The Influence of Demographics on an Introductory Circuits Course

Carlotta A. Berry
Tennessee State University

Abstract

This paper evaluates the performance of engineering students in an introductory circuits course during the period of Fall 2000 through Spring 2003 at Tennessee State University (TSU). TSU is a historically black university in Nashville, TN with an approximate enrollment of 9000 graduate and undergraduate students with 500 full- and part-time faculty. The College of Engineering, Technology, and Computer Science has an approximate enrollment of 1000 students and 8 majors. This paper will evaluate student performance based upon gender, major, class, requisite performance, and the number of times an introductory circuits course was taken. This circuits course is required by all engineering majors including civil, architectural, mechanical and electrical engineers and it is the gateway to all upper level courses. This data will be used to determine general trends in student performance in order to redesign the course and laboratory to be more successful. Success in this context is defined as a reduced attrition rate as well as increased student performance as determined by final grades. This document will present the results of the statistical analysis of the student data and the presence of any significant negative or positive correlations.

Introduction

This paper explores the performance of engineering students during the 2000 through2003 school years in the College of Engineering, Technology, and Computer Science at Tennessee State University. The College of Engineering, Technology, and Computer Science has an approximate enrollment of 1000 students and 8 majors. This paper will compare student performance based upon gender, major, class, requisite performance, course repeats as well as several other factors. This course is required by all engineering majors including civil, architectural, mechanical and electrical engineers. This data will be used to determine general trends in student performance in order to redesign the course and laboratory to be more successful. Success in this context is defined as a reduced attrition rate as well as increased student performance as determined by final grades. This course is the gateway for all subsequent upper level engineering courses and a negative or unsuccessful experience in this course may negatively affect the student's desire to continue with the degree program. A key motivator for this study was the desire to increase engineering student retention in the college.

The pre-requisites for the circuits course include a series of Physics courses, Calculus courses and one programming course. The students could choose to take FORTRAN, Visual Basic, or Visual C++ as the programming course. The students' classifications included sophomore, junior, senior, and masters level. The majors included electrical engineering, mechanical engineering, civil engineering, architectural engineering, and graduate students in the Computer

Information Systems Engineering (CISE) program. There are two co-requisites for this course: circuits laboratory and differential equations. The circuits laboratory provides hands-on experience with several key concepts introduced in the lecture. The differential equations co-requisite provides the theory for the mathematics needed to evaluate and solve RL, RC and RLC circuits.

The introductory circuits course covers DC circuit analysis including Ohm's law, Kirchhoff's laws, Thevenin's and Norton's theorem, operational amplifiers and RC, RL, and RLC circuits. This course is presently taught in a lecture-style format with three major projects. Two projects involve PSpice simulations and one final project involves writing a computer program to solve a typical engineering circuit analysis problem. PSpice is a simulation software package used to analyze DC or AC circuits. The circuits laboratory includes traditional experiments that build circuits on the breadboard that must be evaluated using Ohm's law, Thevenin's theorem, mesh analysis, nodal analysis, and differential equations. The laboratory groups consisted of teams of 2 to 3 students who performed typical breadboard experiments using a multimeter, oscilloscope, power supply, and function generator. It is hypothesized that the performance of the hands-on lab experiments closely tied to the course topics will increase student performance. It is also conjectured that performance in the course pre-requisites has a strong correlation with course performance. Finally, it is proposed that the number of times the course was repeated would negatively affect student performance. The reasoning is that the redundancy of the same course material will not correct for a student's deficiency in the mastery of key pre-requisite topics. This paper will highlight background literature on student retention based upon several factors. The method of evaluation of the data will include a tabulation of student demographic information and a correlation with student grades. The differences in grade points based upon the aforementioned criteria will then be evaluated using SPSS statistical software. These results will be presented and finally conclusions will be drawn about the DC circuits course and the results used to propose modifications to the course.

