Mathematical Background Versus Success in Electrical Engineering

Dale N. Buechler
Department of Electrical Engineering and Computer Science
University of Wisconsin-Milwaukee

Abstract - Part-time students at the University of Wisconsin-Milwaukee (UWM), an urban commuter campus, make up about thirty-five percent of the students in the College of Engineering and Applied Science. Since Engineering is only offered at a few schools in the UW System, UWM receives a large number of transfer students. We have found that a significant number of the students entering into our core electrical engineering classes do not have the proper mathematics background to succeed. This has been documented using pretests in core classes at the start of the semester. For many students there is a large gap of time between their prerequisite courses and the core engineering courses that follow. Some topics may have not have been properly covered in prior classes or if they were covered the information was not retained. This study looks at the mathematical background of students who graduated with a degree in electrical engineering over the past four years at UWM and attempts to identify sources of these problems. Final grades in the calculus series as well as in algebra (essentials of algebra, intermediate algebra, and college algebra), trigonometry, and precalculus classes were evaluated. Trends involving minimum math ACT scores and scores in the calculus series have been observed. In addition, warning signs for transfer students and part-time students have been identified. Results of this study have been shared with other urban thirteen universities to help establish the validity of these trends for urban schools with similar admissions requirements. Results of this study are being conveyed to colleagues within the Math Department to aid in the proper placement of incoming students and to colleagues within our department and college to be used to alter our programs so that students have the background they need to succeed.

Introduction

Engineering education over the next decade provides numerous challenges. One of the biggest of these is the marked decrease in the mathematics proficiency of first-year college students nationwide. In 2000, nearly 15 percent of first-year engineering majors reported the need for remedial work in mathematics [1]. At the University of Wisconsin - Milwaukee (UWM), an urban thirteen school, we face a much bigger challenge. As part of our mission the college of engineering and applied science at UWM is striving to further academic and professional opportunities for all students including women, minority, part-time, and financially disadvantaged students. Our relatively low admission standards (top half of graduating class or ACT score of 21) provide initial access to disadvantaged students, however most are not ready for calculus upon admission. At UWM, most of our undergraduate students work at least half time and about 30% of our students work full time. UWM also receives a large number of transfer students from local technical colleges and other UW system schools without engineering programs.

In electrical engineering, the concepts learned in prior mathematics courses are essential for the core curriculum. At the University of Wisconsin-Milwaukee (UWM) we have found, through the use of pretests, that a significant number of the students entering into our core electrical engineering courses do not have the proper mathematics background to succeed even after the completion of the required mathematics curriculum. As a result, a significant portion of the semester has to be used to review for those students in mathematically intensive courses who either have not retained or have not learned prerequisite material. The following study attempts to identify sources for these mathematical problems as a function of initial student math course placement and among part-time and transfer students. The relative graduation rates of students as a function of initial math placement are also investigated.

Retention

The results from a study at UWM (Table 1a), which looked at the retention of new freshman engineering students after five years for freshman engineering students entering Fall 1995 and Fall 1996, clearly shows a retention problem. Although over half of the students achieve junior status, only 105 students (28.2%) are likely to be graduating with a degree from our college. The low level of success in obtaining junior status may be due to our relatively low admission requirements and corresponding lack of mathematical preparation upon entrance to the university. Table 1b gives a breakdown of the initial math placement levels for freshman entering the college of engineering and applied science (CEAS) at UWM in the fall of 1996. The enrollment numbers for electrical engineering students from 1993-1999 and graduation numbers from 1999 to 2003 are given in Tables 1c and 1d respectively. These results indicate a large number of part-time students (Note the median time to degree is 6 years (mean 7.25 years) with about 11 % of our graduates taking more than 10 years to complete their degree).

