A TEN YEAR STUDY OF PREDICTORS OF STUDENT SUCCESS ON THE ADVANCED PLACEMENT COMPUTER SCIENCE EXAMINATION

by

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This dissertation was prepared under the direction of the candidate's dissertation co-advisors, Dr. J. Dan Morris, Department of Educational Foundations and Technology, and Dr. Dan Weppner, Department of Teacher Education, and has been approved by the members of his supervisory committee. It was submitted to the College of Education and was accepted in partial fulfillment of the requirements for the degree of Doctor of Education.

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DEDICATION

I dedicate this document to my wife, Lorraine, my daughters, Heather and Haley for their support and understanding, and to my parents, Walter Aden and Alice O'Connor Cornnell for demonstrating that dedication and hard work are truly a means to an end.

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Dr. Don Gorman	Dr. Gorman championed the use of instructional technologies to challenge educators and students alike.
Dr. Fred Harold	Dr. Harold exposed me to the art of computer programming and proved that clarity is the key to effectiveness.

Abstract

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This study examined a model to predict success on the Advanced Placement Computer Science (APCS) examination. The sample included all students (N = 423) who participated in the APCS program in the Palm Beach County Public School System from 1985 to 1994. Predictor variables consisted of the number of courses taken in specific content areas at the secondary level, semester grades in the APCS course, grade point average, and gender. Multiple regression analysis indicated the significance of these variables in predicting the score on the APCS examination (F[12,280] = 5.848, p < .001). Further discriminant analysis identified the most accurate subset of predictors. All students were divided into two groups based on their scores on the APCS examination (pass/fail). The variables that occurred most frequently in the best subsets included the number of semesters taken in advanced mathematics; overall high school grade point average; gender; the grades achieved in both first and second semester in Advanced Placement Computer Science; and the semesters in computers. A model based on these six predictors had the highest ($p < .01$) predictive accuracy of all models studied (67.6% hit rate). Additional study of other independent variables that contribute to success on the APCS examination is needed.

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CHAPTER ONE

INTRODUCTION

Statement of the Problem

In 1937, the Educational Policies Commission of the National Education Association published The Unique Function of Education in the American Democracy. One of the major precepts proposed in that document was the responsibility of the instructional community to adjust its focus and goals to meet both curricular and societal change. That responsibility has not changed. Whether the current reference is Reinventing the Corporation (1985), Schools of Quality (1992), or Value-Added Leadership (1990), the emphasis is to give the constituency, the stakeholders, the appropriate information to make decisions. This can only be accomplished in an environment with a clear direction.

The function of the school center is to provide students with an instructional curriculum that prepares them for the future. The curriculum is governed in part by the requirements of the state, the local school district, and the actual school itself. More specifically in Florida, State Statute 232 identifies the principal as the instructional leader of the school. In that role, the principal's responsibility is to establish a clear direction for the instructional programs of the school center.

Once a clear direction has been established, the principal must work with the teachers and the community in a consensual modification of the curricular goals of the school. By incorporating input from the instructional staff and the community, both become stakeholders in the curricular goals of the school (Sergiovani, 1990). Teachers, guidance counselors, students, and parents then have the ability to examine the programs and the results of particular courses of study.

Instructional programs in many cases reflect opportunities that are brought about by economic or political changes in the society. Subsequently, information about these options surface in the schools. However, information without direction is of little use (Shertzer & Stone, 1981). Students, parents, and school personnel need specific information to assist in planning an appropriate course of study for each student. One such course of study involves computer science. The culminating course for advanced students at the high school level is Advanced Placement Computer Science. This study examines a model of the courses offered to secondary students and specifically targets those planning careers in computers science, mathematics, science or related fields.

Purpose

The purpose of this study was to develop a model for predicting success on the Advanced Placement Computer Science (APCS) examination.

Hypotheses

The following hypotheses were tested in the study:

(1) There is no relationship between the number of computer courses taken and passing the APCS examination.

(2) There is no relationship between grades in the Advanced Placement Computer Science course and passing the APCS examination.

(3) There is no relationship between the number of advanced mathematics courses taken and passing the APCS examination.

(4) There is no relationship between the number of advanced science courses taken and passing the APCS examination.

(5) There is no relationship between the number of courses taken in advanced English and passing the APCS examination.

(6) There is no relationship between the number of advanced social studies courses taken and passing the APCS examination.

(7) There is no relationship between the number of semesters of foreign language taken and passing the APCS examination.

(8) There is no relationship between the number of semesters of music taken and passing the APCS examination.

(9) There is no relationship between student grade point average (GPA) and passing the APCS examination.

(10) There is no relationship between a predictive model and passing the APCS examination. (Said model includes the independent variables: gender, first and second semester grades in APCS, the numbers of semesters in computers, foreign language, music, vocational education, advanced English, advanced social studies, advanced science, advanced mathematics, and grade point average.)

Significance of the Problem

Since the early 1900's, courses offered as a function of the Advanced Placement Program have given high school students the opportunity to participate in courses with the content and rigor of a collegiate. The Educational Testing Service (ETS) in concert with Princeton University has specified the curricular content and developed the assessment instruments for students within the AP program.

Prior to the 1980s, advanced placement courses existed in the fields of mathematics, language arts, fine arts and science. The development of the personal computer in the late seventies and cost-effective compilers made computer science at the secondary level a possibility. As more schools taught computer programming, the need for an advanced placement program in computer science was identified.

The ETS began its preparation of the Advanced Placement Computer Science course outline and examination in 1980 (Wadkins, 1993). The first APCS examination subsequently occurred in 1984. To date, there have been only a limited number of studies that have investigated factors that predict students' success on the Advanced Placement Computer Science Examination, although there have been several that have investigated other advanced placement course offerings. Since the use of the computer in the academic, business, and scientific communities continues to expand, determining a predictive model for the APCS test is worthy of interest and investigation.

Definition of Terms

APCS The Advanced Placement Computer Science program (APCS) is a course of study with specific requirements and a standardized examination. The scores on the examination have the following values:

5	extremely well qualified
4	well qualified
3	qualified
2	possibly qualified
1	no recommendation

A score of 3 or better is considered passing by the College Board (1993).

CEEB The College Entrance Examination Board (CEEB) is the sponsor of nationally normed tests used in placement and entrance considerations by the university system in the United States and abroad.

CTBS The Comprehensive Test of Basic Skills (CTBS) is a nationally normed achievement test that identifies competency levels in reading, language arts, and mathematics.

ETS The Educational Testing Service (ETS) is the group that develops assessment instruments for the College Board. This group works in conjunction with Princeton University to monitor and grade all advanced placement instruments. The APCS examination is one such instrument.

GPA The grade point average (GPA) for a particular student is determined by dividing the total number of points earned by the total number of courses attempted. Grades in each course generate points:

A=4, B=3, C=2, D=1, and F=0.

PSAT Preliminary Scholastic Aptitude Test (PSAT) is a nationally normed aptitude test that identifies potential ability levels in science, social studies, language arts, and mathematics. This test is taken as a preparation for the Scholastic Aptitude Test.

SAT Scholastic Aptitude Test (SAT) is a nationally normed aptitude test that identifies potential ability levels in science, social studies, language arts, and mathematics.

Delimitations

The sample was composed exclusively of students who participated in the Advanced Placement Computer Science program in Palm Beach County, Florida. The results of the program from 1985 to 1994 were evaluated. The program was available at twelve of the sixteen secondary schools in the district.

Limitations

The total sample consisted of 423 students. All students had access to similar hardware (IBM computers) and software (Turbo Pascal). Teachers of the APCS program in the Palm Beach County Public School System utilized the same curriculum objectives, support materials, and textbooks.

Though the instructional materials were the same, no consideration for the differences in teacher-made test difficulty or test frequency at individual school was considered. Additionally, the educational background, subject area certification, number of years teaching programming, or teaching style of the instructors were not analyzed. The sample included students from the diverse population of the county. Neither socioeconomic factors nor demographic factors were considered.

CHAPTER II

REVIEW OF THE LITERATURE

Curriculum

Secondary schools prepare students to enter the work force or to continue with post-secondary instruction. In either case, the students elect to participate in a course of study that most closely approximates the needs of their anticipated occupation or goal. The curriculum is thereby the focus of the school.

The curriculum can be fragmented into various levels. The ideal curriculum is one that prepares students to the best of their ability. The formal curriculum is prescribed by the state department of education in concert with the local school board. The operational curriculum articulates between the textbooks and materials as they are presented to the students. The experiential curriculum is all that the student experiences and brings to the next level of learning. Curricular issues are thereby complex and subject to interpretation at all levels.

In 1957, Sputnik became the catalyst for examination of curricula in the secondary schools of the United States (Doll, 1986). The government allocated additional funding to place emphasis on mathematics and science. Additionally, the instructional process and curriculum were increasingly the subject of national concern.

In 1963, Bruner, in his book The Process of Education, proposed that "mastery of fundamental ideas of a field involve not only grasping general principles, but also the development of an attitude toward learning" (p. 20). In The Dynamics of Educational Change: Toward Responsive Schools, Goodlad indicates that "curriculum builders should organize curricula in a spiral fashion around the concepts ... not merely processing facts" (p.31). Additional emphasis by both federal and local agencies led to continuing investigation.

