8-1993

Academic background and prerequisite skills for success in college freshman physics

Jean Friend Condrey

ACADEMIC BACKGROUND AND PREREQUISITE SKILLS FOR SUCCESS IN COLLEGE FRESHMAN PHYSICS.

by

Jean Friend Condrey

B.S., Radford College, 1974

A Thesis

Submitted to the Graduate Faculty

of the University of Richmond

in Candidacy

for the degree of

Master of Education

in

Supervision

August, 1993

Richmond, Virginia

I certify that I have read this thesis and find that, in scope and quality, it satisfies the requirements for the degree of Master of Education.

Dr. Elaine Traynelis-Yurek
Thesis Advisor

Dr. H. Bruce Cobbs

Dr. R. Wayne Major

Abstract:

Instructors of college freshman introductory physics in Virginia, North Carolina and West Virginia were surveyed to determine which academic courses, technical skills and general skills acquired in high school are essential for success in their courses. Faculty responses were analyzed using mean and percent frequency, while comparison of their responses by size of physics department was analyzed using chi square. Each student's responses were compared to those of his or her instructor using a paired sample t test. The general skills of English language usage were found to be the most important skills. Results from the students surveyed indicated similar findings with some exceptions. No significant difference between frequency distributions was found in comparing responses according to the size of the physics department.

Preface

This work is dedicated to Matt and Chuck, my primary reasons for improvement in physics education.

I would like to offer my heartfelt thanks for the help and support extended to me in this endeaver by Dr. Elaine Traynelis-Yurek, Dr. Wayne Major, Dr. Van Bowen, and Dr. Bruce Cobbs.

Table of Contents

Introduction

High school students have an interesting menagerie of motives for completing a physics course. A few are inclined to pursue a major in physics or engineering in college. They seek comprehension of the basic principles and the mathematics involved in their application. Some high school physics students simply wish to understand the interaction of the basic tenets of the physical world, but are apprehensive of the necessary mathematical manipulations. Others take the course having been coerced with the suggestion that it may affect their admission into a specific college. After graduation, a small portion of students will attend college in fields which require physics. Others will not be taking another physics course again due to their choice of major or the decision not to continue their formal education. Academically, high school teachers are challenged to educate all of their students about the physical world and to prepare them pedagogically for the challenges of college physics, future training, and real life.

This study endeavors to determine the minimum prerequisite skills and academic background for college freshman level physics courses as required by college physics faculty in three states from four year institutions which offer physics as a major. The research was completed for use by high school physics teachers to enhance the development of their methodology using those skills and technologies that will be the most advantageous for their students. These data can also assist high school teachers in advising their students of the prerequisite coursework considered mandatory for success in college freshman level physics by the physics faculty.

Background:

Physics curricula for the high school has been under study since the 1950's and suggestions for change in content and pedagogy have been numerous. Even more suggestions for change emerged with the publication of A Nation at Risk in 1984 and increased allocations of federal monies for science education. Criticism of current physics instruction is typified by Sheila Tobias (1990). She states that only the needs of first tier students are being met in physics instruction, first tier students being those who will not be deterred from studying science even by poor teaching. Her recommendation is for differentiated recruitment of second tier "nonscience" students and a change in teaching technique to appeal to their different learning styles, expectations, levels of discipline, and "kinds of minds".

One current and broad sweeping recommendation for change is the Scope, Sequence, and Coordination Project developed by the National Science Teachers Association (NSTA). Bill G. Aldridge (1989), Executive Director, recommends the alteration of the entire science curricula by changing to a fully integrated science program, thereby nullifying the delineation between the separate disciplines and exposing all students to all of the sciences. The American Association for the Advancement of Science (AAAS) has also proposed a major change in the present science education system. Its proposition, Project 2061, espouses the central goal of "science for all Americans" and basically follows similar reform suggestions for the integration of science and mathematics through the use of broad themes (Yager & Blosser, 1991).

The vast majority of research in physics education today offers recommendations for change that are substantially smaller in scope than the NSTA and AAAS programs but with the capacity for significant levels of effect on the outcome of physics education. Shavelson, Carey, and Webb (1990) introduce the possibility that simply changing the way science achievement is measured will improve science education. Their study on the symbolic representation of questions and responses showed that performance on tests was highest when the symbolic representation of the question and requested response were the same. Specifically, performance was high when numeric/algebraic questions solicited a numeric/algebraic response and when word problems solicited a verbal response, but performance was exceptionally low when word problems required a numeric response. They conclude that the current science achievement tests measure facts and only isolated skills, but not conceptual understanding and problem solving skills. They suggest that by changing the way achievement is measured, teaching to the test will require improved instruction on concept comprehension, procedures, and problem solving strategies.

Many physics educators promote the introduction of teaching methods using microcomputer based laboratory instruction (MBL) to enhance comprehension of the concepts as well as increase the connections between the abstracts of graphing and real time interactions (Laws, 1991; Thornton, 1987; Morse, 1991).

Ernest L. Boyer, president of the Carnegie Foundation for the Advancement of Teaching, recommends the development of school-business partnerships to allow for the enrichment of gifted students, particularly in the science and mathematics fields (1983). He also suggests the development of high school-college partnerships to establish standards, educate teachers, enrich the progress of advanced students, and enrich the schools.

Increased inservice programs that are more relevant to the needs of teachers have been endorsed by Baird and Rowsey (1989). In their survey of 797 high school science teachers in Alabama the top four rank order needs for inservice were to:

"1) Motivate students to want to learn (80%).
2) Identify sources of free/inexpensive instructional materials (78%).
3) Use computers to deliver science instruction (70%).
4) Update personal knowledge of human utilization of science/technology (69%)."

It is important to scrutinize and evaluate all of the recommended changes for physics education to direct our attention to deficiencies and lead us to constructive growth. But it is also necessary to determine what is salubrious in the current system. High School physics teachers need to have an accurate assessment of the specific academic background and basic skills college physics faculty consider necessary for success in freshman level physics as it is taught now. Research to determine what college physics faculty are utilizing has not been conducted with secondary education in mind.

The current studies make strong cases for the use of new techniques and technology; inservice programs are available in physics for curriculum development, teacher enhancement, and on the use of these new technologies and their associated equipment. High school teachers have not had any clear direction as to which of the plethora of new programs and technological advances warrant either the time and expense necessary to seek training or an allotment of the few budgeted dollars set aside for physics equipment. Physics teachers cannot relinquish class time to teach skills and technologies that will not be used or are not considered beneficial by college physics faculty. Time can be better spent instructing students in the use of those skills and technologies which will be the most productive for their continued learning.

Rationale:

A survey of secondary school physics teachers conducted by the American Institute of Physics in 1986 found that 82% of all public and private high schools in the United States offer a regular physics course or physics for "nonscience" students. Approximately 5% of all students in the public high schools will enroll in a physics course (Welch, Harris, and Anderson; 1984). Few schools offer AP Physics, the determining factor being total school enrollment. Of schools with two or more physics teachers, 46% offer an advanced level of physics as compared to 6% in schools with only one physics teacher. Only 1% of all students take more than one year of physics in the high school (Neuschatz and Covalt; 1988).

