Influences for Engineering Majors: Results of a Survey from a Major Research University

Dr. SANDRA B NITE, Texas A&M University

Sandra Nite, Ph.D., is a Research Scientist at in Department of Mathematics at Texas A&M University, where she has taught 10 different courses in mathematics and mathematics education. She has served on several committees in the mathematics department, including course development for teacher education in mathematics. Her research agenda includes engineering calculus success, including high school preparation for college. Previously, she taught 8 additional courses at the college level and 13 different high school courses in mathematics and science. She has worked with teacher professional development for over 20 years, and served as mathematics curriculum coordinator for 8 years. She works with teachers from all corners of Texas with teacher quality grants, including a number of teachers in the juvenile justice schools.

Devyn Chae Rice
Rayan Tejani, Allen Academy

Rayan Tejani is a high school senior, taking AP Calculus BC and planning to major in engineering in college beginning Fall 2020. He is interested in engineering education and entrepreneurship. Currently, he's working with a Texas A&M University professor on an innovative device and possible patent. He is also the president and founder of the Entrepreneurship Club at his high school.

Influences for Engineering Majors: Results of a Survey from a Major Research University

Abstract

Engineers are critical to sustain and increase the innovation needed to solve U.S. and world problems. Of the fastest-growing jobs, 75% are based in science and mathematics, particularly with an engineering focus. But the U.S. is still short of qualified engineers to fill the jobs available. As part of the effort to increase the engineering pipeline, this paper explores the influences that are important in college students' decision to become engineering majors. Social cognitive career theory developed by Xeuli Wang (2013) is the basis of the study. According to this model, an individual's decision to choose a STEM major is affected by a variety of high school experiences, determined largely by prior mathematics success. Those experiences are important in determining the individual's goals and interests. In other words, an individual's background and participation in certain activities affect their learning experiences, and subsequently their self-efficacy, and eventually their career choices. A survey about influences on their decisions to major in engineering was completed by 251 students at a major research university. Possible influences were categorized by type (e.g., informal activities/camps, formal schooling, standardized test scores, success/abilities in STEM courses, social, job opportunities). The survey was a 4-level Likert scale (0 = Not applicable, 1 = None at all, 2 = A little, 3 = A moderate amount, and 4 = A great deal) on which participants were asked how much a given factor influenced their decision. After answering questions about these influences, students were then asked to rank the factors in order of the level of influence. Descriptive statistics, particularly frequency tables, were used to determine the importance of the various factors. Findings include the following: 1) The greatest informal STEM influence was after school programs, as opposed to other opportunities such as summer activities or camps. 2) Of the students who said formal schooling had an influence, the most important was the teacher and student success in the course with 50.8% indicating their science teacher had a "great deal of influence" and 60.5% that their success in science had a "great deal of influence." 3) Technology class's greatest effects were hands-on experiences, success in the courses, and the teacher. 4) Of students who had pre-engineering or engineering classes, 56.8% said those classes had a moderate influence on their decisions to major in engineering; and 5) The greatest influences in pre-engineering or engineering classes were hands-on experiences and the teacher. Clearly, three factors were important for engineering majors in their science, technology, and engineering classes: hands-on experiences, great teachers, and student success in the class. Many dynamics affect students' major choices, and understanding some of these may be helpful in fostering interest through these influences. This study shows that teachers and their provisions for hands-on experiences are important for engineering majors in one major university. If replication in other places finds agreement, university faculty can help K-12 teachers increase such opportunities.

Introduction

Success in the world market depends heavily on engineering and other STEM jobs. Stronger economies are strongly positively correlated with a strong engineer population [1]. There has been a growth in the availability of engineering jobs, but shortages persist [2], [3]. In fact, globally 7% of the fastest-growing jobs are based in science and mathematics, especially in

relation to engineering. U.S. universities are graduating a significant number of engineers, but many are studying on visas and returning to their countries or decide to work in another field. Engineers' salaries are continue to be 20% higher than non-engineering graduates [1].

High school experiences and high school teachers are important in the mathematics and science background needed to pursue an engineering major [4]. However, one-third of U.S. mathematics and science teachers have a major in the field they teach [1]. In particular, mathematics preparation is often inadequate for students to successfully pursue engineering degrees [5]. Students who perform poorly in mathematics on national standardized tests are unlikely to choose engineering majors [6]. Engineering preparatory courses have become more prevalent in high schools, and students who completed a sequence of those courses were more likely to choose STEM majors [7].