Four curricular studies in the 1980's included A Nation at Risk (National Commission on Excellence in Education, 1983), A Place Called School (Goodlad, 1984), High School (Boyer, 1983), and The Paideia Proposal (Adler, 1983). Of the four, only Adler's was not based on specific school center research. However, a common thread exists among all of these studies. Each proposes that the principal, as the lead teacher, work to develop the instructional programs at the school to meet the needs of the students and the teachers.

Research in the non-academic fields pinpointed methodologies to generate more productive workers and a more responsive environment. Megatrends (Naisbitt, 1984) and In Search of Excellence (Peters & Waterman, 1982) documented that as members of the work force are given more input into the process, they become more productive. Similar ideas are investigated in the educational field by Owens who proposed methods to make school organizations more efficient (1987).

The push for efficiency translates into quality in school centers. A "better environment in which to learn, a more informed (better prepared) student" become the postulates of the Total Quality School as proposed by Bonstingl (1992, p.34). The focus of the school is no longer considered isolated. The school is now considered a complex entity where the push for excellence starts with the principal.

The Role of the Principal

The instructional process within the bounds of a school system is a function of interaction between the administration, the teachers, the curriculum, and the students. The principal, as the instructional leader of the school, must initiate the identification of specific goals (Sergiovani, 1990). Teachers, students, and members of the community further refine the goals as part of the school improvement process. The curriculum is then modified to reinforce the goals as established.

In order for the instructional goals to materialize in the school, teachers must become part of the decision making process (Byham, 1988). The principal as the leader must present a clear vision and at the same time include the teachers in a decentralized decision-making process about curricular and school-based problems (Wasley,1995). Sergiovani postulates that an organization that adapts a means-ways-ends approach to planning assumes that everybody is responsible for prosperity of the school (1989). Prosperity translates into higher program enrollment and in some cases may justify the existence of the program itself.

The principal must work in collaboration with the teachers to evaluate those programs that deserve to be maintained and those to be eliminated. The schools must make decisions based on the needs of their clients (Beach & Reinhartz, 1989). The Business Roundtable, a subgroup of the National Alliance of Business, similarly advised that the schools need to adopt a flexibility in decision making when considering program feasibility and/or justification (1990).

The principal must assist the staff in making the final analysis of programs and possibilities at the school in order to meet the needs of the students and community. Programs such as the advanced placement programs and honors levels courses are generally more costly to provide due to the increased demand for books, materials, and lab time (in this case, access to computers by individual students).

History

The College Board was organized as a function of the need for a standardized assessment mechanism for students entering post secondary educational institutions. This body first introduced the Scholastic Aptitude Test (SAT) in 1926 and objective achievement assessments in 1936 (Fuess, 1967). Subsequently, the Educational Testing Service (ETS) evolved as an outgrowth of a collaboration between the College Board, the American Foundation on Education, and the Carnegie Foundation. As such, ETS was and remains responsible for the development, publication, and revision of materials relating to the Advanced Placement (AP) programs.

An AP program includes a course description, a curricular syllabus, guides and examinations from previous years. Courses taken within the AP program age generally more rigorous than regular or advanced courses at the high school level. As such, both secondary and post-secondary institutions award different credit for participation (Honeywell, 1987). One mechanism at the high school level awards more one credit (usually 1.25). (This option affords the student the possibility of earning higher than a 4.0 GPA on the scale of 0 to 4.0 generating an honors point average (HPA). This study did not utilize the HPA). At many post-secondary institutions, students are allowed to participate at other than entry level courses or are given credit for participation in the AP program (Honeywell, 1987). In general, the AP courses and the results of participation in the program are diverse.

The Advanced Placement Program offers courses of study in mathematics, science, language arts, social science, foreign languages, art and, most recently, computer science. Table 1 identifies the total number of students participating nationally in the Advanced Placement examinations and more specifically those who took the APCS during the period of 1984 to 1994. Also listed is the comparison, in percent, of APCS test takers to all AP examination takers. While the total for number of students taking any advanced placement exam has continued to rise, the number of students participating in the APCS examination rose initially but has continued to decline since 1986.

The most recent curriculum guide published by the College Board (1994) identifies the focus of the APCS course as follows:

> The primary purpose of the course is to provide the student with a conceptual background in computing and computer science, with specific skills ... and aid the students in developing an ability to apply general concepts. (p.2)

The document describes the need for the ability of the students to "code fluently in a well-structured fashion using Pascal" (p.7). It also includes examples of the examination items and case studies. The examination and the scoring process are explained at length.

Table 1

Students Participating in Advanced Placement Examinations by Year

Year	Total Number of AP Exams	APCS Form A	APCS Form AB	% taking Form AB
1984	176,282	--	4,185	2.4
1985	203,369	--	6,886	3.4
1986	228,606	--	8,049	3.5
1987	259,222	--	8,368	3.2
1988	288,372	10,447	7,203	2.5
1989	309,751	9,309	5,942	1.9
1990	323,726	9,403	5,623	1.7
1991	351,144	9,616	5,853	1.7
1992	378,692	4,917	4,474	1.2
1993	413,939	5,785	4,253	1.0
1994	447,972	6,176	4,009	0.9

Note: Form A of the APCS examination covers the first semester. Form AB of the examination assesses information covered during a year-long curriculum.

The assessment instrument for the APCS program was developed over the period from 1980 to 1984 by personnel at ETS. The first nation-wide implementation was undertaken in May of 1984. The assessment covered a year-long curriculum in computer science. The exam was revised in 1987 and subsequently two APCS exams were made available to participating schools. The APCS examination version "A" covered the first semester of the course. As such, the "A" version contained a subset of the test items available on the "AB" examination. The "AB" version evaluated student achievement for a full-year curriculum in computer science and included a more in depth analysis of data structures. Table 1 also identifies the total numbers of students participating in both the "A" and "AB" form of the examination (the only assessment instrument options available). The largest number of participants for examination form "A" was 10,447 in 1988 and 8,368 for examination form "AB" in 1987. The total number of students taking either test has declined since then. (Economics, the decrease in the demand for programmers, the increase in the flexibility of application software, or some combination thereof may be to blame.)

The revision of the Advanced Placement Computer Science examination in 1987, as indicated in Table 2, resulted in the lowest mean score of any of the four years in which the exam had been given. This mean score also represents the lowest mean of any of the years in this study. There has been a steady increase in the overall mean for the examination since that time. Additionally, 1987 marked the year with the highest number of students participating in the APCS examination.

Table 2

Number of Students at each Score of the Advanced Placement Computer Science Examination by Year

	Score						
Year	5	4	3	2	1	Total	Mean
1984	809	765	1,320	536	755	4,185	3.08
1985	1,104	1,255	2,284	774	1,469	6,886	2.96
1986	1,355	1,567	2,211	1,419	1,497	8,049	2.98
1987	1,370	1,517	2,115	1,614	1,752	8,368	2.38
1988	1,095	643	1,951	1,038	2,476	7,203	2.56
1989	1,010	706	1,292	1,782	1,152	5,942	2.77
1990	1,080	591	1,480	1,140	1,332	5,623	2.81
1991	888	518	1,518	1,423	1,506	5,853	2.63
1992	1,187	536	1,291	764	696	4,474	3.17
1993	1,053	522	1,140	871	667	4,253	3.10
1994	1,018	619	1,071	746	555	4,009	3.20

Note: Data represent those students who took the exam that evaluated the full year APCS program. To obtain means for each year, multiply the number of students by their respective score. Divide the total of those products by the total number of students for that year.

There has been a trend for the overall number of students taking any of the AP exams to increase each year.

This same trend does not exist for the APCS examination. In 1984, 4185 students took the APCS examination. That number rose to a high of 8368 in 1987. After 1987, the numbers of students taking the examination fell to a low of 4474 in 1992. The 1994 figure represents only 0.9% of all students taking exams whereas the 1987 figure represents 3.2%. It should be pointed out that after 1987, the examination was modified. Thereafter, the examination was available in two formats. One, test form "A", covered only the first semester and the other, exam form "AB", covered the entire year.

Use of the Computer

The advent of the personal computer afforded schools an opportunity to provide students a curriculum in computer programming. Students come to programming with different motivations, backgrounds, and biases. Instruction in computer programming must anticipate and extrapolate on that diversity (McGrath, 1990). Programming involves problem solving, the understanding of syntax, and logical thinking (Braswell, 1984). Two views of how to teach programming evolved: completion strategy (the modification of existing code) and generation strategy (the design and coding of new programs). In Van Merrienboer's study (1990), students exposed to completion strategy developed better templates (sets of coded instructions) for program construction. In an earlier study, Van Merrienboer found that programs based on comprehension, modification, and amplification resulted in better achievement in an introductory programming course (1988).

Programming should be flexible and experimental in approach (Harvey, 1991) as well as relevant to the students (Chen, 1992). Instruction should emphasize the end result: the product. Other practitioners hold that syntax and method should be rigid and in a top-down design format that starts with flowcharting. The flowchart is a method of depicting computer code with symbols mapping out the movement of data prior to actual programming. Yet, McCormick and Ross (1990) found that flowcharting negatively affected student performance and attitude toward computers.