The quality of these physics courses differs substantially with some of the variations caused by the teacher's undergraduate grade point average and graduate degree (Bodenhausen, 1989), the personality and value system of the teacher (Rothman, Welch, and Walberg; 1969), the geographic region of the school and the percentage of minority group enrollments (Neuschatz and Covalt, 1988).

These divergences in quality have left researchers divided as to the virtues of Physics and AP Physics offerings in the high school. Some feel that any physics is better than no physics (Fort, 1990), and that all students must be encouraged to take the course, but on a level that is commensurate with their style of learning (Tobias, 1990). Aldridge (1989) takes the position for an integrated science curriculum because teaching physics in a one year course is too massive a task to expect retention of much of the material for any length of time. Yager and Krajcik (1989) suggest that physics is not necessary in the high schools.

Their study showed students without high school physics could achieve as well as those who completed the course, provided they spent 3 - 4 times the number of hours in tutoring.

Mathematics requirements for most high school physics courses include Algebra II, Trigonometry, or Calculus. Physics courses on the university level also vary in the level of mathematics used in instruction. Conceptual courses require limited mathematic background while introductory level calculus based physics courses require students to have a working knowledge of the highest level of mathematics made available in the high school. In her paper <u>They're not dumb, they're different: Stalking the second tier.</u>, Tobias (1990) states that mathematics is more important for success in college science than more science in the high schools and stresses "early and continuous exposure" to higher levels of mathematics for the majority of students. On the premise that a higher level of mathematics means success in science, it is possible that courses which require lower levels of mathematics may be reinforcing students to be unsuccessful in science.

Effective instruction requires the completion of specific objectives. In the high school, the goals of physics courses include subject content as well as technical skills and the proficient use of language. As with mathematics, the level of technology and the quality and quantity of written and verbal skills used in the high school physics classroom varies significantly.

The use of computers in the science classroom is recommended by many researchers for its positive effects on attitudes (Thornton, 1987; Morse, 1991; Hounshell and Hill, 1989). MBL is stressed as a constructive tool to increase creative and critical thinking skills in the physics classroom (Thornton, 1987) and afford the students greater opportunity to develop transferable skills in scientific inquiry through concrete experience with everyday phenomena (Laws, 1991). McDermott, Rosenquist, and van Zee (1987) concluded from their research that students are unable to make the connection between graphical analysis and the physical concepts, but recent studies have shown improved comprehension of graphs using real time analysis with MBL (Brasell, 1987; Laws, 1991). Through the use of MBL the laboratory can become discovery-based with the students taking an active collaborative role in their own learning (Thornton & Sokoloff, 1990). In his research of computers as a teaching tool, Morse (1991) concludes that the use of MBL and computer assisted instruction (CAI) can improve learning in the science classroom.

Prior to the 1980's, large numbers of studies praised the use of CAI in the classroom, but showed little increase in productivity. In studying its use in chemistry, Wainwright (1989) concurred with these earlier findings concluding that CAI was no more effective for comprehension of the concepts than traditional paper and pencil work. Responses to a 1989 College Board survey on the use of calculators and computers confirmed this impression of equity (Pfeiffenberger and Zolandz, 1989). The survey concluded that computer usage is generally varied in the high schools, but computers are not used in the majority of classrooms. One possible reason for this as suggested by Reif (1987) is the inadequacy of instructional design in the educational use of computers in the classroom. Courses have not been modified to accommodate their usage in either high school or college physics (Pfeiffenberger and Zolandz (1989).

The use of scientific calculators is permitted or required by the vast majority of physics teachers in both high schools and colleges as determined by the 1989 College Board survey. Scientific calculators are preferred over programmable and simple function calculators by students and faculty (Pfeiffenberger and Zolandz, 1989). Graphing calculators are lauded by mathematics researchers as a means of closing the gap between algebra and calculus and enabling students to develop a deeper understanding of algebraic concepts (Demana and Waits, 1990). The National Council of

Teachers of Mathematics assumes that all 9th through 12th grade students will have access to a graphing calculator and a demonstration computer (1989).

To complete the goals of secondary physics curricula the proficient use of language must be cultivated. The development of general skills in the English language is achieved through instruction and modeling from experiences with others. These skills are essential for clear communication, critical thinking, and problem solving.

Chomsky (1972) describes language as a creative activity. He maintains that to have command of a language is to internalize a system of rules which allows a relation between sound and meaning; an ability to understand what is said and generate meaningful speech with an intended interpretation. Thought embodied in speech gives meaning to words, but words do not necessarily generate the intended connotation (Vygotsky, 1962).

Clear communication is an acquired skill. To effectively use a language, communication skills must be developed to make speech meaningful. This development is dependent on memory, skill acquisition, and reasoning ability (Vygotsky, 1962) as well as the cognitive capabilities of symbolic representation, abstraction, categorization, and generalization (Ausubel, 1968). Ausubel perceives these cognitive capabilities as directly related to linguistic developments. The internalization of logical operations, the ability to understand and correlate abstracts and the ability to synthesize hypothetical relations are directly correlated by Ausubel to the developments of linguistic symbolic representation, syntax, language internalization, and development of abstracts. He generalizes that growth in language capability will result in a growth in logical thinking.

Verbal expression is a significant factor in the transfer of learned concepts within problem solving situations (Ausubel, 1968) and for concept attainment (Heidbreder and Zimmerman, 1955). Group problem solving is a suggested method of increasing discussion among students and improving achievement (Slavin, 1982). It is recommended by the College Entrance Examination Board that students planning to attend college have basic academic competencies in reading, writing, speaking and listening, reasoning, studying, and mathematics (1983). In secondary schools these competencies must be acquired within the content area and planned for within the curriculum if they are to be of significant value.

Given the diverse background of college freshman in academics, technical skills, and the general skills of language usage, offering courses which vary in content and methodology is one solution to the dilemma of meeting the instructional needs of all students taking introductory physics. Many colleges and universities establish prerequisites that differ for physics courses developed to educate physics and engineering majors from those developed for other students. This practice generates two or three different levels of instruction for an introductory physics course with variation in content, level of mathematics, technology used, and conceptual level.

Method:

The purpose of this survey was to determine the relative significance of certain skills and academic courses for the high school physics student as established by physics faculty of four year institutions which offer physics as a major in the states of Virginia, North Carolina, and West Virginia. Freshman level physics students were surveyed for comparison with their instructor's responses to determine if the importance established by the instructor was the same as the emphasis actually transferred in the classroom and laboratory as perceived by the student.

Subjects

The faculty surveys represent 50 different colleges and universities. The colleges were separated into groups of large, mid-size, and small according to the number of full time faculty supported by the institute. Small departments represented 28 colleges and universities with a 1 - 6 member physics faculty (N=52). Mid-size departments had between a 7 - 15 member physics faculty and represented 13 colleges and universities (N=35). Large departments had a physics faculty of 16 - 35 members and represented 9 universities (N=13).