Review of the Literature

As opposed to some of the more traditional factors for measuring student retention, a key factor that affects retention in an engineering program is the students' attitude about engineering in general. Besterfield-Sacre et al. explored this trend by using a closed-form survey that was administered to freshman engineering classes during the 1993 and 1994 school years. [1] This document highlights the fact that more than knowledge and skills affect the performance of an engineering student. The results indicated that students who were in good standing but still changed majors had a less of positive attitude about engineering and its importance during their freshman year. [1] These students also appeared to have different math and science interests and confidence about the ability to complete an engineering major than those students who were retained in the program.[1] These students also tended to be influenced more by family to pursue a certain major (i.e. engineering). Although not specifically addressed here these results indicate a need to have a pre-course and post-course assessment of student's attitudes about circuit analysis, electrical engineering, and engineering in general.

Innis and Perry explore the student retention dilemma in electrical engineering from the different perspective of those who have successfully completed a degree program.[2] Several studies have indicated that the student's first year of college is the most crucial metric to use for determining retention. Therefore, there has been the advent of introductory engineering courses at most universities. As opposed to evaluating freshman year retention factors, Innis and Perry studies students who have successfully attained a Bachelor of Science in Electrical Engineering between 1999 and 2002 at the Florida A&M University (FAMU) – Florida State University (FSU) College of Engineering (COE).[2] This work was going to be used to create a profile of a successful graduate based upon age, race/ethnicity, gender, GPA, and pre-requisite grades.[2] The first-semester GPA indicate that there was no discernible difference among all of the groups and most had an average of at least a 3.0. With respect to the circuits course, it was shown that on average it took African American students longer to reach graduation upon the completion of this course. Also, it was shown that white females at FSU took the least amount of time to graduate compared to males and females at FAMU. The results indicated that on average it took a 1.23 attempts for a student to successfully complete the circuits course. By evaluating the histogram, it was shown that 81.7% of graduates complete this course on the first attempt. With respect to persistence to graduation, students who received a grade of C or better in circuits, 63% had graduated with an electrical engineering degree, 9.5% changed majors and graduated and 11% were still in school and 16.5% had dropped out.[2] Conversely, of those students who received a D or F in the course initially, only 17% had graduated with an electrical engineering degree, 14% changed majors and graduated, 23% are still in school and 46% dropped out of school.[2] Generally, it was shown that the number of course attempts needed by African Americans was greater than for white students. This study also indicated that the number of unsuccessful attempts at the course negatively affected the student's persistence to graduation.

A recent study by Zhang et al. explored the performance of engineering students at nine universities for a five year period. This statistical analysis demonstrated that there were several factors that significantly affected a student's tendency to remain in a degree program until graduation. It was found that the high school GPA and math SAT scores had a positive correlation with the student's graduation rate. There were also some effects of gender, ethnicity, and citizenship, but it was not consistent over all universities.[3] This paper will determine if there is any significance in these factors for the small population used for this course. Although, there were no overall results that could be generalized, it was shown that males had a tendency to have a higher graduation rate than females.[3] Van Alphen and Katz[4] also studied predictive factors for success in electrical engineering based upon high school GPA, college-level GPA, and pre-requisite course performance. This analysis showed that the highest Pearson correlation using the success metric of final grade was for the student's overall college-level GPA.[4] Although, not as strong of a correlation there was also a positive correlation between the student's success in pre-requisite courses (calculus, physics, differential equations) and course success. Finally, this study results indicated that there was no correlation between SAT scores and student success.

Finally, Milks et al. has presented work on the modification of a DC circuits course from a traditional lecture format to a learner-centered approach to determine if it improves student retention. Some of the factors stated by the author as causes of low retention are a poor math background, disconnection from classmates, and a lack of understanding the relevance of the material presented.[5] The preliminary results indicate that after one semester of implementation the grades changed from an inverse bell curve grade distribution to a normal grade distribution. These findings indicate that some of the students with the lower grades actually achieved a C in the course.[5] Surprisingly, there was another section of the class for those same two semesters which showed no significant improvement in the grade point distribution. Milks et al. conjectures that the multitude of changes to the course all at once as well as the large difference in the course meeting time may have produced some spurious results. This has been a small review of the multitude of literature available on student retention. In particular, this paper would like to focus upon some of the key factors presented and how they affect student success in the introductory circuits course at TSU.