Entering Students	Achieved Jr. Status	Graduated (Engr. College)	Graduated (Other College)	Still Enrolled (Engr. College)	Still Enrolled (Other College)
373	195	54	29	51	32

Table 1a. Retention of freshman engineering students entering Fall 1995 and Fall 1996

Calculus	Precalculus	College Alg.+ Trig.	Intermed. Alg.	< Intermed. Alg.
23%	7.5%	35.8%	25.7%	8%

Table 1b. Initial Math Placement CEAS freshman in Fall 1996

	1993-4*	1994-5*	1995-6	1996-7	1997-8	1998-9
Total Majors	153	147	237	229	259	259
New Fr.	0	0	38	32	45	44
Fr. & Soph. Transfers	0	0	17	21	17	21
Jr. & Sr. Transfers	1	1	29	8	19	8

Table 1c. Enrollment Numbers Electrical Engineering at UWM [2]

*(Note: Intended Majors as Freshman are Included Beginning in 1995-96)

Year	1999-00			2000-1			2001-2			2002-3		
Semester	Fall	Spr.	Sum.	Fall	Spr.	Sum.	Fall	Spr.	Sum.	Fall	Spr.	Sum.
Graduates	9	19	3	13	13	4	11	27	1	20	25	3

Table 1d. Graduation Numbers in Electical Engineering at UWM

Mathematical background of prior graduates

In this study, we looked at the transcripts of all electrical engineering graduates at UWM from Fall Semester 1999 through Spring Semester 2003. The study includes data from 142 students who graduated during this period. Of these 142 students, 70 completed all their math and engineering work at UWM. Another 12 transfer students completed their entire calculus sequence at UWM. Forty-three transfer students took their entire calculus sequence at another institution. Seventeen other students took part of their calculus series at UWM and the rest at another school. Table 2 below lists the distribution of UWM graduates during the last 4 years as a function of where they completed their calculus sequence and their initial math placement. At UWM, all incoming students take a UW-system math placement exam and this alone determines initial placement.

Initial University Math Placement	UWM Calculus	Transfer Calculus	Partial UWM Calculus
Calculus Series	36/82	13/43	3/17
Precalculus	13/82	1/43	2/17
College Alg. or Trig.	5/82	8/43	0/17
College Alg.+ Trig.	8/82	10/43	5/17
≤ Intermed.Alg. College Alg.+ Trig.	9/82	9/43	6/17
≤ Intermed. Alg. Precalculus	11/82	2/43	1/17

Table 2. Distribution of Students as a function of initial university math placement

Assessment was made using the final course grades of students. Comparison of student performance was based on Degree GPA, Calculus Sequence GPA, and Electrical Engineering Core Course GPA. Student data was categorized by initial math placement, by math sequence taken, and by where their calculus series was taken. The tables below list characterize student performance as a function of where they took their calculus series (all at UWM, all at another school, part at UWM).

Math taken at UWM

The relative performance of those 82 graduates who took their entire calculus series at UWM as a function of initial math placement is given in Table 3a. Not quite half (43.9%) of the graduates were calculus ready when they entered the university (~ double the percentage in Table 1b). Another 22% of the students had a minor deficiency in either algebra or trigonometry (requiring placement in the appropriate class) or were required to take a survey class including both algebra and trigonometry (~ triple the 7.5% in Table 1b). Some of these students took College Algebra and Trigonometry before proceeding to the calculus series. Others took a precalculus survey class including both algebra and trigonometry. Nearly a quarter of graduates began the university at the intermediate algebra level (14.6%) or below (9.8%). Half of those beginning

below the intermediate algebra level transfer to UWM prior to beginning the calculus series. Precalculus survey courses (algebra + trigonometry) only appear to have benefited those students with slight deficiencies in these areas and should not be taken by those students beginning at lower levels (Intermediate Algebra or below).

