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Determination of a Predictive Model for the Fundamentals of Engineering Examination

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DETERMINATION OF A PREDICTIVE MODEL
FOR THE FUNDAMENTALS OF ENGINEERING EXAMINATION

by

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Dedication

This work is dedicated to the memory of my father,

a truly great educator and an even greater man.

Acknowledgements

For me the dissertation process started like all journeys, with that first tentative step. More than once during the journey I questioned if I had taken a wrong turn or made a wrong decision. A few times I even wondered if I had journeyed down the mythical rabbit hole in *Alice in Wonderland*. Now I have concluded the journey still surprisingly of sound mind and body. This journey was impossible to make alone, and I would like to thank those individuals who helped this journey become a success.

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Abstract

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In early 1995, the University of Tennessee at Martin (UTM) sought permission to terminate three existing engineering technology degree programs and replace them with a single Bachelor of Science in Engineering (BSE) degree. As part of the requirements to proceed with the implementation of an engineering program, the University of Tennessee system mandated the program be unique and different from any other engineering program in the state. In compliance with those guidelines, the curriculum was built with no separable majors. In addition, passing the Engineer-in-Training (now the Fundamentals of Engineering (FE)) examination was incorporated as a degree requirement. This examination tests fundamental knowledge of engineering. The requirement to pass the exam was viewed as a means to validate the content and rigor of the program. Also, in view of the fact that the BSE program was developed as a general engineering program, including the passing of the general FE examination was consistent with the goal of graduating engineers who would have a broad understanding of the basic fundamentals of engineering.

Using logistic regression, this study identified the factors that influence the first-time pass rate on the Fundamentals of Engineering Exam (FE) at UTM. The study focused on the basic mathematics, science and engineering science courses that are part of the curriculum. Grades received in each course and the number of times each course is taken were considered as the influencing factors.

The predictive model was built using SPSS's logistic regression forward stepwise likelihood ratio, backward stepwise likelihood ratio, and enter methods. In order to test the significance of each model developed, the null hypothesis, H_0: The model can predict, was tested using the Hosmer-Lemeshow statistic, with $\alpha = .05$. For each model developed, the calculated p was greater than .05 resulting in a model that was capable of predicting the pass/fail outcome. The variables remaining in the final model were prior semester GPA and the GPA in engineering economy using all attempts in the course.

Keywords: fundamentals of engineering, FE, logistic regression, prediction

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Chapter 1

Introduction

The path to a career in engineering is long and difficult. It begins with obtaining a Bachelor of Science degree in engineering and culminates with professional registration. Stephanie N. wanted to be an engineer for as long as she could remember. She had grown up fascinated by the way things were built. From middle school through high school, she had taken every math and science course available in her school and excelled in each one of them. It seemed natural for her to gravitate to a college major such as engineering.

Bill W. knew he wanted to work in a field which allowed him to work with people and to be outdoors. Bill's people skills developed at an early age as he was elected class president each year from his freshman to senior years. Bill also excelled in math and science courses. His high school guidance counselor suggested engineering as a college major.

Stephanie and Bill entered the University of Tennessee at Martin (UTM) as freshman engineering students the same semester. Stephanie excelled in her studies and developed into an excellent student earning A's and B's in her math, science, and engineering courses. As she began her senior year, she decided to find a job related to structural design upon graduation. Bill struggled through his math, science, and engineering courses but continued to develop his relationship skills. His plans were to finish the degree and obtain a job in an engineering field that would allow him to supervise and manage others. Both are faced with passing the Fundamentals of Engineering Examination (FE) before graduation at the end of the Bachelor's degree.

Each of them is concerned about the exam and wish a way existed to predict if he or she was going to pass it the first time it was attempted.

Statement of Problem

The FE exam is offered by the National Council of Examiners for Engineering and Surveying (NCEES) twice each calendar year in April and October (NCEES, n.d.b.). Of the first 30 UTM engineering students to take the exam, from October 1996 to April 2000, twenty-nine passed on the first attempt for a first-time pass rate of 96.7% The first-time taker pass rate has since declined and stabilized at approximately 75% to 80% (Helgeson & Wheeler, 2006).

The UTM engineering department has struggled to determine the factors that affect students' ability to pass the exam. Determining the factors that influence the first-time taker success rate of UTM students and the development of a model to predict success on the exam are the problems addressed by this study.

Statement of Purpose

The purpose of this study was to develop a predictive model which could be used to implement department policy changes in order to promote and maintain the highest first-time pass rate possible.

Significance

The Complete College Tennessee Act of 2010 brought about a dramatic shift in the higher education funding formula for the state of Tennessee. Before passage of the Act, enrollment comprised approximately 60% of the funding formula. The Act shifts the formula model from one based on enrollment to one based on mission-driven outcomes. Because of this shift, the importance of graduation rates has increased for each institution of higher education in Tennessee (THEC, 2010). This new emphasis on graduation rates creates an imperative that every department within a university provide the necessary services to assist students with fulfilling graduation requirements, in this case passing the FE exam. The ability to predict success or more importantly failure on the exam allows the UTM engineering department to provide student support services and intervention when failure is predicted. The identification of factors affecting the passing of the FE also allows the department to set policy and possibly curriculum to better prepare the students to pass the exam.

Conceptual Framework

According to Ellis (2004), curriculum can be defined as either prescriptive or descriptive. The prescriptive curriculum is defined by what should happen as students matriculate through their studies. These curricula often take the form of a plan or prescribed program. The descriptive curriculum involves the total experience of the students as they are exposed to the teachings in the curriculum and the classroom and college environment. Engineering curriculum more closely ascribes to the prescriptive definition.

Smith (1996, 2000) proposes four viewpoints of curriculum theory:

1. Curriculum as a body of knowledge to be transmitted.
2. Curriculum as an attempt to achieve changes in students based on a set of objectives (product).
3. Curriculum as process.
4. Curriculum as praxis.

Engineering curricula is intended to produce students who are prepared for professional practice; therefore, this research focuses on the second viewpoint. Bobbitt (1918) states in *The Curriculum*, “The central theory [of curriculum] is simple. Human life, however varied, consists in the performance of specific activities. Education that prepares for life is one that prepares definitely and adequately for these specific activities” (p. 42). Smith (1996, 2000) discusses the similarity in Bobbitt’s viewpoint to F. W. Taylor’s scientific management. Taylor (as cited in Morse & Babcock, 2010) believed that a job should be broken into elementary motions, discarding those motions determined to be unnecessary, refining the remaining motions into the most efficient method and teaching the resulting method to workers. Bobbitt (1918) believed as Taylor did that curriculum should pay detailed attention to what people needed to know in order to work and live their lives.

The Accreditation Board for Engineering and Technology-Engineering Accreditation Commission (ABET-EAC) requires a basic curriculum of 32 semester hours of math and basic science and 48 semester hours of basic engineering science courses (ABET, 2010). The desired outcome of any ABET-EAC accredited program is a product or a graduate who is prepared for professional engineering practice. The first step to professional registration is passing the FE exam. As part of the engineering degree requirement at UTM, a student must pass the exam. This theory of curriculum as producing a student with a set of skills grounds this study and allows us to ask two questions. Does the required "basic" curriculum as prescribed by ABET prepare the student to pass the exam? What courses are instrumental in helping students successfully pass the exam?

Definitions

- Accreditation Board for Engineering and Technology-Engineering Accreditation Commission (ABET-EAC): ABET, Inc., the recognized accreditor for college and university programs in applied science, computing, engineering, and technology, is a federation of 29 professional and technical societies representing these fields (ABET, n.d.b.).
- Fundamentals of Engineering Examination (FE): The FE exam is an 8-hour exam: 120 questions in the 4-hour morning session and 60 questions in the 4-hour afternoon session. Each examinee is supplied with a reference manual containing formulas relevant to the exam (NCESS, n.d.b.).
- Grade Point Average (GPA): In colleges and universities that use discrete evaluation (a grade of A = 4, B = 3, C = 2, etc.), the grade point average is calculated by multiplying the quantitative values of the letter grades by the credit value of the correlative course and then dividing the total by the sum of all credits.
- Logistic Regression: Logistic regression is a statistical method for analyzing a dataset in which one or more independent variables determine a dichotomous or binary outcome. The outcome, or dependent variable, contains data coded as 1 (pass) or 0 (fail) (MedCalc, n.d.).
- National Council of Examiners for Engineering and Surveying (NCEES): A national nonprofit organization dedicated to advancing professional licensure for engineers and surveyors (NCEES, n.d.a.).