Methods of Evaluation

In order to evaluate the hypotheses, data was collected from the Fall 2000 through Spring 2003 semesters such as final course grades, number of repeats, and pre-requisite grades. Additional data collected included the students' race, gender, class, and major. Finally, the students were categorized by the aforementioned criteria and the mean grade in the circuits course was evaluated for statistical significance. Due to the small sample size (approximately 300 students) and the abnormal distribution of the data, non-parametric tests were used to examine correlations. With respect to the evaluation results, a significance of 10% indicated a trend for a certain factor while a significance of 5% indicated that this factor had a significant negative or positive influence on student performance.

Results

Overall, there were 324 different circuits course records evaluated for this analysis. This number included 28 students who withdrew from the course without receiving a grade. This number also included 42 students with several records: 1 in 4 different semesters, 3 in 3 different semesters, and 38 in two different semesters. The gender demographics for the circuits course are presented in Table 1. In order to calculate the grade point for A, B, C, D, and F grades, they were assigned quality points of 4, 3, 2, 1, and 0, respectively. These results indicate that consistent with the general trend for engineering and college students in general, the class was predominantly male. However, during the Fall 2002 semester there was almost an even distribution of males and females. Furthermore, the most recent trends in college enrollment have shown that there are actually more females in college than males but they are not typically engineering majors. These tabulations illustrate that females typically performed better in this course than males. However, this difference was not significant at the 5% level. The mean grade point for all students taking the course was shown to be 2.06. This value does include those students who may have taken the course in more than one semester and therefore may have multiple grades in the mean.

Table 1. Course grade by gender

Letter Grade	Female	Male	Total
A	7	24	31
B	26	40	66
C	49	72	121
D	15	31	46
F	7	25	32

Total	104	192	296
Quality points	219	391	610
Grade point	2.11	2.04	2.06

Also consistent with the course being taught at a historically black university, the vast majority of the students were African American. Table 2 presents the race demographics for the course and the grade distribution. The results indicate that Hispanic and Caucasian students attained the largest mean grade point and it was significant at the 5% level. However, with such a small sampling, this result may indicate a spurious outlier.

Table 2. Course grade by race

Letter Grade	**Asian**	**Black**	**Hispanic**	**White**	**Total**
A	1	22	2	6	31
B	1	57	0	8	66
C	3	113	0	5	121
D	0	46	0	0	46
F	1	29	0	2	32
Total	6	267	2	21	296
Quality points	13	531	8	58	610
Grade point	2.17	1.99	4.00	2.76	2.06

The classification categories were sophomore (SO), junior (JR), senior (SR), masters (MS), and other (OTHER). These results indicate that the majority of the students taking this course are juniors followed by seniors. Table 3 presents the distribution of the grades by classification. Not surprisingly, graduate students performed the best and this was significant at the 5% level. However, once again it may represent an outlier.

Table 3. Course grade by classification

Letter Grade	**SO**	**JR**	**SR**	**MS**	**OTHER**	**Total**
A	2	16	11	2	0	31
B	10	36	19	0	1	66
C	10	69	42	0	0	121
D	4	22	20	0	0	46
F	7	16	9	0	0	32
Total	33	159	101	2	1	296
Quality points	62	332	205	8	3	610
Grade point	1.88	2.09	2.03	4.00	3.00	2.06

The student distribution based upon major (electrical engineering (EE), mechanical engineering (ME), civil engineering (CE), architectural engineering (AE), computer and information systems engineering (CISE), other (OTHER)) are shown in Table 4. These results indicate that the majority of the students taking this course are electrical engineering majors. The CISE students had the highest mean grade point, but once again there was only a small sampling. With respect to the undergraduates, the highest mean grade point of 2.08 was for the electrical engineering majors. This difference in mean grade point was found to represent a trend at the 10% level.

Table 4. Course grade by major

Letter Grade	AE	CE	EE	ME	CISE	OTHER	Total
A	3	1	18	6	2	1	31
B	8	7	34	14	0	3	66
C	31	6	54	29	0	1	121
D	10	4	23	8	0	1	46
F	7	2	15	8	0	0	32
Total	59	20	144	65	2	6	296
Quality points	108	41	305	132	8	16	610
Grade point	1.83	2.05	2.12	2.03	4.00	2.67	2.06

The success rate for students passing the introductory circuit course on the first attempt was not quite as high as the FAMU-FSU study these are given in Table 5. The results show that although the majority of the students pass on the first attempt, there is still a substantial amount who took 2 attempts for success. Note that there was actually a small portion of the population who had to take the course 3 to 5 times before successfully completing it. Table 5 also indicates that the more times a student takes the course the less of a chance the student will make a passing grade or a grade higher than a C. Overall it takes the average student 1.35 attempts before successfully completing the course.