The students who completed the survey (N=369) were 53% male and 37% female with 9% giving no response. None of the students were between the ages of 15 -16, 36% between the ages of 17 - 19, 52% between the ages of 20 - 22, 5% between the ages of 23 - 25, and 5% declared to be 26 years of age or older. No response was given for 2% of those surveyed. The final grade for the last English course taken was an "A" or "B" for 83% of the students with 12% declaring a "C".

Apparatus:

A survey was developed to generate data on the relative importance of specific prerequisites in the areas of academic background, technical skills, and general skills (see Appendix I). A five point Likert scale was used for responses as follows: 1 = "mandatory", 3 = "beneficial but not mandatory", and 5 = "not mandatory".

Procedures

A list of four year institutions of higher learning which offer a major in Physics in the states of Virginia, North Carolina, and West Virginia was acquired using the Guidance Information System (GIS). There are 54 institutions which fit these criteria. Phone contact was made to 37 of these colleges and universities to generate a list of faculty members who teach the freshman level physics courses. A total of 114 surveys were mailed to the instructors of freshman level physics with a 88% return rate. Faculty members from 10 of these colleges were requested to distribute and return the student surveys. From these 10 colleges 369 student surveys were returned.

Results:

Faculty responses were compiled to determine the percent of frequency, mean, and standard deviation for each question (see Table 1). Comparison of the student responses to the responses of their instructor was completed through the use of a paired-sample t test with a probability of error of $\pm .05$. Analysis of faculty responses according to the size of the institute was made using chi square with 4 to 8 degrees of freedom depending on the question. A five point Likert scale was used for responses as follows: 1 = "mandatory", 3 = "beneficial but not mandatory", and 5 = "not mandatory".

Table 1

Statistical Analysis of Faculty Responses:

Academic Background

	% Frequency						
	1	2	3	4	5	Mean	SD
Algebra II (n=100)	91	3	5	0	1	1.17	0.6
Trigonometry (n=100)	74	14	7	2	3	1.46	0.9
Calculus (n=99)	28	8	40	10	13	2.72	1.3
Physics (n=84)	6	13	64	5	12	3.04	0.9
AP Physics (n=82)	2	0	50	12	35	3.73	1

Table 1 (continued)

Statistical Analysis of Faculty Responses:

Technical Skills

	% Frequency						
	1	2	3	4	5	Mean	SD
Computers	2	8	56	12	22	3.44	0.9
Scientific calculator	63	16	17	3	1	1.63	0.9
Graphing calculator	0	2	25	20	53	4.24	0.9
Prior experience	1	19	54	13	13	3.18	0.9
Graphs and interpretation	43	45	10	2	0	1.71	0.7

n = 100

General Skills

	% Frequency						
	1	2	3	4	5	Mean	SD
English (n=100)	75	23	1	1	0	1.28	0.5
Ability to communicate (n=100)	55	41	4	0	0	1.49	0.6
Solve problems independently (n=100)	44	38	15	2	1	1.78	0.8
Solve problems in a group (n=99)	15	37	37	4	6	2.46	1
Illustrate problems (n=100)	40	35	22	2	1	1.89	0.9
Infer conclusions (n=99)	36	36	25	2	0	1.93	0.8

Data from the faculty survey denotes the general skills as the most consistently mandatory attributes of those listed in the survey for success in freshman level physics. These include the ability to read, write, and speak English clearly, the ability to communicate ideas logically and clearly, the ability to solve problems or situations independently, the ability to visually illustrate a situation described in a problem, and the ability to infer conclusions from data (see Figure 1). Only one general skill surveyed, the ability to solve problems as part of a student group, was considered more beneficial than mandatory (see Figure 2).

In the comparison of the student responses to those of their instructor, the students consistently valued all of the general skills surveyed as mandatory. Their values for the ability to solve problems or situations independently, the ability to solve problems as part of a student group, the ability to visually illustrate a situation described in a problem, and the ability to infer conclusions from data were consistently higher than the value assigned by their professor (see Table 2). The ability to read, write, and speak English clearly, and the ability to communicate ideas logically and clearly were consistently rated less mandatory by the students than by their instructor.