- Real GPA: A calculation of the GPA using all grades received for each course, including the grades for courses that have been repeated.
- Statistical Package for the Social Sciences: Commonly known as SPSS. Software used for creating and saving data files and for analyzing data (Hinkle, Wiersma, & Jurs, 2003).
- Success: Passing the FE exam on the 1st attempt.

Assumptions

In order to perform this study, the following assumptions were made:

- Material covered in a course is equivalent regardless of the instructor. Each department is responsible for course descriptions and instructors use common syllabi for courses.
- The quality of instruction is equivalent across those courses taught by multiple instructors.
- In courses which are not taught by the same instructor for all sections of the course, each instructor uses a similar evaluation technique and assigns grades based upon the same assumptions of acquired knowledge. In other words an A in one instructor's class is roughly equivalent to an A in another instructor's class.

Limitations

This study considered FE subject area courses in engineering, math, and the basic sciences. The courses used for this study are unique to UTM. ABET requires the 32 hours of mathematics and science courses but does not prescribe specific courses. For example, a curriculum at one university could include a 3-hour linear algebra course while another university requires a 2-hour course or no linear algebra at all. The same is true with the 48 hours of basic engineering science courses. UTM uses a three-course sequence (9 hours) to cover the topics of statics, dynamics, and strength of materials. The University of Tennessee at Knoxville incorporates statics, dynamics, and physics into a two-course sequence (12 hours). Because of this variability among institutions in the way courses are formatted, the results and conclusions are unique to UTM.

Organization of the Study

Chapter 2, a review of literature, follows this introduction. Chapter 2 will discuss the history of engineering education, the FE exam, curriculum theory, and logistic regression. The research questions that guided this study are also presented in this chapter. Chapter 3 describes the research methodology, population description, data collection and analysis. Chapter 4 describes the results of the analysis, and the final chapter discusses future implications.

Chapter 2

Literature Review

This study will investigate factors contributing to the success of students taking the Fundamentals of Engineering Examination for the first time. The literature review provides a summary of relevant literature with five major themes. These themes are the history of engineering education, the history of the engineering program at the University of Tennessee at Martin, the Fundamentals of Engineering Examination, curriculum theory, and logistic regression.

History of Engineering Education

American engineering education is rooted in the country's fight for existence as a sovereign state. Unlike Europe, no formal system was in place to educate American engineers. Technical problems were solved by craftsmen who had served apprenticeships and learned the practical aspects of engineering. During the Revolutionary War, military engineers from Europe were essential to the war effort and the defeat of the British Empire. The efforts of these engineers were redirected to civilian matters at the close of the war. American military officials recognized the need for trained American engineers, and in 1802 the US Military Academy was established at West Point to train artillery and engineering officers. The Academy was transformed into the nation's first engineering school in 1817 (Grayson, 1993).

Initially, colleges offered apprenticeship and certificate programs emphasizing the practical aspects of engineering that were completed in addition to the traditional classical education programs. Because of the practical nature of engineering, it was regarded as utilitarian and was not considered a respectable collegiate pursuit. Colleges refused to recognize engineering as a curriculum worthy of study (Grayson, 1993).

The Morrill Land Grant Act of 1862 was perhaps the critical step that placed engineering inside of American universities. The Act provided for federal support of colleges of agriculture and mechanical arts (engineering). Fletcher (1896) reported that the number of engineering schools increased from fewer than two dozen in 1862 to 70 in 1872.

The seminal point in engineering education occurred at the World's Columbian Exposition on July 31, 1893. On this date the Society for the Promotion of Engineering Education, today known as the American Society for Engineering Education (ASEE), was created. Before this date engineering education was developed without any coordination or planning resulting in uneven quality of curriculums. Since its creation, ASEE has played a significant role in the formation and delivery of engineering curriculum in America (Grayson, 1993).

The Engineers' Council for Professional Development (ECPD) was formed in 1932. It was created as an agency to set curriculum and faculty standards and inspect engineering programs for compliance with those standards. Established by a joint effort of engineering societies and the National Council of State Boards of Engineering Examiners, the ECPD allowed the profession to have a direct impact on engineering education in America. The ECPD was renamed the Accreditation Board for Engineering and Technology in 1980 (ABET, 2010a). Currently, there are 2,055 programs associated with 424 colleges and universities that are ABET-Engineering Commission accredited (ABET, 2010b).

As part of the accreditation standards, ABET requires the lesser of 48 semester credit hours or three-eighths of the total credit hours required for graduation in engineering science and the lesser of 32 semester credit hours or one-fourth of the total credits required for graduation in math and basic science courses (ABET, 2010). An example of the typical ABET accredited program requirements in engineering science, math, and basic science courses is presented in Table 1. In addition to curriculum, ABET evaluates instructional and lab facilities, faculty credentials, and university support. For those engineers seeking professional licensure, a prerequisite is graduation from an ABET accredited engineering program.

Table 1

Typical Required Courses in an ABET Accredited Program

ABET Category	Course(s)	Total Credit Hours
Mathematics	Differential Calculus	21.0
	Integral Calculus	
	Calculus of Several Variables	
	Linear Algebra	
	Differential Equations	
	Probability and Statistics	
Basic Science	Calculus-Based Physics	12.0
	General Chemistry	
Engineering Science	Engineering Graphics	48.0
	Engineering Design	
	Statics	
	Dynamics	
	Strength of Materials	
	Engineering Materials	
	Fluid Dynamics	
	Thermodynamics	
	Electrical Circuit Analysis	
	Engineering Economy	
	18 Hours of Engineering Electives	

The History of Engineering at the University of Tennessee at Martin

The history of engineering and engineering technology on the University of Tennessee at Martin (UTM) campus extends back to the 1930s when the school was a junior college. The University was known as The University of Tennessee Junior College, and the engineering program consisted of the first two years towards a baccalaureate degree in the student's chosen field of engineering. The University became a four-year college in 1951. The majority of campus degree programs were transformed into full four-year baccalaureate programs at that time. The engineering program remained a two-year transfer program with students transferring to the University of Tennessee at Knoxville to complete the degree.

In the fall of 1967, a formal proposal was developed by the UTM Department of Engineering and submitted to the College of Engineering at Knoxville for an engineering degree with majors from one of six areas: graphics, electrical power, electronics, industrial, mechanical, and surveying. In the fall of 1969, the University of Tennessee system approval was granted for a four-year engineering technology degree. The six engineering majors were reduced to three technology majors: electrical, mechanical, and surveying. (The surveying major later became a major in civil engineering technology.) The Tennessee Higher Education Commission granted approval to offer the Bachelor of Science in Engineering Technology degree in 1970. The program received ABET-Technology Accreditation Commission accreditation in 1976 and maintained the accreditation until the degree was discontinued in 1997.

In early 1994, at the request of UTM constituents, a study team was formed to appraise the need by employers and the demand by students for engineering technology and engineering at UTM. A final recommendation was made in January 1995 to terminate the three engineering technology degree programs and to replace them with a single Bachelor of Science in Engineering (BSE) degree. The program was to be built with no separable majors and was to be consistent with goals set forth in the ASEE report, *Engineering Education for a Changing World*. The University of Tennessee system imposed the requirement that the program be unique and different from any other engineering program in the state. In order to meet this requirement and with the full support of the UT Martin engineering faculty and central administration, passing the Engineer in Training (now the Fundamentals of Engineering (FE)) exam was set as a degree requirement. Inclusion of this requirement was viewed as a means to validate the content and rigor of the program. The FE examination tests fundamental knowledge of engineering and because the BSE program was developed as a general engineering program, including the passing of the FE examination was consistent with the goal of graduating engineers who would have a broad understanding of the basic fundamentals of engineering.

