevant information that can be used by educational institutions in the preparation of individuals for careers.

DEDICATION

This dissertation is dedicated to the memory of my mother, Mary M. DeWitt, who gave so much of her life to raising her nine children. Throughout the years of hardship, she continually provided the love and support of all her children. On behalf of all my brothers and sisters , you are loved and remembered always.

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The challenge of completing a doctoral program has been a difficult task. There have been many late nights spent alone working in an office to complete this dissertation. I look forward to spending sunny days enjoying the outdoors, not sitting in the library.

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The time that I have spent working on this degree has been time away from you. It was the most difficult part of this whole process. Hopefully, each of you has gained from the experience in whatever path you choose in life.

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CHAPTER ONE

Introduction

The performance of students enrolled in American public schools has received a great deal of attention from many quarters since the release of the report *A Nation at Risk* in 1983. This report heavily criticized the capability of our nation's schools to prepare its students to perform in math, science and communication skills. Compared to their peers in other industrialized countries, American students were far behind in every core subject area, especially math. The Workforce 2000 report indicated that "very few jobs will be created for those who cannot read, follow directions and use mathematics" (Johnston & Packer, 1987, p. xiii). This problem has been passed on to employers who in turn try to remediate the lack of math skills needed in the workforce. Business and industry spend as much on remedial mathematics education for their workers as is spent on mathematics in schools, colleges, and universities (National Research Council, 1989). The question for the government, educators and employers alike becomes, "What math is required on the job?"

Since the release of *A Nation at Risk,* (Gardner, 1983) reform has taken the approach of adding more math rather than changing what or how it is taught in schools. Almost every state has mandated a more rigorous set of math standards before a student can graduate from high school. Some local school districts have even added their own requirements, while other groups call for national standards. Most states now require graduates to meet minimum performance standards in math including algebra (Loase, 1983; Daggett, 1994). In a survey of 50 state education agencies, (Webster & McMillin, 1991) it was found that 45 states have developed reform efforts focusing on high schools within the last five years. The survey also revealed that 27 of the states had increased the requirements for both science and math; 40 states reported having a state-mandated testing program that all students must take.

The high school curriculum has become so crowded with required courses, especially for those preparing for college, that little room is left for electives or exploratory courses in vocational-technical areas. Students are counseled to take only courses which will reflect well in the eyes of a college admissions board.

Mathematics is the foundation of science and technology; it serves as a key to career opportunities (National Research Council, 1989). Mathematics education is an immense enterprise, accounting for over 10% of the nation's education resources, estimated at $25 billion annually. In comparison to other subjects, mathematics filters students out of programs leading to scientific and professional careers. Probably no other school subject accounts for more student failure than mathematics. Besides eliminating students from careers, it may be responsible for some who drop out of school (National Research Council, 1989).

For years mathematics achievement and performance on aptitude tests have been used in the screening of applicants for admissions to a variety of professional and occupational schools. Although it may be just one of several criteria used by admissions committees, it carries an influence factor possibly disproportionate in the decision-making processes. Some professional and occupational schools demand a specific course sequence in mathematics, while others value mathematics competence, and many require or strongly recommend mathematics courses (Association of American Medical Colleges, 1994).

Professional and occupational schools are established to provide education or training leading to particular career paths. Schools of this nature establish goals, objectives, and outcomes designed to meet occupational expectations and criteria (Cleve-Hogg & Muzzin, 1993). Applicants to occupational schools are self-selecting in that they choose an occupation that meets their interests, abilities, and ambitions, along with numerous other factors. Some of our brightest young people chose their careers based on their ability to get into a professional school.

Most occupational schools limit the number of students accepted into a program and therefore develop criteria to direct the selection process. Essentially, there are three main reasons for creating a selection process: (1) the need to reduce the number of applicants because occupational programs consistently have more applicants than openings, (2) the need for a method to exclude candidates who are unsuitable, and (3) the need for a method to select the candidates with the best qualifications (McManus, Powis, & Cleve-Hogg, 1992).

Professional schools have two important missions; the first is to meet their academic responsibilities and the second is to meet their social responsibilities (Clawson, 1990). All professions need to reflect and represent the society from which they come.

A screening process is used by personnel representing professions who provide education and training to new people in their career field. Individuals seeking to enter certain professions are often required to take exams that are written and constructed by members of the profession. The intended purpose of these exams are to assess and evaluate the applicant's qualifications. Along with an exam, applicants are usually required to provide a history of academic records or transcripts detailing their formal education. Additionally, they may be asked to provide written documentation outlining their personal backgrounds and achievements.

Issues of selection criteria for particular programs are something admissions committees must wrestle with. Past academic achievement is often viewed as the best, in some cases the only, indicator of success, however it is defined. Selection can be done on the basis of applicants with the highest subject proficiency scores, grade point averages (GPAs), and/or college entrance exam scores (Cleve-Hogg & Muzzin, 1993).

Statement Of Problem

Since the early 1980s there has been a series of reports calling for educational reform to improve the academic and technical capabilities of students. The Goals 2000: Educate America Act and the School-To-Work Opportunities Act passed by Congress in 1994 are directed at preparing students to meet the challenge of the changing workplace. Educational reform will require school systems to develop new core curriculums which focus on teaching concepts all young people can apply to become productive members of society. Making the transition from school to work will require students to possess competencies in communication and math skills. Preliminary investigation shows that many professional careers including medical doctors, lawyers and others do not use the math levels they are required to study.

Over the years educational institutions have put into place a series of mathematics courses requiring people to study and master large amounts of math that have no perceived relevance and, therefore lack an important ingredient in motivating youth and adults. According to the National Research Council's (1989) publication, *Everybody Counts,* three of every four Americans stop studying math before completing career or job prerequisites.

A commentary from the Ford Foundation (1989, p. 2) stated:

> The mathematics taught in school bears little resemblance to what mathematics really is, namely a way of making sense of the world of perceived patterns, analyzing data, and reasoning carefully. By and large the mathematics taught in schools is arithmetic that has been stripped

of its connections to intrinsically interesting problems and ideas and reduced to a series of computational tasks with only one correct approach.

Part of the problem is that we are a society that heavily relies on tradition. We do what we know how to do. Today's schools still operate under the structure designed for the industrial age, which is not well suited to educate children for the future. Professional associations of subject-matter specialists have an impact on stabilizing the curriculum. Another stabilizing factor is the textbooks adopted by school systems. Most textbooks attempt to take a middle of the road approach and publishers strive not to alienate groups who are responsible for selecting materials. As a result much of what is produced tends to be dull and adhering to routine methods. "According to virtually all studies of this matter, textbooks have become the de facto curriculum of the public schools," (National Research Council, 1989, p. 67). Textbooks can define the content and shape the form in which students will encounter its content, perpetuating the same curriculum year after year (Eisner, 1990). Goodlad (1984) supported the generalization that the mathematics curriculum was dominated by textbooks in the classrooms in his national study.

For decades the high school mathematics curriculum has been designed to provide a background to prepare students for calculus. The traditional route of preparation has been in algebra, geometry, and pre-calculus mathematics. This has been based on the idea that calculus is a powerful tool in the study of additional mathematics and other applied fields (Meiring, 1992). This type of curriculum imposed expectations of memorization of isolated facts and required a proficiency in doing calculations with paper and pencil (Meiring, 1992). The American society has long held the view that such levels of math and science achievement were suited only for the most academically talented. As long as we trained some small segment of our population to fill these roles, we would continue to maintain our position as a leader in technology, science and world affairs (National Research Council, 1989)..

Lack of success in high school level mathematics and beyond eliminates many graduates from all but low wage and low skill jobs. This lack of success was noted by Kate Maloy in her report *Toward A New Science of Instruction* (1993, p. 19), "Far too many children have done poorly. They have never understood the principles that lie beneath their calculations, have never seen a connection between math and their lives outside the classroom."

The secondary math level course work has served to teach students how to prepare for postsecondary math studies. Broad categories of skills can not adequately define the specific math skills required in an occupation. Individuals who work in an occupation use specific math skills and usually can not be simply grouped as algebra or geometry (Pucel, Davis-Feickert, & Lewis, 1992).

There is a built in connection between knowledge of mathematics as a precursor to learning the content in subjects such as chemistry and physics. This connection has a recognized influence on the curriculum in the field of science. Students are told that they have to take higher level math courses before they can learn chemistry. Those who choose to pursue chemistry as a career or simply take a course in preparation for other careers such as biology or medicine may be eliminated if they lack high level math skills. Perhaps math could be taught on an applied level for the student to learn enough chemistry for what is really needed to succeed in their chosen occupation. The higher level of chemistry would be maintained for those requiring a deeper understanding of the subject for future application.

Despite all this some students do manage to excel and usually move on to college to get a four-year degree and beyond. America's system of universities and colleges are still viewed as the finest in the world. We continue to produce the most engineers and medical professionals of any country in the world (Thurow, 1992).

Out of all the American students who receive bachelor's, master's, and doctoral degrees in the physical sciences (e.g. mathematics, physics, and engineering), 95% are whites and Asians. Students enrolled in advanced high school mathematics courses are disproportionately from white upper-class backgrounds. Many women drop mathematics in high school or in the early years of college (National Research Council, 1989). Women are performing as well as men in college math courses but drop out at twice the rate of men beyond the bachelor's degree. The American society continues to perpetuate stereotypes that "girls can't do math." This idea discourages young women; many drop out of math during their adolescent years, losing opportunities for future careers.
Educational institutions and professional organizations need to work together to dispel the myth that math and science are not appropriate fields for women (Burge, 1995).

A majority of math teachers realize that many of their students have lost interest in mathematics because of the routine, repetitive way in which it is frequently taught. A report titled "Mathematics Report Card for the Nation and the States", found students in grades four, eight, and twelve showed some success in solving problems involving addition and subtraction. However, their performance began to drop as problems required multiplication and division. A significant finding was that fewer than six percent of students in grade twelve could solve relatively complex problems involving geometry, algebra, or functions (Mullis, Dossey, Owen, & Phillips, 1993). There was very little difference in the performance of students in public versus private schools.

Recent attempts by conservative groups have promoted legislation on the federal and state level to gain funds for charter schools and vouchers to create their own private schools. By managing their own schools, they believe students enrolled will excel in comparison to public education. At least in mathematics, current evidence does not support this idea. (National Research Council, 1989).

Purpose of Study

The purpose of this study was to determine the mathematics levels commonly used in the performance of four selected occupations: (1) family practice physician, (2) finance officer, (3) electronics technician, and (4) machinist, and then compare the uses to what is required in the preparation of these occupations. If the performance of math required during the program of studies in these four occupations is not being used, this poses questions for those who determine the educational curricula. Improving the communication between the educational setting and the actual practices of experienced personnel within an occupation should result in a more relevant curriculum. This has implications for groups who have historically been screened out of the opportunity for admission to these occupational training programs.

Research Questions

The research questions of this study were:

1. How is math used by those who work in the occupations of (1) family practice physician, (2) finance officer, (3) electronics technician, and (4) machinist?

2. What are the highest math levels required of students enrolled in the education and training of the four occupations?

3. How do the math levels required in the educational programs compare to the math levels used by the selected occupations?

Significance of the Study

Our present educational system is not meeting the needs of a majority of the students it serves (Gardner, 1983). As a result students are leaving school not prepared for future jobs; employers tell us many are not even prepared for today's jobs (Drucker, 1994). This study examined the connection of the educational mathematics requirements of four selected occupations and the mathematics used to practice these occupations. The results of this study provide relevant information that can be used by educational institutions in the preparation of individuals for careers.

Limitations

This study, being descriptive in its approach, used a nonprobability sample for all four groups. Since no previous study has been conducted on this subject, the researcher is confident that the information gathered can be beneficial to the field. One of the principle limitations of this study was that it was not a true experimental design since there was no random assignment to groups, therefore caution should be taken. Any conclusions drawn from this study should not be interpreted as representative of the occupations that participated in the study.

The sample was drawn from four states: Virginia, Maryland, North Carolina, and Kentucky. The reason for limiting the study to this geographic region was a matter of logistics, availability of subjects, and financial considerations. Each of the four selected occupations were located in one or more areas, depending on the availability of participants. Participants were asked to designate which math courses they have had previously. Respondents in this study had to rely on their ability to recall information about math courses they had taken in the past during their formal education while in high school and college. This was more difficult for some than others considering their age difference and length of time since they were last enrolled in a math course. Individual's inability to recall their history of math classes may have prevented them from answering items on the questionnaire or may have resulted in incorrect information being given.

Definition of Terms

The following terms were identified as they applied to this study:

Certified--the status earned by an individual in an occupation as result of completion of a state approved education program.

Electronics technician--a certified technician in the electronics industry who worked full time building, testing, repairing, and modifying electronic equipment such as computers, communications equipment, and industrial and medical control devices.

Family practice physician--a full time physician who was educated and trained in family practice, a broadly encompassing medical specialty.

Finance officer--a finance or business college graduate who was employed full time in the banking industry.

Higher mathematics--any math above the level of pre-algebra.

Machinist--an individual employed full time as a benchworker, tool and die maker, or machine tool operator under the occupational title machinist.

Chapter Summary

The report *A Nation at Risk* in 1983 heavily criticized the capability of our nation's schools to prepare its students to perform in math, science and communication skills. Compared to their peers in other industrialized countries, American students were far behind in every core subject area, especially math. The Workforce 2000 report indicated that "very few jobs will be created for those who cannot read, follow directions and use mathematics" (Johnston & Packer, 1987, p. xiii). For years mathematics achievement and performance on aptitude tests have been used in the screening of applicants for admissions to a variety of professional and occupational schools. Some professional and occupational schools demand a specific course sequence in mathematics, while others value mathematics competence, and many require or strongly recommend mathematics courses (AAMC, 1994).

Mathematics is the foundation of science and technology; it serves as a key to career opportunities (National Research Council, 1989). In comparison to other subjects, mathematics filters students out of programs leading to scientific and professional careers.

This study was designed to examine the mathematics levels commonly used in the performance of four selected occupations. The math levels were compared to the levels generally required during the education and training of these selected occupations. This study contributes to the existing literature and provides a basis for further research.

CHAPTER TWO

Literature Review

Very little research has been done on the connection of math education levels and career application. Practically all the research has been directed at remedial or basic math skills related to workforce literacy issues. Other studies tend to focus on occupations requiring a high school education or less. Occupations gained through postsecondary degrees or training appear not to have elicited the attention of the research community. Over the past 10 years a great deal has been written about the need to increase the level of mathematics students must have. This connection between mathematics and occupational education is an area of needed research.

This review of literature includes five areas relevant to the research on mathematics and occupational education: career information, instrument development, interviews and observations, theoretical foundations, and math skills related to work.

Career Information

Having inspected the 1994 *Occupational Outlook Handbook,* it became apparent that the relationship between the mathematics prerequisites to enter certain occupational fields contributed to the compensation scales. In a study by Loase (1983), occupations which usually require considerable mathematical coursework at the collegiate level consistently pay higher wages. Some examples he pointed out were engineering, computer science, and actuarial work.

The 1991 edition of the *Dictionary of Occupational Titles* published by the U.S. Department of Labor contains definitions of 26,000 separate occupations listed by titles. Contained within each job definition is a detailed description of the work performed in a variety of settings commonly affiliated with the job. Only a very general discussion of academic skills is incorporated. An example from the definition of a machinists states; "applying knowledge of machine shop theory, procedures, and shop mathematics" (U.S. Department of Labor, 1991 p. 514).

At the end of each definition there is a set of codes used to assist the reader in forming a clearer understanding of the potential educational and physical aspects required of the worker for satisfactory job performance. Years of experience and exposure to further training is taken into account using this coding system. The three coded areas of General Education Development (GED) are reasoning, mathematical, and language. Interestingly, both the machinist and finance officer are rated a 4 on the math scale. This rating level suggests the worker will need to apply algebra, and geometry, along with practical applications of trigonometry. Family physicians and electronics technicians are rated a 5 on the math scale. At this scale a worker should be able to apply principles of algebra, trigonometry, and calculus. These math scales, although only used as a general guide to occupational information, place the U.S. Government in the position of supporting the levels of mathematics through these publications.

On the shelf of high school and college guidance counselor offices, one is very likely to find a three volume set of the *Encyclopedia of Careers and Vocational Guidance* (Hopke, 1993). Counselors use these as a resource when students express a general or specific interest in an occupational field. More than 900 occupations are defined and described in detail. The information contained within this encyclopedia was compiled from government workers, teachers, industry and trade representatives, vocational counselors, and field specialists. This information has been updated with a revised edition having been published about every three years since 1972. Under each occupation is a requirements section which offers advice on how to get into the field, along with the traditional path of education and training. This section includes the subjects and the length of courses that should be taken during secondary and postsecondary education. Academic and vocational courses are discussed in the context of this component. Specific mathematics course sequences are listed. Some examples are given of the four occupations selected for this study:

Electronics technician--a high school student should take two years of mathematics including algebra and geometry. On the postsecondary level one year of technical mathematics will be typical. Most employers prefer to hire graduates of two-year postsecondary programs.

Finance officer--a young person who wishes to be a finance officer should have a college education with an emphasis on business administration. Larger banks recruit on college campuses.

Machinist--student preparation should include algebra and geometry. Employers like to hire graduates of high school or postsecondary training programs.

Physician--students who hope to enter medicine should prepare themselves with an undergraduate major in pre-med, biology, or chemistry with courses in mathematics and physics.

Computer data bases offering career information have been developed and expanded in the last 10 years. Students can gain access to these information systems, usually located in the guidance office in secondary and postsecondary institutions. These interactive systems have been developed by private enterprise and marketed for use on a national basis. Two of the most successful systems in use today in conjunction with career guidance are: (1) System for Interactive Guidance and Information PLUS (SIGI Plus), and (2) Discover. Both systems allow a first time user to gain immediate access with a self-guided format. These systems are a tool in assisting guidance counselors in helping their clients to focus on issues, values, goals, and vocational interest in determining potential occupational fields.