In their study, Pommershein and Bell (1986) found that males had higher levels of achievement in programming in BASIC compared to females in their study. They also found that males tended to have computers at home and that they continued to participate in programming courses beyond BASIC.

In a study of students who were taught Pascal, Shute found that working-memory capacity, good problem solving abilities and being an active learner were the best predictors of success (1991). Subsequently, she proposed that in the programming environment, supplemental instruction should be provided in problem solving. In a related study, Loftin (1987) found that the grade point average and the mathematics score of SAT were the best predictors of achievement in computer programming. Abstract reasoning and non-verbal intellect were also found to be contribute significantly.

The attitudes students bring to the computer classroom vary considerably. A certain degree of anxiety is associated with the use of the computer. Simonson et al. (1987) developed a Computer Anxiety Index with a reliability of 0.86 to assist in the appropriate placement of students in computer courses. A study completed by Harrington et al. (1990) suggests that computer anxiety can be influenced by the type of training provided and the receipt of a desired training approach. Marcoulides (1986) found that the higher the level of computer anxiety, the lower the level of computer achievement. This same inverse relationship between attitude toward computers and achievement was reported by Hayek and Stephens (1989). A further study completed by Marcoulides and Wang (1990) demonstrated that computer anxiety crosses cultural boundaries and is present to a similar degree in both American and Chinese students. The anxiety of students with respect to learning with computers appears to lessen if the first course taken is a computer tools course as opposed to programming (Lesson & Peck, 1992).

In addition to studies of the effect of anxiety on computer learning, studies of computer attitudes have been undertaken. In their 1984 study, Loyd and Gressard developed a computer attitude scale. The scale consisted of three major components: freedom from anxiety, appreciation of computers and confidence with computers. Their results indicated that the total score based on the three subscales could be reasonably interpreted to represent a general attitude toward working with computers. In a similar study, Kay (1989) found no significant differences between males and females in attitudes toward computers. Another study completed in 1989 by Levin & Gordon (1989) found that males had a significantly more positive attitude about computers. In Coates' and Stephens' study (1990), success for females in computer science depended on the development of a positive attitude and an interest in the field of computers. In 1989, Munger and Loyd found that students with more positive attitudes toward computers and calculators performed better in computer classes than students with negative attitudes. In a more recent study, Chirwa (1992) developed a different computer attitude scale for high school students with a twenty-nine item instrument with an 0.80 reliability. In all the studies cited, the need to provide an orientation to the computer that would foster positive attitudes was suggested.

For educators who are interested in motivating students to adequately prepare themselves in computer usage, knowledge of their reasons for taking courses in the field of computer science is essential (Campbell & Williams, 1990). However, computers are not limited to programming and literacy courses. Computers are utilized in both academic and vocational classrooms. It should be noted that the mere presence of computer equipment does not constitute instruction (Disessa, 1987). Teachers should be trained to incorporate the computer as a mechanism for instructional delivery. Computer assisted instruction has been shown to be superior to the lecture method of teaching (Emerson, 1987). However, software must be appropriate to the level of the student and the subject orientation of the class (Diem, 1986).

In contrast to subject-specific computer software, developers are addressing broad concepts like critical thinking skills. In particular the software should assist students having difficulty with complex problems (Akbari-Zarin & Gray, 1990). The goal of science instruction as presented by the Association for the Education of Science Teachers is to develop higher level thinking skills by using the computer in conjunction with instruction (1985). In a similar fashion, the National Council of Teachers of Mathematics proposed that the use of computer and calculators be included in all secondary mathematics courses to assist in making the courses more relevant and provide for the development of computing skills (1985).

Computer science is a relatively new field, and some of the required mathematical skills have not been included in traditional secondary mathematics courses (Cowles, 1988). The change in availability of computers makes modifications in instructional delivery both possible and necessary. Twice as many math and science teachers used computers in their classrooms during the 1989 school year compared to the same group in 1985 (Becker, 1991). However, regular and systematic use of the computer as an instructional delivery system is much lower in the mathematics and science classroom compared to computer courses (both computer literacy and programming courses).

Student Achievement

Achievement of students in the secondary schools is measured by performance in specific courses, an overall grade point average (GPA), and on nationally normed tests. The grade point average is a composite value derived from the grades in all courses taken by the student. The high school GPA is a contributing factor in a multitude of studies predicting the GPA at post-secondary institutions.

In a 1994 study, Abbott found that high school GPA is the most significant predictor of GPA for students in the community college. In a related study, Lips (1995) found that high school GPA was associated with a higher GPA during freshman year of college. In his study, Mand (1994) found that high school GPA was the best predictor of student success on the SAT and ACT exams. Similarly, Dunford (1994) found that high school GPA, the overall score on ACT and learning style were associated with academic achievement in college. Likewise, Adcock (1993) in his study of 10,327 students at the University of Tennessee, found that high school GPA and the composite ACT score provided the most accurate predictor of college GPA. In a less inclusive study, Sowles (1991) found the high school GPA to be the only variable that significantly predicted college GPA.

Gender is a variable that has been investigated in various fields with respect to student achievement. In 1989, Becker found that significant differences exist between the achievement of females and males in the subjects of biology, general science, and physics. However, the study did not indicate a method to minimize these differences. In a paper presented to the American Educational Research Association, Stanley (1987) found that females scored lower in achievement tests than males in those areas requiring a scientific background and aptitude. Additionally, he pointed out that gender differences tend to be stronger for required-for-college courses than for the AP examinations. Doolittle and Cleary (1987) reported, in a study of high school students taking the ACT, that geometry and mathematical reasoning were more difficult for females than males. The inclusion of a "hands-on" computer component in a mathematics course does not yield an improvement in either the attitude toward computers or mathematics achievement of female students (Collis, 1987). It appears that female students feel more in control in language arts than they do in mathematics and science and thereby exhibit a positive attitude in the classroom (Ryckman & Peckham, 1987). Additionally, females with low mathematics achievement scores are just as likely to participate in computer courses as their higher achieving counterparts (Pedersen et al., 1986).

When considering science instruction, participation in laboratory activities is the most important factor with respect to student performance in practical chemistry (Okebukola, 1987). Additionally, Tamir (1988) found that an important goal of science instruction is to nurture a preference for questioning and application and a low preference of recall. In his study, Nordstrom (1990) found that the best predictors of success in college chemistry were the mathematics score on the college entrance exam and the high school GPA. In 1989 a report published by the College Board found that scores for males on the AP biology examination were about one-third a standard deviation higher than those for females. Additionally, Herr (1992) found that teachers generally devote less time to laboratory work in AP science classes than occurs in regular science classes. Bateson (1990) found that students in year-long courses score higher on achievement tests than those in semester length courses. Achievement in science has also been demonstrated to be a function of previous achievement in the subject (Gooding et al., 1990). Task orientation (learning in order to increase understanding) proved to be the most significant motivator for students in high school science (Nolen & Haladyna, 1990). In a study by Hounshell and Hill, students in a biology class that incorporated the use of computers demonstrated higher achievement and better attitudes toward the subject (1986).

Issues other than academic focus of the students also play a role in achievement of students regardless of the subject matter. Tocci and Englehard (1991) found that parental behaviors also affect students' attitudes toward mathematics: students who are expected to do well usually do. Allen and Freitag (1988) proposed that parents are the primary teachers. As such, teachers who include the parents in the process assist the students in being successful. By communicating with the parents, teachers can develop an additional support mechanism for the students. Cooper (1989) reported that homework has a positive effect on achievement particularly at the high school level. Similarly, Holmes and Croll (1989) demonstrated the positive relationship between homework and student achievement (1989).

Race and socioeconomic status have been documented to have a relationship to achievement. Reyes and Stanic (1988) found that the mathematics achievement scores of black students have been consistently lower than those of white students. Fewer black and Hispanic examinees respond to items at the end of a section than do white students on the SAT verbal section (Schmitt & Dorans, 1990). This tendency may correspond to the lower scores. However, Jones (1984) reported that regardless of color or sex, students with similar levels of mathematics achievement can expect similar levels of improvement by taking additional courses in mathematics.

One question concerning national achievement tests is content validity. It has been demonstrated that scores on the SAT in 1975 did not significantly differ from the results of the 1985 test in assessing student achievement at the high school level (Sticker, 1991). Both high school grades and ACT scores are significant predictors of college performance (Price & Kim, 1976).

Advanced Placement Examinations

A search of Dissertation Abstracts International for the years 1980 to January of 1995 yields ninety-three dissertations with particular reference to the Advanced Placement Program (APP). Six investigated teaching or curricular content of the APP. Thirteen of the dissertations contained independent variables that represented student participation in AP programs. Nine dissertations dealt with gifted students and the AP offerings available to them. Thirty of the research projects were longitudinal studies of the status of the AP program in a district, state, or regional of the country. Last, thirty-five of the studies dealt with a particular subject area. (It should also be pointed out that the term "advanced placement" is also utilized in association with nursing and vocational programs. Those studies are not referenced herein.)