Studies on student choices to major in STEM fields are increasing, but there are relatively few recent studies about why students specifically chose engineering majors [8]. Many university and college guide websites give reasons for choosing engineering in order to recruit students, but there are fewer available quantitative studies on why students actually decided on that choice. A search yielded a recent case study about a single female [9]; studies about gender differences in engineering students [10]; and studies about STEM fields collectively. The most relavent and recent studies were found in the ASEE proceedings of 2017 – one quantitative [8] and one qualitative study [11]. Similarly, the current study consisted of participants that were largely White, but the prior studies had very small percentages of females that participated in the study (< 30%) while the current study had a little larger female percentage (42%). The prior quantitative study addressed some similar influences, but more broadly than in the current study. Thus this study helps to fill the gap in research about why students choose engineering as a major.

The theoretical framework of this study is based on social cognitive career theory (SCCT) as developed by Wang [12]. Under this theory, a variety of high school experiences affects a student's choice, but mathematics success is a strong underlying factor. Thus, background, experiences, and choices to engage in certain activities all affect self-efficacy, which has a substantial impact on career choice. The SCCT and social cognitive theory (SCT) [13] assert that personal characteristics and opportunities together make up a student's learning experiences. Reinforcement by parents or teachers, education preparation, and inspirational events are a few of the items that make up opportunities. Interest and self-efficacy play a large role in student choices regarding the experiences they choose, thus continuing the cycles as a student moves toward a choice of college major. Many factors affect a student's choice, and these factors are highly interrelated. The purpose of this study is to examine the question, "What influences were important in college students' decisions to become engineering majors?"

Methodology

Data were collected from undergraduate engineering majors (N=251) at a large tier one research university in the southwest U.S. Participants took a survey measuring to what extent various factors impacted their decisions to pursue engineering studies. The survey was created by researchers and used a 4-level Likert scale (0=Not applicable, 1 = None at all, 2 = A little, 3 = A

moderate amount, and 4 = A great deal). Because of the nature of the survey with various branching based on former responses, there was no meaningful way to calculate Cronbach's alpha for reliability of scores for the 26-page survey. However, an expert statistician outside the research group reviewed the survey to ensure content validity. The questions list the following factors and influences: gender, ethnicity, income, school types (e.g., charter, private, public), quality of STEM teachers, instruction types (e.g., hands-on or traditional), technology support, extracurricular activities, academic career opportunities, salary, and media. Students were then asked to rank these factors in order of the level of influence in their decisions.

Descriptive statistics through SPSS-25 was conducted to determine influences students associated with their choices to pursue an engineering degree. Frequencies and percentages were tabulated for factors such as gender, ethnicity, and high school size and type.

Results

Characteristics of the engineering majors in the study are shown in Table 1. There were a few more males than females, and the vast majority were White from suburban public schools. School size was more than 1100 students for almost 60% of the students. Of those who answered the question about family income, about 46% came from a home with income greater than $120,000. Note that there were no freshmen surveyed because the study was conducted in the fall, and freshmen cannot be accepted into engineering before their first semester. No significant differences in survey responses were found between races or socioeconomic status.

Table 1. *Characteristics of the Engineering Majors*

Characteristic	**Breakdown**
Gender	106 females; 145 males
Age	242 at 18-23 years; 6 at 24-30 years; 3 at >30
Classification	41 sophomores; 80 juniors; 130 seniors
Ethnicity	198 White; 18 Asian; 8 Native/African American; 27 prefer not to answer
School Type 1	14 homeschooled; 40 rural; 161 suburban; 36 large city
School Type 2	31 private; 4 charter; 202 public
School Size	**59** 1A-3A (<480); **43** 4A (480-1099); **72** 5A (1100-2149); **77** 6A (2150+)
Family Income	**45** at <$60k; **75** at $60-120k; **101** at >120k; **30** prefer not to answer.

Informal STEM Education was one of the influences, and 93.6% of engineering majors surveyed experienced some type of learning opportunities outside the normal school day. Examples were field trips with parents or school personnel, after school programs such as robotics, STEM clubs, summer camps or shorter-term activities. Of those 235 students, 139 (59%) said that these experiences influenced their decision to major in engineering. Students without informal STEM experiences were not included in the specific survey items related to these experiences. Table 2 shows the results by percentage of students with these experiences. Figure 1 illustrates the percentage of students who selected "A great deal" for the level of impact of these influences.