Some other successful career systems were developed and financed in large measure from state funds. Virginia View (Vital Information for Education and Work) is an example of such a system. Originated in 1979, materials were gathered and later disseminated on microfiche to guidance counselors across the state. About ten years later, the accumulated information had grown to the point that a computer database (Virginia VIEW, 1989) was developed as the best means to access the system. It now serves over 1,400 sites across the state providing career information to its users in schools, public libraries, and government employment agencies.

Each of these career information systems provides suggested levels of mathematics needed to work in the occupations listed under its directories. Information rendered was compiled from many of the same sources as the encyclopedia of careers, i.e. government workers, teachers, industry and trade representatives. Since the mid-1980s the National Occupational Information Coordinating Committee (NOICC) has been working on a system for reporting and interpreting education program data. Their goal is to have in place before the end of the century a comprehensive reference system (NOICC Master Crosswalk, 1994) that can be accessed by educational institutions and others, and will provide useful information on U.S. education program data. Referred to as the "crosswalk", this will allow schools at the secondary and postsecondary level to examine and compare their curriculum relevant to others. This will be a valuable tool for educational leaders who plan and design academic and occupational programs. Much of this system is currently in place and being used by computer career guidance enterprises and career information publishers.

Establishing a set of national occupational standards will require access to information on a broad array of occupational training programs being conducted in all 50 states. Criteria are being implemented into the curriculum of community college occupational programs using this resource.

Instrument Development

In a 1992 project study for the National Center for Research in Vocational Education, Pucel Davis-Feickert & Lewis attempted to develop methods for determining the occupational math requirements of jobs and the math skills needed by individuals who wished to enter such jobs. From this project, Pucel developed the Occupational Math Requirements Assessment (OMRA). The OMRA is a performance-based instrument for assessing the occupational math requirements of occupations. It is designed to determine the mathematics operations (skills) required for success in an occupation. The OMRA is limited to use with occupations requiring a non-college level of education. It was also designed as a tool for local agencies in curriculum and training program development.

Standardized testing is generally used to determine the global math requirements of a job. This is done without concern for identifying the specific math skills in which people may be lacking. Such an approach yields a grade level score or cut-off score, which is often used to screen people in terms of their ability to succeed in training or on the job. Standardized testing is typically used to assess an individual's skill level in reference to a norm group.

Mathematical ability is viewed as a trait people bring with them to the job. Math requirements are identified by administering standardized tests to people with job experience or people preparing for jobs. These scores are then compared to ascertain a "norm" among the individuals. There are two basic types of standardized tests related to math: (1) tests which have been developed to measure student potential or aptitude (e.g., General Aptitude Test [GATB] and (2) basic skills tests (e.g., Adult Basic Learning Examination [ABLE] (Pucel, et al. 1992). Two major problems associated with these methods are obtaining a representative sample and the fact that these tests rarely provide sufficient information on specific math skills used in a particular occupation (Pucel, et al. 1992).

Educators along with members of industry use occupational analyses in determining the basic skills needed by an individual on the job as a foundation for the development of a training program. Once they determine the requirements of a job, people are then prepared to meet those requirements. The occupational analysis approach has most often used expert judgment and group consensus techniques (Brooks, 1991) to arrive at a list of math skills required for a particular job. These lists of math skills are used in association with specific occupations as a basis for creating math curriculum and for comparing the math skills of persons with those required on the job as a way to identify possible remedial needs.

Interviews and Observations

The state department of education in New York analyzed the job demands of 1,400 jobs. The purpose of this study was to identify the skill levels high school graduates need to obtain and maintain employment. Approximately 1,400 observations/interviews took place during a two month period in 1990 with slightly more than half occurring in small businesses which employ fewer than 100 people. Almost 300 small and large businesses were sampled. Each interview was categorized into one of 35 occupational clusters. Researchers used Department of Labor data to calculate the percentage of the New York State workforce employed in each of the occupational clusters. One thousand observations/ interviews were summarized by randomly selecting these into each occupational cluster based on the percentage of the workforce employed in that cluster. They found that 78% of the clusters required no algebra, and less than 10% required more than just a little (Board of Regents, 1990). A parallel study was planned to validate competency levels required of college preparation, but was never done due to lack of funding.

Students for many years have asked their math teachers, "When are we ever gonna have to use this?" High school math teacher Hal Saunders took a year of sabbatical to explore this question by interviewing 100 members of different occupations to determine just what kind of mathematics they actually use in their work (Saunders, 1980). Those interviewed included roofer, doctor, waitress, and electrical engineer to name a few. Saunders collected typical math problems encountered by his subjects and classified them into 63 math topics. To summarize his findings, the greatest majority of the 100 occupations used basic math, while less than twelve of these occupations affirmed using higher mathematics (calculus). Of those twelve, almost half were various types of engineering occupations. Close to 95% of those interviewed said that they used calculators for computations. Their use of a calculator was based on speed and to avoid errors.

Theoretical Foundation

The theoretical foundation for this study is based on the assumption that the subject matter required during an individual's occupational education preparation should be applied later in the performance of that occupation. The connection between what schools require and what is actually used later is the basis for this research. Students by their own choice select occupational programs related to their interest and abilities for which to enroll or compete for admission. It is their obvious expectation that the program of instruction will be concentrated on subject matter relevant to the occupational field of study. This expectation is also held by employers who hire people who have matriculated in such programs.

A.N. Whitehead (1929), writing in his classic *Aims of Education,* asked "What is the point of teaching a student a quadratic equation if it has no practical application?"(p. 8). He went on to state, "Students need to understand the application of ideas and the relevance of these ideas later in life" (p. 3). Dewey (1910), like Whitehead suggested that mathematics could best be learned when taught in an applied manner. Both of these noted scholars saw applied learning as a means to train the hand, eye, and mind together. Whitehead supported the teaching of mathematics "but not in a blind demand for more mathematics as some would call for" (p. 118). These words have relevance today in response to those who want to increase the math level requirements for students to be eligible to graduate from high school. "Except for a highly selected class, mathematics as it is taught with its multiplicity of details bewilders the masses" (Whitehead, 1929, p. 119). In 1910 Dewey observed that, "mathematics as it is taught in schools is disconnected and too abstract for the greatest majority of students. It is presented as a matter of technical relations and formulas separated from practical use or application" (p. 55). Dewey was more emphatic saying, "these math operations should be omitted entirely or else taught in relevant social realities" (p. 56). The report by the National Research Council (1989), *Everybody Counts* echoed this statement calling on mathematics educators to seek new ways to reach out to a larger population of students. Much of what was written in that report reflects the thinking of Dewey stating, "requiring students to memorize complex numerical operations is neither arithmetic nor common sense" (p. 56).

Occupational programs of study are not limited to non college bound students seeking training in some vocational skill area. Students enrolled in college degree programs such as finance, business administration, engineering, and medicine are seeking specific skills that will eventually prepare them to perform in their chosen profession. "The way in which a university should function in preparation for careers is by promoting the various principles underlying that career" Whitehead (p. 144). Higher education must focus more sharply on its mission to prepare students to work effectively in a technologically advanced society (Musick, 1994). Higher education has always prepared women and men for entering the job market. Colleges and universities need to increase their efforts to prepare students for careers and career changes (Musick, 1994). The greatest concern of parents and students is getting qualified skills along with job readiness. A survey of undergraduate students at 36 colleges and universities done by Muffo (1993) showed the top four areas of greatest need concerned career development issues.

Curricula and credentials in schools need to be more closely linked to employer requirements, and this can result from a collaboration between schools and employers (Carnevale & Paro, 1994). Goodlad (1984) said that the future calls for a better understanding and engineering of the relationships between education and work and between schools and the workplace.

Critical Thinking

Mathematics is viewed in this country as a cornerstone in education. It is one of the three R's that is to be taught to all students who attend school. Our number system is one of precision. It underlies all forms of exact measurement. Algebra represents the shorthand representation of symbolic thinking adapted by scientist. Geometry is the basis for postulating scientific theories. While, trigonometry has led the exploration of space by opening up indirect measurement of the vast expanse of the universe. Leaders in the math and physical sciences field point out that modern civilization has been built through the application of calculus and higher mathematics. If it were not for calculus and differential equations, modern man could not build complicated machines, skyscrapers, bridges, subways, large ships, power plants, computers, and telecommunication networks (National Council of Teachers of Mathematics, 1966).

Those who teach math have historically promoted the idea that learning more math develops a mental discipline. From the days of Pythagoras and Plato, the study of mathematics has allowed a select group of scholars to gain special intellectual abilities. A strong contingent in the field of science supports the acquisition of critical thinking skills with the prolonged study of mathematics. Some argue that this higher level of critical thinking ability can only be achieved from studying courses like trigonometry, and calculus. Possessing critical thinking skills allows an individual to examine and apply solutions to problems. The idea is to teach these problem solving techniques during elementary math courses and continue throughout a persons math training. By mastering higher math courses, it is thought that students will have better problem solving skills.

Extensive research and discusses with university math professors shows little has been written regarding the direct connection between the learning of higher mathematics and associated critical thinking skills. This is a commonly accepted thesis in our society with no significant scientific research to support this claim. Two math professors both stated that such research would be purely "anecdotal at best." In recent years other curriculum professionals such art, social studies and vocational educators have become to claim their area of instruction is also responsible for developing critical thinking among it's student population.

Math Skills Related To Work

The review of literature suggested that most jobs require only a subset of all mathematical skills. With the identification of this subset, teaching people who will perform a job becomes more efficient and effective (Fitzgerald, 1983). Pucel (1992) supported this finding, adding mathematics skill requirements for different occupations and the way it is applied differ significantly between occupations. Pucel indicated that there are major differences in not only the mathematics required in different occupations but in the way mathematics is applied in different occupations.

Specific math skills that are required to perform in a given occupation can vary from job to job. Occupational programs will need to be less job-specific, and more occupationally based (Greenan, 1983). Higher order mathematics and computer technology knowledge should be integrated into the individual education programs and occupations that require them (Greenan, 1983). Educators need to show how math is connected to the world in which students will live and work. Mathematics taught in the context of a job may help people overcome their fear of math, as result of past failures. Increasingly, more schools are beginning to teach mathematics through applied academics. Mathematics is taught in relation to the ways it may be used in the world of work. The belief is that when people can see how it can be used, it will motivate them to learn it. Secondary and postsecondary institutions should offer math education and training directly related to the performance of the occupations students are being prepared for. Schools must now prepare *all* students for some type of postsecondary study.

Courses tend to have established sequences for delivery which concentrate on the hierarchy of math skills as determined by mathematicians (Pucel, Davis-Feickert, & Lewis, 1992) rather than on the functional usage of math in job environments. Maximal retention of knowledge and skills that are learned occurs when the content and skill acquired are considered by the learner as usable, sensible, and valuable (Sadler, 1992). Much of the math content (Meiring, 1992) students learn bears little resemblance to how mathematics is applied in the real world, except for a very small minority of highly skilled professionals.

Strong relationships between schools and businesses will improve the quality of the learning and performance on the job. Effective school-to-work outcomes will be a result of the collaboration between academic and workplace skills standards. These widely called for skill standards combine academic, occupational, and behavioral skills. Educators will need to assimilate both academic and occupational curriculums, ideally taught in an applied context (Carnevale & Paro, 1994). Applied academics is viewed as a balance of "head skill" and "hand skill" as an approach to learning (Hull & Parnell, 1991). To meet the needs of the workplace, education must change. The classroom of the future is one that integrates academics and technical knowledge and skills within an applied occupational learning model (Kolde, 1991).

The problem with the U.S. is that there are too many people in college and not enough qualified workers (Thurow, 1992). By the end of this decade more than a third of the workforce in the United States will be *knowledge workers*. A great deal of knowledge work requires fine motor skills which involves a significant amount of work with one's hands (Drucker, 1994).

Curricula in schools need to be more closely linked to employer requirements (Carnevale & Paro, 1994). This will encourage employers to rely more on school performance as a criterion for hiring decisions. In turn students may be more motivated to meet these academic standards for employment opportunities.

There appears little evidence that most of the jobs or careers needing a college degree or more requires a high level of mathematics (Hoerner & Wehrley, 1995; Daggett, 1994; Meiring, 1992). A review of literature found no evidence of mathematics performance criteria developed for screening occupations requiring two years of postsecondary education and beyond.

Chapter Summary

Research has been very limited on the connection of math education levels and career application. Most of this research has been directed at remedial or basic math skills related to work force literacy issues. Other studies tend to focus on occupations requiring a high school education or less. Occupations gained through postsecondary degrees or training appear not to have elicited the attention of the research community. Over the past 10 years a great deal has been written about the need to increase the level of mathematics students must have. This connection between mathematics and occupational education is an area of needed research.

This review of literature deals with the research on mathematics and occupational education in the areas of career information including government and private business publications, along with data systems, instrument development for assessing math skills related to occupations, plus a discussion of studies based on interviews and observations. Theoretical foundations are included to show the historical precedence, and the chapter concludes with the relationship of math skills related to work.

CHAPTER THREE

Methodology

Research Design

The research design used in this study is predominantly descriptive in nature. Some important characteristics of descriptive research are to collect detailed information that describes existing phenomena; to make comparisons and evaluations; and to determine what others are doing that may benefit future planning and decision-making (Issac & Michael, 1971). The descriptive method is useful for investigating a variety of educational problems (Gay, 1992).

Descriptive methods were applied to determine from the participants what was currently happening. Data collected were used to describe what currently existed, in comparison to events relative to past educational training. This study was not concerned with an individual's characteristics, but instead sought to examine an aggregate set of characteristics from a number of cases. Probability sampling techniques were not used in this study. Instead, nonprobability sampling was utilized in conducting this research. Purposive sampling methods were used because probability sampling proved to be too expensive. Probability sampling techniques such as random selection were not applied. Purposeful sampling is used as a strategy when one wants to learn something and begin to understand more about select cases without generalizing to all such cases. While studying typical cases does not technically permit broad generalizations to the population, logical generalizations can often be made from the evidence produced in purposive sampling (Patton, 1990).

Purposive sampling is characterized by the use of judgment and a deliberate effort to obtain representative samples by including presumably typical groups in the sample (Kerlinger, 1986). The participants in this study are typical of their peer group in that they work in urban and rural areas for large and small companies, and perform the duties associated with the occupation. Since purposive sampling was used, caution must be used by the researcher when viewing the initial data drawn from this type of sample. Improper interpretation could result due to lack of control over the responses given as explanations by the participants. To minimize this from occurring this researcher was available to offer an explanation prior to and clarification during the collection of data. All the participants who completed a questionnaire for this study did so on a voluntary basis. The voluntary status does not alter the value of this research since motivation was not being judged.

A sample survey, a popular method of descriptive research, allows the researcher to infer information about a population of interest based on the responses of the sample drawn from that population (Gay, 1992). Validity of all research of this nature is strengthened by increasing the size of the sample.

Research Questions

The research questions for this study were:

1. How is math used by those who work in the occupations of (1) family practice physician, (2) finance officer, (3) electronics technician, and (4) machinist?

2. What are the highest math levels required of students enrolled in the education and training of the four occupations?

3. How do the math levels required in the educational programs compare to the math levels used by the selected occupations?

Participants

The number of subjects from each of the four occupations were 81 family physicians, 66 machinists, 62 finance officers, and 52 electronics technicians. Access to members of each of the four occupations studied was gained from information gathered during the research portion of this study. The survey was mailed to members of the family practice physicians and finance officers from a list provided by respective professional organizations. Representatives of electronic technicians and machinists participated by filling out the questionnaire during a session at their worksite. Information was gathered from other resources to ascertain on a broader scale the math levels required to practice these four occupations.

Finance officers were chosen because of their status as a symbol within the American financial system. For the purpose of this study a finance officer is a finance or business college graduate who is employed full time in the banking industry. It is recognized that finance officers work in a variety of business organizations other than banks. Finance officers in the banking industry hold a wide range of degrees other than business. All indications highly suggest these individuals deal in decisions regarding approval of loans and other important financial matters.

A list of names of graduates with business and finance degrees was obtained from university career centers of alumni who worked in the banking industry as finance officers and were willing to assist others with career information. A cover letter, questionnaire, and an envelop with return postage was mailed to 80 finance officers requesting their participation.

Finance officers' math levels were judged in comparison to the required programs of study from twelve major universities' undergraduate programs in business and finance. Preliminary research showed a representative number of individuals in this field have degrees in business and finance.

Family practice physicians were chosen to represent medical doctors because they specialize in caring for people from birth to the elderly stages in life. This traditional method of treating all members of the family is what most people might think of as a "doctor." Their basic philosophy is to apply medical care in a holistic fashion. Until late 1971, they were known as general practice physicians. The family practice physicians participating in this study were located in Northern Virginia, Roanoke and the New River Valley area of Southwest Virginia.

Data were collected through the use of a questionnaire from family physicians who practice medicine in the state of Virginia. A list of 100 names of family physicians who fit this criteria was obtained from their professional organization. A cover letter, questionnaire, and an envelop with return postage was mailed to 100 family physicians requesting their participation in this study.

Family practice physicians' math education information was gathered from three medical training resources. The first was the Association of American Medical Colleges (AAMC) located in Washington, DC. This organization has information on all medical students enrolled in medical schools here in the United States. The AAMC compiles statistical data on the undergraduate work done by students prior to being admitted to medical school. Second, the American Academy of Family Physicians (AAFP) has collected survey research data from its members from across the country on a wide variety of topics pertinent to their education and medical practice. The American Medical Association (AMA) headquarters in Chicago was contacted regarding information about the mathematical education of family physicians. From these resources it was learned that each had no information on levels of mathematics taken by students prior to entering medical education.