The BSE degree was approved by the University of Tennessee system in June 1995 and received final approval by the Tennessee Higher Education Commission in July 1996. Previous to program approval, students had been allowed to take a limited number of junior courses as final program approval was pursued. This resulted in the first graduates from the program in May 1997. The program received ABET-EAC accreditation in 1999.

The total hours required for the BSE degree are 128. In 1999, concentration area electives were approved and published in the University catalog. The total number of concentration area elective hours required was set at 21 hours at that time. At the urging of faculty, students, and employers, the designation on a student's transcript of an area of concentration was also approved. The four concentrations of civil, electrical, industrial, and mechanical were now established as the *de facto* majors within the degree. The number of concentration elective hours was increased in 2001 to 24 hours and again increased in 2004 to a total of 27 (Wheeler, 2003).

The FE Exam

Although by 1950 all states plus Alaska, Hawaii, the District of Columbia, and Puerto Rico had engineering registration laws, no nationally common fundamentals exam existed. The first Fundamentals of Engineering (FE) exam was administered in 1965 by the National Council of State Boards of Engineering Examiners. Prior to 1965 each state or territorial licensing board was responsible for determining what was to be tested by the exam. Not until 1984, was the FE adopted for use by all state and territorial registration boards (NCEES, n.d.c.). The first exam consisted of a four-hour morning session comprised of 140 general engineering multiple-choice questions. The four-hour afternoon session was comprised of 50 required multiple choice-questions and an additional 20 questions which were selected from two of five subject areas (Koehn, 1989).

In 1996, the National Council of Examiners for Engineering and Surveying (NCEES) began offering the discipline-specific afternoon portion of the exam. The number of questions in the morning session was reduced to 120 and the number of afternoon questions was reduced to 60. The morning session, which is common for all examinees, covers 12 topic areas. These areas and the approximate percent of exam content are as follows: Mathematics (15), Engineering Mechanics (Statics and Dynamics) (10), Chemistry (9), Electricity and Magnetism (9), Engineering Economics (8), Computers (7), Engineering Probability and Statistics (7), Ethics and Business Practices (7), Fluid Mechanics (7), Material Properties (7), Strength of Materials (7), and Thermodynamics (7). For the afternoon session, examinees are required to choose one of the following seven modules: Chemical, Civil, Electrical, Environmental, Industrial, Mechanical, and Other Disciplines (NCEES, 2010).

Scoring the FE Exam

Statistical equating is used to compare results when multiple forms of a standardized assessment are administered. The purpose of the equating process is to “accurately and fairly compare educational skills using multiple test forms from an educational assessment” (Von Davier, 2011, p. 1). The process of statistical equating is used to normalize the FE exam scores to ensure that the desired level of competence is consistent across multiple administrations of the exam. Another goal of equating is to ensure that an examinee's chances of passing remain constant regardless of the particular exam’s difficulty. If the exam is more difficult than usual, a lower “cut-score”, the demarcation between passing and failing, is calculated to equate to the passing score of 70 (NCEES, n.d.d.).

Watson (1998) states, based on analysis of data collected in the mid-nineties at the University of Missouri Rolla, that students need to answer less than half of the questions correctly on the morning and afternoon sessions to pass the exam. This finding reinforces the generally accepted thought that the “cut-score” ranges from 45% to 50%.

Watson (1998) concluded that the exam appears to contain a significant amount of material that the students have not mastered and are not required to master in order to successfully complete the first step for professional licensure. He attributes the low "cut-score" to the fact that students will not perform well on questions in areas they perceive as not important to their chosen engineering discipline and for which their education has not prepared them.

Based on 450 observations, Watson contends that the FE exam score loosely correlates (r^2 = .25) with GPA for individual students and that stronger correlation exists for students who are majoring in a field where professional registration is important; hence, students are more motivated to succeed. The highest correlation was found in civil engineering (r^2 = .42), a field that places a very high value on professional licensure.

Aids to Passing the FE Exam

Universities often offer a review course for the FE exam. Koehn and Malani (1989, 2005) discuss such a course that is offered at Lamar University. Students review material over a seven-week period dealing with the engineering aspects of the exam. The remaining topics (math, basic sciences) are left to students to review on their own. An introduction and pretest, seven four-hour review sessions, final practice exam, evaluation of the final exam, and independently directed study are essential components of the review course. Ninety-four percent of the students completing the course between 1986 and 2005 (*n* = 346) have passed the FE exam. Koehn and Malani (2005) conclude that completion of such a review course by a well-motivated student results in a high probability of success.

Lee (2000) believes one of the most important aspects of preparing for the FE exam is review and practice test taking. Instructors attempting to generate an adequate supply of exam-style questions (multiple choice) find it difficult to continually develop new problems. Once a question is used, it cannot be used again for a period of time without modification. Lee presents a new method, employed at the University of Oklahoma, to produce an online review for the exam. The Generator program uses the concept of unique problem generation to be used in review sessions for students preparing to take the exam.

Mazurek (1995), when studying the use of FE exam scores to assess program effectiveness, found that two factors greatly influence the exam pass rate; the mastery of knowledge of engineering science, math and basic sciences and the student's level of motivation. He concludes that the strongest factor affecting the student's level of motivation was the failure of the student to understand the importance of professional registration.

As each examinee is seated for the exam, they are provided a new, unused copy of the *Fundamentals of Engineering Reference Handbook*. The reference book contains all essential equations and conversions needed to complete the test. Miller (2006) concluded there are three problems which exist as impediments to passing the exam with regards to the handbook:

1. The FE is a timed exam. This requires a good working knowledge of the contents of the handbook and the general location of equations, etc. in the handbook. Typically, course work completed prior to the exam does not require the use of the handbook. This results in unfamiliarity with the

handbook. Students are forced to search for equations, etc. wasting valuable time which could be better spent solving problems.

2. The handbook often uses different notation than the texts used during their course studies. The student must spend time translating between the familiar notation and the handbook to become familiar and comfortable with the FE notation.
3. The handbook supplies the students with general equations. It is assumed that the student can apply the general equation to various specific situations. Most courses today do not require students to derive even the simplest equation. Students have become dependent on being given the required variations of an equation thus enabling them to simply plug the appropriate numbers into the equation and arrive at an answer.

In order to maximize the probability of passing the exam students must prepare properly. Mastering the material included on the exam and becoming proficient with the use of the supplied reference manual are two essential components to success.

Predicting Success on the FE Exam

Helgeson and Wheeler (2006) state that a student with a higher cumulative GPA is more likely to pass the exam on the first attempt and as the cumulative GPA goes down, so does the chance of passing on successive attempts. In addition, the average cumulative GPAs of first-time takers of the exam who fail ($\mu = 2.64$, $\sigma = 0.36$) are generally below the average cumulative GPAs of those students who pass ($\mu = 3.18$, $\sigma = 0.46$). A contradiction to this simple relationship exists. Students with relatively low cumulative GPAs have managed to pass the exam while students with higher GPAs have failed; therefore, cumulative GPAs may not be the best predictor of success.

Helgeson and Wheeler (2006) analyzed the transcripts of 159 students at UTM who took the FE between 1996 and 2005 and calculated the real GPA for each student where real GPA was defined as the GPA calculated using all attempts in a particular course. For example, assume a student enrolls in calculus I and fails the first attempt and receives an A in his/her second attempt. The real GPA for the calculus I course is 2.0, (0.0 + 4.0)/2. They determined that a subset of core courses and the real GPA obtained in the courses is a better predictor of success than cumulative GPA. This subset of core courses includes Physics I and II, Calculus I, II, and III, Statics, Strength of Materials, and Dynamics. Based on the same transcript analysis it was determined that 132 out of 133 students who had achieved a real GPA of 2.0 in these courses passed the exam in one or two attempts equating to a 99.2% chance of passing the exam in, at most, two attempts. This study expands this research by attempting to determine the factors that directly influence the ability of a student to pass the exam. If these factors can be isolated a more focused approach to assisting the students in the department can be developed.

Curriculum

The word curriculum originates from the Latin word meaning “a running course or race course.” Combining the Latin meaning and the French word *courir* meaning “to run,” curriculum literally means “to run a course.” The word curriculum is defined in Webster’s *Third New International Dictionary* (1961), as “the whole body of courses offered by an educational institution or one of its branches” (p. 557).