Figure 1
General Skills

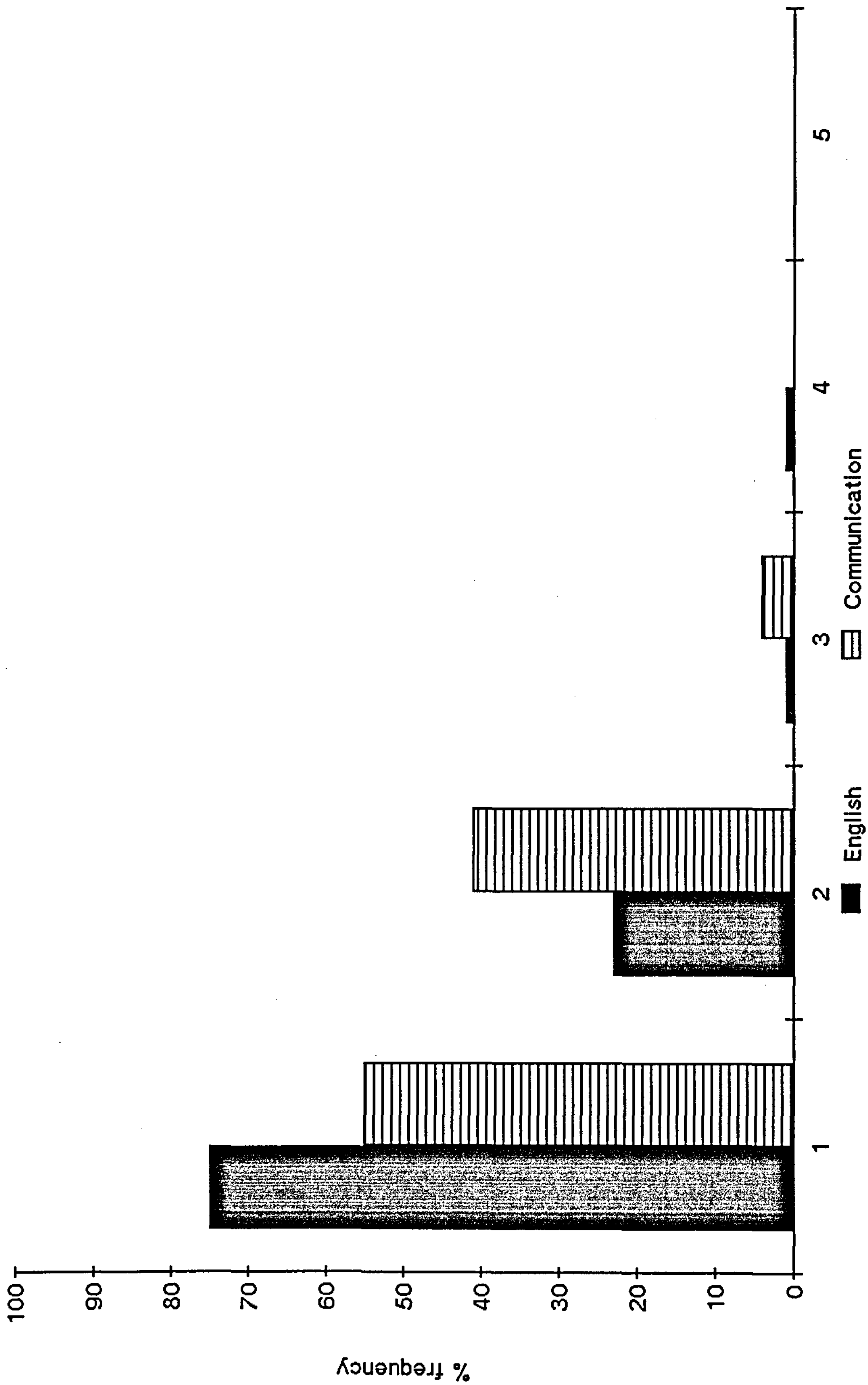

Figure 2
General Skills

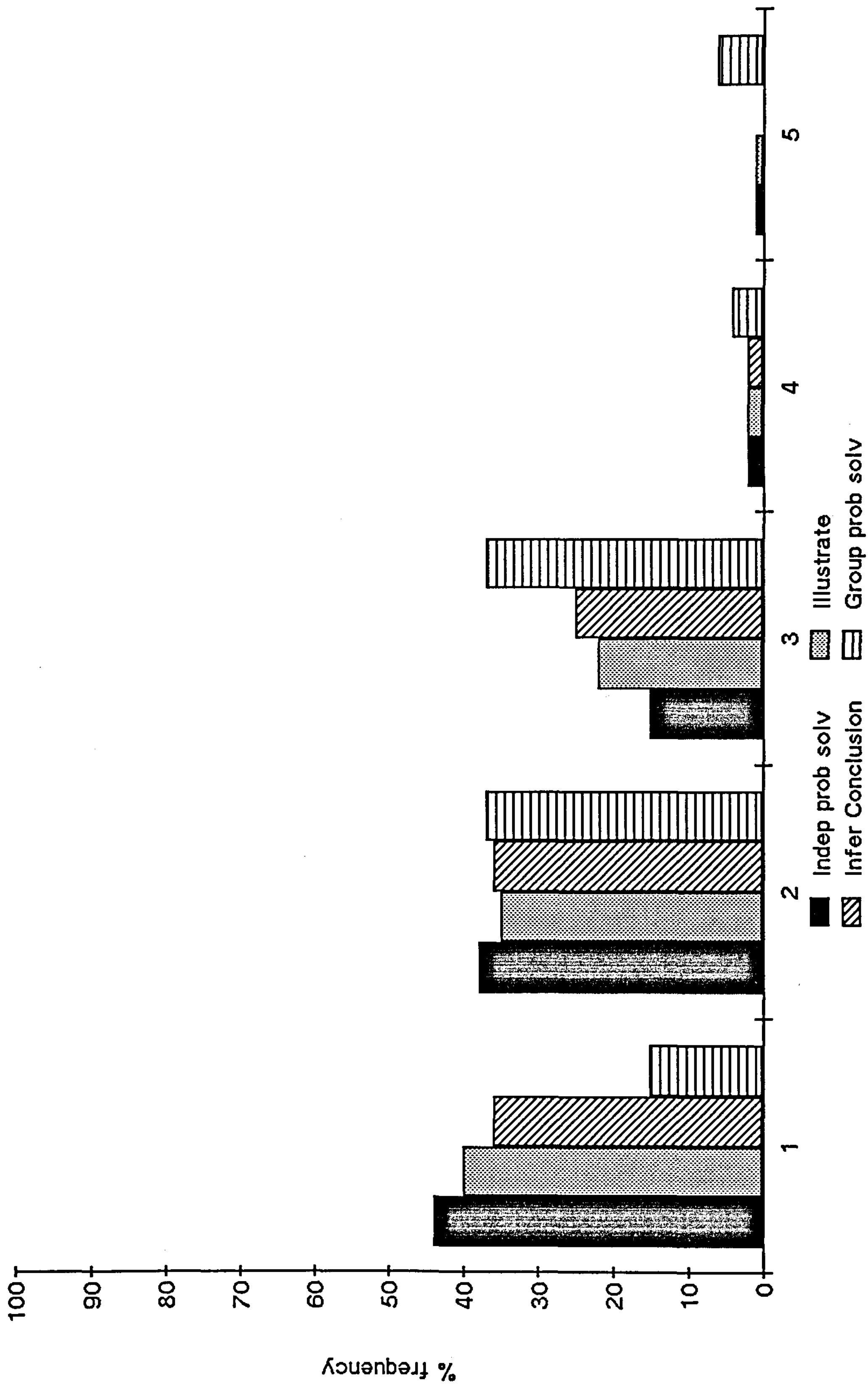

Table 2

Analysis of Students Responses to their Instructor's Responses

	Faculty mean	Student mean	t - value	df
Algebra II	no correlation		1	365
Trigonometry	no correlation		1.8	365
Calculus	no correlation		1.2	325
Physics	2.92	2.35	7.7	244
AP Physics	no correlation		0.09	235
Computers	3.44	3.86	5.4	364
Scientific calculator	2.07	1.55	6.8	365
Graphing calculators	no correlation		1.7	363
Prior experience	3	3.42	7.9	365
Graphs/interpretation	2.23	1.61	10	365
English	1.17	1.55	7.1	365
Communicate	1.27	1.56	6.2	364
Solve problems/indep	2.15	1.36	14.7	363
Solve problems/group	2.53	2.09	7.3	363
Illustrate problems	2.04	1.51	7.8	364
Infer conclusions	2.05	1.52	9.4	365

The technical skills the faculty identified as mandatory include the ability to use a scientific calculator, and the ability to graph data/interpretation of data (see Figure 3). Beneficial but not mandatory value was assigned to the ability to use computers, and the acquisition of some non-classroom experience in anything mechanical, optical, or electrical (excluding videogames). Graphing calculators were considered to be not mandatory (see Figure 4).

Students agreed with the full faculty survey on the isolation of mandatory technical skills but consistently rated these skills higher than their instructor. The students also agreed with the full faculty survey identification of beneficial but not mandatory technical skills, but consistently rated them as less beneficial than did their instructor. T test analysis of graphing calculators data did not indicate any correlation between the student responses and the response of the instructor.