The term machinist encompasses several job titles within this occupational area. There are bench workers, tool and die makers, and machine tool operators recognized nationally under the occupational title machinist. Machinists set up and operate machine tools, and assemble parts to make or repair machine tools and industrial machines. This is considered to be a low tech job in the vocational field, but they apply practical levels of math to perform their job. A decision was made after discussions with educators and business persons from a local community college advisory board to include in this study only those who hold a postsecondary machinist's diploma or an associate degree. Programs of study from ten community colleges located in the states from which the participants were drawn were examined to determine the mathematical levels required of students who complete programs which award the various types of certification. Being certified also gave the machinist sample a valid title recognized by the industry and state licensing agency.

All education and training programs for machinists in Virginia and Maryland were concentrated at the secondary and community college level. There was no evidence found of any on-going training being conducted at four-colleges and universities in these states. This study examined the programs at community colleges only. In public education, community colleges offer a variety of machinist programs which best suit the needs of students, workers, and local industry. Community colleges are important to local businesses, as companies rely on a combination of school and on-the-job training to impart qualifying skills to their employees (Dervarics, 1993). These institutions were chosen for this study because they offer a structured program and environment from which math is included as a part of the curriculum. Students who are enrolled in the machinists courses are learning skills that are marketable among those companies who employ persons in the machine tool trades.

The two largest community colleges in the state of Maryland do not offer any type of machine tool courses. In Virginia, there are 11 community colleges within their statewide system that offer some type of machine tool operator program. Programs offer a variety of degrees, certificates, diplomas, and classes to prepare or upgrade an individual's skills for employment in the machinist trade. Three of the colleges award a two-year A.A.S. Degree in mechanical technology, with a required 72 total credits. Graduates of this program can enter the job market, or they can continue their education with the bulk of credits transferable toward a four year degree program in mechanical engineering at a state university.

One of these community colleges also had a two-year, 62 credit diploma in machine tool. Three college offered a dual set of programs aimed at training machinists. These programs award their graduates the two-year diploma in machine tool, requiring a total of 63 to 69 credits. They along with the remaining community colleges, award a certificate in machine tool technology after a one-year series of courses ranging from 32 to 47 total credits.

Approval was granted by a gasket manufacturing company in Blacksburg, Virginia and an automobile parts production plant in central Maryland to allow employed machinists to participate in this study during work hours.

The phenomenal growth in technology over the past twenty years has created a great demand for people in the electronics technician field. These skilled technicians build, test, repair, and modify electronic equipment such as computers, communications equipment, and industrial and medical control devices. Most electronics work, although technical, demands a hands-on approach. They were chosen as one of the occupations for this study since they will play a key role in the future of the progress of technology. The U.S. Department of Labor projects that employment opportunities for electronics technicians including computer repairers is expected to grow substantially by 2005, to over 600,000 (U.S. Department of Labor, 1991). Most of the electronic technicians who participated in this study worked on repairing computers and consumer home entertainment equipment in business and industry settings. The technicians who took part in this study did so voluntarily during regular business hours with the approval of their employers. Questionnaires were handed out and collected by supervisory personnel.

Only electronic technicians who are certified through some type of postsecondary training were included in the purposive sample for this study. This was decided after learning that the term electronics technician is defined broadly in the industry. Their training ranged from one to two years of electronics technical education with individuals earning diplomas and associate degrees and beyond. Participants earned their certification from proprietary, community college, military, or four-year college institutions. Programs of study from ten community colleges located in the states from which the participants were drawn were examined to determine the mathematical levels required of students who complete programs which award various types of certification. Being certified gave the sample a valid title recognized by the industry and state licensing agencies.

The electronics technician programs on the community college level located in the states of Virginia and Maryland all awarded a two-year A.A.S. degree. Program guides obtained from the college catalogs showed 10 Virginia community colleges ranging from 67-81 credits required for completion of the degree. The two largest Maryland community colleges required 67 and 68 credits for a student to graduate. There were two Virginia community colleges that also offered a 34 & 36 credit Electronics Technician Certificate.

Instrumentation

The questionnaire was composed in a concise manner to allow for ease of answering each item. The initial portion of the questionnaire was designed to gain general information, followed by a group of questions concerning how math is related to the performance of their jobs. As part of this questionnaire and study a mathematics continuum chart from "Math and Your Career" (Martin, 1983) was modified to meet the specific needs of the subjects chosen. This mathematics chart was the final segment of the survey, and it gave participants specific math topics from which they selected those used in their work (see Appendix A). Designating specific math topics provided focus on more detailed descriptions of what was currently being used by the four selected occupations. This instrument was pilot-tested with a group of family physicians.

As a result, some items were eliminated or slightly altered prior to being mailed.

Demographic information was gathered from each of the participants as a means of providing a descriptive profile of the members of each occupation. Some of the demographic information obtained included gender, age, race, number of years in occupation, and highest education level completed.

Data Collection

A survey was used to collect data from members of the population of four distinct occupations to determine the current status of the mathematics requirements to practice each occupation. The occupations were defined as: (1) family practice physician, (2) finance officer, (3) electronics technician, and (4) machinist. Constructing the initial questionnaire was based on the information gleaned from discussions with leaders and members in each of the occupations being studied. Questionnaires were labeled and directed at each of the four occupations (see Appendix A). This was done to avoid asking machinists, for example, if they have a degree in medicine or vice-versa. No information was given to the participants regarding which occupations were involved in this study other than their own. It was also thought that having the occupational label on the questionnaire would promote higher participation among those being surveyed.

Each survey was numbered for control and accuracy prior to distribution. Surveys were mailed or handed out directly to the participants at their place of business. Those surveys personally distributed at worksites were collected within a two week period and checked for accuracy. All surveys were perused for accuracy and completeness. Surveys were mailed when insufficient numbers of members of an occupation were available in the geographic region. A list of members was obtained from professional organizations representing finance officers, electronic technicians, and family physicians in the four-state region. Selected occupational groups were mailed a packet, which included a cover letter, questionnaire, and a self-addressed return envelope requesting their participation in this study (see Appendix B). Two weeks after the initial mailing, a follow-up letter or a personal phone call was used to stimulate completion of the surveys. After three weeks a second packet was mailed to the non-respondents from the original mailing.

Interview Procedures

Personal interviews were conducted with two members of each of the four occupations during the course of this study to gain additional insight. These interviews produced in-depth information that was not obtained through the questionnaire. Each of the eight people interviewed were asked an identical set of 14 questions (see Appendix C). These questions were based on the items contained in the questionnaire used in the survey of all four occupations. Persons being interviewed were encouraged to elaborate on any of the questions posed from this format. Clarification was sought during the interview sessions if something was not understood to the satisfaction of both sides.

All interviews were conducted in the participant's work setting. All of the participants were advised that all comments were confidential between the researcher and the person being interviewed. The interviews lasted approximately 30 minutes each due to the time constraints of the work place. The interviews were not tape recorded as requested by company management. Notes were taken during the interviews so that they could be referred to later to help ensure all of the answers given corresponded to the questions posed. All eight persons who were interviewed were given an opportunity to make any comments regarding the topic of the math requirements in their occupation. This same opportunity was afforded all those who completed the questionnaire portion of the study (see Appendix D).

Data Analyses

After thoroughly examining the returned questionnaires the data provided were compiled and analyzed. The responses and general information gathered were analyzed to determine measures of central tendencies, variability, means, standard deviations, and measures of relationship. Data were coded according to the format of the questionnaire. General information derived from the questionnaire and interviews were organized in a manner to relate to the research questions. Once the data were coded they were entered in the computer using Microsoft Excel 5.0 statistical software. This statistical package allowed for the manipulation of the data. The data collected were used to produce descriptive statistics such as standard deviations, means, percentages, and proportions. All the items in the survey produced a range of values for examination for meaningful differences within the context of the study. From these results, the information was applied in appropriate categories to show a summary of frequencies.

In order to answer the three research questions posed for this study, a comparison was drawn from the data collected. On question one, how is math used by those who work in the occupations, information was gathered from government and occupational resources. This was combined with data collected through the research questionnaire and interviews conducted with two members of each occupation. The second research question concerning the highest level of math taken in preparation for the occupation was derived from programs of study from state accredited postsecondary institutions. The required math course content was compared to the level of math applied in the daily performance of the occupation to answer the final research question. The researcher followed the guidelines for data collection and analysis articulated in Babbie's (1990) "Survey Research Methods" and Issac and Michael's (1971) "Handbook in Research and Evaluation."

Chapter Summary

This chapter contains a description of the methodology employed in the study of mathematics required to perform selected occupations. The basic approach used in the research is described, beginning with research design, followed by research questions, participant selection, data collection techniques, interview procedures, instrumentation, and analysis procedures.

Four occupations were selected for participation in this study. A questionnaire was used to collect data from members of the population of the four occupations (1) family practice physician, (2) finance officer, (3) electronics technician, and (4) machinist to determine the current mathematics used in the practice of each occupation. Interviews were also conducted with two members of each of the four occupations during this study to gain more in-depth information. Additionally, data were compiled from other resources such as occupational organizations, educational institutions, government documents, businesses and other relevant means.

Descriptive statistics were calculated from the general characteristics (gender, age, race, years in occupation, highest education level completed) from the four occupations. These descriptive statistics included percentages, mean scores, and frequencies. General information derived from both the questionnaires and interviews was organized in a manner to examine the related research questions. This research information was used to draw comparisons between the educational and occupational levels of mathematics required in the four selected occupations.

CHAPTER FOUR

Findings of the Study

The results of this study are reported in this chapter. The chapter begins with a brief discussion of background information. The findings in this chapter are presented under the headings of each of the four separate occupations. Each section begins with a description of the questionnaire responses. This is followed by a description of the respondents in each occupational group. Next, the data analysis findings among the four occupations are presented relative to the three research questions. The research questions of this study were slightly amended to reflect the occupation and simply clarify which group was being discussed in this chapter. The data analysis findings are presented after each research question.

Background Information

The main purpose of this study was to determine the mathematics levels commonly used in the performance of four selected occupations: (1) family practice physician, (2) finance officer, (3) electronics technician, and (4) machinist. These mathematics levels were compared to the levels generally required during the education and training of these selected occupations.

Prior to initiating this study, it was learned that very little research had been done on the connection of math preparation for different occupations and applications of math in the practice of those occupations. This study contributes information regarding the required levels of math needed to perform selected occupations.

Extensive research conducted over several months produced no national or regional standards related to the mathematics required during the education and training of any of the four occupations. In several cases, training programs would vary greatly in the community college and state university system. Some professional occupational programs maintained their own set of admissions criteria. Medical school admissions in many cases only suggested the mathematics background needed to secure a place in their program.

In the case of machinists and electronics technicians, the level of math required depended on the extent or length of training a student selected as well as the type of certification sought. These training programs were conducted on the postsecondary level at a community college. Students were required to meet certain levels of math prerequisites before they could be admitted to most technical training programs. If the student did not meet these prerequisites, they were enrolled in remedial math courses to prepare them for the rigors of the technical math portion of the curriculum.

Finance Officers

Questionnaire Responses

For this study a finance officer was defined as a finance or business degree college graduate who is employed full-time in the banking industry. Data were collected through the use of a questionnaire from finance officers who work in Virginia, Maryland and North Carolina. Initial attempts at collecting data during monthly meetings proved to be unsuccessful due to time restraints and concerns about pressuring those in attendance to participate.

Fifty-nine completed surveys were returned of which 7 were rejected due to the participants holding non-business degrees, leaving a total of 52 by mail. An additional 10 completed surveys were secured from finance officers who belonged to a volunteer organization in Northern Virginia. From a total of 90 mailed questionnaires this provided 83 eligible respondents. From this group 62 were returned for analysis with a response rate of 74%. A total of 21 finance officers (26%) did not respond. These data are presented in Table 1.

Description of the Finance Officers Group

Demographic data were gathered from those responding to the questionnaire allowing for cross-tabulations to form a composite of the finance officer group. There were 62 usable responses from this group, 38 were male and 24 female. All 62 respondents held a bachelors degree in business or finance from a four year college program. Nineteen of these individuals had earned an MBA, which accounted for 31% of the total group.

The ethnic breakdown by gender is shown in Table 2. There were 55 (90%) white, 3 (4%) black , 3 (4%) Hispanic, and 1 (2%) other. Four of the six non-whites were female, with one black and one Hispanic male. The age distributions and the number of years in the occupation for the finance officers were tabulated. Their ages ranged from 23 to 44 years with an average age of 33.14 for female finance officers and 31.23 for male finance officers. The largest segment of the group belonged in the 30 to 36 year category. The number of years working in the occupation ranged from 1 to 20 years; the average time employed as a the finance officer was 8.44 years.

Table 1

<u>Responses to the Questionnaire</u>

Respondents	Fin. Offs.		Doctors		Machinists		Elec. Techs.	
	N	%	*N*	%	*N*	%	*N*	%
Total Surveys Mailed	90		100		90		85	
Non-Eligible	7							
Eligible	83		100		90		85	
Number of Responses	62	74	81	81	66	73	52	61
Non-Responses	21	26	19	19	24	27	33	39
Total Percentage		100		100		100		100

<u>Note</u>. Percentages are based on usable responses.

Table 2

Distribution of Finance Officers by Race and Gender

	Gender					
	Male		Female		Total	
Race	*n*	%	*n*	%	*N*	%
Black	1	3	2	8	3	5
Asian	—	—	—	—	—	—
Hispanic	1	3	2	8	3	5
Native American	—	—	—	—	—	—
White	36	94	19	80	55	88
Other			1	4	1	2
Total	38	100	24	100	62	100

Note. Each category shows the number of finance officers and the respective percentage.

Analyses of Data

The statistical computer software Microsoft Excel (1993) was used to analyze data. This statistical package allowed for the manipulation of the data. The data collected were used to produce descriptive statistics such as means, percentages, proportions and frequencies. From theseresults, the information was applied in appropriate categories to answer the three research questions.

Finance Officers Research Questions Responses

1. How is math used by those who work in the occupation of finance officer?

Finance officers who work in the banking industry apply mathematics in a wide variety of business matters. These matters can range from simple arithmetic calculations of a checking or savings account transaction, to producing potentially long-range forecasts of interest rates. As a result the level of mathematics used by a finance officer can range from simple arithmetic to calculus functions.

Some traditional services related to banking include evaluating customers loan applications for purchasing homes, automobiles, obtaining credit cards and other needs. They assess the income and debt ratio of a customer to determine their potential ability to repay such loans. Over the last five years the banking industry has expanded the financial services offered to both business and commercial customers. Many banks now offer investment counseling services in retirement planning, stocks and mutual funds, insurance, and long-term savings plans. These additional services require a finance officer to use more math in communicating with customers and fellow workers.

The finance officers who completed the questionnaire reported spending 7 to 8 hours per week using math in the performance of their duties. As a group they reported using a computer "frequently" in the course of their work. Interviews with two finance officers and comments drawn from the questionnaire suggested the frequent use of a computer stems from an application of internal banking network software, spread sheets, processing and calculating interest rates on loans.

When asked how often they use a calculator on the job, they responded "frequently". The use of a calculator was seen as a useful business tool for computing basic and more complex math calculations. It was faster and more accurate than doing paper and pencil or mental math.

2. What are the highest math levels required of students enrolled in the education and training of finance officers?

In order to ascertain the mathematics level requirements of college of business or finance graduates, programs of study were examined from current college catalogs. Undergraduate program information was collected from the college of business from a total of 12 state universities in Virginia, Maryland, and North Carolina. These were selected on the basis of colleges offering degrees in business and finance. These universities were:

1. Virginia Tech
2. University of Virginia
3. Radford University (VA)
4. James Madison Univ. (VA)
5. George Mason Univ. (VA)
6. Virginia State
7. Virginia Commonwealth
8. Longwood College (VA)
9. University of Maryland
10. Towson State (Maryland)
11. Univ. of North Carolina
12. North Carolina State

It was determined that 11 out of the 12 universities required students as part of their program to take at least one three hour credit course of introductory calculus, plus a statistics course. The program at Towson State University in Maryland does not require calculus, it does require business statistics, plus an additional course in math or statistics. As one business professor put it, "colleges of business lean heavily on the quantitative approach." These state universities represent the level of math required of business school graduates currently working in the banking industry as finance officers. Of those surveyed 91% reported having completed a course in calculus or higher during their formal education. The other 9% listed algebra II/trigonometry as their highest math.

3. How do the math levels required in the educational programs compare to the math levels used by finance officers?

Over 90% of finance officers respondents earned their degrees from college programs that required a minimum of 3 credit hours of calculus. When asked to designate what level of math was used most often in their daily routine, results showed basic math the predominate level used. Results from the questionnaire showed 51 (82%) using basic math compared to 10 (16%) using math at the level of algebra and only 1 (2%) using algebra II/ trigonometry most often on the job.

A small cadre of finance officers work within a department of a bank whose function is to create future projections concerning interest rates, competitive loan rates, and high yield investments. It is this type of environment where higher levels of math such as principles of calculus may be applied. The results of these projections are used by the directors of a bank to make decisions affecting the financial stability of their organization.

The vast majority of finance officers appeared to need good arithmetic skills to perform the duties of their occupation. Banking organizations attempt to isolate the need for extensive mathematical computations by contracting independent accounting firms, according to one bank president.

Finance Officer's Interview and Written Comments

Interviews were conducted with two finance officers at a large bank headquarters in Northern Virginia during business hours with the approval of their employer using a set of 14 questions for this study (see Appendix C). All of the interviews with each of the four occupations lasted approximately 30 minutes. The two officers were a 29 year old male and a 41 year old female. Each held a degree in finance, entering the banking business after completing college. Both admitted they never used the higher levels of math they took in college. The greatest use of mathematics in banking today is still application of basic math skills especially, being able to calculate percentages and do basic accounting. Written comments supplied by finance officers who completed the questionnaire (see Appendix D) seemed to support this thinking. There were some who supported the preparation in higher math as good training.