Taba (1962) states that all curricula generally contain the same elements. These include a statement of aims and objectives, selection and organization of content, and certain patterns of learning or teaching. Also, each curriculum includes an evaluation component. The development of clear objectives of the curriculum is essential to the evaluation of the success of the content of the curriculum.

Smith (1996, 2000) advances four approaches to curriculum theory:

1. Curriculum as a body of knowledge to be transmitted;
2. Curriculum as an attempt to achieve changes in students based on a set of objectives (product);
3. Curriculum as process; and
4. Curriculum as praxis.

Curriculum viewed as a body of knowledge to be transmitted focuses on the content and the delivery of the content to students by the most effective means. When considering curriculum as an attempt to produce a product, objectives are set, a plan of action is determined, and the outcomes are measured. Curriculum as a process involves the entirety of the educational experience, the interaction of the teachers, students, and knowledge. The process model places emphasis on judgment and meaning making. The praxis model is an extension of the process model. The praxis model emphasizes judgment and meaning making, and it stresses the importance of the person or interests it serves.

Kliebard (1986) described four competing views of curriculum in America at the beginning of the twentieth century. He identifies these groups as humanists, developmentalists, social efficiency educators, and social meliorists. Humanists believed the curriculum should be used to develop mental reasoning and that education was not a tool for social reform. Developing students' ability to reason would lead to the betterment of society. Developmentalists focused attention on the social and emotional development of the student. By properly developing a curriculum to nurture the development of the student, the innate power of the individual could be unleashed. The social efficiency educators believed that by using education as an efficiency tool, society would be controlled. Students would be educated in a manner which would move them toward their "correct" position in society. The "correct" position would be determined by scientific evaluation of their abilities and interests. The social meliorists viewed education as a means for social change. Schools and their curriculum were seen as the principle force for social change and social justice. Engineering education and its curriculum does not fit neatly into a single view as espoused by Kliebard. Engineering curriculums are a blend of the humanist and the meliorist views. The technical portion of engineering curriculums is intended to develop the problem solving and reasoning skills of engineering students. The curriculum in total is intended to instill in the student the desire to use the acquired skills for the betterment of society.

Tyler (1949) discusses four fundamental questions that should be addressed when constructing curriculum:

1. What educational objectives, goals, or purposes should the school seek to obtain?
2. What are the necessary educational experiences which should be provided to obtain the objectives, goals, or purposes?
3. How can the educational experiences be organized in order to be effective?

4. How is success measured?

The first question, which is germane to this study, deals with educational goals or objectives. He states that without a clear conception of the goals or objectives it is improbable that any continuous improvement efforts can be made. In order to judge the success of the curriculum, a goal must be in place. One of the goals of the engineering curriculum at UTM is preparing students to pass the FE exam.

ABET (2010) requires a structured curriculum which addresses the most basic components of engineering sciences, math, and basic science. The goal or purpose of this curriculum is to transmit to the student the knowledge required to be successful as an engineer. One validation of possessing that knowledge is passing the FE exam.

Logistic Regression

Pohlmann and Leitner (2003) compared logistic regression to ordinary least squares (OLS) regression using two data sets. Based on their analysis, if a researcher is only concerned with testing relationships between independent and dependent variables both models worked equally well. The model and the independent variables were both found to be significant at $\alpha = .05$. If the researcher is concerned with classification of the dependent variable, logistic regression produced more accurate estimates. They concluded that using logistic regression results are comparable to OLS results, but the ability to predict a binary dependent variable outcome is best suited to logistic regression.

Peng, So, Stage, and St. John (2002) discuss the supremacy of logistic regression to other statistical techniques that have been suggested for handling categorical data. The techniques mentioned are discriminant function analysis, log-linear models and linear probability models. Logistic regression is superior to the other techniques because it can accept both continuous and discrete independent variables and is not constrained by normalcy assumptions.

Morgan and Teachmen (1988) address the question of why logistic regression should be used with binary dependent variables instead of OLS regression. The drawbacks to using OLS regression are as follows:

1. Predicted values may be outside of the binary range of 0 to 1.
2. Heteroscedasticity can occur. Incorrect standard errors of the coefficients will lead to incorrect conclusions regarding the significance of the model.
3. The model will be overly sensitive to changes in the predictor variables.

Logistic regression yields prediction probabilities between 0 and 1 and unbiased estimates of the standard errors of coefficients thus alleviating the first two drawbacks. With respect to the third drawback, OLS regression assumes that the dependent variables will exhibit a constant (linear) increase or decrease throughout the range of independent variables. With low or high values of the independent variable, this may or may not be true. Logistic regression by its non-linear nature decreases the effects on the low and high values at the tails of the distributions of the independent variables.

Brannick (n. d.) explains three reasons logistic regression is used instead of linear regression:

1. As x-values increase, the predicted y-values will possibly become less than zero and greater than one with such values being theoretically impossible.
2. Homoscedasticity is a basic assumption of regression; the variance of Y is constant across all values of X. This is not true with dichotomous variables. The variance is defined as PQ where P is the probability of occurrence and Q

is 1−P. Assume 50 percent is the probability of occurrence; therefore, PQ = 0.5*(0.5) = 0.25. If P = 20 percent, the variance = 0.2*(0.8) = 0.16. As P approaches 1 or 0 the variance approaches zero.

3. Regression significance tests are based upon the assumption that errors of prediction (Y-Y') are normally distributed. Because Y only takes on the values 0 and 1, this assumption cannot be justified; therefore, the results of tests of regression significance are questionable if you use linear regression with a binary dependent variable.

For this investigation logistic regression is the appropriate analysis technique due to the presence of a binary dependent variable. The presence of both continuous and discrete independent variables also indicates the superiority of logistic regression over available methods such as discriminant function analysis, log-linear models and linear probability models.

Research Questions

A student who successfully completes the UTM Bachelor of Science degree curriculum requirements should be prepared and capable of passing the FE exam. History has proven that not all students pass the exam on the first attempt. Curriculum theory states that a program of study should meet an objective such as passing the FE exam. Logistic regression analysis can be used to predict, within reason, outcomes based on inputs of independent variables. This study was guided by the following research questions:

1. Can a predictive model that will predict success on the FE exam be built?
2. What courses influence a student’s ability to pass the FE exam?

3. Does the grade received in a course play a role in passing the FE exam?
4. Does the number of times a student takes a course play a role in passing the FE exam?

Chapter 3

Methodology

The purpose of this chapter is to describe the methodology employed in this study. The population for the study is defined; independent and dependent variables used in the study are defined; and data analysis procedures are described. A brief description of the statistical methods utilized for data analysis is included in this chapter. The chapter concludes with a summary of the research questions and the hypothesis which was tested for each question.

Statistical Methodology

Regression analysis is used to predict a continuous variable from a number of independent variables. When the dependent variable is dichotomous, in this case with the student passing or failing the exam, the appropriate regression analysis is logistic regression. Therefore, logistic regression was used to identify the courses that affect the first-time pass rate and to build a predictive model.

Population and Sample

The population for this study consisted of students who had completed the prescribed course requirements for the Bachelor of Science in Engineering (BSE) degree. This is an infinite population as described by Johnson (2011). An infinite population consists of all units; in this case UTM students, past, present, and future who might take the exam.

In order to stabilize the Maximum Likelihood (ML) estimators of logistic regression the sample size must be large. Summarizing logistic regression research findings, Peng et al. (2002) stated that minimum sample size should be of the magnitude of 10 to 1, 10 data points for each variable introduced into the model. Lawley and Maxwell (1971) suggest that a sample size of $N - k - 1 \geq 50$ is appropriate for significance test of the ML factors where N is the sample size, and k is the number of predictors.

The sample used for this analysis consisted of students who have completed the course requirements for the BSE degree prior to January 1, 2011. This date was chosen to facilitate the collection of data and the permissions required to collect the data. Transcripts of 339 students were examined and the grades for each of the 17 FE courses were recorded. Following detailed analysis of the data, 18 students were removed from the sample. These data were removed due to incomplete grade information for the student. The final sample analyzed consisted of 321 unique students.