Table 2. *Informal STEM Experiences*

Factor	None at all	A little	A moderate amount	A great deal
After School Activities	10.3%	25.6%	36.8%	27.4%

Field Trips	20.0%	38.5%	28.5%	13.1%
Summer Activities (short)	24.1%	32.1%	27.7%	16.1%
Summer Camp (week or more)	32.0%	28.9%	19.6%	19.6%
Volunteer Experience	41.1%	28.0%	24.3%	6.5%

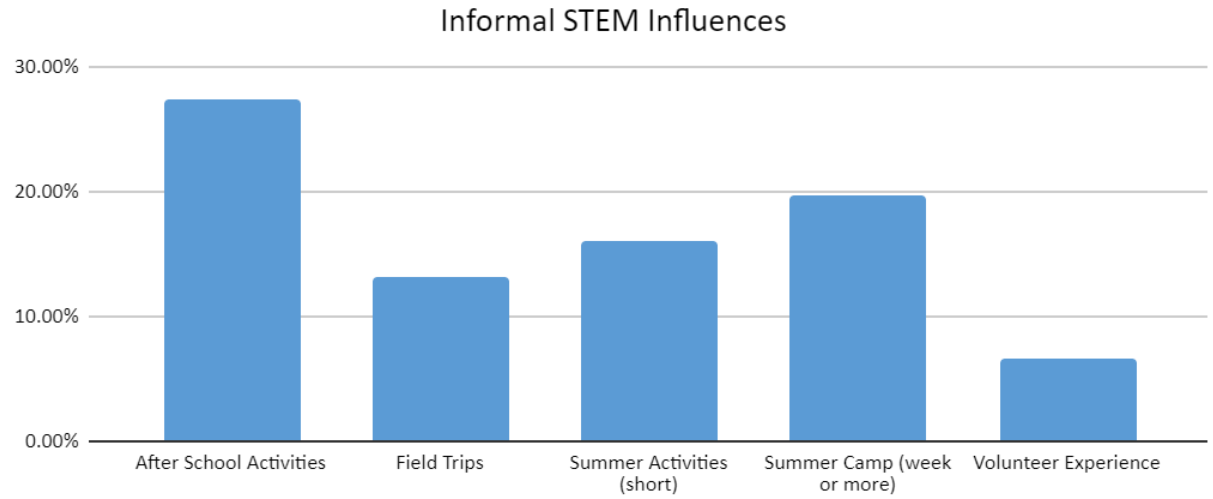

Figure 1. Percent of students who selected "A great deal" for Informal STEM Influences

Students then chose the informal experience that had the greatest influence. 48.1% chose After School Activity; the second-highest percentage was Field Trips at 16.5%

Formal schooling also had an impact on students' decisions to major in engineering. About 74% of students surveyed said science class had an influence; 75% said mathematics class had an influence; 40% said technology/programming classes had an influence; and 27% said engineering class(es) had an influence. However, 40% said they took no technology classes, and 57% reported that they did not have engineering classes available. Among formal school influences, the teacher and success in STEM subjects were most dominant. Teachers who engaged students in the subject had a positive impact on students' desire to study a STEM field, resulting in their choice of an engineering major. Table 3 summarizes the influence of these factors regarding science, mathematics, and pre-engineering (where available) courses. Figure 2 illustrates the percentage of students who chose "A great deal" for the effect of these influences.

Table 3. *Teacher Factor and Subject Achievement*

Factor	None at all	A little	A moderate amount	A great deal
Science Teacher	4.5%	14.7%	29.9%	50.8%
Science Achievement	1.1%	10.7%	27.7%	60.5%
Mathematics Teacher	9.5%	20.8%	27.4%	42.3%
Mathematics Achievement	1.8%	6.5%	32.0%	59.8%
Technology Teacher	7.0%	20.9%	29.1%	43.0%
Technology Success	2.2%	10.1%	30.3%	57.3%
Engineering Teacher	7.9%	17.5%	23.8%	50.8%
Engineering Achievement	3.1%	10.8%	43.1%	43.1%