Family Practice Physicians

Questionnaire Responses

There are no math courses taken during medical school; all math is completed prior to entering medical college. The four years of medical school are spent concentrating on subjects related to the practice of medicine and treating patients. Doctors are encouraged to attend seminars and lectures as a means of keeping abreast of the changes and innovations taking place in the field of medicine. Most states require physicians to attend continuing education programs as part of the state licensure agreement.

From a total of 100 mailed questionnaires 81 completed surveys were returned of which none were rejected. This group of 81 surveys was used for analysis giving a response rate of 81%. A total of 19 family physicians (19%) did not respond. These data are presented in Table 1.

Description of the Family Physicians Group

Demographic data were gathered from those responding to the questionnaire allowing for cross-tabulations to form a composite of the family physician group. There were 81 responses from this group, 68 were male and 13 female. The ethnic breakdown by gender is shown in Table 3. There were 78 (97%) white, 1 (1%) Asian , 1 (1%) Hispanic, and 1 (1%) other.

The age distribution and the number of years in the occupation for the family physicians were ascertained from the data. Their age ranged from 29 to 73 years with an average age of 38.22 for female doctors and 45.16 for male doctors. The largest male segment of the group belonged in the 36 to 45 year category, and females in the 25 to 35 year category. The number of years working in the occupation ranged from 2 to 43 years; the average time employed as a family physician was 15.32 years. Female physicians have worked an average of 9.46 years compared to an average of 16.31 years for male doctors.

Family Physicians Research Questions Responses

1. How was math used by those who work in the occupation of family practice physician?

All the family physicians in this study worked in a private practice environment instead of a hospital or medical center atmosphere. The math used by a doctor would be applied during the examination and evaluation of a patient. In their daily practice physicians are continually exposed to numbers related to patient care, such as blood cell counts, body weight, temperatures, cholesterol levels, and fluids to name a few. Doctors need to calculate the amount of the dosage of a medication being prescribed relevant to the body weight of a patient. Basic math was being used through the application of fractions, decimals, ratios, percentages, measurements, and basic statistics.

Both of the doctors interviewed by the researcher stated that handy reference charts supplied by drug companies were used by their peers rather than depending on taking time to actually calculate this mathematically. Since these doctors were self-employed they were concerned with numbers on financial statements.

Some of the written comments solicited from respondents supported the need for a basic understanding of statistics. They felt this was necessary for understanding the research reported in medical journals and could be gained through a basic statistics course. Higher levels of mathematics were

Table 3

Distribution of Family Physicians by Race and Gender

	Gender					
	Male		Female		Total	
Race	*n*	%	*n*	%	*N*	%
Black	—	—	—	—	—	—
Asian	1	1			1	1
Hispanic	1	1			1	1
Native American	—	—	—	—	—	—
White	66	98	12	92	78	97
Other			1	8	1	1
Total	68	100	13	100	81	100

Note. Each unit is divided to show the number of family physicians and the respective percentage.

seen as potentially being used by those who work in some type of medical research setting.

The dominant use of a computer in the office was related to billing of clients and scheduling appointments. Less than 4% stored patients medical records on the computer. Some 67% of the respondents in a national study reported having a computer in the office (AAFP, 1994).

2. What are the highest math levels required of students enrolled in the education and training of family physicians?

According to officials at the American Medical Association (AMA) and Association of American Medical Colleges (AAMC), there are no data available concerning the math courses taken by medical students currently or previously enrolled in U.S. medical schools. A formal letter was sent to both the AMA and AAMC requesting this information. The senior research associate at AAMC, in a phone conversation said such data have never been compiled to his knowledge. Numerous searches of data banks, medical journals, and dissertation abstracts showed no research done on this topic. A formal request was also sent to The American Academy of Family Physicians (AAFP). This organization compiles a vast array of information on the

69,000 family physicians in the Unites States. The AAFP responded, they too had no such information on file.

As of January 1993 there were over 69,000 family practice physicians in the United States accounting for 13% of all office-based physicians. Of all the active medical doctors, family practice was ranked second to internal medicine among all specialties (AAFP, 1994). Females make up 18.4% of the family physicians in practice.

There are 126 accredited schools of medicine in the United States. Approximately 22% of all U.S. medical schools require entering students to have taken a course in calculus (Brown, 1989). The publication, *Medical School Admission Requirements, 1995-96* offers this advice to those thinking about applying to medical school, "While the greatest majority of medical schools do not demand a specific course sequence in mathematics, all value mathematical competence, and many require or strongly recommend mathematics courses. Mathematics courses provide a good basis for the student's understanding of rigorous courses in chemistry, physics, and modern biology" (AAMC, 1994, p. 24).

The greatest majority of medical school applicants reported they decided to study medicine before entering high school. This early commitment to pursue medicine as a career shaped their program of studies (AAMC Trends, 1994). The educational path of a physician in this country begins with the completion of a four-year college degree, entrance into medical school, also four years, and finally a residency program. In the case of family practice physicians, a three-year residency program is required, along with completion of exams to secure board certification.

In 1993, there were 42,808 medical school applicants, an all time record number. This was a 60% increase over a five year period since 1988. Approximately two-thirds of these applicants' undergraduate majors were in biological sciences and physical sciences. The biggest increase was applicants with social sciences backgrounds accounting for over 12% of the total (AAMC Trends, 1994).

One of the major criteria for gaining entrance into a medical college here in the United States is passing the Medical College Aptitude Test (MCAT). This test is usually taken by potential medical school applicants following their completion of a four-year college program. The MCAT is divided into four sections: (1) physical sciences , (2) biological sciences, (3) written essays, and (4) chemistry.

Prospective candidates for medical school are evaluated on their ability to score well on this important examination along with past academic performance and an interview before a panel.

Some of the problems in the physical sciences section of the MCAT require the person to understand and use mathematical concepts. The instructions for the test suggest the level of concepts are the same as used in introductory science courses. A suggested list of eight levels of knowledge are offered to inform the test taker of what they can expect related to applied math skills. Some examples of the level of math skills encountered on the MCAT are listed below:

1. The ability to perform arithmetic calculations including proportion, ratio, percentage and estimation of square root.

2. An understanding of fundamental topics in the areas (at the level of second-year high school algebra): exponentials and logarithms, scientific notation, and quadratic equations.

3. The knowledge of the definitions of the basic trigonometric functions (sine, cosine, and tangent).

4. The use and conversion of metric units.

5. An understanding of vector addition and subtraction.

6. The ability to calculate mathematical probability.

7. The ability to calculate the mean and range of

a set of numerical data, an understanding of standard deviation and correlation.

8. An understanding of calculus is *not* required.
(Medical College Admission Test, 1995, p.34-35)

Of those who are attending medical school in the United States the vast majority, some 75%, graduated from college with majors in three areas. The three major areas are biological sciences, physical sciences, and health sciences (AAMC Trends, 1994). The undergraduate majors of the 81 family physicians in this study reflect this national figure. Table 4 provides a breakdown of undergraduate majors of the participants. There were 39 (48%) biology, 19 (24%) chemistry, and 9 (11%) pre-med majors. The top three undergraduate majors accounted for 83% of the participants.

To establish the link between higher math levels and those who get accepted to medical school, an analysis was done of the undergraduate programs of the three leading majors. Undergraduate programs of study were collected from a total of 13 universities in Virginia, Maryland, and the District of Columbia. These universities provided a copy of their programs of study in biology, chemistry, and physical sciences. All 13 undergraduate curricula required students majoring in chemistry or physical science to take a minimum of two courses in calculus. Five programs required four semesters of calculus.

Biology majors, in contrast, from the same 13 universities had more options with regard to the level of math needed as an undergraduate. Within the 13 university programs, three required two semesters of calculus, one college one semester, and the remaining nine departments of biology allow their students an option of 6 credits or two semesters of mathematics. The optional two semesters of math were one course in calculus, one course in statistics, or one course in computer science. Another option was one course in statistics and one course in computer science. Of the 39 doctors who majored in biology prior to entering medical school, only 10% had math courses below the level of calculus.

Pre-med programs are generally administered under the direction of the biology department. At the University of Virginia "students anticipating a career in biological sciences and medicine are strongly advised to take at least one additional math course" (UVA Biology Handbook, 1995 p. 13).

Table 4

Family Physicians Distribution of Undergraduate Major

Undergraduate Major	*N*	%
Biology	39	48
Chemistry	19	24
Pre-med	9	11
Engineering	3	4
Economics	2	3
Pharmacy	2	3
*[English, History, Math, Psychology, Religion, Spanish and Zoology]*one each	7	7
Total	81	100

3. How do the math levels required in the educational programs compare to the math levels used by family practice physicians?

Of the 81 physicians who responded to the survey 86% had taken a course in calculus or higher level mathematics. Another 11% had math credits at the algebra II/trigonometry level. The total represented 97% of all doctors had mathematics at or above the level of algebra II/trigonometry with the vast majority in calculus.

The level of mathematics used most often in the daily routine of the respondents was basic math. A large majority of the 81 doctors, 66 (82%), reported that basic math was the predominant level used. The remaining 15 physicians (18%) listed algebra on the questionnaire as the level used on the job. This is in great contrast to the large percentage of physicians in this study who took math courses at the calculus and higher math levels. The disparity between the higher levels of math courses required or taken as an undergraduate compared to the level used by a vast majority of physicians is an important finding in this study.

Family Physician's Interview and Written Comments

Two separate interviews were conducted with two family physicians at their offices where they were shared a private practice. A set of 14 standard questions for this study were used during the interviews (see Appendix C). Of the two doctors interviewed one was a female who has practiced medicine for 22 years in a small rural setting. The other doctor was a 34 year old male with less than 7 years in a family practice in a wealthy suburb of Washington, DC. Their attitude about their the importance of higher mathematics during their pre-med educational training were completely diverse. The female doctor thought higher mathematics was of no value to her in preparing her to become a qualified family physician. The male doctor on the other hand felt that his extensive exposure to higher math has helped him to develop better problem solving skills that he applies on a regular basis in his medical practice. Family physicians contributed the most written comments from all four occupations who completed a questionnaire (see Appendix D). The written comments appear to reflect those expressed by the two doctors interviewed and something in between those two contrasting points of view.

Machinists

Questionnaire Responses

Machine tooling has recently experienced a strong resurgence here in the U.S. due to the expansion of foreign markets. This too has required an adaptation to metric measurement and calculations on the part of the working machinists to fill orders. Global competition has shown, that tool and die operations are still very competitive here in the U.S. Manufacturers are looking for machinists who are well trained and have the math skills to get the job done right.

The certified machinists who took part in this study did so voluntarily during normal business hours with the cooperation and approval of their employers. Questionnaires were handed out and collected by supervisors or owners. Ninety surveys were distributed at eight separate machine tooling sites in the states of Kentucky, Maryland, and Virginia. From these 90 questionnaires handed out, 66 completed surveys emerged, accounting for a 73% return rate. There were 24 machinists who chose not to fill out a survey or a 27% no response rate. See Table 1. There were a limited number of businesses that would agree to take part in this research study. This was compounded by the fact that machine tooling companies are not abundant in the three state region selected. The goal was to collect a minimum of 60 questionnaires and this was achieved.

Description of the Machinists Group

Demographic data were gathered from those responding to the questionnaire allowing for cross-tabulations to form a composite of the machinists group. There were 66 responses from this group, all 66 were male.

The ethnic breakdown is shown in Table 5. There were 55 (83%) white, 2 (3%) black, 2 (3%) native American, and 7 (11%) other ethnic groups.

Machinists' age distribution and the number of years in the occupation were tabulated. Their ages ranged from 22 to 75 years with an average age of 42.0 for the group. The largest segment of the group belonged in the 36 to 45 year category. The number of years working in the occupation ranged from 2 to 54 years; the average time employed as a machinist was 19.64 years.

Machinists Research Questions Response

1. *How is math used by those who work in the occupation of machinist?*

Machinists operate all kinds of machine tools and use special hand tools to cut, drill, and grind to form a piece

Table 5

Distribution of Machinists by Race and Gender

Race	*n*	%
Black	2	3
Asian	_	_
Hispanic	_	_
Native American	2	3
White	55	83
Other	7	11
Missing Data		
Total	66	100

Note: all respondents were males.

of metal into a desired shape and size. In a machine shop environment, workers study blueprints and drawings to determine the dimensions and tolerances of finished pieces, sequence of operations, and setup requirements. A high degree of accuracy is required in their work. Some specifications call for accuracy of one ten-thousandth of an inch or less. To achieve this precision, they must use instruments such as calibrated micrometers. Mathematics is being applied in their work through the daily use of basic math, algebra, geometry, and trigonometry. A machinist may apply ratios and proportions to calculate tapers; ascertain compound gear and belt ratios; factor linear equations and binomials; compute the difference of squares; bisect lines or angles; compute areas and perimeters of polygons; and determine hole spacing along an arc (Gunnerson, 1991).

Machinists reported spending an average of 5 to 6 hours per week using math on the job. Among the four occupations they placed second behind finance officers for the most time spent using math per week. With the addition of computer numerical control (CNC) equipment being introduced over the past years, the use of higher mathematics expanded for those who needed to operate them. This CNC equipment is capable of being programmed to machine or grind a part to very minute dimensions.

2. What are the highest math levels required of students enrolled in the education and training of machinists?

The two-year A.A.S. degrees in machine technology required two semesters of technical mathematics. Of the two-year diploma programs, two of the four colleges also required two semesters of technical mathematics, while the other two required only one semester. Three programs with a one-year certificate required two semesters of technical mathematics, while in the remaining five programs students needed just one semester of such math.

Technical mathematics is taught by faculty members in the college mathematics department. Course instruction and materials are not aimed at a specific occupational group, such as machinists. Instead, the course material is presented in traditional math instruction, with students from a variety of occupational concentrations. According to one technical math instructor, textbooks and teaching methodology encourage practical applications whenever possible. Collaboration among the math and technical education faculties has grown over the past three years.

This was reinforced during conversations with both groups while gathering information for this study. Additional math instruction took place in the college machine shop environment with the occupational instructor teaching students in an applied fashion.

Almost all of the college catalogs offered a strikingly similar course description of what is covered in a technical mathematics course. This consistency is a result of the collaboration between the representatives of community college math and technical education committees. An agreement was reached between these two groups to provide guidelines to be used throughout the state. Below is an example of a technical mathematics course description.

> Technical Mathematics I-II (3CR.) (3CR.)
> Prerequisites are a satisfactory score on an appropriate mathematics proficiency examination and two units of high school algebra and one unit of geometry or equivalent. Presents a review of arithmetic, elements of algebra, geometry, and trigonometry. Directs applications to specialty areas.
> (Northern Virginia Comm. College, 1994, p. 130)

Each catalog added a caveat, "students with deficiencies in math will require developmental studies." A machine tool instructor at one of the dual programs thought the developmental math class of five credits had a negative impact on students willingness to commit to the extra time.

The state of Virginia did not have a mandatory set of guidelines regarding all programs in machine tool technology for its high school and community colleges. The state does provide a set of suggested guidelines. Many of these guidelines covered course content, safety, and development of math and communication skills needed in the occupational area. However, the State Council on Higher Education of Virginia (SCHEV), which oversees all academic and occupational education and training, does mandated the number of credit hours needed in humanities for students seeking an associate's degree in machine technology.

3. How do the math levels required in the educational programs compare to the math levels used by machinists?

Due to the wide variety of work being done in a typical machine shop, the level of math application varied. This was reflected in the survey results, the interviews conducted, as well as in the comments offered by some of the participants. Machinists in this study had the lowest level of education attainment with the group holding a postsecondary technical certification. Of the 66 machinists surveyed, the highest level of education completed was 5% GED, 28% high school diploma, 39% technical school, 23% A.A.S. degree and 5% BA/BS degree. However, their use of higher level mathematics on the job ranked first among the four occupations studied.

Machinists were queried about the level of math that was used most often in their daily routine. Results from the questionnaire had 28 (46%) using basic math most often in the work place, 24 (39%) geometry, and 9 (15%) a combination algebra and technical math. As a group 54% were applying math above the level of basic math. The level of mathematics being applied by machinists fell in the mid-range of algebra and geometry. Among the highest uses of math topics other than those under basic math were angle measurement, right triangles, circles and area under the heading of geometry.

On the question of how often a computer is used for math purposes, the average response was "rarely." In a typical machine tool business environment the use of a computer was associated with the setup, program and operation of a computer numerical control (CNC) machine. This work is highly specialized requiring a machinist with formal technology training.

Machinist's Interview and Written Comments

Two machinists were interviewed during business hours at a plant that made gaskets for foreign cars manufactured here in the United States. A set of 14 questions for this study was used (see Appendix C). The two male machinists had 15 and 24 years of trade experience. Both men strongly supported the connection of mathematics to the application of their work on a daily basis. The gaskets that they manufactured called for a high level of precision and skill. Setting up the machines to grind and fabricate these parts called for the application of geometry and trigonometry. A good machinists from their experience must have solid math skills. A comment from the questionnaire of a machinist with 21 years experience stated, "higher level math is important for a machinist, it is most necessary for a CNC programmer."

Electronics Technicians

Questionnaire Responses

The electronic technicians who participated in this study worked on repairing computers and consumer home entertainment equipment in business and industry settings. These technicians built, tested, repaired, and modified electronic equipment such as computers and commercial and industrial equipment. A group of electronic technicians who were certified through some type of postsecondary training were included in this study. Being certified technicians gave the sample more credibility. This certification is a standard recognized by the industry and state licensing agencies.