Academic background results indicated Algebra II and Trigonometry are given mandatory value for freshman level physics courses by the faculty (see Figure 5). Physics and AP Physics were considered beneficial but not mandatory along with Calculus which was slightly more mandatory than the two physics courses (see Figure 6). No correlation was found between the student responses and their instructor for

Figure 3
Technical Skills

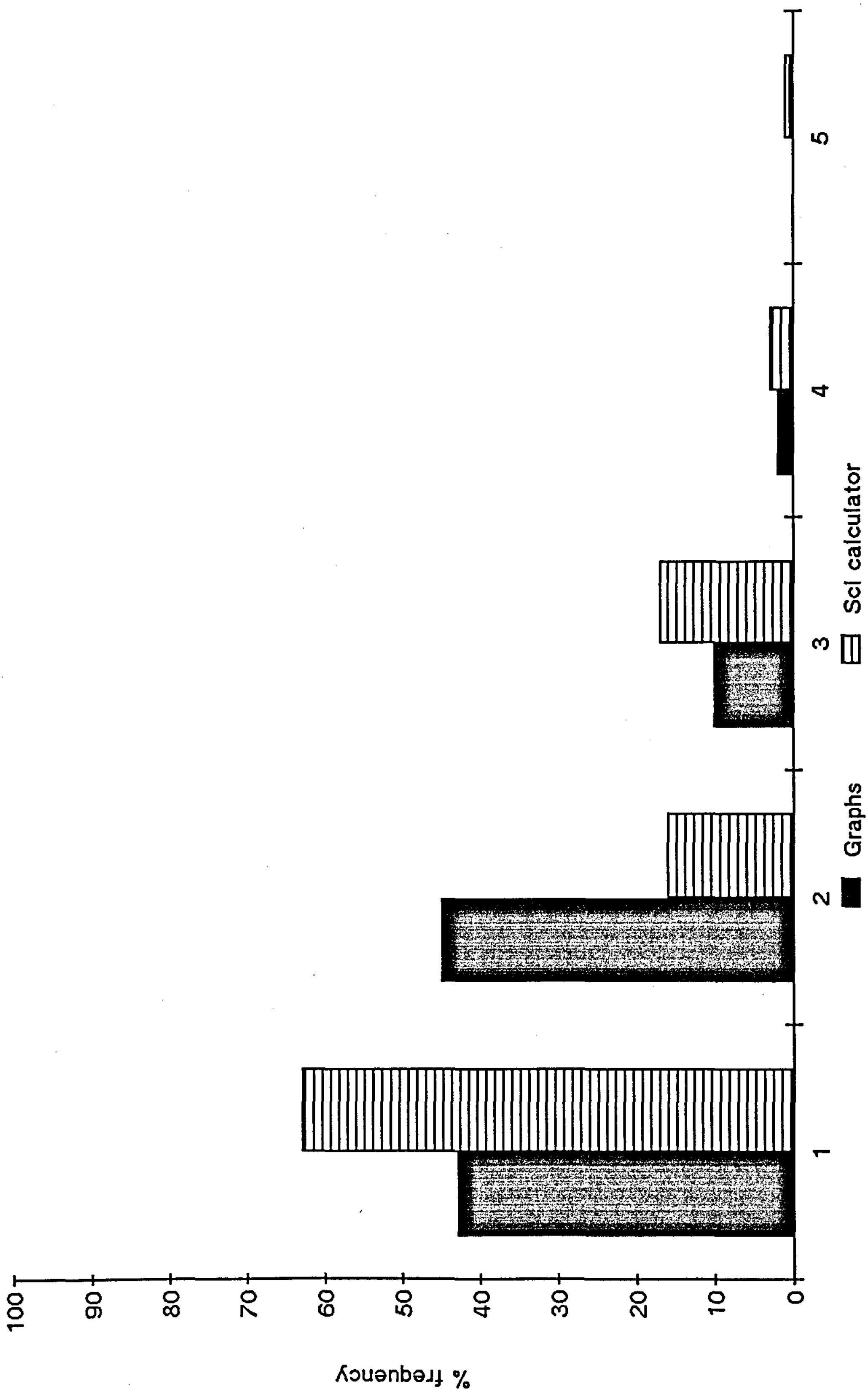

Figure 4
Technical Skills

Algebra II, Trigonometry, Calculus, or AP Physics. However, the students did consistently agree on the value of Physics. They felt it was mandatory and consistently rated it higher than the value assigned by their instructor (see Table 2).

Rank order listing of the mean of faculty responses in the three categories (see Table 3) shows that of all questions on the survey, Algebra II was rated higher than any other course with Trigonometry the second highest course rating (see Figure 5). Apparently college physics faculty agree with Tobias' thoughts on the importance of mathematics in the high school. In the area of General skills, the ability to read, write, and speak English clearly was rated higher than any other general skill with the ability to communicate ideas logically and clearly the second highest (see Figure 1). The ability to use a scientific calculator has the highest rating of the Technical Skills area of the survey with the ability to graph data; interpretation of graphs taking the second highest rating (see Figure 3).

The final question on the survey asked if the minimum prerequisite skill requirements for a first semester college physics course should be the same for non-majors and physics/engineering majors. The response requested was yes or no. Of the faculty 78% felt the prerequisites should not be the same for majors and non-majors. The students' responses were consistent with their instructor and agreed