The studies varied in their approach to the AP program. Upshaw (1994) investigated the effect of graphing calculators on student performance in AP calculus. She found that students scored significantly higher on graphical problems. In another study concerning AP calculus, Parnell (1994) investigated the achievement of students in college calculus. She found that the positive effect of having taken the AP courses in high school was evident only in the first semester of the college level course. In a related study, Swartz (1993) identified what appeared to be a positive link between a year of high school calculus and achievement in college calculus. Massel (1994) found that even though the best students participate in the AP calculus class, they exhibit a fear of taking calculus at the post-secondary level. In a study of students taking calculus, Peterson (1990) reported that gifted students scored higher on the AP calculus exam than other students. In an earlier study of AP calculus, Bowers (1984) identified the courses students take and their interest in the AP program as the best predictors for success on the AP Calculus examination.

Bergman (1992) investigated students participating in Advanced Placement English. She found that students viewed themselves as writers and saw writing not only as problem solving but also as an art. In a related study, Ellison (1990) identified the strategies to assist students' memory of literary passages. In another study of student writing, Ware (1990) found significant differences in the writing styles in terms of gender use of narrative style, and persuasive strategies. In his study of AP English, Carrol (1989) proposed that the strength of the program is that it motivates the students and strengthens the rest of the English department.

Advanced Placement art was investigated by Davis (1992) to determine the overall effect of legislation on the program. She pointed out that there was an increase in the number of schools offering the program once it had been approved for funding (by the legislature). Additionally, she indicated that there was an even greater growth in the program once the state-funded teacher training began.

Teachers were also considered in a study completed by Henderson in 1993. He investigated teachers in the AP American History program and found that they exhibit effective teaching strategies (lecture, discussion, and research). Students in their classes out-performed students whose teachers used less effective strategies. Sisler

(1991) reported that the students gave high marks to the teachers involved in the AP programs. Herr (1991) found that in general the AP program is more effective in stimulating the professional growth of the teachers and the academic performance of the students. In a study of characteristics related to student performance, Kanarick (1992) found that the most significant predictor was the total number of Advanced Placement courses taken.

Albright (1990) investigated the effects of a state-mandated college preparatory curriculum (including AP courses) and the grade point average of college freshman. In this study, (adjusted $R^2 = 0.438$, ($F[18,407] = 19.43$, $p < 0.001$]), he found the state's program accounted for only 0.09 of a point (on a 0.0 to 4.0 scale).

In 1984, Bowers undertook an investigation of the Advanced Placement program in calculus. His discriminant analysis of students enrolled in AP calculus over a sixteen year period indicated that courses taken, interest in advanced placement courses, and interest in science were all significant predictors of success on the AP calculus examination at the $\alpha = 0.05$ level.

Investigation of the Advanced Placement Computer Science examination is not common and those studies proposing predictive models are even less common. There are, however, eight studies with implications for the APCS examination; they include studies by Hunter (1986), Flaherty

(1987), Honeywell (1987), Ott (1988), Peterson (1989), Guzo (1989), Troy (1991), and Timoney (1993).

The first administration of the APCS examination was in 1984. Hunter (1986) examined a sample from students who had taken that first APCS exam. The population studied included students from 23 states. Of the sample (N = 186), only 24 were female. Hunter concluded that GPA (r = 0.39), grades in mathematics (r = 0.30), grades in science (r = 0.37) and grades in previous computer courses (r =0.30) demonstrated a significant relationship with the scores on the APCS examination. However, gender did not have a significant relationship with the APCS score.

In Flaherty's (1987) study, the sample (N = 74) included students who had participated in APCS program over a three year period at one school. Flaherty concluded that GPA (r =0.23) and the $PSAT_{mathematics}$ score (r = 0.43) were statistically significant in predicting the scores on the APCS examination.

In her study of the results of four Advanced Placement examinations (American History, Calculus, Computer Science, and English), Honeywell (1987) examined the relationship between a set of student characteristics and success on the advanced placement examinations. The sample included 67 students who participated in the computer science examination. (Additionally, she studied 553 other students who had taken at least one of the other three exams.) The students selected all participated in the advanced placement examinations in the month of May 1985. This sample represents students from the fourteen public high schools from the school system of Pinellas County (Florida). She found a significant relationship between IQ and success on the AP examination ($t_{History}$ = 7.08, $t_{Computer\ Science}$ = 3.63, $t_{Calculus}$ = 2.39 and $t_{English}$ = 4.57). She identified a relationship between the student's GPA and success on the AP exam ($t_{History}$ = 7.04, $t_{Computer\ Science}$ = 1.70, $t_{Calculus}$ = 4.03 and $t_{English}$ = 3.82), of which only Computer Science failed to be significant.

She also investigated the results of the ninth grade <u>Test of Academic Skills</u> and success on specific AP examinations. This test contained three subsets: reading, language arts and mathematics. In the reading component, ($t_{History}$ = 6.22, $t_{Computer\ Science}$ = 2.49, $t_{Calculus}$ = 1.87 and $t_{English}$ = 4.21), only Calculus failed to be significant. In the language arts component, ($t_{History}$ = 5.29, $t_{Computer\ Science}$ = 1.45, $t_{Calculus}$ = 0.61 and $t_{English}$ = 4.75), both Computer Science and Calculus failed to be significant. In the mathematics component, ($t_{History}$ = 5.55, $t_{Computer\ Science}$ = 2.91, $t_{Calculus}$ = 2.57 and $t_{English}$ = 3.52), all areas proved to be significant.

She also observed the effect of race and gender on success on the AP examinations. There were only nine non-white candidates, so no conclusions were reached with respect to race. There were no significant relationships between performance and gender, ($\underline{t}_{History} = 0.39$, $\underline{t}_{Computer\ Science} = -1.08$, $\underline{t}_{Calculus} = 0.25$, $\underline{t}_{English} = -1.10$ and $\underline{t}_{all\ participants} = -1.03$). Though negative, relationships were identified for English and for all participants when investigating unsuccessful candidates and gender, ($\underline{t}_{History} = -1.66$, $\underline{t}_{Computer\ Science} = 0.69$, $\underline{t}_{Calculus} = -0.06$, $\underline{t}_{English} = -2.17$ and $\underline{t}_{all\ participants} = -2.06$).

In her study, Ott (1988) attempted to identify factors that predict achievement in a first course in computer science. The sample ($\underline{N} = 63$) included students who participated in a computer course at one high school. She indicated that the student grade point average, a school aptitude index and the mathematics score on the SAT examination were the best indicators of success in a computer course ($\underline{F}[8,62] = 25.03$, $\underline{p} < 0.001$). She also found a significant relationship between GPA and success in the course ($\underline{r} = 0.82$, $\underline{p} < 0.001$).

In a similar study, Peterson (1989) investigated factors affecting student achievement in an AP calculus course. Her regression equation yielded an $\underline{R}$ of 0.656, ($\underline{F}[3,201] = 27.95$) on a study of high school students. The predictors included grades (algebra, geometry, and calculus), SAT scores (both verbal and mathematical), the mathematics component of the PSAT, and class rank.

Guzo's study (1989) examined both student and teacher in the APCS program. Information was obtained from teacher questionnaires, student questionnaires, and student transcripts. Factor analysis by Guzo pointed to the importance of several overall factors: experience and proficiency ($F[3,116] = 3.35$, $p = 0.02$), teacher comfort ($F[2,117] = 4.84$, $p = 0.009$), and number of students in the APCS class ($F[3,116] = 3.40$, $p = 0.02$). A significant correlation was determined to exist between the teacher's highest degree and the score on the APCS examination ($r = 0.269$). Conversely, the correlation between the number of computer courses taken and the student score did not prove to be significant ($r = 0.041$). Additional factor analysis by Guzo identified several other factors: the teacher's experience teaching programming, teacher comfort with teaching, and the total number of students in the classroom.

Guzo's (1989) results for students indicated a negative correlation between student score on the AP exam and the number of students per computer, $r = -0.28$ and ($F[3,116] = 3.36$, $p = 0.02$). He also found that the textbook utilized in the APCS program had no significant effect ($F[7,112] = 0.95$, $p = 0.469$) on student scores on the APCS examination.

Troy (1991) completed her study on students learning recursion (a subset of the AP computer science). She investigated different strategies utilized in the teaching of recursion and found that the use of graphics, diagrams, and traces were the best methods to elicit student learning. Her study was topical in nature and as such made no statistical conclusions regarding the student score on the APCS examination, but did provide information to support the APCS curriculum.

In a study similar to that of Guzo, Timoney (1993) completed an investigation of the AP program and its effect on the academic experience for both teachers and students. She noted that the program had a strong positive impact on academic attitudes in students. She also noted that the teachers felt intellectually challenged and derived a higher degree of job satisfaction than those not involved with the AP program. (Note: the data presented were topical in nature and did not include numerical representation. Surveys were sent to 138 former students and 152 teachers of AP courses. Additionally five teachers and five students were interviewed.)