Electronics technicians who took part in this study did so voluntarily during normal business hours with the cooperation and approval of their employers. Questionnaires were handed out and collected by supervisors or managers. These surveys were distributed at six electronics technician service companies in the states of Maryland and Virginia. From the eighty five questionnaires handed out, 52 completed surveys emerged accounting for a 61% return rate. There were 33 electronics technicians who did not fill out and return a survey. See Table 1. There were a limited number of businesses that would agree to take part in this research study. Companies that declined to participate were concerned about employees losing valuable work time. This was compounded by the fact that electronics service companies were not abundant in the two states selected.

Description of the Electronics Technicians Group

Demographic data were gathered from those responding to the questionnaire allowing for cross-tabulations to form a composite of the electronics technician group. There were 52 responses from this group; 51 were male and one female.

The ethnic breakdown by gender is shown in Table 6. There were 36 (68%) white, 6 (12%) black, 5 (10%) Asian, 2 (4%) American Indian, 2 (4%) Hispanic, and 1 (2%) other ethnic origin. The female in this group was white.

The age distribution of the electronics technicians and the number of years in the occupation are as follows. Their ages ranged from 21 to 64 years with an average age of 37.4 for male electronics technicians. The lone female electronics technician was 38 years old with 17 years of experience. The age group with the largest segment of electronics technicians were equal with 18 members each in the 25 to 35 and 36 to 45 age categories. The number of years working in the occupation ranged from 1 to 37 years; the average time employed as an electronics technician was 11.77 years.

Electronics Technicians Research Questions Response

1. How is math used by those who work in the occupation of electronics technician?

Electronics terminology is based on powers of ten and metric prefixes. An electronics technician must be able to use simple algebraic expressions to calculate current, resistance, voltage, and other values. Electronic circuit analysis is based on these calculations. A working

Table 6

Distribution of Electronics Technicians by Race and Gender

	Gender					
	Male		Female		Total	
Race	*n*	%	*n*	%	*N*	%
Black	6	11			6	12
Asian	5	10			5	10
Hispanic	2	4			2	4
Native American	2	4			2	4
White	35	69	1	100	36	68
Other	1	2			1	2
Missing Data						
Total	51	100	1	100	52	100

knowledge of trigonometric functions is applied analyzing the phase relationships within an alternating current circuit. Technicians will commonly use higher mathematics applying algebra through exponential and logarithmic functions, trigonometry, vectors, analytic geometry, and complex numbers. Most need a prerequisite of algebra and geometry to perform many of the tasks encountered on the job (Pasahow, 1984).

2. What are the highest math levels required of students enrolled in the education and training of electronic technicians?

Only electronic technicians who were certified through some type of postsecondary training were included in the purposive sample for this study. Their training ranged from one to two years of electronics technical education with individuals earning diplomas and associate degrees and beyond. Participants earned their certification from proprietary, community college, military, or four-year college institutions.

Programs of study from community colleges located in the two states from which the participants were drawn were examined to determine the mathematical levels required of students who completed programs which awarded various types of certification. All electronics technician curriculums included 6 to 10 credit hours of technical mathematics. There was a consistent technical mathematics course description found in each of the college catalogs. The following was taken from the Piedmont Community College catalog:

> Technical Mathematics I-II (3 cr.)(3 cr.)
> Presents algebra through exponential and logarithmic functions, trigonometry, vectors, analytic geometry, and complex numbers. Prerequisites: Algebra I and Geometry, or Algebra I and Algebra II or equivalent. (Piedmont Community College, 1994, p. 79).

Mathematics required as part of the curriculum in these programs was consistent in content, but varied in the number of credits needed. Out of the 10 Virginia A.A.S. programs, six required students to take 10 hours of math course work, usually broken down into two equal units. Those that required this extended course load offered what appears to be a more rigorous math challenge. Technical math course descriptions in this case included "an introduction to calculus."

Here too, the state of Virginia did not mandate specific course requirements; it provided suggested guidelines. All of the participating colleges, including those in Maryland, followed the criteria set forth by the Southern Association of Community Colleges (SACC). This organization established academic and occupational curricula standards for community colleges in the southern states. Virginia and Maryland officially adhered to the independent organization, the Technology Accreditation Commission (TAC), guidelines to maintain certification of their technician programs. One of the commission guidelines required a minimum of six credit hours in technical mathematics as described in the Piedmont College catalog.

3. How do the math levels required in the educational programs of electronic technicians compare to the math levels used by those in the occupation?

The 52 electronic technicians who responded had attained the average level of algebra II/trigonometry during their formal education and training. This math level is consistent with the technical programs of study offered by community colleges located in both Virginia and Maryland.

Electronic technicians were asked about the level of math that was used most often in their daily routine. The questionnaire results indicated that 32 (62%) technicians were using basic math most often in the work place, 9 (17%) geometry, 9 or (17%) technical math, and 1 (2%) both algebra and algebra II/trigonometry. A majority of the technicians used math topics under basic math. The topics that were heavily used were fractions, decimals, percent, measurement, powers and roots, negative numbers, and scientific notation. The electronics group had 38% applying math above the level of basic mathematics. Almost 40% of electronic technicians were applying the level of mathematics associated with this occupational group. More than 40% of the electronic technicians identified topics from algebra I, geometry, and trigonometry labeled using formulas, linear equations, basic terminology, angle measurement and logarithms.

On the question of how often a computer is used for math purposes, the average response was "rarely." Ironically, these technicians spent much of their day repairing computers. They spent very little time actually using them for math purposes related to their work. Some predict computers will become more involved in diagnosing the trouble spots associated with electronic equipment with built in sensors.

Electronics Technician's Interview and Written Comments

Interviews were conducted with two electronics technicians at their worksite during business hours with the permission of their employer using a set of questions for this study (see Appendix C). Both were male technicians who repaired electronics equipment such as VCR's, televisions, and personal computers. Their experience in the field of electronics was 8 and 14 years respectively. Both agreed that their math training was important toward gaining an understanding of the principles that underlie electronic circuitry. While they rarely use the higher levels of math they took during their training, it is applied occasionally to find a solution to repairing a piece of equipment. Both admitted that having stronger math skills would allow them to work at a higher level technically in the electronics field. Written comments drawn from technicians who completed a questionnaire (see Appendix D) appeared to support this idea.

Math Topics Usage Data

A frequency of usage table of the selected 60 mathematical topics was compiled from the questionnaire data and is displayed in Table 7. Frequency of use for each topic is broken down into the percentage of each of the four occupations that selected the category. A mean frequency was calculated from all four occupations. Each category was included in the table. The topics with the greatest rate of usage were on the level of basic math. Basic math was frequently used by all members of the four selected occupations. As one progresses higher through the math

Table 7

Math Topics Usage Frequency

Math Topics	Freq %	Freq%	Freq %	Freq %	Mean
Basic Math/Pre-Algebra	Finance Officers	Doctors	Machinists	Electronics Technicians	
1 Fractions	83	96	83	64	82
2 Decimals	89	96	95	78	90
3 Ratio & Proportions	87	95	31	67	70
4 Percent	93	96	61	71	80
5 Measurement	20	94	95	76	71
6 Metric Measurement	2	98	80	53	58
7 Measurement Conversion	2	88	70	56	54
8 Basic Probability	46	56	5	11	30
9 Basic Statistics	43	72	8	16	35
10 Graphing	43	68	20	33	41
11 Powers & Roots	17	22	27	62	32
12 Negative Numbers	67	23	31	58	45
13 Scientific Notation	0	37	10	62	27
14 Problem Solving	78	64	53	60	64
First Year-Algebra					
15 Using Formulas	64	46	58	76	61
16 Linear Equations	22	26	27	44	30
17 Polynomials	7	2	7	7	6

Table 7 (continued)

Math Topics Usage Frequency

Math Topics	Freq %	Freq%	Freq %	Freq %	Mean
First Year-Algebra	Finance Officers	Doctors	Machinists	Electronics Technicians	
18 Rational Expressions	9	7	3	20	10
19 Graphing 2-D	20	25	10	27	21
20 Linear Systems	20	7	12	24	16
21 Radicals	22	4	7	20	13
22 Quadratic Equations	7	1	15	20	11
23 Algebraic Representation	15	11	15	31	18
Geometry					
24 Basic Terminology	13	26	39	44	31
25 Angle Measurement	0	28	79	40	37
26 Congruent Triangles	0	6	34	11	13
27 Parallel Lines	2	7	41	18	17
28 Quadrilaterals	0	2	15	9	7
29 Pythagorean Theorem	0	2	30	20	13
30 Right Triangles	2	7	75	33	29
31 Circles	7	19	74	22	31
32 Constructions	2	4	22	20	12
33 Area	15	32	46	22	29
34 Volume	9	36	29	16	23
35 Transformations	0	2	8	9	5
36 Make/Use 3-D Drawings	13	10	31	18	18

Table 7 (continued)

Math Topics Usage Frequency

Math Topics	Freq %	Freq%	Freq %	Freq %	Mean
Second-Year Alg/Trig.	Finance Officers	Doctors	Machinists	Electronics Technicians	
37 Functions	19	7	21	29	19
38 Variation	7	5	10	7	7
39 Polynomial Equations	7	4	10	4	6
40 Logarithms	4	19	10	42	19
41 Matrices	7	4	3	11	6
42 Advanced Probability	13	11	7	9	10
43 Advanced Statistics	11	14	7	7	10
44 Non-Linear Systems	0	2	5	16	6
45 Circular Functions	2	0	27	11	10
46 Graphs of Trig. Functions	2	0	20	13	9
47 Trig. Identities	0	0	32	13	11
48 Equation/Inverses	11	7	15	18	13
49 Oblique Triangles	0	0	25	7	8
50 Polar Coord. Graphs	0	1	14	22	9
51 Vectors	0	11	8	36	14
Other Topics					
52 Calculus & Higher Math	4	0	10	13	7
53 Use Calculator	83	59	76	64	71
54 Use Scientific Calculator	19	10	37	58	31
55 Computer Use	83	38	41	62	56
56 Computer Programming	19	7	25	27	20
57 Group Problem Solving	39	9	17	31	24
58 Mental Math	69	38	41	60	52
59 Induct/Deduct Reasoning	52	36	24	49	40
60 Math Communication	33	6	35	17	23

continuum it becomes clear that frequency of use decreases.

In Table 8, math topics with categories selected by the respondents above the 50 percentile range are isolated to demonstrate those used most frequently. Nine out of the 14 categories under the basic math heading were used by two or more of the four occupational groups. There was only one topic on the level of first-year algebra in this percentile, it was *using formulas*. Machinists use of geometry in their work accounted for three topics under the same heading. There was no category on the level of algebra II/ trigonometry that qualified. Under the heading *other topics* there were five categories in the upper percentile. All four occupations marked the *use calculator* topic with a 59% to 83% range. Fifty-eight percent of electronic technicians stated they regularly use a scientific calculator. The topic "computer use" drew support from 83% of finance officers and 58% of electronics technicians in their response groups. The final two topics in the 50 percentile were mental math and inductive/deductive reasoning.

Table 8

Math Topics Mean Usage

	Math Topics	Freq %	Freq%	Freq %	Freq %	Mean
	Basic Math/Pre-Algebra	Finance Officers	Doctors	Machinists	Elect. Techs	
1	Fractions	83	96	83	64	82
2	Decimals	89	96	95	78	90
3	Ratio & Proportions	87	95	31	67	70
4	Percent	93	96	61	71	80
5	Measurement	20	94	95	76	71
6	Metric Measurement	2	98	80	53	58
7	Measurement Conversion	2	88	70	56	54
8	Basic Probability	46	56	5	11	30
9	Basic Statistics	43	72	8	16	35
10	Graphing	43	68	20	33	41
11	Powers & Roots	17	22	27	62	32
12	Negative Numbers	67	23	31	58	45
13	Scientific Notation	0	37	10	62	27
14	Problem Solving	78	64	53	60	64
	First Year-Algebra					
15	Using Formulas	64	46	58	76	61
	Geometry					
25	Angle Measurement	0	28	79	40	37
30	Right Triangles	2	7	75	33	29
31	Circles	7	19	74	22	31
	Second-Year Algebra/Trig.	0	0	0	0	0
	Other Topics					
53	Use Calculator	83	59	76	64	71

Higher Level Math in Career Preparation and Professional Duties

All participants in this study were asked the extent to which they agreed or disagreed with four statements in the survey concerning the relationship of higher level math to their occupation. For items 12 to 15, higher level math was defined as any math above the level of pre-algebra. The four part scale used was (A) Agree, (TA) Tend to Agree, (TD) Tend to Disagree, and (D) Disagree. The responses were coded and tabulated by occupational group. The results are presented in Figures 1-4.

On three out of four questions family physicians tended to agree that higher math was not being used in their professional duties. They disagreed with the statement that higher math would be needed by persons entering their profession to perform on the job (see Figure 3). The doctors in this group agreed that higher math courses were very important to their career preparation (see Figure 2). This may be due to the courses required during their undergraduate education.

Finance officers who completed the questionnaire were equally split on all four questions. As a response group, they fell in the tend to agree, tend to disagree mid-range of the scale. These finance officers had 91% who had at least one course in calculus in their college training.

Electronics technicians tended to agree on all four questions asked in this section of the survey. The technicians saw higher mathematics as important but agree that the related skills are not generally used in the performance of their professional duties (see Figure 1). Machinists had strong opinions about the use of higher math in their occupation (see Figure 4). Higher math levels are important in their career preparation and are generally used by workers in the profession.

Chapter Summary

This chapter presents the findings from the data collection relevant to the research questions on the connection of the math required prior to entering four selected occupations. These data were compared to the math levels used most often in their daily performance on the job. Background information was provided to clarify the relationship of math required and the math used within these four groups. Each group is presented in the following order: finance officer, family physician, machinist, and electronics technician. The section for each occupational group begins with a description of the questionnaire

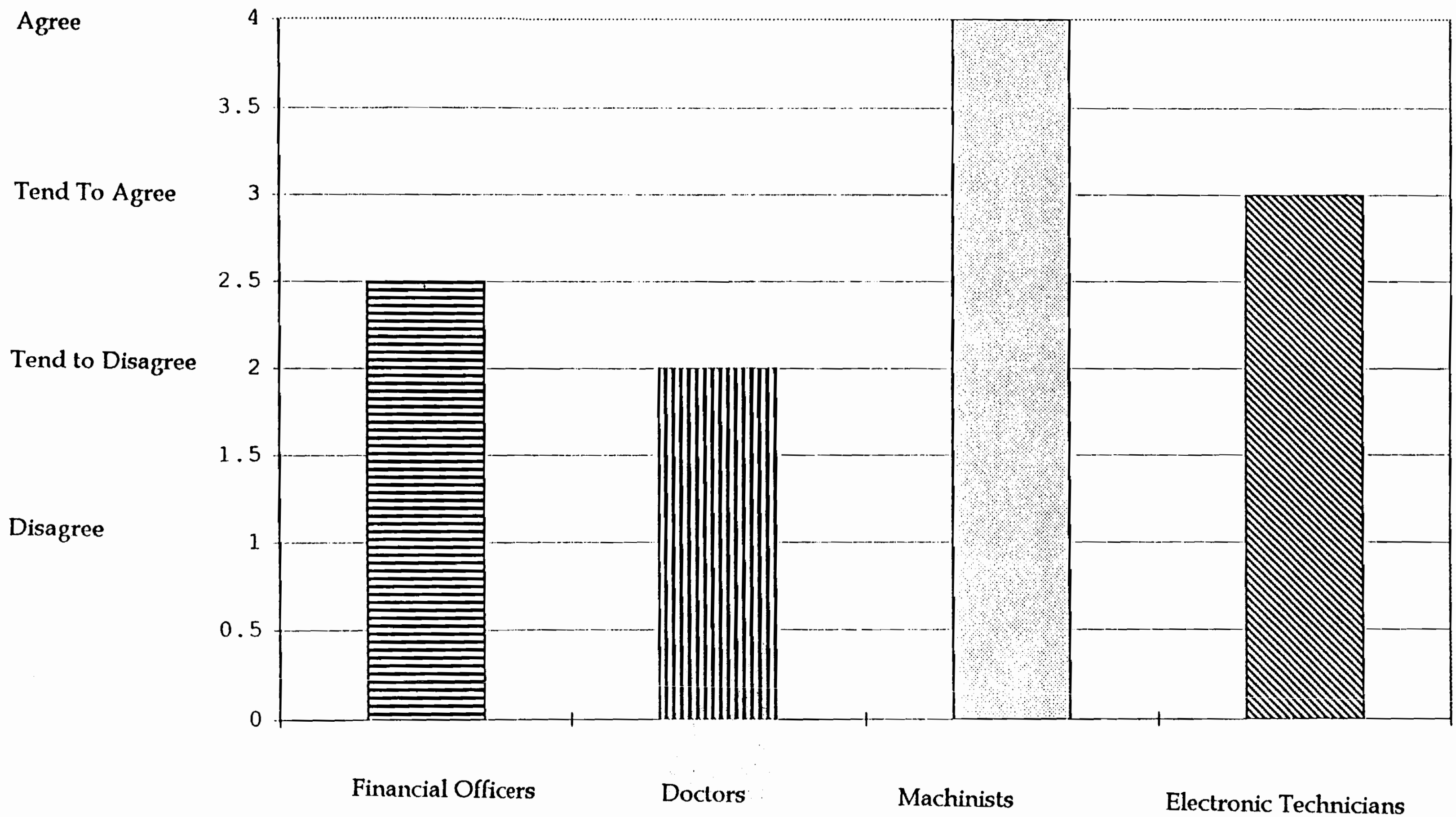

Figure 1. Higher math is important in professional duties.