According to Peng et al. (2002), the sample size for this study should be a minimum of 360 data points. Lawley and Maxwell (1971) indicate that the sample size should be at least 87 ($N \geq 50 + 1 + 36$). The sample size of 321 therefore was deemed to be sufficient for this study, falling between 87 and 360.

In order to conduct this research, permission to collect the grades from the students' transcripts was obtained from the UTM and University of Memphis Institutional Review Boards (IRB). The UTM IRB granted permission to proceed with data collection on August 10, 2011 (IRB# 12-81-E05-4025/Whee,Edw). The University of Memphis IRB granted permission to proceed with data collection on October 21, 2011 (IRB ID# 091411-904) (see Appendix). To ensure anonymity, no identifying information such as race, gender or student identification number was recorded from the transcripts.

Variables and Data Collection

Independent variables. The FE tests over 12 subject areas. The UTM engineering curriculum requires 17 courses comprising 55 credits which cover FE subject areas. Three courses are taught by the Department of Chemistry and Physics: general chemistry I and calculus-based physics I and II. The Department of Mathematics and Statistics teaches three of the 17 courses: differential calculus, integral calculus, and multivariate calculus. The remaining 11 courses are taught by the Department of Engineering. These include courses in engineering mechanics, materials, fluid mechanics, thermodynamics, electricity, computers, probability and statistics, and engineering economy. The 17 courses and corresponding FE subjects are summarized in Table 2.

The first group of independent variables considered in this study was the real GPA in each of the 17 FE courses. The real GPA is calculated using all attempts in a course. For example, assume a student receives a grade of D in a course and retakes the course and earns an A, the real GPA = (1 + 4)/2 = 2.5. This variable is a continuous variable.

In order to graduate from the UTM engineering program, every student must earn a grade of C or better in all math, science, and engineering courses required for the degree. The second group of independent variables was the number of course attempts required to earn a grade of C or better for each of the 17 FE courses. This variable is a discrete variable taking on a value of one, two, three, etc.

Table 2

General FE Exam Topics and Corresponding Program Required Courses

FE Topic	Program Course(s)	Total Credit Hours
Mathematics	Math 251, 252, 320 Calculus I, II, III Engineering 315 Differential Equations	15.0
Probability and Statistics	Engineering 311 Applied Probability and Statistics for Engineers	3.0
Chemistry	Chemistry 121 General Chemistry	4.0
Computers	Engineering 231 Digital Logic	3.0
Engineering Economy	Engineering 380 Engineering Economy	3.0
Engineering Mechanics	Engineering 121 Statics Engineering 241 Dynamics Physics 220 Physics of Kinematics and Kinetics	12.0
Strength of Materials	Engineering 220 Strength of Materials	3.0
Materials Properties	Engineering 310 Engineering Materials	3.0
Fluid Mechanics	Engineering 341 Fluid Dynamics	3.0
Electricity, Magnetism	Engineering 232 Analog Circuits Physics 221 Physics of Electricity and Magnetism	6.0
Thermodynamics	Engineering 340 Thermodynamics	3.0

Source: The University of Tennessee at Martin Undergraduate Catalog (2010-2011)

The cumulative real GPA in the 17 FE subject area courses and the overall cumulative GPA at the time of sitting for the exam were the final independent variables considered. Both of these variables are continuous.

Dependent variable. The dependent variable was the pass/fail status on the first attempt of the FE. The dependent variable is a dichotomous variable. A binary scheme, pass (1)/fail (0), was used to code the variable data for analysis.

Data collection. Data was collected and recorded in an Excel spreadsheet by accessing the UTM transcripts of each of the subjects of this study and recording the grade (A, B, C, D, F) that was received for each attempt of the 17 FE courses. Pass/fail data for the FE exam is forwarded by the Tennessee Board of Architectural and Engineering Examiners to the UTM Department of Engineering after each administration of the exam. The pass/fail status for the exam was obtained by accessing these records.

The letter grades recorded in the Excel spreadsheet were converted to the equivalent numerical grade based on a 4.00 GPA scale. Excel was then used to calculate the real GPA for each of the 17 FE courses. The cumulative real GPA for the 17 FE courses was also calculated using Excel. The calculated real GPA for each of 17 FE courses and the cumulative real GPA for the 17 FE courses was imported to the SPSS package for further analysis. In addition to the data imported from the Excel spreadsheet, the cumulative university-wide GPA of each student at the time the exam was taken and the pass/fail status was entered into SPSS.

Validation

For this study the validity of the model is based on the percentage of pass/fail status correctly classified. Statistical significance of the model was tested using the X^2 goodness-of-fit statistic as presented by Hosmer and Lemeshow (2000).

Data Analysis

Using SPSS's logistic regression function, the data was analyzed using the forward stepwise likelihood ratio method (FSLR). In order to determine if there was a more suitable model based on percentage of correctly classified cases, additional models were built using SPSS's backward stepwise likelihood ratio (BSLR) and enter methods.

Research Questions and Hypotheses

Research question 1. Can a regression model that will predict success on the FE exam be built? Using SPSS's FSLR method, a logistic regression function was calculated using the sample data. In order to test the significance of the developed model, the null hypothesis tested was that the model can predict the dependent variable. The Hosmer-Lemeshow statistic, with $\alpha = .05$, was used to test the null hypothesis. The same analysis was performed using SPSS's logistic regression BSLR and enter methods. This was done in order to determine the model which correctly classified the highest percentage of cases and was statistically significant.

Research questions 2, 3, and 4. What courses influence a student's ability to pass the FE exam? Does the grade received in a course play a role in passing the FE exam? Does the number of times a student takes a course play a role in passing the FE exam? The logistic regression equation developed in response to research question one was used to address these research questions.

Summary

Using logistic regression and data obtained from UTM engineering students' transcripts, a predictive model for performance on the Fundamentals of Engineering examination was developed. The next chapter will present the model produced by this study, and the final chapter will present conclusions and recommendations based on the results of this research.

Chapter 4

Results of Study

The purpose of this chapter is to report the findings from the data analysis discussed in Chapter Three. The data used in the analysis will be discussed followed by the findings related to each of the four research questions that guided this study.

Data

The engineering program at the University of Tennessee at Martin was established in 1996. This study used a sample consisting of students who had completed the course requirements for the Bachelor of Science in Engineering (BSE) degree from the inception of the program through January 1, 2011. The total number of students in the study was initially 339. Each of the 339 transcripts was examined, and each student's grade for every attempt of the 17 FE courses was recorded in an Excel spreadsheet.

Upon detailed examination of the 339 records, 18 were found to either contain pass/fail credit received through advanced placement or credit granted without a corresponding grade. The later generally occurs when a student transfers to UTM with multiple courses that cover the material covered in a single UTM course, and the department grants credit for the single course without assigning a grade. These 18 records were eliminated from the dataset. The remaining 321 student records were used for all analysis performed in this study. The focus of this study was to determine the possible curriculum factors influencing the pass/fail status for UTM engineering students. Its purpose was not to determine if race, gender, or ethnicity affected the pass/fail status, therefore the data were not delineated along gender, racial, or ethnic lines.

Statistical Results

Research question 1. Can a regression model that will predict success on the FE exam be built? For Question 1, logistic regression was used. The dependent variable for the model was the pass/fail status on the first attempt for each of the 321 students included in the study

The null hypothesis for Question 1 was that the model could predict. In order to reject the null hypothesis, the calculated *p*-value must be less than .05. For the forward stepwise likelihood ratio (FSLR) method and the backward stepwise likelihood ratio (BSLR) method, the Hosmer and Lemeshow Test, $X^2 = 10.384$, df = 8, $p = .239$, indicated that the null hypothesis could not be rejected. The Hosmer and Lemeshow Test, $X^2 = 6.651$, df = 8, $p = .575$, calculated for the enter method also indicated that the null hypothesis could not be rejected. Tables 3-5 summarize the Hosmer and Lemeshow X^2 test results for each analysis method. The null hypothesis was not rejected for any of the three models. This indicates that each of the developed models is capable of predicting the pass/fail outcome.