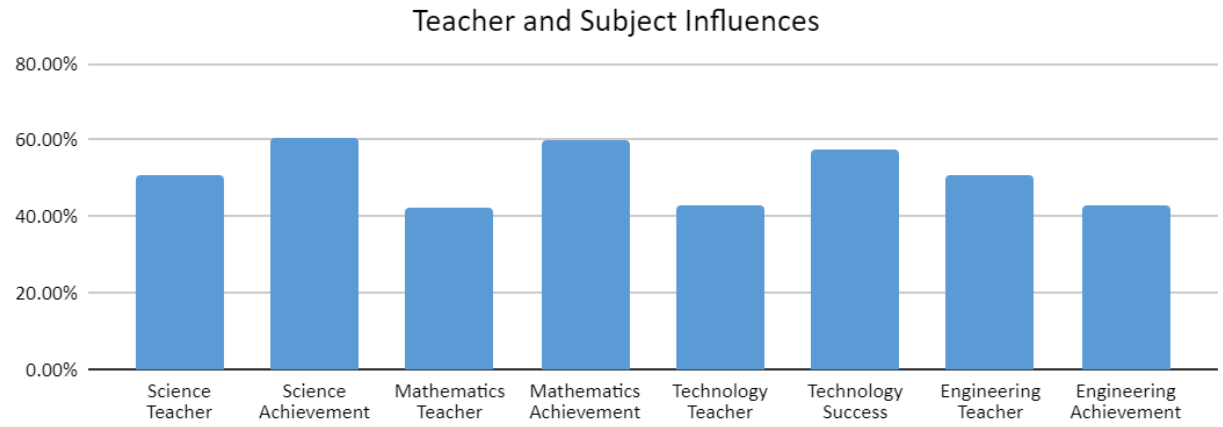

Figure 2. Percent of students who selected "A great deal" for Teacher and Subject Influences

For formal schooling in science, mathematics, and engineering, students chose the greatest influence in each subject. For science, a teacher who engaged student scored highest (41.6%); for mathematics success in the subject was highest (55.9%); for engineering, the hands-on nature of instruction was highest (42.4%).

Interesting results were obtained for influences related to future jobs in engineering. Table 4 shows the importance of future job factors identified in the study for the 251 students in the study. There were 225 students who said that future job opportunities were an influence. Not applicable means that nothing in the category of job factors was an influence (26 students). It is clearly seen that engineering majors considered job factors, and a large percentage of them reported that these factors were moderately to heavily influential in their engineering decision. Job security was an especially important influence.

Table 4. *Job Influences*

Influence	**None at all**	**A little**	**A moderate amount**	**A great deal**	**Not applicable**
High level of employment after college	8.8%	12.4%	33.9%	34.7%	10.4%
Job salary	7.8%	17.1%	31.1%	33.9%	10.4%
Job environment	12.7%	19.5%	31.9%	25.5%	10.4%
Job promotion opportunities	13.9%	21.9%	29.9%	23.9%	10.4%
Job support for graduate school	37.1%	23.5%	18.7%	10.4%	10.4%
Job security	6.0%	9.6%	32.3%	41.8%	10.4%