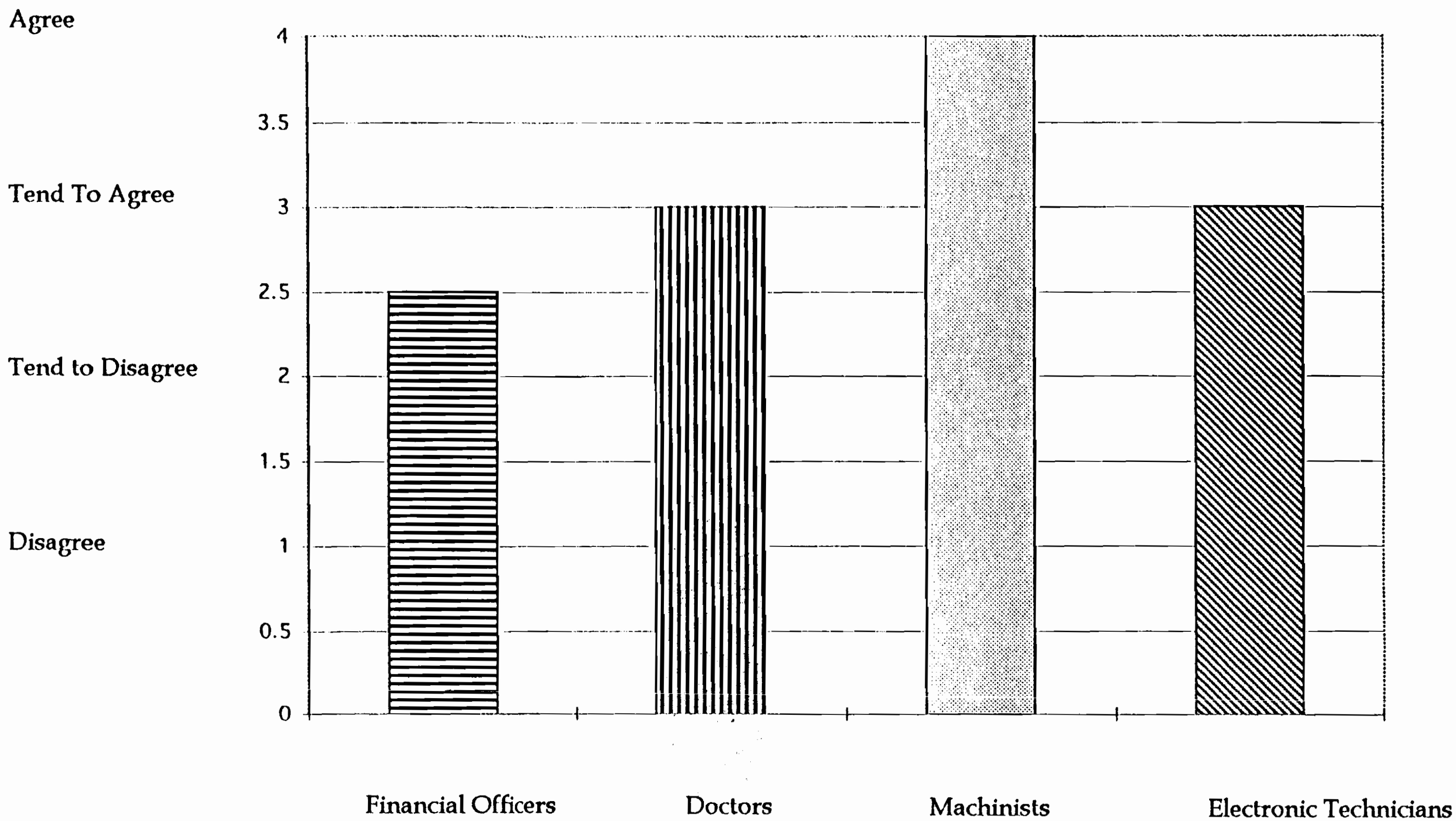

Figure 2. Higher math is important in career preparation.

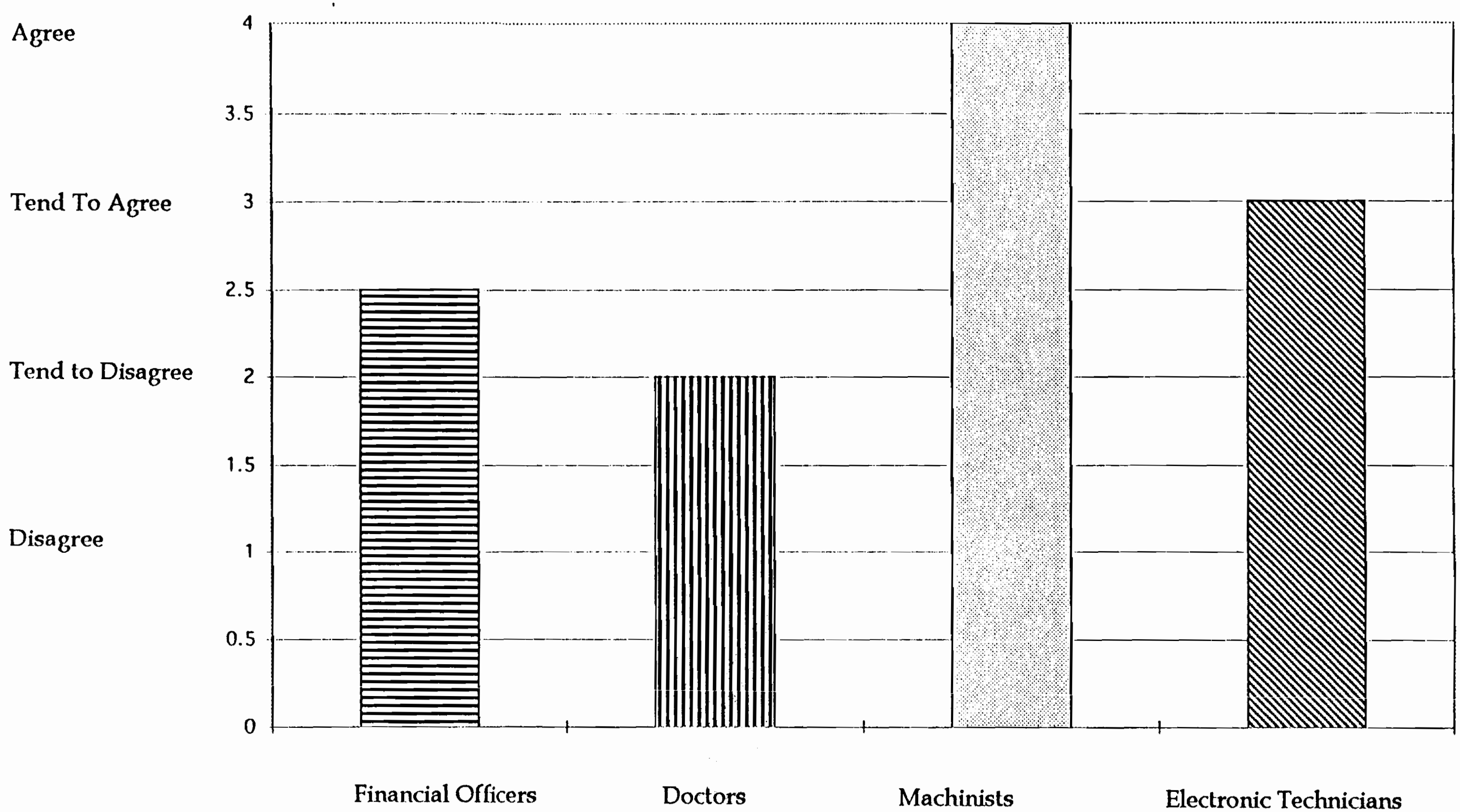

Figure 3. Higher math is needed by new workers

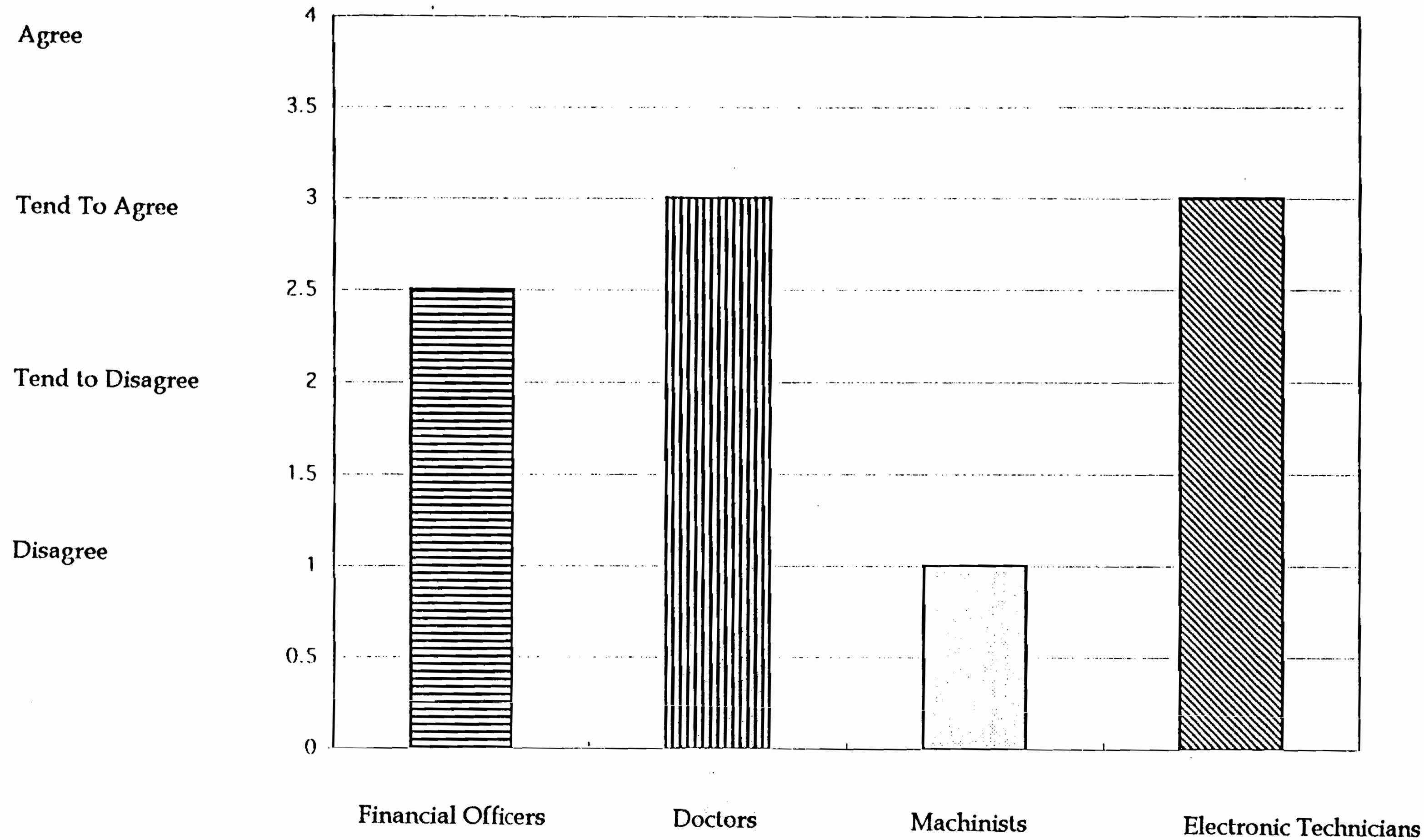

Figure 4. Higher math skills are not used to perform duties.

responses. There were a total of 261 completed questionnaires returned for a 72% response rate. The response rate for each occupation was: finance officers 62 (74%), family physicians 81 (81%), machinists 66 (73%), and electronics technicians 52 (61%).

The second portion of this chapter provides a description of respondents in their four occupational groups. A description of the selected groups includes gender, race, age, and years worked in the profession.

The third portion discusses the data analysis findings among the four occupations relative to the three research questions. The research questions were amended to simply reflect the occupation group being discussed in this chapter. The data analysis findings are presented following each of the research questions. Basic math was used most often in the performance of the four selected occupations. Math topics were designated by the participants who completed the questionnaire. Elementary arithmetic of adding, subtracting, multiplying and dividing remained the math skills level being applied including fractions, decimals, ratios, percent, and measurement.

The four occupations examined in this research study come from education and training programs that require a diverse set of math courses. They used these math skills in a variety of ways to solve problems related to their work. Results indicate a disparity between the levels of math required or taken as an undergraduate compared to the level used by a large majority of finance officers and physicians. Conversely, the use of higher mathematics in the technical machinists and electronics technicians groups corresponded with the level of math courses required in their education and training programs.

CHAPTER FIVE

Summary, Conclusions, Discussion, and Recommendations

This study investigated the levels of mathematics commonly used in four selected occupations compared to the levels of math required in the education and training of these occupations. This chapter presents a summary of the research study, the conclusions, and recommendations.

Summary

> Mathematics as it is taught in schools is disconnected and too abstract for the greatest majority of students. It is presented as a matter of technical relations and formulas separated from practical use or application.
>
> (Dewey 1910, p. 55)

Introduction

Since the release of the report *A Nation at Risk* in 1983, a great deal of attention has been given to the performance of students enrolled in American public schools. This report and others that followed have been critical of our nation's schools in preparing its students academically in math, science and communication skills. Comparisons have been used to show their peers in other industrialized countries are out performing American students in every core subject area, especially math. Our educational system is not meeting the needs of a majority of the students it serves (Gardner, 1983). As a result many young people are leaving school unprepared for entering the workforce or further learning. Employers suggest that they are not prepared for many of the jobs available. Since the mid-eighties, almost every state has responded with a tougher set of math standards students must pass to graduate. A study in 1991 (Webster & McMillin) reported that over half the states have increased their standards for both math and science.

A student's proficiency in mathematics can potentially broaden their career opportunities. Mathematics is the foundation of science and technology; it can be the gateway to scientific and professional careers. Programs that provide professional and technical training require or strongly recommend that students complete a series of specific math courses (Association of American Medical Colleges, 1994). An important question in this study for the government, educators and employers alike was, "What math is required on the job?"

Theoretical Framework

The theoretical foundation for this study was based on the presumption that the subjects required during the occupational education phase should be utilized later while working in that occupation. The connection between what schools require and what is actually used on the job was the basis for this research. Individuals expect an instructional program to be concentrated on substantive matter to the occupational field of study. Employers share this expectation when they employ persons who have completed such programs.

"Students need to understand the application of ideas and the relevance of these ideas later in life" A.N. Whitehead (1929 p. 3), stated in his classic book *Aims of Education.* Whitehead further suggested that mathematics could best be learned when taught in an applied fashion. Sadler (1992) contended that knowledge and skills are learned best when the content and skill acquired are judged as usable, sensible, and valuable by the learner.

Mathematics courses usually have established sequences which concentrate on math skills largely determined by mathematicians (Pucel, Davis-Feickert, & Lewis, 1992). The National Research Council (1989), has called on mathematics professionals to find new ways to make the subject of math more relevant to more students than ever before.

Critical Thinking

Mathematics along with reading and writing makes up the foundation of our educational system in this country. It is a subject that is taught to all students who attend school. Every student will need a good working knowledge of basic math in their personal lives and the workplace. Our number system is one of precision. Those in the math and physical sciences field point out that modern civilization has been built through the application of higher mathematics. If it were not for higher mathematics, most of our advanced technologies could not have been built. Complicated machines, skyscrapers, bridges, subways, computers, and telecommunication networks were made possible through the application of higher math (National Council of Teachers of Mathematics, 1966).

Math professionals have for many years promoted the idea that learning more math develops a mental discipline. This philosophy dates back to the days of Pythagoras and Plato. The study of mathematics has allowed a select group of scholars to gain special intellectual abilities. Leaders in the field of science continue to support the acquisition of critical thinking skills with the prolonged study of mathematics. This acquisition of higher level critical thinking ability was enhanced from studying courses like trigonometry, and calculus. By mastering higher math courses, it is thought that students will have better problem solving skills. Critical thinking skills allows an individual to seek solutions to problems encountered on a daily basis. Ideally, these problem solving techniques should be taught during elementary courses, including math and continue throughout a persons education and training.

Extensive research and discussions with university math professors have shown little research exists regarding the direct connection between the learning of higher mathematics and associated critical thinking skills. This commonly accepted thesis in our society has no significant scientific research to support this claim. Curriculum professionals such as art, social studies and vocational educators have begun to claim their areas of instruction are also responsible for developing critical thinking. It seems fair that all students could gain from exposure to a variety of subject areas that emphasize critical thinking.

Occupational programs of study include those students enrolled in college degree programs such as business, accounting, engineering, and medicine. These students are seeking specific training in an occupational skill area. Like other vocational students, they too are acquiring skills that will hopefully prepare them to perform in their chosen field. A university plays an important role in the preparation of its' students for careers by promoting the various principles underlying that career (Whitehead, 1929). Strong relationships between schools and businesses will improve the quality of the learning and performance on the job. Effective school-to-work outcomes will be a result of the collaboration between academic and workplace skills standards.

The review of literature suggested that most occupations need only a subset of all mathematical skills. The mathematics skill requirements for different occupations and their application will vary significantly between occupations (Pucel, 1992). In a given occupation, specifically required math skills can vary from job to job. Only a very small minority of highly skilled professionals consistently uses higher levels of mathematics (Meiring, 1992). Jobs or careers needing a college degree or more appear to show little evidence that most require a high level of mathematics (Hoerner & Wehrley, 1995; Daggett, 1994; Meiring, 1992).

Purpose

The purpose of this study was to determine the mathematics levels commonly used in the performance of four selected occupations: (1) family practice physician, (2) finance officer, (3) electronics technician, and (4) machinist, and then compare the uses to what is generally required in the preparation of such occupations. This research sought to first determine the levels of math required during the program of studies in these four occupations and, second to determine whether they are being used. If they are not, this poses important questions for those who determine the educational curricula. In order to prepare our youth for the transition from school to work, we need to improve the communication between the educational setting and the actual practices of experienced personnel within an occupation. This should result in a more relevant curriculum.