Table 5. Course grade by number of times the course was taken

Letter Grade	1	2	3	4	5	Total
A	24	7	0	0	0	31
B	54	8	2	2	0	66
C	81	33	6	0	1	121
D	32	13	1	0	0	46
F	24	3	3	1	1	32
Total	215	64	12	3	2	296
Quality points	452	131	19	6	2	610
Grade point	2.10	2.05	1.58	2.00	1.00	2.06

The attrition rate for this course was determined by finding all students who withdrew or received a non-passing grade (D, F) in the course divided by the number of students who initially enrolled in the course. The reason for using this as the attrition rate was because all engineering students must repeat and pass this course before taking upper level courses. Table 6 presents the statistics for all semesters evaluated along with the % attrition. It was shown that overall one-third of the students withdrew from the class or did not receive a passing grade and had to repeat it.

Table 6. Attrition statistics

Letter Grade	**Spring 2003**	**Fall 2002**	**Spring 2002**	**Fall 2001**	**Spring 2001**	**Fall 2000**	**Overall**
A	12	1	4	3	6	5	31
B	14	6	11	9	9	17	66
C	21	31	16	20	13	20	121
D	10	6	9	6	6	9	46
F	0	8	2	10	7	5	32
W	4	4	5	6	4	5	28
Total	61	56	47	54	45	61	324
Successful completion	47	38	31	32	28	42	218
% attrition	23%	32%	34%	41%	38%	31%	33%
Grade point	2.49	1.73	2.14	1.77	2.02	2.14	2.06

As previously stated, the pre-requisites for this course were calculus, physics, and a programming course. The final analysis will evaluate student performance based upon pre-requisite grades. In order to perform this analysis all graduate and transfer students and students who withdrew from the course will be eliminated. Students who completed at least two of the courses at TSU were included in the analysis. Tables 7 through 9 present the pre-requisite statistics with respect to the grades. The mean grade point for calculus, physics, and programming was 3.12, 2.91, and 3.00. respectively. These results indicate that students performed the best in calculus and worst in physics although it was a very small difference. All of the correlations between the circuits course grade and pre-requisite grade were found to be significant at the 5% level. It should be noted that although this is a summary of requisite performance, there were several students who took the pre-requisite concurrently with the circuits course and a few who took the pre-requisite after completing the circuits course. Also note that a minimum grade of ‘C’ is required in all pre-requisites although some students were able to surreptitiously take the course without meeting this guideline. Additionally, the number of attempts the students made before passing the pre-requisite is not accounted for in this analysis. It should be noted that in some instances, at student may have taken the physics and calculus course multiple times before successfully completing it. The correlation between the repeats in those pre-requisites and the performance in the circuits course may be the subject of future analysis. Since duplicate students were eliminated from this analysis, this results in a higher mean overall grade point for the total group. As highlighted by the Zhang et al. study, some of the contribution of the high grade in the circuits performance based upon the pre-requisite performance may be attributable to the overall college-level GPA of the student. However, the author also proposes that the high correlation between the pre-requisite material and the material addressed in circuits may also influence this grade on some level. Figure 1 presents a graphical depiction of the reduction in course grade based upon pre-requisite grade. This trend seems to be the greatest for the calculus course.

Table 7. Circuits course grade based upon Calculus IV grades

	Calculus Letter Grade						
Circuits Letter Grade	**A**	**B**	**C**	**D**	**Total**	**Quality Points**	**Grade Point**
A	16	9	3	0	28	97	3.464
B	35	18	7	1	61	209	3.426
C	33	48	38	1	120	353	2.942
D	6	10	6	0	22	66	3.000
F	1	6	4	0	11	30	2.727
Total	91	91	58	2	242	755	3.120
Quality points	241	196	115	5	557		
Grade Point	2.648	2.154	1.983	2.500	2.302		