Figure 5
Academic Background

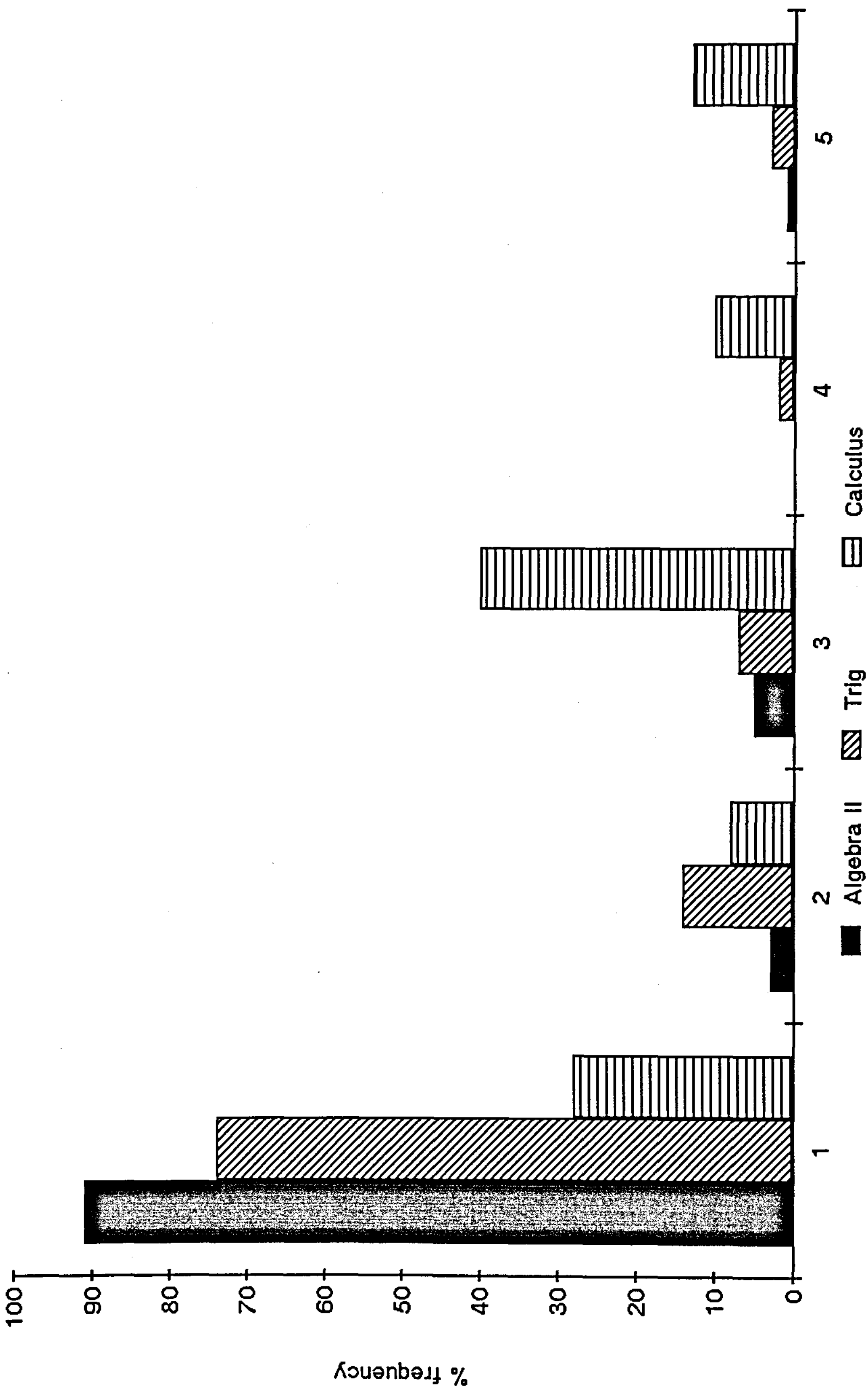

Figure 6
Academic Background

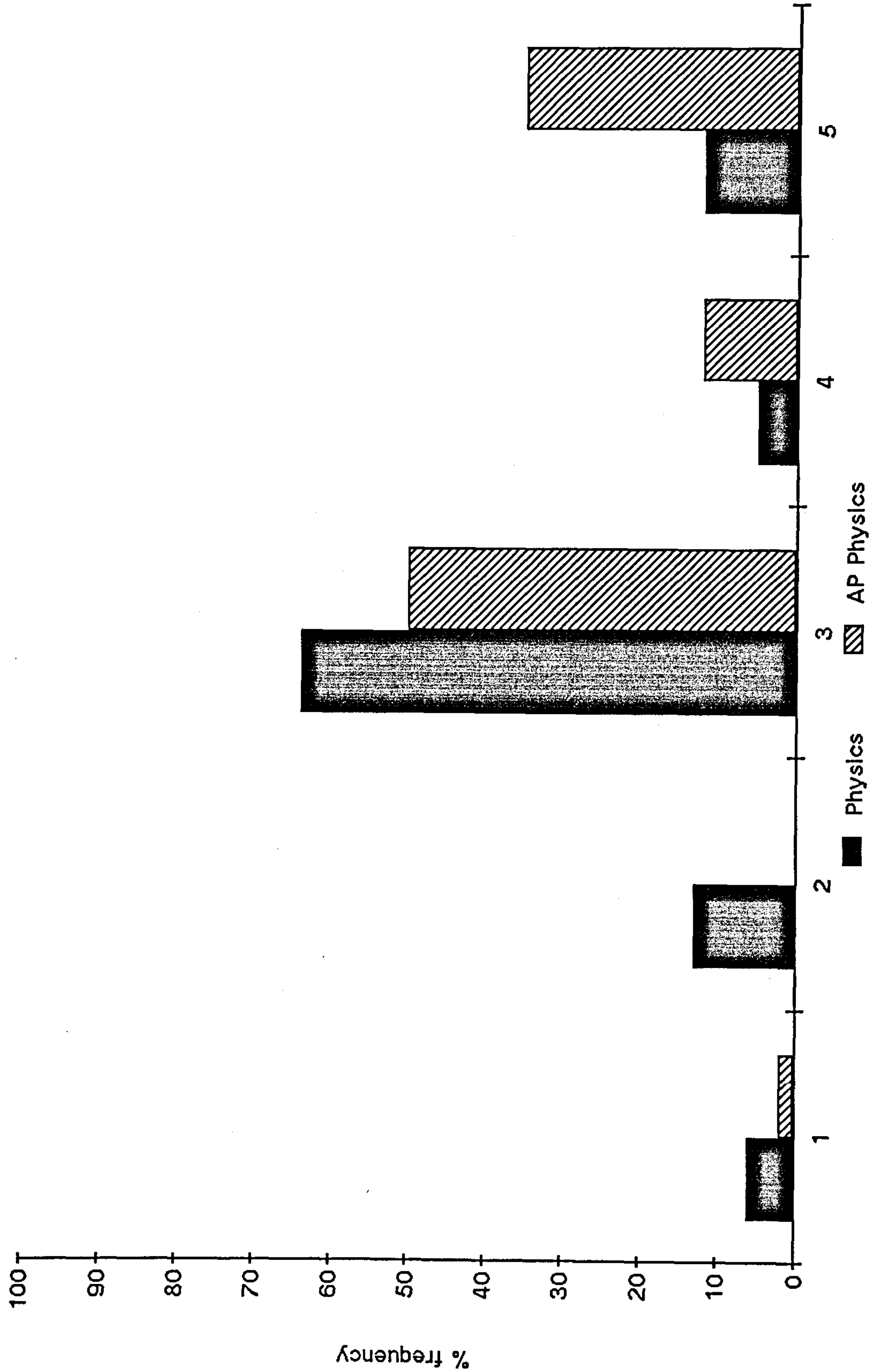

Table 3

Faculty Survey Rank Order According to Mean Response

	Mean
Algebra II	1.17
Ability to read, write, and speak English clearly	1.28
Trigonometry	1.46
Ability to communicate logically and clearly	1.49
Ability to use a scientific calculator	1.63
Ability to graph data; interpretation of graphs	1.71
Ability to solve problems or situation independently	1.78
Ability to visually illustrate a situation described in a problem	1.89
Ability to infer conclusions from data	1.93
Ability to solve problems as part of a student group	2.46
Calculus	2.72
Physics	3.04
Some non-classroom experience in anything mechanical, optical, or electrical(excluding videogames)	3.18
Ability to use computers	3.44
AP Physics	3.78
Ability to use graphing calculators	4.24

that the requirements should not be the same, but with slightly less conviction.

In an attempt to determine if the larger number of surveys from small colleges affected the mean responses on the full faculty survey, chi square analysis was used for comparison of the frequency distribution according to the number of full time physics faculty members in each institution. Small departments were defined as having from 1 - 6 full time faculty members in physics and included 28 institutes (n=52). Universities with from 7 - 15 full time physics faculty members were defined as mid-sized. There were 13 universities in this category (n=35). A large department was defined as having from 16 - 35 members and included 9 universities (n=13). Results from the analysis showed no significant difference in the frequency distribution according to size of the physics department on any of the 17 requested responses on the survey.

The survey was conducted to determine the minimum prerequisite skills and the necessary academic background required for any freshman level physics course, either calculus or noncalculus based. Although there is a distinct difference in the mathematics level of the two courses, only high schools which offer advanced physics can make this prerequisite distinction. This study was written with all high schools in mind, not just those large enough to support an AP Physics class.