In general, appropriate use of the computer is a function of a positive attitude (lack of anxiety) towards computers. Student success in programming is a function of prior computer courses, mathematics and science courses, and background. Student achievement is also heavily influenced by attitude and prior courses or aptitude in a given subject. Success on the Advanced Placement examination is related to academic aptitude, attitude towards self and learning, success on standardized tests, and prior courses in the field in which the AP examination was taken. Likewise, student success on the Advanced Placement Computer Science examination is a function of performance in other fields (math and science in particular), performance on standardized tests, access to computers, and the influence of the computer science teacher.

CHAPTER III

METHODOLOGY

Subjects

Palm Beach County covers an area of more than 2000 square miles in the southeastern part of the State of Florida. The population is a diverse mixture of the inhabitants of heavily populated coastal cities to sparsely populated rural farming communities. The students in this study were a subset of the students attending the public schools coordinated by the School District of Palm Beach County. The sample consisted of 423 students from high schools in the county who participated in the Advanced Placement Computer Science program. This program was available to all students at ten of the district's sixteen secondary schools during the years 1985 through 1994. The availability of the program is a function of both student demand and the presence of a teacher who was willing and capable of teaching the course. Table 3 identifies the sample (N = 423) and the schools that provided the APCS program. It should be noted that the records for 19 students were unavailable on microfiche or hardcopy at the school.

Table 3

Number of Advanced Placement Computer Science Examinations by School and Year

School	85	86	87	88	89	90	91	92	93	94
1	2	0	0	11	0	0	0	0	1	0
2	0	0	0	0	0	0	0	0	27	18
3	0	0	0	0	2	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0
5	10	9	0	0	0	0	0	3	1	1
6	0	10	0	5	0	7	24	5	10	11
7	0	0	0	0	0	0	0	0	0	0
8	0	0	3	7	5	11	7	12	9	8
9	0	0	0	1	2	4	9	11	9	13
10	0	6	0	1	8	0	0	0	0	0
11	0	1	6	0	1	0	6	7	3	4
12	0	0	0	0	0	0	0	0	0	0
13	0	0	7	10	3	6	17	11	0	0
14	0	0	0	0	0	0	0	0	4	2
15	0	0	0	0	0	5	10	14	14	9
16	0	0	0	0	0	0	0	0	0	0
TOTALS	12	26	16	35	21	33	73	63	78	66
									TOTAL	423

Instruments

The Educational Testing Service prepares and supervises the examination process for the Advanced Placement program. The APCS examination is a formal instrument that teachers are not allowed to handle. Administrators or members of the guidance department are usually charged with the administration of the examination. Once the students have completed the examination process, the documents are returned to ETS. Several months later, the examination report is returned to each of the schools and the students are informed of their results. An aggregate report is sent to each school documenting all student scores.

In addition to the AP report, student transcripts for all participants were analyzed. The transcript is the official record of courses and grades associated with each student. A majority of school transcripts are accessible by means of the district-wide computer system. Additional documentation is accessible from within each student's cumulative record folder at the school site. Records of students are routinely kept at the school for five years after the graduation of a given student. At that point, the records are forwarded to the district records department and converted to microfiche.

Procedures

Once permission had been granted by the school district, each school was contacted and the mechanism for access and review of student records was established. (All reference henceforth to the student records will relate to data contained on individual student transcripts.) The transcripts contain the course titles and grades. In general, student records at the school are the responsibility of the guidance department.

The guidance department also maintains the AP Report, which documents the yearly listing of student names, AP tests taken and associated grades. That list was the key factor in the search for members of the study located at each school. Once the students who had participated in the APCS examination were identified, the cumulative record for each student was duplicated. The next option included access to student records on the district-wide computer system. Student name and school number helped to isolate several missing records. Records on microfiche provided the last option for data acquisition (only in the case of records older than five years). In some instances records were unavailable. The information contained on the student records was then converted to a formatted record for statistical analysis by computer.

The variable for gender was given a value of zero or one corresponding to female or male status as listed on the transcript. In the case of the variables representing the student grades from first and second semester in the APCS course, the letter grade (A, B, C, D, or F) was converted to a corresponding numeric value (4, 3, 2, 1, or 0). In the case of the variables representing the number of semesters in foreign language, music, vocational education, and computer science, the number of semesters became the value for the variable. If no semesters of either course were taken, the value was set at zero. All other variables represent the number of advanced courses in particular disciplines. The value in these cases is the number of semesters. All values for the variables were assessed and entered into a data file for statistical analysis.

Data Analysis

Multiple regression analysis was used to test whether the predictors (number of semesters of each discipline taken, gender, and semester grades in the APCS courses) accounted for a significant portion of the variance in the dependent variable (score on the APCS examination). Predictive discriminant analysis was used to classify subjects according to the minimum chi squared rule (Tatsuoka, 1988). As recommended by Morris and Huberty (1995), McNemar's (1947) correlated proportions statistic was used to compare the difference in classification accuracy of the full and reduced models. Calibration sample estimates as well as the leave-one-out (LOO) cross-validation estimates recommended by Morris and Meshbane (1995) were used. All possible subsets of the model were tested to determine if they performed significantly better than chance expectations (Huberty, 1994).

The statistical package SPSS/PC+ Studentware Plus was used for regression analyses. An alpha level ($\alpha = 0.05$) was utilized to determine acceptance/rejection of the null hypotheses in conjunction with *t*-tests. Software developed by Morris and Huberty (1995) was utilized to compare the predictive accuracy of full to partial models with respect to chance. Additional software (Morris & Meshbane, 1995), was utilized to identify the best subset of all variables with respect to predictive accuracy. All analyses were completed on personal computers using 80386 and 80486 based processors (the computer with 486 processor also had a math coprocessor).

CHAPTER IV

RESULTS

The purpose of this study was to examine the relationship between the predictor variables and success on the Advanced Placement Computer Science (APCS) examination. The variables included the number of advanced courses in several disciplines, the first and second semester grades in the APCS programming course, grade point average (GPA), and gender. The study also examined the predictive accuracy of models based on subsets of predictor variables and considered individual contributions to the model's accuracy. Multiple regression analyses were employed to examine the relationships between predictor variables and the AP score. The multiple regression analyses included adding individual predictor variables to determine their contribution.

The regression analyses were completed on two models. In the first, the dependent variable was interpreted as continuous data (APCS scores of 1, 2, 3, 4, or 5). The second analysis was completed utilizing the classification of cases on the basis of APCS scores (pass = 3 through 5, and fail = 1 or 2). A predictive discriminant analysis was completed to note the specific contribution of each variable.

Table 4

Students Who Took the Advanced Placement Examination (1984 to 1994) in Palm Beach County

	Male	%	Female	%	Total
APCS (pre-1987)	47	88.7	6	11.3	53
APCS Form A	206	87.7	29	12.3	235
APCS Form AB	258	91.2	25	8.8	283
Group excluding any record with missing data	267	91.1	26	8.9	293
Total sample	377	89.1	46	10.9	423

The sample for the study consisted of 423 students. At least one form of APCS examination was taken by all students in the study. The subjects were grouped based on the version of the APCS examination they took. The data in Table 4 identifies the numbers of students represented in each group. The assessment instrument was consistent from 1984 to 1987. After 1987, the students were given the option of taking form A (covering the first semester) or form AB (covering the entire year). Several of the students opted to take both forms of the examination. However, due to the differences in the content of the examinations, comparisons were made exclusively on data from the examinations of the year-long course. In the multiple regression analysis and the discriminant analysis, only records for which there were no missing elements were considered.

There was a degree of consistency in gender for all groups, regardless of the form of the APCS examination students took. Table 5 identifies that 10.9% of the sample was female. By comparison the number of females in the pre-1987 examination was 11.3%. The data for the group representing post-1987 students who had taken test form AB (full year curriculum) was 8.9% female.

The initial analysis of the data is summarized in Table 5, which depicts the mean (M), standard deviation (SD) and range (Maximum and Minimum) of the variables in the study. Further investigation of the frequencies of each of the variables (with the exception of gender, and grades in the APCS) identifies specific trends in the coursework for the students in the study. The three highest frequencies for each are documented in Table 6.

The number of semesters of computers, with $\underline{M} = 5.62$, has the highest frequencies for four, six, and eight semesters. This reflects the course of study that represents two, three or four years of computer courses. Generally, students are enrolled in BASIC (the first year), Computer Programming II (the second year; BASIC and Pascal), and Advanced Placement Computer Science (Pascal).

Table 5

Mean, Standard Deviation, and Range of AP Exam Scores, AP Computer Grades, Numbers of Semesters in Computers, Foreign Language, Music, Advanced English, Advanced Science, Advanced Social Science, Vocational Studies, Advanced Mathematics, and Grade Point Average.