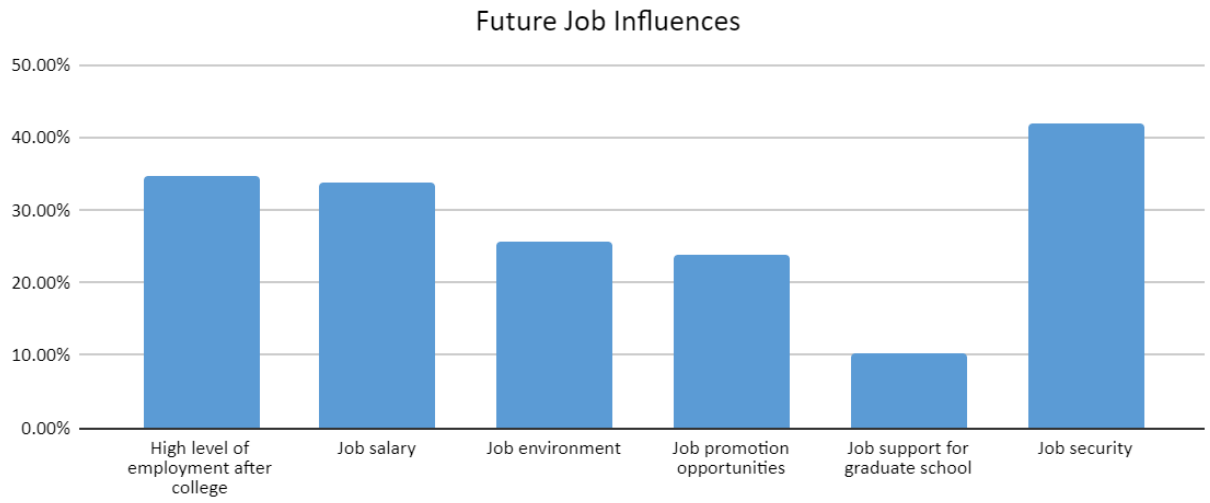

Figure 3. Percent of Students who chose "A great deal" for Future Job Influences

Students were asked to rank the four major categories of influences surveyed. Formal schooling factors were ranked the highest, with informal educational opportunities second. Table 5 gives the first and second choice ranking percentages. Figure 4 provides a visual comparison of these results.

Table 5. *Categories of Influence Rankings*

Influence Categories	**Percent Ranked First**	**Percent Ranked Second**
Informal Education	21.5%	19.9%
Formal Education	27.5%	22.3%
Job Influences	21.5%	27.5%
Social Influences	15.1%	15.1%
None of these	2.8%	4.0%

These four categories of influence were by far the most important influences. Formal education was very important, but job influences and informal education also played a significant role in student choice to major in engineering.

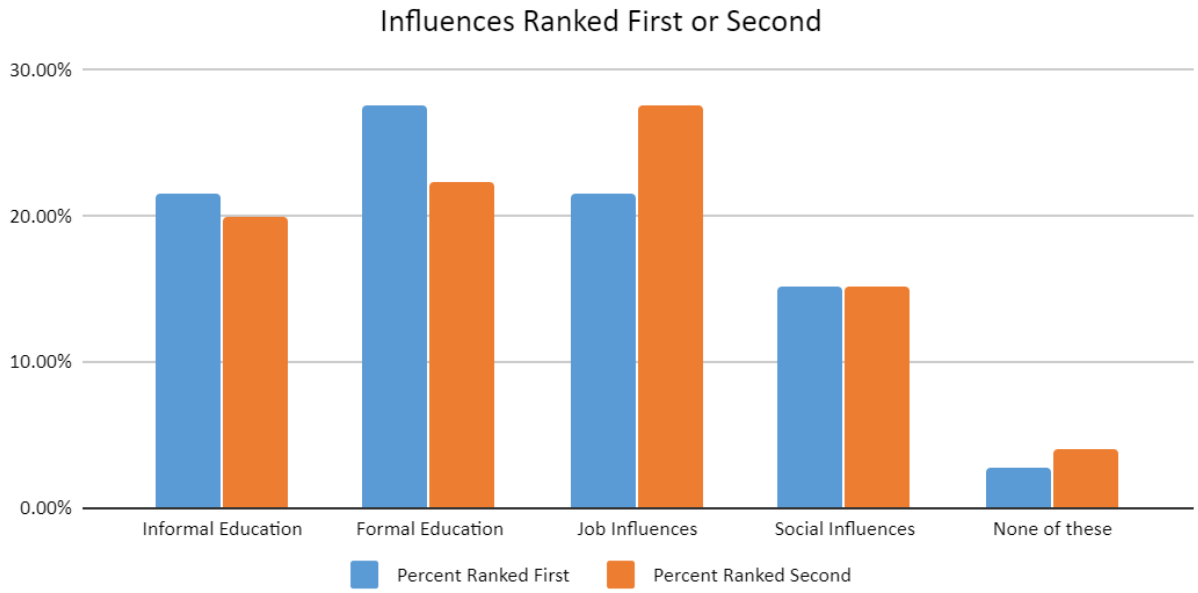

Figure 4. Percent of Students who Ranked Influence Groups First or Second in Impact.

In summary, a large number of students believe their science and mathematics classes were significant influences on their choice. Within that category, "a teacher who went out of his or her way to engage students" and success in the subject was important in mathematics, science, technology/programming, and engineering classes. Informal education added to the knowledge base and engagement for these students. Engineering majors also considered job factors when they made the choice to major in engineering.