In the data collected on academic background, Calculus, Physics, and AP Physics showed a decreased number of responses on the student surveys. This may have been caused by the students not having taken the courses in high school, therefore being unable to recognize their use or respond as to their utility. Also, the location of the Physics and AP Physics on the survey may have effected the decreased number of responses. These factors may have significantly contributed to the lack of correlation with their instructors responses.

Conclusions

College professors of freshman level physics seem to be in general agreement as to the importance of language and communication skills. Ernest L. Boyer, president of the Carnegie Foundation for the Advancement of Teaching, reiterates the conclusions of many linguists in connecting writing and thought processes. He states that "clear writing leads to clear thinking; clear thinking is the basis of clear writing." (1983) This supposition should serve to remind educators of the importance of providing opportunities for challenge in the classroom and laboratory, both in the productive use of language skills and mathematics. Reading scientific journals, writing reports, communicating ideas, and developing problem solving skills must all be a central part of every physics curriculum. A professor from West Virginia contends students need strong language skills because "physics is an exact science and requires a precision of expression." This precision of expression must be cultivated within the course content.

Technology is still seriously delayed in making its way into college and high school curricula. Immediately after the publication of A Nation at Risk in 1984, all three of the states included in this study announced the generation of task forces to remedy their problems in education. Virginia and North Carolina developed task forces for

Science and Technology while West Virginia generated a task force for Technology and declared a new emphasis on science curricula (United States Department of Education, 1984). Since that time technological advances have been slowed or halted by budget cuts and staff decreases.

Graphing calculators are strongly encouraged in every high school mathematics classroom in the United States by NCTM national curriculum standards, yet they are not mandatory for freshman college level physics and the students are unable to agree on their usefulness. Computers have enormous potential in the laboratory through MBL, CAI, or data analysis from spreadsheets, yet they are also not considered mandatory by the college faculty for introductory level physics. Computer usage in the high school is as sparse and pedagogically disjointed as it appears to be in the colleges. These disparities serve to discourage further development of creative teaching techniques by those high schools which have and productively use computers and graphing calculators. If these technologies are not reinforced on the college level they are reduced to mental exercises on the high school level for those few schools equipped with modern teaching tools. According to the 50 colleges and universities which participated in the survey, the department size within the university does not alter these conclusions.

Inservice and summer teacher enhancement programs are available for high school and post-secondary teachers by progressive colleges and universities across the nation. Teachers can choose between programs emphasizing content, methodology, and technology which often feature the effective use of computers, graphing calculators, and/or telecommunications for the classroom. This training is not necessarily concordant with technological expectations of the college freshman physics courses. Physics teachers in secondary and postsecondary institutions need to seek training in computer usage and its integration into the curriculum. As computer use increases, more MBL and CAI software will be developed to facilitate this integration.

By integrating computers and graphing calculators into the freshman physics curriculum the educational environment may become less didactic, and perhaps become more appealing to students who currently avoid the course. The increased use of computers will educate students using the technology they will encounter in the business world, and may empower the high schools with renewed energy for the acquisition of computers and software.

Academic background for success in freshman level physics requires algebra and trigonometry basics. Comments on the survey from faculty members lamented the low achievement of students who had completed upper level mathematics courses. While these students usually had a basic knowledge of the trigonometry and calculus, the instructors felt they lack many of the basic algebraic skills. One professor from West Virginia wrote a comment typical of others concerning mathematics, "In many cases failure to solve a calculus problem is due to insufficient experience with algebraic manipulation."

Physics and AP Physics are considered beneficial but not mandatory by college physics faculty. The immense variation in the quality and course offerings of high schools makes the college physics classes a melting pot of diverse levels of cognition. This was true in the 1950's when the research on physics education began to gain in momentum and is still true today. A North Carolina professor states, "Some (high school) courses are so terrible that the student would be better off not taking the course, some are excellent and those students really benefit from them." Another comments, "High school physics helps create a physics major, but is not needed for college physics." And still another writes that students who have taken AP Physics "seem to have a head full of facts and very few developed abilities."

Interestingly enough, the students' surveys indicated that they perceive high school physics to be mandatory for success in college freshman level physics. Ausubel would argue the high school introduction to the material would benefit cognition in a college level course. Students should have at least an introduction to the basic concepts of physics during the latter part of their secondary education. Those students who do not take high school physics have a knowledge base formed from information learned in an eighth or ninth grade physical science course. At that level, the vast majority of students are concrete in conceptual ability and rely on memorization. Without abstract concepts, comprehension of physics will be severely limited.

In the comparison of student responses to those of their instructor in the other academic courses of Algebra II, Trigonometry, Calculus, and AP Physics no correlation was found. Many of the students did not respond to these areas at all. This could be because they did not take the courses in high school or that they did not recognize their application in the physics course. Regardless of the reason, the data supports the earlier statement of immense variation in academic background of students in freshman level physics courses.

College professors need to take a more active part in physics education in the local high schools. Collaboration between the two would be beneficial to the high schools as a source of support and professional development. Colleges would benefit by initiating an input into the content and concepts introduced in the high school curriculum. For education on the secondary level to improve, education on the college level must make stronger demands on its students. College physics faculty should expect their students to have completed a high school physics course, to be able to use a computer productively, to have experience in solving problems conceptually and mathematically, and to be able to communicate through verbal and written use of the English language. These demands in turn will make changes in the high school physics pedagogy and curriculum essential, generating final goals consistent with the needs of the students.

Professional organizations such as the American Association of Physics Teachers (AAPT), the National Science Foundation (NSF), the National Science Teachers Association (NSTA), the American Association for the Advancement of Science (AAAS), and the American Physical Society (APS) are leading the way to constructive change, but the work is not finished. Further studies must be conducted to determine what training must be provided for postsecondary and secondary teachers to facilitate an increased use of technology in the physics classroom on all levels. The development of a national secondary physics curriculum is another suggestion for creating constructive change in the current system. A national curriculum would provide high school teachers with distinct guidelines which may in turn reduce the enormous variation in academic background, technical skills and general skills currently exhibited by the students in the present system of physics education. With pre-established expectations colleges and universities can productively generate curricula which will meet the academic needs of a greater portion of post-secondary students and the technological needs of the business community.

Bibliography

Aldridge, Bill G. (1989). Essential Changes in secondary science: Scope, sequence and coordination. NSTA Reports!, 1, 4-5.

Ausubel, D. P. (1968). Educational psychology; a Cognitive a view. Holt, Rinehart and Winston.

Bodenhausen, J. (1989). Advanced placement instruction; Teacher credentials and student outcomes. The College Board Review, 153(Fall), 48-56.

Boyer, E. L. (1983). High school: A Report on secondary education in America. Harper & Row.

Brasell, H. (1987). The Effect of real time laboratory graphing on learning graphic representations of distance and velocity. Journal of Research in Science Teaching, 24(4), 385-395.

Chomsky, N. (1972). Language and Mind. Harcourt Brace Jovanovich.