	M	SD	Min	Max	N
Exam pre-1987	2.06	1.28	1.00	5.00	53
Exam Form A	2.88	1.34	1.00	5.00	235
Exam Form AB	2.65	1.34	1.00	5.00	283
APCS First Sem. Grade	3.31	0.82	0.00	4.00	406
APCS Second Sem. Grade	3.30	0.90	0.00	4.00	403
Semesters in Computers	5.63	1.52	1.00	12.00	423
Semesters in For. Language	5.01	2.06	0.00	18.00	423
Semesters in Music or Band	0.86	3.13	0.00	16.00	423
Semesters in Adv. English	5.64	3.12	0.00	16.00	423
Semesters in Adv. Science	5.95	3.12	0.00	13.00	423
Semesters in Adv. Soc. Sci.	4.20	2.34	0.00	9.00	423
Semesters in Vocational	2.90	2.71	0.00	15.00	423
Semesters in Adv. Math	6.46	3.45	0.00	14.00	423
GPA	3.25	0.53	1.65	4.00	394

Table 6

Value, Frequency and Percent of Cases for Three Largest Categories

	Value	Frequency	Percent
Semesters in Computer Courses	4.0	71	16.8
	6.0	232	54.8
	8.0	40	9.5
Semesters in Foreign Language	4.0	220	52.0
	6.0	97	22.9
	8.0	53	12.5
Semesters in Music or Band	0.0	324	76.6
	1.0	23	5.4
	2.0	37	8.7
Semesters in Adv. English	0.0	69	16.3
	6.0	66	15.6
	8.0	193	45.6
Semesters in Adv. Science	0.0	45	10.6
	4.0	44	10.4
	6.0	88	20.8
	8.0	130	30.7
Semesters in Adv. Social Science	0.0	58	13.7
	5.0	101	23.9
	6.0	88	20.8
Semesters in Vocational Courses	0.0	78	18.4
	1.0	75	17.7
	2.0	79	18.7
Semesters in Adv. Mathematics	2.0	50	11.8
	6.0	61	14.4
	8.0	103	24.3
	10.0	53	12.5

The number of semesters of foreign language, with M = 5.01, has the highest frequencies for four, six, and eight semesters also. The highest individual frequency is 52.0% for the two year program. This reflects the State of Florida's requirement that students attending an in-state college must have a minimum of two years of a foreign language.

The number of semesters of music, with $\underline{M}$ = 0.86, has the highest frequencies for zero, one, and two semesters. The frequency for zero, meaning no courses taken, represents 76.6% of the students. Music is considered to be one of the fine arts. The state requires only one half credit in fine arts and that includes art, drama and music.

The number of semesters of advanced English, with $\underline{M}$ = 5.47, has the highest frequencies for zero, six, and eight semesters. The frequency for eight semesters represents 45.6% of the students. Students who had taken eight semesters (4 years) took Honors English 9, Honors English 10, Advanced Placement English Language, and Advanced Placement English Literature. It should also be noted that the second highest frequency represents 16.3% of the students and indicates that they took no advanced courses in English.

The number of semesters of advanced science, with $\underline{M}$ = 5.95, has the highest frequencies for zero, six, and eight semesters. Students who took eight semesters had a frequency of 30.7%. The minimum science requirement is three years, six semesters, and consists of Earth Science, Biology, and Chemistry. The advanced courses include both honors and AP options including the courses listed in addition to Physics, Biology II, and Anatomy & Physiology.

The number of semesters of advanced social science, with $\underline{M} = 4.21$, has the highest frequencies for zero, five, and six semesters. Students who took five semesters had a frequency of 23.9%. Those who took six semesters had 20.8%. Year long course requirements for World History, and American History account for four semesters. American Government and Economics are both one semester courses. Again as in advanced English courses, students who elected to take no advanced courses represent the third highest percent frequency at 13.7%.

The number of semesters of Vocational courses, with $\underline{M} = 3.38$, has the highest frequencies for zero, one, and two semesters. Students who took two semester had a frequency of 18.7%. Those who took zero or one semester had frequencies of 18.4% and 17.7% respectively. One semester of practical arts is required. Additionally many of the vocational courses are offered as year-long courses.

The number of semesters of advanced mathematics, with $\underline{M} = 6.46$, has the highest frequencies for six, eight, and ten semesters. Students who took eight semesters of advanced mathematics courses had a frequency of 24.3%. This represents the students who took four years of mathematics at the honors level or higher including a combination of courses from: Algebra I, Geometry, Algebra II, Trigonometry & Analytic Geometry, Math Analysis, and Calculus. The second highest frequency at 14.4% represents three years at the advanced level. The lowest frequency at 12.5% indicates completing the equivalent of five years of advanced mathematics.

The correlations between the variables in this study are presented in Table 7. These correlation coefficients represent data analyzed with respect to a continuous dependent variable (Scores on the APCS examination from 1 to 5). The highest correlation between a predictor and the criterion variable was the grade in the first semester APCS course ($r = 0.41$) Also significant, ($p < 0.05$), were the number of semesters of advanced mathematics ($r = 0.33$), GPA ($r = 0.33$), grade in the second semester APCS course ($r = 0.33$), semesters of advanced science courses ($r = 0.22$), semesters of advanced social science courses ($r = 0.20$), and the number of advanced English courses ($r = 0.20$).

The regression equation with all predictor variables yielded an R of 0.510, and ($F[12,280] = 8.22$, $p < .01$). This R represents the correlation between the dependent variable and the least squares optimized composite of the predictor variables. The R^2 value of 0.260 is the proportion of the variance in the dependent variable accounted for by the predictors. The β values indicate the standardized regression coefficient and as such are used in

Table 7

Intercorrelation Matrix for Predictor Variables and the Criterion Variable (AP) (with AP a continuous variable)

	AP	SEX	APCA	APCB	SC	SF	SM	SE	SI	SS	SV	SA	GPA
AP	1.00	-.07	.41	.33	-.06	.12	.00	.20	.22	.20	-.17	.33	.33
SEX		1.00	.19	.06	-.03	.11	-.10	.13	.10	.11	.03	.15	.20
APCA			1.00	.60	.00	.12	-.07	.28	.31	.23	.01	.33	.52
APCB				1.00	-.00	.12	.04	.19	.22	.11	-.01	.27	.49
SC					1.00	-.15	-.04	-.06	-.08	.03	.03	-.02	-.05
SF						1.00	-.10	.22	.25	.22	-.31	.30	.26
SM							1.00	-.02	-.02	.03	-.11	-.11	-.04
SE								1.00	.60	.70	-.22	.53	.42
SI									1.00	.59	-.31	.67	.48
SS										1.00	-.29	.49	.41
SV											1.00	-.38	-.21
SA												1.00	.49
GPA													1.00

Note:
AP = score on the APCS examination
SEX = gender of the student
APCA = grade in first semester of APCS
APCB = grade in second semester of APCS
SC = number of semesters in advanced science
SF = number of semesters in foreign language
SM = number of semesters in music
SE = number of semesters in advanced English
SI = number of semesters in advanced science
SS = number of semesters in advanced soc. sci.
SV = number of semesters in vocational courses
SA = number of semesters in advanced mathematics
GPA = grade point average

the regression equation:

$$AP = -0.173\ SEX + 0.312\ APCA + 0.070\ APCB - 0.069\ SC - 0.009\ SF + 0.012\ SM + 0.030\ SE + 0.051\ SS - 0.099\ SI - 0.082\ SV + 0.217\ SA + 0.086\ GPA$$

Where:

AP = predicted score
SEX = gender of the student
APCA = grade for first semester in APCS
APCB = grade for second semester in APCS
SC = semesters of computers
SF = semesters of foreign language
SM = semesters of music
SE = semesters of advanced English
SS = semesters of advanced social science
SI = semesters of advanced science
SV = semesters of vocational courses
SA = semesters of advanced mathematics
GPA = grade point average

Note: Units are $\underline{z}$ scores.

The correlation coefficients identified in Table 7 represent data analyzed with a continuous dependent variable (Scores on the APCS examination as one through five. When the data were analyzed with a dichotomous dependent (pass/fail Scores), the highest correlation between a predictor and the criterion variable was the grade in the first semester APCS course ($\underline{r} = 0.37$) Also significant ($\underline{p} < 0.05$) were the number of semesters of advanced mathematics ($\underline{r} = 0.29$), GPA ($\underline{r} = 0.27$), grade in the second semester APCS course ($\underline{r} = 0.29$), semesters of advanced science courses ($\underline{r} = 0.20$), semesters of advanced social science courses ($\underline{r} = 0.18$), and the number of advanced English courses ($\underline{r} = 0.23$).

Once the subjects had been classified into two groups (pass or fail), cases with missing data were deleted. The remaining 293 cases were examined using predictive discriminant analysis. The two groups are more specifically identified in Table 8. The data in Table 8 represent means for the groups with the dependent variable dichotomized as pass/fail ($\underline{N}$ = 293). It depicts trends similar to those found in the original study ($\underline{N}$ = 423) as listed in Table 5. Additionally the table indicates slightly higher means for each variable in the study with one noticeable exception: semesters of computers (but not a significant one). Group 1, those who failed the APCS, showed a slightly higher incidence in the number of semesters they had taken.

Also included in Table 8 are the $\underline{t}$-test results for the comparison between passing and failing group. There is a significant relationship demonstrated for the independent variables representing: grades in APCS for both first and second semester ($\underline{t}_{APCA}$ = 3.950, $\underline{t}_{APCB}$ = 3.110), the number of semesters of computer courses taken ($\underline{t}_{SC}$ = 1.219), and the number of semesters in advanced mathematics ($\underline{t}_{SC}$ = 1.219). Because of the error rate inflation due to the number of significance tests, the results are only indicative of marginal significance.