The enter method produced a model consisting of 35 of the 36 variables. The FSLR and the BSLR methods produced identical models consisting of two variables. The percentage of pass/fail outcomes classified correctly by the FSLR and the BSLR methods was 85% while the enter method classified 84.7% correctly. Tables 6-8 summarize the classification results for each of the methods of analysis.

Table 3

Forward Stepwise Likelihood Ratio Method Hosmer and Lemeshow Test Results

Step	Chi-square	df	Sig
1	2.458	8	.964
2	10.384	8	.239

Table 4

Backward Stepwise Likelihood Ratio Method Hosmer and Lemeshow Test Results

Step	Chi-square	df	Sig
1	5.901	8	.658
34	10.384	8	.239

Table 5

Enter Method Hosmer and Lemeshow Test Results

Step	Chi-square	df	Sig
1	6.651	8	.575

Table 6

Forward Stepwise Likelihood Ratio Method Classification Table

			Predicted		
			Binary Pass/Fail		
			0	1	Percentage Correct
Step 1	Binary Pass/Fail	0	7	49	12.5
		1	3		98.9
	Overall Percentage				83.8
Step 2	Binary Pass/Fail	0	10	46	17.9
		1	2	263	99.2
	Overall Percentage				85.0

Table 7

Backward Stepwise Likelihood Ratio Method Classification Table

			Predicted		
			Binary Pass/Fail		
			0	1	Percentage Correct
Step 1	Binary Pass/Fail	0	9	47	16.1
		1	3	262	98.9
	Overall Percentage				84.4
Step 34	Binary Pass/Fail	0	10	46	17.9
		1	2	263	99.2
	Overall Percentage				85.0

Table 8

Enter Method Classification Table

			Predicted		
			Binary Pass/Fail		
			0	1	Percentage Correct
Step 1	Binary Pass/Fail	0	17	39	30.4
		1	10	255	96.2
	Overall Percentage				84.7

The overall goal when developing a model is to obtain the best fit while minimizing model parameters (Hosmer & Lemeshow, 2000). Based on minimizing the model variables and the higher percentage of outcomes correctly classified by the FSLR and BSLR, the remainder of this study focused on the model produced by these two methods.

Forward stepwise likelihood ratio (FSLR) method begins with no variables in the predictive equation. The model is generated by entering variables one by one based on the statistical significance of the coefficient for the variable. The significance is assessed by the likelihood ratio chi-square test. The order of entry begins with the one that produces the greatest change in the log-likelihood relative to the model. Variable entry ends when no further statistically significant variables are candidates for the model. The score statistic generated by SPSS represents the chi-square likelihood ratio. The first variable to enter the model was GPA the Prior Semester (GPA_P_S) with a $p = .000$. The second and final variable to enter the model was Engineering 380 Real GPA (E380R_GPA) with $p = .047$. The constant for the model was also determined to be significant with $p = .000$. The final logistic equation as presented in Table 9 is

$$Z = 1.952\,(\text{GPA\_P\_S}) + .438\,(\text{E380R\_GPA}) - 5.184. \quad (1)$$

Table 9

Logistic Equation Predicting the Pass/Fail Status on FE Exam

							95% C.I. for Exp(B)	
Variable	B	S.E.	Wald	df	Sig	Exp(B)	Lower	Upper
GPA_P_S	1.952	.513	14.459	1	.000	7.045	2.575	19.271
E380R_GPA	.438	.220	3.960	1	.047	1.549	1.007	2.383
Constant	-5.184	1.233	17.674	1	.000	.006		

Backward stepwise likelihood ratio (BSLR) method begins with all variables in the predictive equation. The model is generated by removing variables one by one based on the statistical insignificance of the coefficient for the variable. The insignificance is assessed by the likelihood ratio chi-square test. The order of exit begins with the variable that produces the least change in the -2 log-likelihood relative to the model. Variable removal ends when no further statistically insignificant variables are candidates for removal from the model. After 34 steps, the BSLR method produced the same model as the FSLR as presented in Table 9.

Using Equation 1, the probability (p) of passing the FE exam can be determined by calculating the logit. The logit can be interpreted as the probability of the event occurring, in this case, passing the exam. If the logit is less than .5, the binary variable is assigned a value of zero (fail). If the logit is between .5 and 1.0, the binary variable is assigned a value of one (pass). The generic equation for the logit is $p = 1/1 + e^{-Z}$. For this model the logit is

$$p = 1/1 + e^{-(1.952\ (GPA\_P\_S)\ +.438\ (E380R\_GPA)\ -\ 5.184)}. \quad (2)$$

Based upon the analysis performed for this study, it appears that a model to predict performance on the Fundamentals of Engineering Exam can be constructed.

Research questions 2, 3, and 4. What courses influence a student’s ability to pass the FE exam? Does the grade received in a course play a role in passing the FE exam? Does the number of times a student takes a course play a role in passing the FE exam? The logistic regression equation developed in response to research question one was used to address these research questions.

Based upon the variables which remain in Equation 1, the only course which has influence on the student’s ability to pass the exam is Engineering 380 Engineering Economy. The influencing factor is the real GPA obtained by the student in this class.

To be included in the model, a variable must have a calculated $p < .05$. The real GPA in engineering economy just met the criteria for inclusion with $p = .047$. Including the variable improved the classification percentage correct from 83.8 to 85.0. No other course was a candidate for the model with the next lowest $p = .098$

Summary

Using logistic regression and data obtained from UTM engineering students' transcripts, two unique predictive models for performance on the Fundamentals of Engineering examination were developed. Both of the models were proven to be statistically significant. The model produced by the forward stepwise likelihood ratio method and the backward stepwise likelihood ratio method was judged to be superior to the model produced by the enter method due to the fewer number of variables in the model and the higher percentage of correctly classified cases. The next chapter will present the conclusions and recommendations based on the results of this research.

Chapter 5

Conclusions

The purpose of this study was to develop a model to predict the Fundamentals of Engineering (FE) exam pass/fail status of University of Tennessee at Martin (UTM) engineering students which could be used to implement department policy changes in order to promote and maintain the highest first-time pass rate possible. A secondary consideration for this study was the identification of the courses which influence a student's ability to pass the exam. This chapter discusses the conclusions that can be drawn from this research, the relevance of these findings for prior research and theory, recommendations for its application at UTM, and future research considerations.

Conclusions

A predictive model was built using SPSS's logistic regression forward stepwise likelihood ratio (FSLR) method. In order to test the significance of the developed model, the null hypothesis tested was that the model can predict the dependent variable. The Hosmer-Lemeshow statistic, with $\alpha = .05$, was used to test the null hypothesis. The same analysis was performed using SPSS's logistic regression backward stepwise likelihood ratio (BSLR) and enter methods. For each analysis, the calculated p was greater than .05 resulting in the failure to reject the null hypothesis in all cases. Each of the three analysis methods produced a predictive model that was capable of predicting the pass/fail outcome. The same variables, prior semester GPA and real GPA in engineering economy, were used to construct the FSLR and the BSLR models. The identical FSLR and BSLR models were chosen as the final model because of their simplicity and higher number of correctly classified cases.

All three models correctly classified a higher percentage of the passing students than the failing students. According to Hosmer and Lemeshow (2000), classification is sensitive to the relative sizes of the two groups and will favor classification into the larger group regardless of the model fit. The sample used in this analysis contained 321 student records. Two hundred sixty-five of these students passed the exam; the remaining 56 failed it. This is approximately a 5 to 1 ratio of pass to fail; therefore, it would be expected that the model would be more likely to predict passing the exam even when the student had failed. This results in poor classification percentages for failure.

Based upon the variables which remained in the logistic regression equation, the only course that has influence on the student's ability to pass the exam is Engineering 380 Engineering Economy. The influencing factor is the real GPA obtained by the student in this class.

Engineering economy is a course based upon financial decision making. The major learning outcome for this course is the development of the student's ability to make economically justified decisions for engineering projects and capital expenditure proposals. The inclusion of the real GPA for this course with $p = .047$, was barely less than the chosen $\alpha = .05$ level. Intuitively, inclusion of this random course does not appear to be logical. Further investigation offers a possible explanation as to why it remained in the final model.