College Entrance Examination Board. (1983). Academic Preparation for College. What students need to know and be able to do. New York, New York: Office of Academic Affairs. (ERIC Document Reproduction Service No. ED 232 517)

Demana, F., & Waits, B. K. (1990). The Role of technology in teaching mathematics. Mathematics Teacher, 83(1), 27-31.

Fort, D. C. (1990). From gifts to talents in science. Phi Delta Kappan, 71(9), 664-679.

Heidbreder, E. F. & Zimmerman, C. (1955). The Attainment of concepts. IX. Semantic efficiency and Concept attainment. Journal of Psychology, 40, 325-335.

Hounshell, P. B. & Hill, Jr., S. R. (1989). The Microcomputer and achievement and attitudes in High School biology. Journal of Research in Science Teaching, 26(6), 543-549.

Laws, P. W. (1991). Calculus - based physics without lectures. Physics Today, 44(12), 24-31.

McDermott, L., Rosenquist, M. L., & van Zee, E. H. (1987). Student difficulties in connecting graphs and physics: Examples from kinematics. American Journal of Physics, 55(6), 503-513.

Morse, R. H. (1991). Computer uses in secondary science education. ERIC Digest. (ERIC Document Reproduction Service No. ED 331 489)

National Council of Teachers of Mathematics. (1989). Curriculum and evaluation standards for school mathematics. Reston, VA.

Neuschatz,M. & Covalt, M. (1988). Physics in the high schools: Findings from the 1986-87 nationwide survey of secondary school teachers of physics. American Institute of Physics. (ERIC Document Reproduction Service No. ED 302 398)

Pfeiffenberger, G. W. & Zolandz, A. M. (1989). Surveys of the use of hand calculators and microcomputers in college preparatory and college science classes. (Report No. 89-4). New York: College Entrance Examination Board. (ERIC Document Reproduction Service No. ED 315 302)

Reif, F. (1987). Instructional design, cognition, and technology: Applications to the teaching of scientific concepts. Journal of Research in Science Teaching, 24(4), 309-324.

Rothman, A. I., Welch, W. W., & Walberg, H. J. (1969). Physics techer characteristics and student learning. Journal of Research in Science Teaching, 6, 59-63.

Shavelson, R. J., Carey, N. B., & Webb, N. M. (1990). Indicators of science achievement: Options for a powerful policy instruments. Phi Delta Kappan, 71(9), 692-697.

Slavin, R. E. (1982). Cooperative learning: Student teams. National Education Association: Washington, D.C.. (ERIC Document Reproduction Service No. ED 222-489)

Thornton, R. K. (1987). Tools for scientific thinking - micro-computer based laboratories for physics teaching. Physics Education, 22(4), 230-238.

Thornton, R. K. & Sokoloff, D. R. (1990). Learning motion concepts using real-time microcomputer-based laboratory tools. American Journal of Physics, 58(9), 858-866.

Tobias, S. (1990). They're not dumb, they're different: Stalking the second tier. Tucson, Arizonia: Research Corporation.

United States Department of Education. (1984). The Nation responds: Recent efforts to improve education. Washington, D.C.

USA Research. (1984). A Nation at risk: The full account. Cambridge, MA.

Vygotsky, L. S. (1962). Thought and Language. Cambridge, Massachusetts: M.I.T. Press.

Wainwright, C. L. (1989). The Effectiveness of a computer-assisted instructions package in high school chemistry. Journal of Research in Science Teaching, 26(4), 275-290.

Welch, W. W., Harris, L. J., & Anderson, R. E. (1984). How many are enrolled in science? The Science teacher, 51(9), 14-19.

Yager, R. E., & Krajcik, J. S. (1989). Success of students in a college physics course with and without experiencing a high school course. Journal of Research in Science Teaching, 26(7), 599-608.

Appendix

University of Richmond
Graduate School / Department of Education

Survey to determine minimum prerequisite skills and academic background expected by physics instructors for college freshman level courses.

Major ______________________________

Final grade for last English course completed: ______

age: 15-16 17-19 20-22 23-25 26- sex: male female

****

Please determine a numeric value for each of the following where 1 is a prerequisite you strongly feel is mandatory and 5 you strongly feel is not mandatory FOR THIS CLASS.

1	2	3	4	5
mandatory		beneficial but not mandatory		not mandatory

Academic Background

________Algebra II course

________Trigonometry course

________Calculus course

________Physics course

________AP Physics course

Technical skills

________ability to use computers

________ability to use a scientific calculator

________ability to use a graphing calculator

________some non-classroom experience in anything mechanical, optical, or electrical(excluding videogames)

________ability to graph data; interpretation of graphs

General Skills

________ability to read, write and speak English clearly

________ability to communicate ideas logically and clearly

________ability to solve problems or situations independently

________ability to solve problems as part of a student group

________ability to visually illustrate a situation described in a problem

________ability to infer conclusions from data

Do you feel the minimum prerequisite skill requirements for a first semester physics course should be the same for non-majors and physics/engineering majors? (yes/no)________

Comments?

University of Richmond
Graduate School / Department of Education

Survey of <u>minimum</u> prerequisite skills and academic background for <u>college freshman level physics courses</u>.

Number of majors currently enrolled in physics ________

Number of full time physics faculty __________

****

Please determine a numeric value for each of the following where 1 is a prerequisite you strongly feel is mandatory and 5 you strongly feel is not mandatory FOR <u>YOUR</u> CLASSES

mandatory		beneficial but not mandatory		not mandatory
1	2	3	4	5

Academic Background

________Algebra II course

________Trigonometry course

________Calculus course

________Physics course

________AP Physics course

Technical skills

________ability to use computers

________ability to use a scientific calculator

________ability to use a graphing calculator

________some non-classroom experience in anything mechanical, optical, or electrical(excluding videogames)

________ability to graph data; interpretation of graphs

General Skills

________ability to read, write and speak English clearly

________ability to communicate ideas logically and clearly

________ability to solve problems or situations independently

________ability to solve problems as part of a student group

________ability to visually illustrate a situation described in a problem

________ability to infer conclusions from data

Do you feel the minimum prerequisite skill requirements for a first semester physics course should be the same for non-majors and physics/engineering majors?(yes/no) _________

Comments?

Vita

As an undergraduate student at Radford College in 1970 I chose a major in elementary education. Teaching was an acceptable field in a women's college and science was not widely considered as a possible career path. In 1972 the college became coeducational and emphasized it's science programs openly. This change sanctioned my moderate break with tradition and strengthened my resolve for a dual major in Earth Science and Secondary Education. After teaching Earth Science, Physical Science, and Ecology for 8 years I became interested in mathematics and computers. I gained the necessary requirements for Virginia certification and a new outlook on my love of patterns and mathematics. From that point on, I have taken many summer physics institutes rediscovering the interdisciplinary nature of the physical world as well as innovative physics technology and effective pedagogy. Joining the professional organization for physics teachers, the American Association of Physics Teachers (AAPT), and the National Science Teachers Association (NSTA) has given me a network of other educators equally interested in the improvement of physics education.

Teaching is an important part of my life. The education of our children in the United States cannot be left to chance for it is their future that will determine the future of our country.