Initial University Math Placement	Calculus Sequence *Average* GPA	Core Course *Average* GPA	Degree *Average* GPA
Calculus Series	3.087	3.268	3.187
Precalculus	2.970	3.218	3.091
Trigonometry	3.334	3.341	3.273
College Alg. + Trig.	2.930	2.995	2.926
≤ Intermed. Algebra College Alg. + Trig.	2.839	3.006	2.950
≤ Intermed. Algebra Precalculus	2.495	2.821	2.750
All Students	2.962	3.149	3.067

Table 3a. Performance of EE Graduates (UWM Calc.) as a Function of Initial Math Placement

Transfer Students

Transfer students comprise a significant percentage (42.25%) of electrical engineering graduates at UWM. This greatly limits our control over the prior math background of these students. Therefore, to help distinguish weaknesses within our own university from those at other schools, the performance of those students completing their calculus entirely at another school (Table 3b), and those students that had only part of their calculus series completed at UWM (Table 3c) were investigated. The overall performance of those transfer students, who completing their calculus entirely at another school, were similar to those at UWM. Transfer students were found to comprise 80% of all students that graduated with initial math placement below intermediate algebra. However, transfer students who initially placed at the lower levels (intermediate algebra or below) did better in the calculus series than those at UWM. This can be attributed to the fact that many of these transfer students came from 2 year schools where these lower level courses are taught by faculty/staff instead of teaching assistants. Students who transferred to the university part way through the calculus series did not perform as well due to differences in the order of topics within the calculus series at different schools.

Initial University Math Placement	Calculus Sequence *Average* GPA	Core Course *Average* GPA	Degree *Average* GPA
Calculus Series	3.276	3.103	3.018
Precalculus	2.110	2.629	2.677
College Alg. or Trig.	2.882	2.644	2.641
College Alg. + Trig.	2.647	3.061	3.124
≤ Intermed. Algebra College Alg. + Trig.	3.176	2.972	3.055
≤ Intermed. Algebra Precalculus	3.223	3.278	3.045
All Students	3.006	2.977	2.973

Table 3b. Performance of EE Graduates (Transfer Calc.) as a Function of Initial Math Placement

Initial University Math Placement	Calculus Sequence *Average* GPA	Core Course *Average* GPA	Degree *Average* GPA
Calculus Series	3.001	3.284	3.078
Precalculus	2.888	2.999	2.897
College Alg. + Trig.	2.289	2.711	2.756
≤ Intermed. Algebra College Alg. + Trig.	2.379	2.877	2.852
≤ Intermed. Algebra Precalculus	3.335	2.890	2.761
All Students	2.579	2.915	2.863

Table 3c. Performance of EE Graduates (Partial Transfer Calc.) as a Function of Initial Math Placement

Part-time Students

At UWM most of our undergraduate students work at least half time and about 30% of our students work full time. Since a significant number of our students are part time it takes a longer time for them to graduate. The results in Table 4 show a significant decrease in performance for those students taking longer than 5 years to finish their degree. It appears that a significant part of the information retention problem is due to the time past between successive classes for our students.

Time for Completion of Degree	Calculus Seq. GPA *Average (Std. Dev.)*	Core Course GPA *Average (Std. Dev.)*	Degree GPA *Average (Std. Dev.)*
Less than 5 Years	3.545 (0.436)	3.440 (0.395)	3.412 (0.355)
5 to 5.5 Years	2.930 (0.644)	3.080 (0.504)	3.021 (0.402)
6 to 6.5 Years	2.909 (0.640)	3.084 (0.561)	3.060 (0.414)
7 to 10 years	2.854 (0.585)	2.964 (0.562)	2.929 (0.496)
Over 10 years	2.756 (0.737)	2.876 (0.550)	2.821 (0.542)

Table 4. Student Success as a Function of Time to Degree

Indicators of Retention Problems

The minimum ACT Math Score of a student who graduated from our program during this four-year study period was a 17, and this student was a transfer student. Of those students who took intermediate algebra and graduated, 89% achieved a B or better in this course before proceeding to the next math course. At UWM, courses can be retaken and only the best grade is used in the calculation of their GPA although all grades remain on their transcript. In the previous tables only the best grade was used for calculation purposes. Most of the students in this study did not retake any of their math courses (59.1%). However, the number of students who had retaken more than one math course was significant (22.5%) and tended to include those students with the lowest GPAs.