Discussion

There are many factors that influence a student's choice of college major. Some factors that heavily influence that choice for engineering have been identified or confirmed through this study at a large, engineering-strong university in the southwest U.S. Studies such as these and the other more recent studies (e.g., [8], [11]) should be replicated in other areas within other institutions. Thus, the limitation of representing only one large institution with an engineering priority could be mitigated by comparing results of similar research within other universities. In this way, researchers and university faculty can learn about experiences that may increase student interest in engineering. Institutions can capitalize on this knowledge to build greater interest in various engineering majors. This study confirmed that teachers have a great impact in many ways. They may provide a strong background in mathematics so that students have confidence in their abilities to major in STEM fields such as engineering that rely heavily on those concepts and skills. They engage students and increase their curiosity about science and mathematics and solving problems in our world. Thus, one important implication is that more funds should be used to provide professional development for mathematics teachers. Science teachers and engineering teachers also have an impact, but mathematics still remains at the forefront of STEM self-efficacy. Teaching strategies that increase success for different types of learners can influence more students to consider engineering as a major. University faculty have a role to play in encouraging and giving direction to high school studies in mathematics, science,

and engineering so that students' experiences can help them become interested and engaged in engineering studies. This can be done through meetings to discuss college expectations in engineering, inviting K-12 teachers to the college campus to visit laboratories and attend lectures, or providing professional development that helps them understand more about the engineering process and ways to better prepare students for college. Studies that delve into student reasons for choosing engineering as a major and future career can help counselors and faculty members in secondary schools, colleges, and universities to identify students who may be interested. They can provide more information and support as they encourage them to consider these fields.

References

[1] English, T. (2016). Why isn't America producing the number of engineers the market needs? Retrieved October 14, 2018 from http://shortsleeveandtieclub.com

[2] National Science and Technology Council. (2011). *The Federal Science, Technology, Engineering, and Mathematics (STEM) Education Portfolio*. Washington DC.

[3] Villorio, D. (2014). STEM 101: Intro to tomorrow's jobs. *Occupational Outlook Quarterly, 58*(1), 2-12.

[4] Hayes, S. (2017). Preparation matters most in STEM. *ACT Research & Policy Brief*.

[5] President's Council of Advisors on Science and Technology. (2010, September). *Prepare and inspire K-12 science, technology, engineering, and math (STEM) education for America's future*. Washington, DC: Author.

[6] Radunzel, J., Mattern, K., & Westrick, P. (2017). Who will declare a STEM major? The role of achievement and interests. ACT Research Report.

[7] Phelps, L. A., Camburn, E. M., & Min, S. (2018). Choosing STEM college majors: Exploring the role of pre-college engineering courses. *Journal of Pre-College Engineering Education Research, 8*(1), 1-24.

[8] Nadelson, L, Mooney, D. K., Rush-Byers, J., & Dean, N. (2017). Why I am an engineering major: A cross-sectional study of undergraduate students. In *Proceedings of the American Society for Engineering Education 2017,* Paper ID #9097 presented at ASEE's 124th National Conference and Exposition. Columbus, OH: American Society for Engineering Education, Washington DC.

[9] Godwin, A. & Potvin, G. (2017). Pushing and pulling Sara: A case study of the contrasting influences of high school and university experiences on engineering agency, identity, and participation. *Journal of Research in Science Teaching, 54*(4), 439-462.

[10] Hartman, M., Hartmen, H., & Kadlowec, J. (2007). Gender across engineering majors. In *Proceedings of the American Society for Engineering Education 2007*. Columbus, OH: American Society for Engineering Education, Washington DC.

[11] Painter, J. K., Snyder, K. E., & Ralston, P. A. (2017). Why engineering:? Students' reasons for choosing an engineering major. In *Proceedings of the American Society for Engineering Education 2017,* Paper ID# 19453 presented at ASEE's 124th National Conference and Exposition. Columbus, OH: American Society for Engineering Education, Washington DC.

[12] Wang, X. (2013). Why students choose STEM majors: Motivation, high school learning, and postsecondary context of support. *American Educational Research Journal, 50*(5), 1081-1121.

[13] Bandura, A. (1986). *Social foundations of thought and action: A social cognitive theory*. Englewood Cliffs, NJ: Prentice-Hall.