With each administration of the exam, the National Council of Examiners for Engineering and Surveying (NCEES) generates a report for each university that had students sitting for the exam. This report analyzes the 12 topic areas for the most recent exam. The national average percentage of correctly answered questions for the country and the average percentage of correctly answered questions for the institution (UTM) are provided for each of the topic areas. These reports consistently indicate that the students from UTM answer a higher percentage of engineering economy questions correctly than the national average. This is the only topic area on the exam where UTM students consistently exceed the national average.

Individual topic areas are not considered when the FE exam is scored. Scoring is based upon the total number of questions answered correctly regardless of topic area. An examinee can incorrectly answer all questions covering a given topic and still pass the exam. The NCEES reports lend credence to the assumption that UTM students who have a high real GPA in engineering economy are answering a higher number of engineering economy questions correctly. This leads to the proposition that a high real GPA in engineering economy can result in a higher overall number of correctly answered exam questions, thus increasing the probability of passing the exam.

Figures 1 illustrates the relationship between the prior semester GPA and the logit discussed in Chapter 4. The logit represents the probability of passing the exam based on the logistic regression model which was developed. As evidenced by the graph, the higher the GPA, the higher the likelihood of passing the exam. This reinforces the supposition made by Watson (1998) that a correlation exists between GPA and FE exam score.

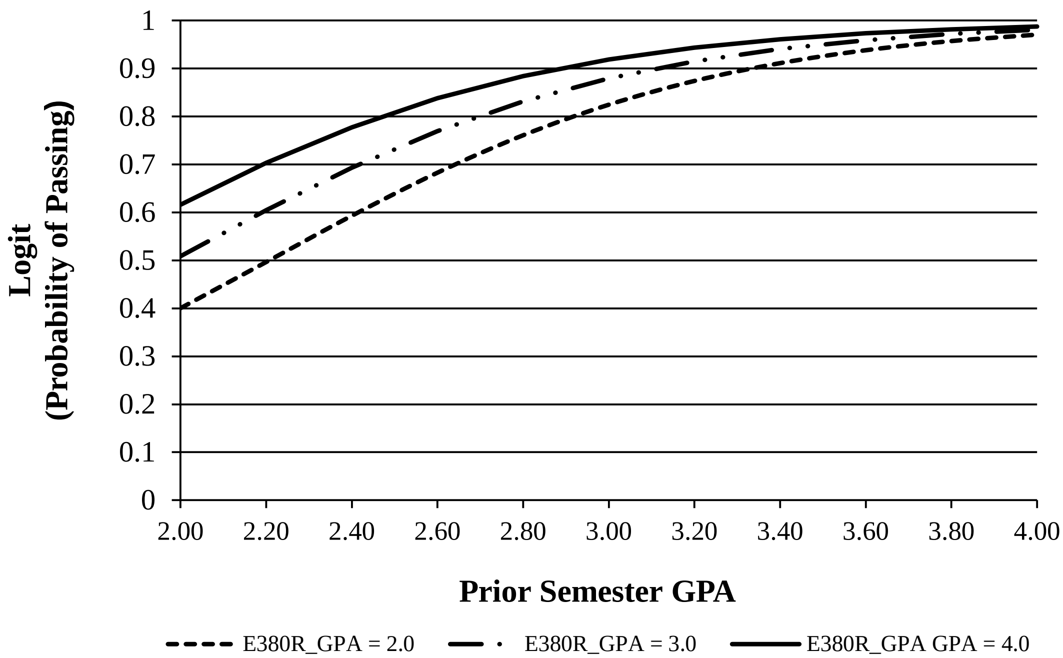

Figure 1. Logit or probability of passing the FE exam based on prior semester GPA and three examples of real GPA obtained in Engineering 380 Engineering Economy.

Relevance

In the linear regression model, the coefficient of determination, r^2, explains the proportion of the variance of the dependent variable that is predicted by the independent variable(s). Greater values of r^2 indicate that more of the variation is explained by the model. The theoretical maximum for the $r^2 = 1.00$. For logistic regression it is not possible to compute r^2. The pseudo r^2 measures, the Cox and Snell r^2 and the Nagelkerke r^2, are often computed for logistic regression models. The Cox and Snell statistic has a theoretical maximum of less than one. The Nagelkerke statistic is adjusted to a scale of zero to one. The Nagelkerke r^2 for this study's model was computed as .23.

Watson (1998) contends that the FE exam score loosely correlates ($r^2 = .25$, $n = 450$) with GPA. Based upon the Nagelkerke r^2 and the inclusion of the prior semester

GPA in the final model, the results of this study support Watson’s contention that a correlation exists between GPA and the student’s ability to pass the exam.

Smith (1996, 2000) states as one of four viewpoints of curriculum theory that curriculum is an attempt to achieve changes in students based on a set of objectives (product). The engineering curriculum at UTM is intended to produce students who are prepared for professional practice; therefore, this research focused on this viewpoint.

This study was grounded by the theory of curriculum as producing a student with a set of skills which prepares him or her to pass the FE exam. The research was focused on the ABET prescribed "basic" engineering curriculum. The entire curriculum, including general education courses, was found to contribute to the student’s ability to pass the exam as evidenced by the inclusion of the prior semester’s overall GPA in the final model. Surprisingly, the overall GPA was the largest influencer in the model. If GPA alone is used to calculate the pass/fail probability 83.8% of the cases will be classified correctly. This study validates the theory of curriculum as producing a student with a set of skills capable of passing the FE exam.

Implications

Although this study did not yield results identifying courses which directly influence the ability to pass the FE, it did yield a useful tool for counseling students who are preparing for the exam. Using the logit presented in Chapter 4, students and/or advisors can easily calculate the probability of passing the exam. The only information required to make the calculation is the cumulative GPA at the end of the semester prior to taking the exam and the real GPA achieved in engineering economy. Students with lower probabilities can be advised to adjust their study plans in an effort to improve their odds of passing the exam.

Current UTM Department of Engineering policy requires that a student must complete Engineering 121 Statics, Engineering 220 Strength of Materials, Engineering 241 Dynamics, Mathematics 251-252 Calculus I and II, Mathematics 320 Multivariate Calculus and Physics 220-221 University Physics I and II with a grade of C or better and obtain a minimum real GPA of 2.00 in order to advance to 300-400 level courses. This policy was implemented in 2006 as a result of a declining first-time pass rate and was based on the findings of Helgeson and Wheeler (2006). The decline is clearly visible in Figure 2. Beginning with the 2002 fall semester the first-time pass rate trended downward with a steep drop to 33.3% in the 2006 spring semester. Although the pass rate rebounded the following semester the trend continued downward.

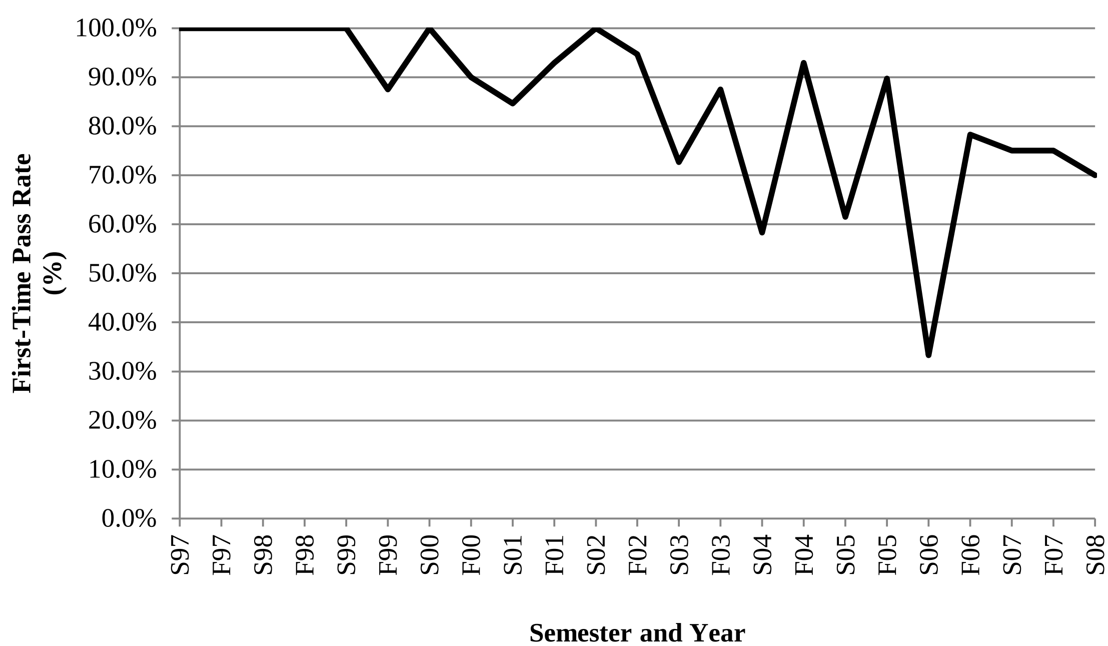

Figure 2. FE pass rate for first-time takers for spring semester 1997 through spring semester 2008.