Research Questions

The research questions of this study were:

1. How is math used by those who work in the occupations of (1) family practice physician, (2) finance officer, (3) electronics technician, and (4) machinist?

2. What are the highest math levels required of students enrolled in the education and training of the four occupations?

3. How do the math levels required in the educational programs compare to the math levels used by the selected occupations?

Participants

This purposive study of a limited sample included members from four selected occupations from the states Virginia, Maryland, North Carolina, and Kentucky. A minimum of 60 members from each occupational group was sought to participant in the study. Information was gathered from each of the participants and cross tabulations provided a demographic profile of the members of each occupation. Some of the descriptive information obtained from the questionnaire included gender, age, race, number of years in occupation, and highest education level completed.

Representing the four occupations were 81 family physicians, 66 machinists, 62 finance officers, and 52 electronics technicians. There was a total of 261 respondents.

Instrumentation

The questionnaire used in this study was developed to collect data concerning the level of math required in the education and training of each of the four selected occupations and the level used in the occupational workplace. The questionnaire was constructed from information gathered from discussions with identified leaders in the four occupations being studied. All questionnaires were labeled with the specific occupation group and directed at each of the four occupations. The initial portion of the questionnaire was designed to gain general information, followed by a group of questions concerning how math was related to the performance of their jobs. As part of this questionnaire a mathematics continuum chart from Martin (1983) was modified to meet the specific needs of this study. The continuum chart with 60 math topics was the final segment of the survey. Participants were asked to specify which math topics they used in their work. By designating specific math topics currently being used by the four selected occupations, a more detailed description was gained.

The data collected were used to draw comparisons of the levels of math required prior to entering their chosen occupation to the level of math used in performing their occupation. This contrast was the foundation of this research study.

Data Collection

A list of members was secured from professional organizations representing finance officers, electronic technicians, and family physicians who worked in the four-state region selected for this study. All the family physicians were located in the state of Virginia. Finance officers were mailed questionnaires to their work sites in Virginia, Maryland, and North Carolina. Less than 30% of the questionnaires for the electronics technicians were mailed out; the rest were handed out at their place of business. All of the machinists surveys were handed out directly on the job site.

The selected occupational groups were mailed a packet, which included a questionnaire, cover letter and a self-addressed return envelope requesting their participation in this study. Two weeks after the initial mailing, a follow-up letter or a personal phone call was used to stimulate completion of the surveys. After three weeks a second packet was mailed to the non-respondents from the original mailing. A total of 365 questionnaires were distributed to members in the four selected occupations. There were 261 completed surveys returned. The overall return rate was 72% for the groups involved.

Findings

This study investigated the levels of mathematics commonly used in four selected occupations. This was compared to the levels of math required in the education and training of these occupations. Descriptive statistics were used to identify and describe the mathematics preparation required prior to entering the four selected occupations and the math levels used in each occupation. These descriptive statistics were then used to answer the three research questions. The findings are presented within the four occupational groups of finance officers, family physicians, machinists, and electronic technicians.

Finance Officers

All finance officers in this study worked full-time in the banking industry. They used basic mathematics to calculate the banking transactions of checking or savings accounts, loans and credit applications, plus a host of other related business tasks. The finance officer spent approximately 7 to 8 hours per week using math in the performance of their duties. This was the highest number of hours spent using math among the four selected occupations in this study. Potentially, higher level math may be needed in projecting long range interest rates, mergers and acquisitions. Over 90% of finance officers graduated from college programs that required a minimum of 3 credit hours of calculus. Almost an equivalent number, 82% of finance officers stated they used basic math most often in their daily routine.

Family Physicians

Family physicians used math primarily during the examination, evaluation, and treatment of patients. On a daily basis they performed simple math calculations in the course of diagnosing the symptoms exhibited by patients. Higher math levels were suggested as relevant in the evaluation of research materials associated with medical journals. From the 81 physicians who completed the survey 86% had taken a course in calculus or higher level mathematics. Conversely, an almost identical number of family physicians, 82% reported the level of math used most often in the daily routine was basic math. The disparity between the higher levels of math courses required or taken as an undergraduate compared to the level used by a vast majority of physicians and finance officers is an important finding in this study.

Machinists

On the technical side, in the machinists environment, workers utilized math to study blueprints and drawings to determine the dimensions and tolerances of finished pieces. Their work consistently calls for a high degree of accuracy as part of their job. Training programs that award certification to machinists consistently required one or two courses in technical math. Over half of the responding machinists, 54% were applying math at a level that falls in the mid-range of algebra and geometry. As a group, machinist had the highest correlation between the level of math studied previously and the level of math used most often on the job. Compared to the other occupations in this study, they used the highest level of mathematics consistently in their work.

Electronics Technicians

Electronics technicians' work is based on mathematical principles. Electronics technicians use simple algebraic expressions to calculate current, resistance, and voltage. Electronic circuit analysis is based on these calculations. Trigonometric functions are applied analyzing an alternating current circuit. Electronic technicians need a prerequisite of algebra and geometry to perform many of the tasks encountered on the job. Postsecondary technical training programs that awarded certification to electronics technicians required one or two courses in technical math. Data results from the questionnaire showed 62% of the electronics technicians using basic math, 17% using geometry, and 17% using technical math most often in the work setting. Almost 40% of electronic technicians were applying the level of mathematics associated with their education and training.

Over 85% of the finance officers and family physicians who took part in this study had higher level math courses in calculus and above while attending college. Both of these professional occupations reported using basic math most often in the performance of their duties. The use of higher level mathematics among the technical occupations of machinists and electronics technicians was consistent with the level of math courses required during their education and training.

Conclusions

The following conclusions are based on the findings of this study:

1. There appears to be a low level of alignment between the math required in the preparation of finance officers and family physicians and the general level of math used in performing their jobs.
2. It is concluded that there appears to be much greater alignment between the level of math required in preparation and used on the job by electronics technicians and machinists than there is by finance officers and family physicians.

3. Since the finance officers and family physicians in this study tended to use only basic math it is reasonable to conclude that the requirement of calculus in their preparation is suspect and warrants further study.

4. Since the findings of this study which included college driven careers (finance officers and family physicians) align with Loase's (1983) study which included actuarial workers and computer scientists, it is reasonable to conclude that the level of math generally required in college frequently does not align with careers requiring college degrees.

5. The findings of this study support the work of Pucel et al. (1992) in that math used within an occupation can vary greatly.

6. The findings of this study are also supported by Meiring (1992), that only a very small minority of highly skilled professionals consistently use higher levels of mathematics.

7. It appears that math criteria are being used as a screening device for selecting applicants.

Discussion

The results of this study suggest that mathematics curricula need to be reviewed at the high school and collegiate level with the focus on what math courses are appropriate in preparing students for the transition to an occupation. A review of math and other work skills should be conducted in conjunction with leaders from business and industry. It appears that there are major differences in both the mathematics skills required in different occupations and the ways in which mathematics are applied in these occupations. Providing accurate information regarding the actual math skills needed to perform successfully in an occupation of interest will allow students to make better career choices.

There is an acknowledged link between higher mathematics and the pedagogy in teaching physical sciences. This linkage has an influence on the science curriculum, requiring students in many cases to take higher level math courses. The results of this study further suggest that the mathematics course levels required in the two technical groups were being applied by a majority of those working in the field. The predominance of higher level math courses in the programs of study in the two professional occupations were not being applied by a large majority of their members.

This descriptive study used a nonprobability sample for all four occupations. Since no previous study has been conducted using these groups, the researcher is confident that the information gathered can be beneficial to curricula planners. A principle limitation of this study was that it was not a true experimental design. There was no random assignment to groups, therefore some caution should be taken. Any conclusions drawn from this study should not be interpreted as representative of the occupations that participated in the study. While this study has limitations in design and methodology, it has however produced a number of concerns within the researcher.

It does seem that for too long various levels of math have been required throughout the schooling process from kindergarten through post graduate studies with little relevance to the real world of applications. The idea of increasing the standards will do little to the level of achievement except for taking tests. Those responsible for setting math requirements appear to offer little rationale that supports the required levels. Math achievement levels would likely be greatly enhanced if math was taught on an applied basis. Math is a tool to be learned and used for practical applications in our daily lives and on the job.

I have attended a large conference of public school administrators and teachers who were asked by the keynote speaker, "How many have used algebra in the past week?" When math teachers where sorted out, very few hands remained in the air. It would be reasonable to predict this same result would likely be achieved in the presence of a large group of college professors excluding the physical science and engineering professors. Among the best educated professionals in our society, very few of these individuals are applying math that many were required to take in order to attain their level of education. Perhaps an interesting study would be to survey all four year college and university professors as to the levels of math they use to perform the duties of a professor.

The results of this study could have an impact on curriculum planners, school boards, administrators, and guidance counselors. The levels of math required to perform in certain occupations should be examined by educators and experienced leaders in the field. Students need accurate information from counselors regarding the subjects they will need to prepare them in a chosen career. If changes are to be brought about in the math and science curriculum of occupational programs, it will require a great deal of cooperation from administration and educational leaders at the secondary and postsecondary levels. The long term benefit would be preparing and training students in occupational areas focused on more relevant subject matter.

School systems will better serve their students and their communities by giving young people the skills needed to succeed in the workplace.

Recommendations

In conjunction with this study's findings and conclusions, recommendations are offered for further research. There has been a scarcity of research done on the relationship of the mathematics required to perform a variety of occupations. This is especially true of occupations requiring two or more years of college. It is recommended that occupations with a requisite of a college degree or professional licensure be thoroughly investigated with regard to their math needs. Although the results are limited with the finance officers and family physicians in this study, a large majority of these professionals did not apply higher math in their work.

It was apparent in the early stages of this study that most people reacted very strongly when asked to discuss the use and value of mathematics related to their education and careers. It is a subject which generated very strong opinions about how applicable higher levels of math training are in the occupations examined in this study (see Appendix D). Therefore, it is recommended that attention be given concerning the value of higher mathematics training among those respondents who took advanced levels of math as opposed to those who did not.

This study should be replicated with a larger and more comprehensive sample. The value of working with a larger sample would be gaining additional data for analyses. It would be beneficial to scrutinize numerous occupations to assess the functional use of math by such workers. If the results of a large scale scientific study were to support the findings of this research study, as I believe it will, a national discussion among educators, business, and government leaders could take place. If this country is to sufficiently prepare it's citizens to enter the workforce with a level of skills that can adapt to a changing environment, it would be in our best interest as a nation to begin holding open discussions concerning these issues.

In future research it is recommended that individuals be given a choice of the levels of math used by the frequency or percentage of usage (i.e. 85% basic math, 10% algebra and 5% trigonometry). By adding this selection of math levels based on 100% of the time math is used, it should provide a more accurate breakdown of the types of math applied in the work setting. Such research should be conducted in partnership with trained math professionals to interview and judge the levels of math being applied on the job by workers. Their participation in future research on this thesis could be valuable in making decisions about where technical mathematics fits in relationship to algebra, geometry, and trigonometry. Sufficient time should be given to observing workers on the job to better understand what and how math is applied. It is suggested that more interviews with members of each occupational group be conducted, perhaps in focus groups to clarify issues concerning the topic of mathematics in the workplace.

A major component of any future research on math skills needed in the workplace should investigate the best methods and environment for teaching these skills. Educators and employers would benefit greatly from the comparison of applied learning on the job versus remedial training away from the work area. Perhaps a combination of both methods may prove to have the best results. This also is something that needs further exploration.

On a larger scale, for many years the study of higher mathematics has been associated with the enhancement of logical thinking and problem solving apart from actual math computation. It would be beneficial for the scientific community to conduct unbiased research on whether there is a direct connection between the study of higher mathematics and the analytic thinking ability of individuals.

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Appendix A

Questionnaires used for surveying family physicians, finance officers, electronics technicians, and machinists.

Family Practice Physician Questionnaire ________

The purpose of this questionnaire is to determine what level of math is required to perform your occupation. No individual will be identified and all information gathered will be used in occupational groups.

Thank you for participating!

I. General Information:

1. Number of years in your current profession: _____

2. Gender: ____ Male ____ Female

3. Your age: ____

4. Ethnic/Racial Background: __ Aleut __ American Indian

__ Asian/Pacific __ Hispanic __ Black __ White __ Other

5. Highest level of education completed:

____ Doctorate: MD DO JD Ph.D. EDD Other_______

6. What was your undergraduate major?

____

7. The highest level math course completed during your formal education was: (check one)

____ Basic Math/Pre-Algebra ____ Algebra ____ Geometry

___ Algebra II/Trig. ___ Calculus ___ Higher than Calculus

8. In your daily routine which level of math do you use most often? (check one)

____ Basic math (Add, subtract, etc.) ____ Algebra

_____ Geometry _____ Trigonometry

____ Calculus _____ Higher than Calculus

____

Finance Officer Questionnaire

The purpose of this questionnaire is to determine what level of math is required to perform your occupation. No individual will be identified and all information gathered will be used in occupational groups.

Thank you for participating!

I. General Information:

1. Number of years in your current profession: _____

2. Gender: ____ Male ____ Female

3. Your age: ____

4. Ethnic/Racial Background: __ Aleut __ American Indian

__ Asian/Pacific __ Hispanic __ Black __ White __ Other

5. Highest level of education completed:

____BA/BS ____MA/MS ____Doctorate ___ Other

6. What was your undergraduate major?

____

7. The highest level math course completed during your formal education was: (check one)

_____ Basic Math/Pre-Algebra ____ Algebra____ Geometry

___ Algebra II/Trig.___ Calculus ___ Higher than Calculus

8. In your daily routine which level of math do you use most often? (check one)

____ Basic math (Add, subtract, etc.) ____ Algebra

_____ Geometry _____ Trigonometry

____ Calculus _____ Higher than Calculus

____

Electronics Technician Questionnaire

The purpose of this questionnaire is to determine what level of math is required to perform your occupation. No individual will be identified and all information gathered will be used in occupational groups.

Thank you for participating!

I. General Information:

1. Number of years in your current occupation: _______

2. Gender: ____ Male ____ Female

3. Your age: _______

4. Ethnic/Racial Background:____ Aleut ____ American Indian

__ Asian/Pacific ___ Hispanic ___ Black ___ White ___ Other

5. Highest level of education completed:

___ Less than high school diploma ____ GED
____ High school Diploma ____ Technical School
____ AA/AS ___ BA/BS ___ MA/MS ___ Other

6. If you graduated from a community or 4 yr. college/ university, what was your undergraduate major?

____

7. The highest level math course completed during your formal education was: (check one)

_____ Basic Math/Pre-Algebra ____ Technical Math

____ Algebra ____ Geometry ___ Alg. II/ Trigonometry

___ Calculus ____ Higher than Calculus

8. In your daily routine which level of math do you use most often? (check one)
___ Basic math (Add, subtract, etc.) ___ Algebra___ Geometry

___ Trigonometry ___ Calculus ___ Higher than Calculus

Machinist Questionnaire

______

The purpose of this questionnaire is to determine what level of math is required to perform your occupation. No individual will be identified and all information gathered will be used in occupational groups.

Thank you for participating!

I. General Information:

1. Number of years in your current occupation: ______

2. Gender: ____ Male ____ Female

3. Your age: ____

4. Ethnic/Racial Background: ___ Aleut ___ American Indian

___ Asian/Pacific ___ Hispanic ___ Black ___ White___ Other

5. Highest level of education completed:

___ Less than high school diploma ____ GED
____ High school Diploma ____ Technical school
____ AA/AS ____ BA/BS ___ Other

6. If you graduated from a community or 4 yr. college /university, what was your undergraduate major?

____

7. The highest level math course completed during your formal education was: (check one)

_____ Basic Math/Pre-Algebra ____ Technical Math

____ Algebra ____ Geometry ___ Algebra II/Trigonometry

____ Calculus ____ Higher than Calculus

8. In your daily routine which level of math do you use most often? (check one)

___ Basic math (Add, subtract, etc.) ___ Algebra ___ Geometry

___ Trigonometry ___ Calculus ___ Higher than Calculus

9. On a regular basis approximately how many hours per week is spent in your work as a (occupation) using math? (estimate)

____ Less 1 hr. ____ 1-2 hrs. ____ 3-4 hrs. ____ 5-6 hrs.

___ 7-8 hrs. ___ 9-10 hrs. ___ 11-12 hrs. ___ 13 or more hrs.

10. In your work how often do you use a calculator?

____ Never ____ Rarely ____ Occasionally ____ Frequently

11. In the course of your duties how often do you use a computer for math purposes?

____ Never ____ Rarely ____ Occasionally ____ Frequently

II. In the following section please respond to each item on the scale of (A) *Agree,* (TA) *Tend to Agree,* (TD) *Tend to Disagree, and* (D) *Disagree.* For items 12-15, higher level math is defined for this survey as any math above the level of pre-algebra.

12.	In your professional duties, higher level math is important in your work.	A	TA	TD	D
13.	Higher level math courses were very important to your career preparation.	A	TA	TD	D
14.	Individuals now entering your profession will need higher level math skills to perform on the job.	A	TA	TD	D
15.	Higher level math skills are not generally used in the performance of your professional duties.	A	TA	TD	D

III Comments: Below please state any comments you wish to make.

____

____.

IV. Use of Math On the Job

Instructions:

Place an X next to all math topics that you use regularly in performing your duties as a (name of occupation).