Trends from other Peer Institutions

It was expected that the results of this study would be representative of other urban thirteen universities with relatively low admission criteria. Many urban thirteen schools, like UWM, have two separate requirements for admission: a minimum score on the ACT or a minimum GPA or class rank. Urban thirteen schools with similar requirements to UWM (UWM ACT=21 or top half of graduating class) include: Cleveland State University, Wayne State University, University of New Orleans, University of Alabama-Birmingham, Portland State University, and the City College of New York. Others use a sliding scale formula, which includes both high school performance and Standard Test Scores. Universities using a sliding scale that have comparable admittance criteria to UWM include the University of Missouri-Kansas City, University of Memphis, and California State University at Sacramento. A survey plus a summary of the data from this study was sent to all urban thirteen universities with engineering programs to get their input as to the validity of the findings. The University of Memphis reported that the students in our colleges are very similar in terms of retention, the length of time to graduation, the large numbers of part-time students, and their incoming mathematical preparation. In a recent section of calculus I for their engineering students only about 35% received a C or better. This is in contrast to the data received from the University of Pittsburgh, an institution with much higher admission criteria (SATs greater than 1170 and ranked in the top 20% of their high school class) where 92% are ready for calculus [3], most students are full time, average graduation occurs in less than 5 years, and retention of freshman is about 60%. However, the University of Pittsburgh did report 50% retention rates during the first two years for those students initially beginning in precalculus.

Discussion and Conclusions

Numerous trends have been observed during this study. First of all, a significant decrease in performance was observed for those students taking longer than 5 years to finish their degree. A significant part of the information retention problem in upper level classes that we see can be attributed to the time past between successive classes for our students, many of whom are part-time. Second, although students may enter the university poorly prepared mathematically, they can succeed if they are properly placed within the mathematical sequence and understand the required concepts before moving on to the next course in the sequence. For those starting at the intermediate algebra level, a grade of B or better in this course before proceeding to the next math course was found to be an indicator of future success. The importance of early achievement in beginning math courses also plays a major role in retention [4]. Intermediate algebra should be followed by college algebra, trigonometry, and then the calculus series. Precalculus survey courses appear to benefit those students with slight deficiencies in these areas prior to taking calculus, however, they should not be used to shorten the mathematical sequence for those beginning lower in the math sequence. Scores in the first semester of calculus were also found to be an indicator of student performance in engineering core classes to follow. Finally, it is evident that closer evaluation of our transfer students is needed. It was found that students who completed a portion of the calculus sequence at more than one institution appeared to be missing topics (Table 3c). Transfer students, mostly from two-year schools or four-year schools without engineering programs, were found to have a lower initial math placement than

those who began their work at UWM (most of the students with initial math placement below intermediate algebra and many of the marginal upper division students are transfer students).

Some of these issues may be addressed by our recent reinstatement of the advancement to major at the end of the 3rd semester. This will provide a time for evaluation of student performance prior to taking upper division classes for both our students and transfer students. The institution of grade requirements for certain key core courses may also need to be implemented to make sure students have the prerequisites. This is not meant as a roadblock to prevent passage, but more like a checkpoint to verify the students have the skills they need to succeed.

An underlying problem emphasized by this study is that our engineering program curriculum, like many others, is based on the assumption that students are calculus ready when they enter the university. This is not a valid assumption for those urban thirteen schools that have relatively low admission criteria. As a result, capable students take much longer to complete their prerequisite mathematics sequence before being able to take their core engineering classes and often feel alienated. Perhaps programs such as ours should consider other alternatives that incorporate part of this mathematical education into the engineering programs instead of relying on others to do this for us.

References

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[2] University of Wisconsin-Milwaukee 1998-99 Department Profiles

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[4] D. Budny, W. LeBold, G. Bjedov, "Assessment of the Impact of Freshman Engineering Courses," Journal of Engineering Education, Vol. 87 No. 4, Oct. 1998, pp. 405-411.