Although this study did not produce similar results, by identifying these eight courses as critical, it is doubtful that the policy will be changed. During the period between the 2002 fall semester and the 2008 spring semester the first-time pass rate was 77.9%. In the years 2008-2011 the first-time pass rate has improved to 85.7%. In order to determine if the policy has positively impacted the first-time pass rate, the *Z*-test for proportions was performed. The null hypothesis $p = .779$ was tested against the alternate hypothesis $p > .779$ at $\alpha = .05$. The null hypothesis was rejected, $Z = 1.889$, $n = 91$, $p = .0295$. This rejection of the null hypothesis clearly indicates the policy has impacted the first-time pass rate in a positive manner.

Future Research

In the course of conducting this research, a number of possible future considerations have arisen. These generally involve the addition of variables or the modification of variables used in this study. One major consideration that does not involve a variable is the disparity between the number of students passing the exam and the number of students failing the exam.

Recall that Hosmer and Lemeshow (2000) stated that classification would tend to favor the dependent variable representing the largest number of outcomes. This study was conducted with 265 students who passed the exam and 56 students who had failed. This could be corrected if there were more data from failing students. Having more data from failing students would be counterproductive to the mission of the department; therefore, this issue will be difficult to address in the future.

Additional variables which might contribute to the success of the student on the exam will now be examined. As each examinee is seated for the exam, they are currently provided a new, unused copy of the *Fundamentals of Engineering Reference Handbook*. The reference book contains all essential equations and conversions needed to complete the test. Miller (2006) concluded that three problems were impediments to passing the exam with regards to the handbook:

1. Lack of a good working knowledge of the contents of the handbook and the general location of equations, etc. in the handbook.
2. The handbook often uses different notation than the texts used during their course of studies.
3. The handbook supplies the students with general equations.

Prior to taking the exam, each examinee would be required to complete a survey consisting of three questions. The responses to these questions would be based on a five-point Likert scale. The first question would deal with how familiar the student is with the reference handbook. Responses for the questions would range from not at all familiar to extremely familiar. The results of this survey would then be an additional variable in the dataset.

The second question would deal with the student's opinion about how academically prepared he or she is to take the exam. Responses to this question would range from not at all academically prepared to extremely academically prepared. In addition to student input for this variable, the faculty would be asked to rate the academic preparedness of each examinee using the same response scale. The student and the faculty scores would be aggregated and averaged to produce an overall academic preparedness factor value. Involving the faculty acts as a means to smooth the effects of overly optimist or overly pessimistic students when self-rating. The factor would become an additional variable in the analysis.

Mazurek (1995), when studying the use of FE exam scores to assess program effectiveness, found that two factors greatly influence the exam pass rate; the mastery of knowledge of engineering science, math and basic sciences and the student's level of motivation. A third and final question would deal with the student's motivation to pass the exam. He concludes that the strongest factor affecting the student's level of motivation was the failure of the student to understand the importance of professional registration. Although passing the exam is a graduation requirement, many students are not motivated to pass the exam the first time they take it. Many also do not understand the importance of professional registration. The student would be asked to rate his or her motivation. Responses to this question would range from not at all motivated to extremely motivated. The results of this question would be another variable in the analysis.

Another possible variable which could affect the model would be the introduction of a coded variable representing the engineering concentration of the student. UTM offers four concentrations: civil, electrical, industrial, and mechanical. Students in each concentration take 27 credit hours of upper division class work that is unique to the concentration. Due to the differences in course content of the 27 credit hours, some of which is covered on the exam, the ability to pass the exam may be effected by the student's concentration. A concentration area variable coded 1-4 would be used to represent each of the four concentrations; civil, electrical, industrial, and mechanical. This variable would be introduced into the analysis.

Summary

Although this model is built upon data collected from UTM, the results can easily be generalized to other universities with an interest in predicting a successful outcome on the Fundamentals of Engineering exam. The final model, which classifies 85.0% of the outcomes correctly, contains the prior semester GPA and the engineering economy real GPA. When the engineering economy real GPA is removed from the model, it still classifies 83.8% of the outcomes correctly. If a university using the A = 4.00 grading scale desires to predict the probability of passing the exam, the model produced at step one (refer to chapter IV) can provide that information.

In conclusion, this study accomplished what was intended. It produced a model which will be helpful to the UTM Department of Engineering in guiding students in their preparations for the FE exam.

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Appendix

THE UNIVERSITY OF MEMPHIS

Institutional Review Board

To:	Edward Wheeler Leadership
From:	Chair or Designee, Institutional Review Board For the Protection of Human Subjects irb@memphis.edu
Subject:	Determination of a Predictive Model for the Fundamentals of Engineering Examination (091411-904)
Approval Date:	October 21, 2011

This is to notify you that the Institutional Review Board has designated the above referenced protocol as exempt from the full federal regulations. This project was reviewed in accordance with all applicable statuses and regulations as well as ethical principles.

When the project is finished or terminated, please submit a Human Subjects Research Completion Form (COMP) to the Board via e-mail at irbforms@memphis.edu. This form can be obtained on our website at http://www.memphis.edu/irb/forms.php.

Approval for this protocol does not expire. However, any change to the protocol must be reviewed and approved by the board prior to implementing the change.

Digitally signed by
Jacqueline Y. Reid
Date: 2011.10.21
11:55:44 -05'00'

Chair or Designee, Institutional Review Board
The University of Memphis

THE UNIVERSITY of TENNESSEE UT
MARTIN

Office of Research, Grants & Contracts
100 Administration Building
Martin, Tennessee 38238
Office: 731.881.7015
Fax: 731.881.7018

August 10, 2011

Mr. Edward Wheeler
Engineering Department
CAMPUS MAIL

RE: 12-81-E05-4025/Whee,Edw
IRB Period: 8/10/2011 to 8/9/2012
Determination of a Predictive Model for the Fundamentals of Engineering Examination (Prepared as a doctoral dissertation as

Dear Mr. Wheeler:

The project listed above has been reviewed and has been certified as EXEMPT from full review under Exempt Category D.

The responsibilities of the investigator(s) are to abide by the regulations governing research involving human participants, including those provisions specifying the means of obtaining informed consent. In all cases, the standards of respect for persons, beneficence, and justice enumerated by the Ethical Principles and Guidelines for the Protection of Human Subjects of Research (Belmont Report) apply to all research involving human participants conducted at UT Martin. Please note that you are also committed to the other Investigator Responsibilities as stated in the Faculty, Staff and Student Handbook for Studies Involving Human Participants found on our website.

All exempt approved research is subject to UTM-IRB review, at least once a year. Please visit our website for the Change/Termination Form that you will need to complete and submit if your project remains active and UTM-IRB approval needs to be renewed for another year. Such a request must be done within the last 30 days of the IRB approval period indicated above. Unless your research moves in a new direction or participants have experienced adverse reactions, then renewal is not a major hurdle. You as Principal Investigator are responsible for determining whether the changes will affect the current status of the project. When you complete your research, the same Change/ Termination Form will need to be submitted indicating completion of the project. This will allow the UT Martin IRB Compliance Section to close your project files.

Please remember that it is the responsibility of the Principal Investigator to keep the data that is collected in a secure location for 3 years after the completion of the research project.

We wish you success in your research endeavors.

Joan K. West, Ph.D.
Director

pqf

cc: Dr. Richard Helgeson
Dr. Somsak Sukittanon