Example: X | Fractions

Basic Math/ Pre-Algebra			*Geometry*	
	Fractions			Circles
	Decimals			Constructions
	Ratio & Proportions			Area
	Percent			Volume
	Measurement			Transformations
	Metric Measurement			Make/Use 3-D Drawings
	Measurement Conversion		*Second-Year Algebra/Trigonometry*	
	Basic Probability			Functions
	Basic Statistics			Variation
	Graphing			Polynomial Equations
	Powers & Roots			Logarithms
	Negative Numbers			Matrices
	Scientific Notation			Advanced Probability
	Problem Solving			Advanced Statistics
First Year-Algebra				Non-Linear Systems
	Using Formulas			Circular Functions
	Linear Equations			Graphs of Trig. Functions
	Polynomials			Trig. Identities
	Rational Expressions			Equations/Inverses
	Graphing 2-D			Oblique Triangles
	Linear Systems			Polar Coord. Graphs
	Radicals			Vectors
	Quadratic Equations		*Other Topics*	
	Algebraic Representation			Calculus & Higher Math
Geometry				Use Calculator
	Basic Terminology			Use Scientific Calculator
	Angle Measurement			Computer Use
	Congruent Triangles			Computer Programming
	Parallel Lines			Group Problem Solving
	Quadrilaterals			Mental Math
	Pythagorean Theorem			Induct/Deduct Reasoning
	Right Triangles			Math Communication

Appendix B

Cover letters, and follow-up letter.

123 Lane Hall, Blacksburg, Virginia 24061-0254

March 14, 1995

Finance Officer
Address
City, State Zip Code

Dear Name:

I am a graduate student at Virginia Tech University pursuing a degree in vocational-technical education. I am seeking your participation in my dissertation study of people in the occupation of finance officer. A finance officer is defined for this study as a finance or business degree college graduate employed in the banking industry. The major focus of this study is to determine the mathematics levels commonly used in the performance of the duties of a finance officer. This will be compared to the mathematics generally required in the education and training of persons in your field. This survey is being sent to approximately 60 finance officers. I value your participation and your response is important. Your responses will help provide data to be used for group comparisons. No individual will be identified.

I am requesting that you respond within one week of receipt of this letter. The time required to complete the instrument should be less than 10 minutes. Please complete the questionnaire and return it in the enclosed postage-paid envelope. If you have any questions, please contact me by mail, phone or fax. Your experience is important in assuring the value of this research.

My goal is to complete my dissertation and graduate in May. This will depend on my ability to collect data in a timely manner. Thank you in advance for your assistance.

Sincerely,

James DeWitt
(703)231-8207 office
231-3292 fax

123 Lane Hall, Blacksburg, Virginia 24061-0254

March 14, 1995

Family Physician
Address
City, State Zip Code

Dear Name:

I am a graduate student at Virginia Tech University pursuing a degree in vocational-technical education. I am seeking your participation in my dissertation study of people in the occupation of family physician. The major focus of this study is to determine the mathematics levels commonly used in the performance of the duties of a family physician. This will be compared to the mathematics generally required in the education and training of persons in your field. This survey is being sent to approximately 60 family physicians in the state of Virginia. I value your participation and your response is important. Your responses will help provide data to be used for group comparisons. No individual will be identified.

I am requesting that you respond within one week of receipt of this letter. The time required to complete the instrument should be less than 10 minutes. Please complete the questionnaire and return it in the enclosed postage-paid envelope. If you have any questions, please contact me by mail, phone or fax. Your experience is important in assuring the value of this research.

My goal is to complete my dissertation and graduate in May. This will depend on my ability to collect data in a timely manner. Thank you in advance for your assistance.

Sincerely,

James DeWitt
(703)231-8207 office
231-3292 fax

123 Lane Hall, Blacksburg, Virginia 24061-0254

March 14, 1995

Electronics Technician
Address
City, State Zip Code

Dear Name:

I am a graduate student at Virginia Tech University pursuing a degree in vocational-technical education. I am seeking your participation in my dissertation study of people in the occupation of an electronics technician. The major focus of this study is to determine the mathematics levels commonly used in the performance of the duties of an electronics technician. This will be compared to the mathematics generally required in the education and training of persons in your field. This survey is being sent to approximately 60 electronics technicians in the states of Virginia Maryland, and North Carolina. I value your participation and your response is important. Your responses will help provide data to be used for group comparisons. No individual will be identified.

I am requesting that you respond within one week of receipt of this letter. The time required to complete the instrument should be less than 10 minutes. Please complete the questionnaire and return it in the enclosed postage-paid envelope. If you have any questions, please contact me by mail, phone or fax. Your experience is important in assuring the value of this research.

My goal is to complete my dissertation and graduate in May. This will depend on my ability to collect data in a timely manner. Thank you in advance for your assistance.

Sincerely,

James DeWitt
(703)231-8207 office
231-3292 fax

123 Lane Hall, Blacksburg, Virginia 24061-0254

March 14, 1995

Machinist
Address
City, State Zip Code

Dear Name:

I am a graduate student at Virginia Tech University pursuing a degree in vocational-technical education. I am seeking your participation in my dissertation study of people in the occupation of a machinist. The major focus of this study is to determine the mathematics levels commonly used in the performance of the duties of a machinist. This will be compared to the mathematics generally required in the education and training of persons in your field. This survey is being sent to approximately 60 machinists in the states of Virginia, Maryland, and Kentucky. I value your participation and your response is important. Your responses will help provide data to be used for group comparisons. No individual will be identified.

I am requesting that you respond within one week of receipt of this letter. The time required to complete the instrument should be less than 10 minutes. Please complete the questionnaire and return it to your supervisor or manager. If you have any questions, please contact me by mail, phone or fax. Your experience is important in assuring the value of this research.

Thank you in advance for your assistance.

Sincerely,

James DeWitt
(703)231-8207 office
231-3292 fax

123 Lane Hall
Blacksburg, VA
24061-0254
(703) 231-8207 office
231-3292 fax

March 26, 1995

Name
Address
City State Zip Code

Dear Name,

Approximately two weeks ago a brief questionnaire was mailed to you requesting your participation in a study of *occupation*. At this time our records show that we have not received a response from you. If you have mailed it, thanks for your time. In case you never received the original, another questionnaire is enclosed for your convenience.

I am an elementary school teacher on leave working on completing my graduate degree. The completion on my degree depends on my ability to gather more surveys from *occupation*. Please take a few minutes from your busy schedule to complete the survey and return it this week.

Thanks for your time and help!

Sincerely,

James DeWitt

Appendix C

Questions used during the interview sessions with two members of the four selected occupations.

Interview Questions

Person being interviewed? ______________________________

Date: ______________ Time: ___________________

1. Your occupation is __________________________.

2. Where do you work ? __________________________

3. How long have you been working in the occupation?_______

4. What is your educational background?

____

Degree? ______________________________________

6. What was the highest math course you completed?

____

7. Tell me how math is used during the course of your duties.

____

8. How much time is spent using math in your work?

____

9. Do you use a calculator? How much?

____

10. Do you use a computer for math purposes? How often?

____

11. Could you discuss the connection between the math you took during your training and its application to your work?

____

____

12. What would you tell someone about to enter your occupation about the use of math on the job?

____

13. What role does the math level required during the education and training play in encouraging or discouraging people from choosing your career field?

____

____

14. Are there any comments you would like to make about math as it relates to your education/training and your work?

____

____

Appendix D

Written comments from the questionnaire

offered by the participants.

Comments Drawn From Finance Officers Questionnaires

Comments are transcribed in original form.

1. (4) Math is used to calculate amortization schedules, interest on loans, and other simpler functions.

2. (22) Although higher math is not utilized on a daily basis a finance officer must have that underlying foundation, knowledge in higher math issues in order to apply them on a practical basis (if not theoretical).

3. (23) Time value of money is most important application- algebra is used for problem solving is rarely, if ever used and applied, in my profession although we may hire companies to do statistical research & employ higher math in their work.

4. (25) Basic math skills required for my job as an administrator are "simple math" = adding, subtracting, percentages. While at college if I had my druthers, I would have preferred to take a class of specific applications to the work place instead of grueling over calculus.

5. (29) Understanding basic algebra is essential.

6. (40) Real estate loans use a much higher level of math in that process, including discounted cash flows and ratios.

7. (47) Mental math is very important but higher level math is not needed.

8. (49) Although basic math skills are used day in to day out, higher math (ie. statistics) is important in understanding the financial products that I deal with.

9. (53) Math skills also translate into logic/ reasoning skills and as such, math should not be viewed solely as numbers.

10. (55) I am a manager in trust operations, the majority of my time is spent planning for the unit and managing the people within the unit.

11. (64) Banking still uses general math and accounting.

12. (68) Higher level math courses were a waste of my time.

13. (74) Since I graduated I have not seen or used any higher levels of math.

14. (85) An understanding of higher level math is important to certain areas of our bank (finance, corporate accounting, mergers and acquisitions, investment banking, etc.) but not in my particular area.

15. (89) Although higher level math is not used often , a basic understanding of the higher level math is needed to manage your portfolio and in everyday conversations with customers.

16. (93) Finance courses are not absolutely necessary but they do add alot to job performance.

17. (94) You need to be a salesman, not a mathematician.

18. (96) I don't need overly sophisticated skills, but being quick minded with addition subtraction, multiplication and division is an asset that aids in my customer service.

19. (97) Although I do not use higher math on a regular basis in my job, those courses in college helped me learn to think logically, which is extremely important in this profession.

Comments Drawn From Family Physician Questionnaires

Comments are transcribed in original form.

1. (4) I use "basic math" everyday but also some trig & freq algebra. Never calculus or higher functions. I consider higher math = calculus.

2. (106) 4th grade math is all I need.

3. (112) Thinking processes required in higher level math are good preparation for problem solving in medicine.

4. (14) I rarely use higher level math in performing my day to day practice. But higher level math skills were very important in preparing me to get to where I am. I use math with almost each patient encounter.

5. (21) Statistics important in interpreting medical research- basic math used daily.

6. (30) Still use some algebra is that considered higher math?

7. (38) Higher levels of math are important in understanding the concepts of medicine.

8. (40) In reviewing an article, some exposure to higher math helps- like it or not. I'm a believer in that, "if you don't use it you lose it." Most of the work is already done for us.

9. (42) Higher level math is not routinely used in family practice daily duties; however, I believe an understanding of higher math, statistics, etc. is still valuable as part of the preparation.

10. (43) Higher level math courses were required for my premedical science courses like biology, chemistry and physics. However once I finished residency, I did not use it at all in my daily routine.

11. (47) Understanding higher math is often important yet I don't need to perform actual functions.

12. (51) Basic math, occasional algebra is all I ever use.

13. (53) I think the type thinking involved with higher math is essential to developing the analytical skills of any profession, especially medicine.

14. (54) The math theory helps me understand the epidemology & physiology & chemistry I need to work.

15. (57) Higher level math need for required premed courses ie. physics, chemistry, etc. but not necessary for practice of medicine.

16. (62) Statistics rather than calculus would have been of more use.

17. (66) Although I don't use the math skills I learned directly, the problem solving and logic training may have helped develop my ability to think and reason.

18. (74) Much of math is not used day to day but rather in comprehension of and review of journal articles.

19. (76) I do not use higher level math on a daily basis to perform my job, the concepts were vital to scientific courses required for medicine.

20. (78) Computer literacy will be very important in the future, however direct use of math skills beyond calculations are used rarely routine office/hospital practice.

21. (80) Computer literacy will be much more important to the physician of the near future.

23. (81) Familiarity with some concepts of calculus & statistics is helpful in evaluating medical journal articles.

24. (83) Higher level math is not used in the actual practice of medicine but is required to understand the foundations which are the groundwork for medicine (eg. physics & organic chemistry) Calculus is not important.

25. (85) Good background to understand what's happening, limits medical use.

26. (86) Higher math is important in understanding many of the biological concepts I need to understand, even if I don't routinely use the math.

26. (89) Higher level math is necessary to understand concepts of medicine and diagnostic imagery etc. in training. Not, however used in day to day practice.

27. (91) If "higher level math skills" may include statistics, then understanding these is far more important than it used to be.

28. (94) Math background helps in basic sciences in med school; also helps in understanding of statistical analysis when reading medical literature.

29. (98) Although higher level math is used infrequently I feel the background is important.

Comments Drawn From Machinist Questionnaires

Comments are transcribed in original form

1. (3) I would like to have a refresher courses in math.

2. (4) As an aircraft parts machinist, computer based operations and calculations are becoming more important with each new generation of aircraft.

3. (33) Math and English are crucial to meet the challenges, demanded by increasingly high technology positions. To be able to compete in the labor force.

4. (34) There are aspects of duties where math is not used and some people can spend the majority of their time working without using math.

5. (37) I believe that everyone should have to complete at least algebra to graduate from high school.

6. (49) It was nice to learn all the math at New River Community College but, you don't need it to turn a <u>wrench</u>.

7. (63) Algebra & geometry are used frequently with CNC equipment, trigonometry is very helpful.

8. (71) There is a need for basic math in the machinist field every day. The need for more math in the machinist field determines how well the individual performs their work with very little supervision.

9. (72) Schools today are requiring students to take courses they do not need, and do not give them enough hands on learning on the machinery they will be required to use when they finish school (Owner of a machine tool shop.)

10. (76) Use basic math and technical math with occasional uses of algebra and trigonometry.

11. (87) I feel that a modern machinist uses a higher degree of math today.

12. (88) Computers are taking away needed math skills and the younger people entering this profession are depended on calculators and computers.

Comments Drawn From Electronics Technician Questionnaires
Comments are transcribed in original form

1. (1) Higher math is needed more in design and engineering work. A technician usually don't calculate circuits on a daily basis unless he is re-engineering an already design circuit.

2. (2) I am an electronics technician in the coast guard.

3. (4) Math was used in classes only, mostly now just Ohms law.

4. (6) Engineering math is used more than scientific notation.

5. (14) Electronics field of repair require little math; engineering requires most of the higher level math.

6. (16) Their is a lot of math skills to be done, if you don't know how to use formula charts, but if you know how to use charts and other short cuts, it eliminates the need for higher level of math. A scientific calculator is a very important tool of a technician.

7. (23) Large difference in engineering tech skills versus maintenance skills for electronic tech. I believe some math skills can be helpful but not absolutely required.

8. (24) I work with math so often because I am an instructor of tech electronics as well.

9. (27) If you are not military trained or have a BS and a lot of experience that all the math skills in the world will not help.

10. (30) It would be very interesting to know the results of your study.

11. (36) Things that you describe as "higher math" may not be needed regularly, but they are needed from time to time. They are also needed if a technician has any thoughts of advancement in his/her profession.

12. (37) Although actual math usage may not be frequent, the ability to understand it and recognize its usage is

necessary, particularly when employed as an engineering technician.

13. (39) Order of importance (math, writing), reading, speaking. Writing holds a close position to math.

14. (41) I work mainly in installation of electronics, antenna, and cable systems. Meters and engineers have done the bulk of the math work.

15. (42) I could do more engineering jobs if my math skills were not limited to a basic calculus course.

16. (58) Higher math should still be introduced for the rare times it is used and to get a better understanding of the basics.

17. (63) You must know basic math, pre-algebra and a little trig. to be an electronic technician. But it seems you hardly ever get down to working out formulas to solve electronic circuit malfunctions.

18. (66) Higher math is essential in electronics education but not essential in the actual profession. I believe a tech who has higher math skills may be more organized in his/her thought processes and have a better developed analytical approach to problem solving.

19. (73) Main job function is design and design consulting is why I use algebra.

20. (76) Calculations are made on the nameplate of most machinery used. All calculations I make are forms of Ohms law, 90% of which are calculating full load amps to judge wire size. All other calculations are done by the CAD system I use.

21. (80) If my opinion counts I would increase the amount and intensity of math courses in almost any curriculum or profession.

22. (84) If working with analog circuits, higher level math is not necessary for just testing, but for troubleshooting and understanding the circuit it is. With digital circuits math generally doesn't come in to play.

VITA

James Edward DeWitt was born on in Louisville, Kentucky. He is one of nine children, having four brothers and four sisters. He credits an early interest in education to his teachers who encouraged him to rise above the limitations of poverty. His stellar attendance record proved a desire to prepare himself for a future beyond high school. In high school he earned a letter as a member of the football and track team.

After graduating from high school, James was drafted into the military service 18 months later. During the 21 months spent in the U.S. Army, he served a one year tour of duty in Vietnam before being discharged. As a result of his military service he was able to attend college on the G.I. Bill, while working his way through to earn a degree. He received a dual BS Degree in Special and Elementary Education from the University of Kentucky in 1975. Following graduation he began teaching the trainable mentally handicapped in a public school schools system. After serving four years as a coach, job counselor, shop teacher and special olympics coordinator, James decided he needed a change.

It was during this time that he gained employment with the airlines. The airlines transferred him to Washington, DC. on a special assignment. The new position on capitol hill was travel coordinator for the U.S. Senate and House of Representatives from 1979 to 1984. The next four years were spent at the Department of State in a similar position working with the diplomatic corps. Working for the airlines afforded James and his family the opportunity to travel extensively all over the world. His favorite place to visit was Tahiti.

In 1988, due to the impeding bankruptcy of Pan American Airlines, he returned to the profession of teaching. This time he was hired to teach elementary school in Fairfax County, Virginia. While teaching 5th grade, he maintained teaching adult education classes at night. These adult education classes were teaching building trades for Arlington County. In 1993, James earned a Masters Degree from Virginia Tech in Vocational & Technical Education. In that same year he was selected to teach in the Gifted and Talented Program with Fairfax County Schools. In this position he has been lead teacher, student council sponsor, and science coordinator.

In 1994 he began working on his Doctor of Philosophy Degree in Vocational and Technical Education. All requirements for this degree were completed in August, 1996 at Virginia Tech University. James holds membership in the American Vocational Association, Omicron Tau Theta and National Education Association.

James Edward DeWitt