Equations generated by the predictive discriminant analysis (PDA) were evaluated to determine which combinations of predictor variables most accurately predicted the criterion. Models were built using all possible (2^{12} - 1 = 4,095) combinations of the predictor

Table 8

Comparison of Means for Groups (Pass/Fail the Advanced Placement Computer Science Examination), with t-Test and Significance.

	Group One (N=154) (Fail)	Group Two (N=139) (Passed)	t-Test	p
APCS First Sem. Grade	3.162	3.698	3.950	0.000
APCS Second Sem. Grade	3.195	3.662	3.110	0.000
Semesters of Computer	5.929	5.770	1.219	0.151
Semesters of For. Language	4.922	5.230	0.987	0.465
Semesters of Music	0.747	0.835	1.026	0.398
Semesters of Adv. English	5.383	6.741	1.471	0.009
Semesters of Adv. Science	5.708	6.871	1.402	0.023
Semesters of Adv. Soc. Sci.	4.162	4.986	1.411	0.040
Semesters Vocational	3.201	2.583	1.141	0.216
Semesters of Adv. Math	5.896	7.813	1.874	0.000
Grade Point Average	3.171	3.449	0.990	0.542

variables. Subsequently the twenty best models of each size were evaluated. The classification accuracy of a model is the ability of a model to predict (hit-rate) passing or failing the APCS.

In general a calibration sample is selected from the group being studied. This sample is then tested against the rest of the same group and yield a positively biased estimate of accuracy. In order to minimize the biasing effect of the calibration sample, each model was subjected to analysis that made use of the "leave one out" method.

> This method involves a two-step process. First, one unit is deleted and the linear classification functions (LCFs) are determined on the remaining N - 1 units. Then these LCFs are used to classify the deleted unit into one of the *k* criterion groups. This process is carried out N times and the proportions of deleted units correctly classified are used as hit-rate estimates. For each classification it may be considered that a training sample of size N - 1 and a test sample of size 1 are being used (Huberty, 1994, p. 88).

This repetitive process estimates the cross-validated classification accuracy and each subject is cross-validated on an equation to which that subject did not contribute. The model with the highest accuracy (highest hit rate) included the following predictors: gender, SA (semesters of advanced mathematics), GPA (overall grade point average), APCA (APCS first semester grade), APCB (APCS second semester grade) and SC (semesters of computers). It should also be noted that the first three predictors were present in all models with more than three variables.

Evaluation of the leave-one-out accuracies of all possible subsets of predictor variables was completed using a method and software advocated and created by Morris and Meshbane (1995). The models which had the highest predictive accuracy are shown in Table 9. The variables gender, semesters of advanced mathematics, and GPA are present in all models with three or more independent variables. The predictors, semesters of advanced mathematics & grade point average, are also present in the top ten models with the highest hit rate. (Hit rate reflects the accurate prediction of passing or failing given the subset of variables in the model and is calculated by dividing the number of correct classifications by the number of cases.)

A method suggested by Huberty (1994) was utilized to determine the significance of each model relative to chance expectation. All models yielded a significant improvement in accuracy relative to proportional chance expectation. When the equation with all 12 variables is considered, the overall improvement over chance was 30.5% (Table 10). Likewise, when the equation with the variables gender, first semester APCS grade, and semesters of computers is considered, the results were 43.04% better than chance expectation.

Table 9

The Twenty Subsets With Greatest Predictive Accuracy (Highest Hit Rate)

HITS Group 1 (N=154)	Group 2 (N=139)	Total (N=293)	Variables in Model
121	96	217	SEX, SA, GPA
112	105	217	SEX, SC, SA, GPA
112	105	217	SEX, APCA, SC, SA, GPA
113	104	217	SEX, APCB, SC, SA, GPA
120	95	216	SEX, APCB, SA, GPA
109	106	215	SC, SA, GPA
119	96	215	SEX, APCA, SA, GPA
114	101	215	SA, GPA
119	96	215	SEX, APCA, APCB, SA, GPA
111	104	215	SEX, APCA, APCB, SC, SA, GPA
108	101	209	SA
114	101	215	SA, GPA
121	96	217	SEX, SA, GPA
112	105	217	SEX, SC, SA, GPA
112	105	217	SEX, APCA, SC, SA, GPA
111	104	215	SEX, APCA, APCB, SC, SA, GPA
109	103	212	SEX, APCA, APCB, SC, SM, SA, GPA
106	103	209	SEX, APCA, APCB, SC, SF, SS, SI, SA, GPA
105	102	207	SEX, APCA, APCB, SC, SM, SF, SS, SI, SA, GPA
103	100	203	SEX, APCA, APCB, SC, SM, SF, SS, SI, SV, SA, GPA

Note: Variables
SEX = gender of the student
APCA = grade for first semester in APCS
APCB = grade for second semester in APCS
SC = total number of semesters in computers
SF = total number of semesters in for. language
SM = total number of semesters in music
SE = total number of semesters in adv. English
SI = total number of semesters in adv. science
SS = total number od semesters in adv. soc. sci.
SV = total number of semesters in vocational ed.
SA = total number of semesters in adv. math
GPA = grade point average

Table 10

Proportional Chance Comparison

HITS Group 1 (N=154)	Group 2 (N=139)	Total Model	Improvement Over Chance Group 1	Group 2	Total
121	96	217	54.83%	41.14%	47.99%
112	105	217	42.51%	53.46%	47.99%
112	105	217	42.51%	53.46%	47.99%
113	104	217	43.88%	52.09%	47.99%
120	95	216	53.36%	39.77%	46.62%
109	106	215	38.41%	54.83%	46.62%
119	96	215	52.09%	41.14%	46.62%
114	101	215	45.25%	47.99%	46.62%
119	96	215	52.09%	41.14%	46.68%
111	104	215	41.14%	52.09%	43.88%
108	101	209	37.04%	47.99%	39.57%
114	101	215	45.25%	47.99%	43.88%
121	96	217	54.83%	41.14%	45.32%
112	105	217	42.51%	53.46%	45.32%
112	105	217	42.51%	53.46%	45.32%
111	104	215	41.14%	52.09%	43.88%
109	103	212	38.41%	50.72%	41.73%
106	103	209	34.30%	50.72%	39.57%
105	102	207	32.93%	49.36%	38.13%
103	100	203	30.19%	46.62%	35.25%
101	98	199*	27.45%	43.88%	32.37%

Note: The model with a total of 199 hits contained all 12 independent variables.

Investigation into the effect of particular variables and subsets of variables was initiated using software described by Morris and Huberty (1995). The software allows the user to examine the influence of variable subsets on the cross-validated predictive accuracy of the complete model.

A comparison of full and restricted model accuracy is presented in Table 11. At issue is the ability of a subset of variables to enhance the accuracy of the full model.

The model containing a twelve predictor variables had a predictive accuracy of 64.5% in the prediction of passing and failing scores. The restricted model (excluding gender) showed an increase of 0.7%. This same increment is reflected in a model excluding GPA. Restricted models excluding gender and GPA or excluding the number of semesters of advanced mathematics and GPA both generated a predictive accuracy of 65.9%. The restricted model that eliminated gender, semesters of computers, semesters of advanced mathematics, and GPA indicated only a 0.3% decrease in comparison to the model with all twelve predictor variables.

When considering models based on the predictor variables, the three most common variables were gender and GPA. Gender, if analyzed as the sole variable in the restricted model, only yields the predictive accuracy of 44.8% (almost 20% less accurate that the model with all twelve predictor variables). That particular model also yielded a significant McNemar's Z value of 4.0659. In a similar fashion, if only GPA is analyzed, the predictive accuracy generated is 62.5% (2% less accurate that the full model. This measure proved to also to be significant and had a McNemar's Z value of 0.6626.

Table 11

Restricted Model Accuracy Compared to the Complete Model

Restricted Model	Subset Tested	Total Hit Rate	McNemars's Z
APCA,APCB,SC,SF,SM, SE,SS,SI,SV,SA,GPA	SEX	.652	- 0.3922
SEX,APCA,APCB,SC,SF, SM,SE,SS,SI,SV,SA	GPA	.652	- 0.8165
APCA,APCB,SC,SF,SM, SE,SS,SI,SV,SA	SEX,GPA	.659	- 0.7845
SEX,APCA,APCB,SC,SF, SM,SE,SS,SI,SV	SA,GPA	.659	- 0.7845
APCA,APCB,SF,SM,SE, SS,SI,SV	SEX,SC,SA,GPA	.648	- 0.1890
SEX	APCA,APCB,SC,SF,SM, SE,SS,SI,SV,SA,GPA	.488	4.0659
GPA	SEX,APCA,APCB,SC, SF,SM,SE,SS,SI,SV,SA	.625	0.6626
SEX,SA,GPA	APCA,APCB,SC,SF, SM,SE,SS,SI,SV	.652	- 0.2673
SEX,APCA,APCB, SC,SA,GPA	SF,SM,SE,SS,SI, SV	.676	- 2.1828

Note: Variables
SEX = gender of the student
APCA = grade for first semester in APCS
APCB = grade for second semester in APCS
SC = total number of semesters in computers
SF = total number of semesters in for. language
SM = total number of semesters in music
SE = total number of semesters in adv. English
SI = total number of semesters in adv. science
SS = total number od semesters in adv. soc. sci.
SV = total number of semesters in vocational
SA = total number of semesters in adv. math
GPA = grade point average

Similarly, the restricted model containing only gender and the semesters of advanced mathematics yielded a predictive accuracy of 65.2% (an increase in accuracy of 0.7%). However, the restricted model with the highest predictive accuracy contained gender, grade in first and second semester of the APCS course, the number of semesters of computers, the number of semesters of advanced mathematics, and GPA. The predictive accuracy of this model was 67.6%, 3.1% higher than the overall model.