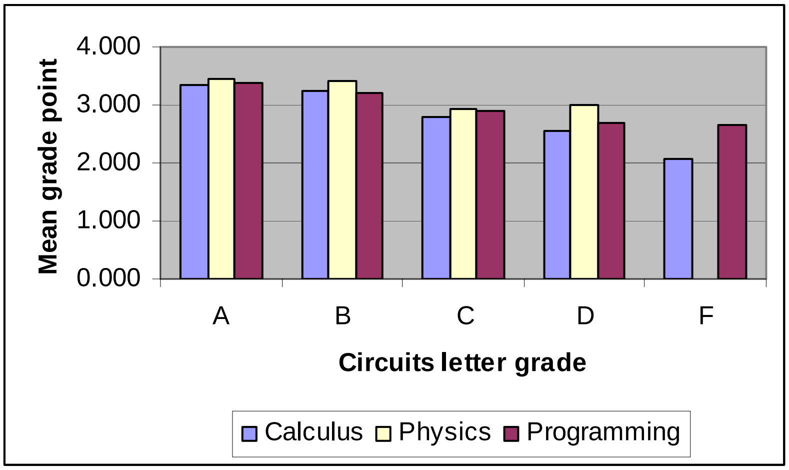
Table 8. Circuits course grade based upon Physics III grades

	Physics Letter Grade							
Circuits Letter Grade	**A**	**B**	**C**	**D**	**F**	**Total**	**Q.P.**	**Grade Point**
A	16	7	4	1	0	28	94	3.357
B	24	28	10	0	0	62	200	3.226
C	32	41	42	0	5	120	335	2.792
D	0	12	10	0	0	22	56	2.545
F	0	2	9	1	0	12	25	2.083
Total	72	90	75	2	5	244	710	2.910
Q.P.	200	206	140	4	10	560		
Grade Point	2.778	2.289	1.867	2.000	2.000	2.295		

Table 9. Circuits course grade based upon Programming grades

	Programming Letter Grade						
Circuits Letter Grade	**A**	**B**	**C**	**D**	**Total**	**Quality points**	**Grade Point**
A	15	10	2	1	28	95	3.393
B	25	27	11	0	63	203	3.222
C	25	56	36	1	118	341	2.890
D	3	9	10	0	22	59	2.682
F	1	6	5	0	12	32	2.667
Total	69	108	64	2	243	730	3.004
Quality points	188	242	123	6	559		
Grade Point	2.725	2.241	1.922	3.000	2.300		

Figure 1. Pre-requisite grades versus circuits course grade



In summary, the typical circuits course was pre-dominantly African American and male. Females and non-African American students performed the best in the course. Graduate students also had the best performance in the course. There were traditionally more electrical and mechanical engineering majors than the other majors. Most students had reached their junior year before their first attempt at completing the course. On average the students took 1.35 attempts in order to successfully complete the course. The analysis also demonstrated that overall one-third of the students did not successfully complete the course on the first attempt. The mean course grade for all students evaluated was 2.05. Finally, student performance in pre-requisites was shown to have a significant affect on the circuits course performance.

Conclusions

In conclusion, this evaluation serves a preliminary exploratory analysis of an introductory circuits course. The purpose of this analysis was to determine specific methods and techniques necessary to improve student performance and success rate. The results indicate the course may need to be re-designed to be more learner-centered and active. This may be done by more in-class activities including board work and team exercises. There will be the formation of cooperative learning teams and team assignments. These teams may be formed by using data from student self-assessments, concept questionnaires, and/or learning styles inventories. Additionally, teams may be created to be have an even distribution of skill sets based upon pre-requisite grades, learning styles, student preference, race, gender, and/or major. With respect to the requisite performance, an out of class pre-requisite review session may need to be held to bring all students up to par. This preliminary data will be compared to future students enrolled in the redesigned active learning circuits to determine if there is an improvement in course attrition and mean grade point. The results of this comparative study will be the subject of future publications.

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CARLOTTA A. BERRY is an assistant professor of Electrical and Computer Engineering at Tennessee State University. She earned a Ph.D. from Vanderbilt University in 2003, M.S. from Wayne State University in 1996, B.S. from Georgia Tech in 1993 in Electrical Engineering, and a B.S in 1992 from Spelman College in Mathematics. Her research interests include human-robot interaction, active learning and student retention.