Based on the absolute accuracy of the models relative to chance expectations, as well as a comparison to the full and restricted models, the model with gender, grades in first and second semester of the APCS course, the number of semesters of computers, the number of semesters of advanced mathematics and GPA appears to predict performance (pass/fail) on the Advanced Placement Computer Science examination effectively.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

Restatement of the Problem

This study investigated the factors associated with success on the Advanced Placement Computer Science examination. Analyses were completed using multiple regression to determine those factors that contributed significantly to success. Once the factors had been identified, the sample was divided into two groups as a function of students' scores on the APCS examination (pass/fail). Predictive discriminant analyses were completed to identify those factors that contributed to the predictive accuracy of the model.

Comparison of Findings with Related Literature

Variables that contributed to models with the highest predictive accuracy in this study included GPA (grade point average), gender, and the number of semesters of advanced mathematics taken. Additionally, the total number of semesters in computer science and the grades in both first and second semester of the Advanced Placement computer science class contributed to the accuracy of the predictive models.

The GPA documents students' grades throughout a particular period, in this case high school. Ott (1988), Honeywell (1987), Flaherty (1987), Hunter (1986) and Bowers (1989) all identified GPA as a predictor of success in the AP program. In this study GPA was a contributing factor in each of the ten models with the highest accuracy.

Though gender was identified as a predictor for success on the APCS examination, it should be noted that the study contained only 10.9% female participants. This observation was reflected in other studies with respect to the Advanced Placement program. Honeywell (1987) also identified problems associated with the limited participation of females in computers and calculus classes and not in history or English. Hunter (1986) also reported low participation by females in the APCS program (13.4%). A study by McCormick and Ross (1990) noted that males and females appear to have much the same potential for learning programming.

Mathematics plays an important role in programming. Hunter (1986) indicated that a composite of prior grades in mathematics is a good predictor of success in the APCS program. Both Peterson (1989) and Bowers (1984) documented the role of grades in mathematics courses and predicting success on the AP calculus exam.

Conclusions and Recommendations

The purpose of this study was to identify predictors of student success on the Advanced Placement Computer Science (APCS) Examination. The grade on the APCS examination was chosen as the criterion variable and the correlation coefficient ($\underline{r}$) was calculated for each of the independent variables. The findings are reported in relation to each of the study's hypotheses:

H_o 1: There is no relationship between the number of computer courses taken and passing the APCS examination.

By studying the research question that was the basis for this hypothesis and evaluating the data which resulted in a $\underline{r} = -0.07$, and $\underline{t} = 1.219$ with $\underline{p} = 0.151$, there was a failure to reject the null hypothesis.

It should be noted that the independent variable, number of semesters of computers, existed in the restricted model that contained the highest predictive accuracy. In other words, the numbers of semesters of computers taken in high school was found to contribute to predicting success on the APCS examination.

H_o 2: There is no relationship between grades in the Advanced Placement Computer Science course and passing the APCS examination.

The analyses resulted in a $\underline{r} = 0.41$ for grade in first semester APCS, and $\underline{r} = 0.33$ for the grade in second semester APCS. Correspondingly, with $\underline{t} = 3.950$, $\underline{p} < 0.001$ for the first semester grade and $\underline{t} = 3.110$, $\underline{p} < 0.001$ for the second semester grade, the null hypothesis was rejected.

Both of these variables were present in the model with the highest predictive accuracy. In other words, not only were they significant by themselves, they also combined with other predictors to accurately forecast success on the APCS examination.

H_o 3: There is no relationship between the number of advanced mathematics courses taken and passing the APCS examination.

This study evaluated the data and yielded $\underline{r} = 0.33$, and $\underline{t} = 1.874$, with $\underline{p} < 0.001$, the null hypothesis was rejected.

The semesters of advanced mathematics, as a predictor, was present in the model with the highest predictive accuracy. In other words, the semesters of mathematics combined with other predictors to accurately forecast success on the APCS examination as well as being significant in the regression model.

H_o 4: There is no relationship between the number of advanced science courses taken and passing the APCS examination.

The review of the data revealed $\underline{r} = 0.22$, and $\underline{t} = 1.411$ with $\underline{p} = 0.023$, the null hypothesis was rejected.

This predictive variable was not present in models yielding the highest predictive accuracy. In other words, in this study the semesters in advanced mathematics was not a significant contributor to predicting student success on the APCS.

H_o 5: There is no relationship between the number of courses taken in advanced English and passing the APCS examination.

By studying and evaluating the data, this study resulted in a $\underline{r} = 0.20$, and $\underline{t} = 1.471$ with $\underline{p} = 0.009$, the null hypothesis was rejected.

Though this predictive variable was significant in the regression analysis, semesters of advanced English was not present in models yielding the highest predictive accuracy. In other words, in this study the semesters in advanced English was not a significant contributor to predicting student success on the APCS examination.

H_o 6: There is no relationship between the number of advanced social studies courses taken and passing the APCS examination.

Analysis of the data resulted in a $\underline{r} = 0.20$, and $\underline{t} = 1.411$ with $\underline{p} = 0.040$, the null hypothesis was rejected.

Though this predictive variable was significant in the regression analysis, semesters of advanced social science was not present in models yielding the highest predictive accuracy. It can be concluded that the number of semesters in advanced social science was not a significant contributor to predicting student success on the APCS examination.

H_o 7: There is no relationship between the number of semesters of foreign language taken and passing the APCS examination.

In that the analysis of the data resulted in a $\underline{r} = 0.12$, and $\underline{t} = 0.987$ with $\underline{p} = 0.465$, there was a failure to reject null hypothesis

This predictor was not significant in the regression analysis nor in the analysis of models of predictive accuracy. Though the numbers of students participating in foreign languages is as high as any of the other variables a significant relationship between studying a foreign language and studying a computer language was not able to be established.

H_0 8: There is no relationship between the number of semesters of music taken and passing the APCS examination.

Review of the data in this study resulted in a failure to reject the null hypothesis. This decision is supported by data that resulted in a r < [illegible] and t = [illegible]26 with p = 0.398.

Music contains structures and syntax similar to those present in computer languages. However no significant relationship between music and success on the APCS examination was established.

H_0 9: There is no relationship between a students' grade point average and passing the APCS examination.

Using the regression analysis alone did not support the rejection of the null hypothesis (r = 0.11, and t = 0.990 with p = 0.542). However, this variable was present in all ten of the top models for predictive accuracy and present in the final model that proved to demonstrate the highest overall accuracy. There fore, a significant relationship between the use of GPA along with other predictor variables and passing the APCS examination was established.

Predictive discriminant analysis identified the three best predictors of success on the APCS examination as: gender, the number of semesters in advanced mathematics, and grade point average. These three independent variables are present in all but two of the twenty models with the highest hit rate.

The grades received by students in the first and second semester of Advanced Placement Computer Science and the total number of semesters of computer courses taken were also significant predictors of success on the APCS examination. In combination with gender, semesters of advanced mathematics, and GPA, these three variables formed the model with the highest overall predictive accuracy (Table 11).

Grades in the APCS course might be a function of student motivation and their seriousness about the possibilities of pursuing a career in computer science. Students with a prior knowledge of mathematical algorithms and programming logic might be inclined to continue taking computer courses.

Additional studies need to be done on a larger scale to increase the generalizability of this study. Additionally, a broader study could synthesize the variables from all the studies to date, and include other standardized test scores, student self-concept and learning styles, teacher attitudes and backgrounds, educational backgrounds of the parents, race, gender and other student descriptors.

In 1997, C will be the programming language to be utilized in the APCS curriculum. Though similar in many ways to the Pascal language, C provides a more specific mechanism to generate graphics and incorporates the use of object-oriented coding. This change in the language offers another investigator the opportunity to assess the APCS starting with the first year of a different programming language.

A final recommendation seems appropriate. In this study, 10.9% of the participants were female. Additionally, 8.9% of the students who took the APCS examination covering the full-year curriculum were also female. However, there is only a marginal difference passing rate between passing rates (female = 42.3% and male = 47.9%). In that females occupy more than fifty percent of the workforce, specific efforts should be made to educate the parents, the community, and educators of the disparities found in many studies with respect to female participation in engineering, the sciences, mathematics, and related fields. Having the opportunity for equal access is not enough. Female students should be encouraged to participate and excel.

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