The Relationship Between High School Mathematical Achievement and Quantitative Grade Point Average in a Pre-Engineering Curriculum

Jennifer L. Bell, Glennelle Halpin, and Gerald Halpin

Auburn University

Paper presented at the Annual Conference of the Eastern Educational Research Association,

Savannah, Georgia, February 2010.

The Relationship Between High School Mathematical Achievement and Quantitative Grade Point Average in a Pre-Engineering Curriculum

According to the National Science Foundation (NSF) (National Science Board, 2006b), in 1983, 11.5% of the freshmen declared engineering as their intended major. This percentage slightly decreased to 9.6% in 2004. In addition to the trend of decreased interest, the rate of retention in the field of engineering has decreased. Of the 1983 college graduates, 7.4% of them earned a bachelor's degree in engineering. As a comparison, 4.6 % of the college graduates in 2002 completed a program in engineering. These percentages indicate that a disproportionately high number of students switch out of engineering majors because they either lose interest in engineering or have academic difficulties (Wulf & Fisher, 2002). From 1975 to 1999, the number of US students who completed bachelor's degrees in the natural science and engineering fields has dropped from 3rd to 14th compared to 19 other countries (National Science Board, 2006a). The declining interest in engineering fields and increasing attrition rates of pre-engineering majors have led to a serious shortage of engineers (Felder, Forrest, Baker-Ward, Dietz, & Mohr, 1993).

In the middle of the 20th century, President John F. Kennedy inspired a nation of scientists and engineers to win the space race after the Soviet Union's launch of Sputnik in 1957. These motivated individuals are reaching retirement age in the beginning of the 21st century, yet the declining interest and increasing attrition rates have reduced the number of scientists and engineers to replace them. This shortage of prepared scientists and engineers can be linked to poor preparation in mathematics and science instruction at the K-12 level. According to the NSF, the competitive edge of the United States is dependent upon its educational system to produce citizens who grasp the academic language, think critically, and make informed decisions based on mathematics and science (National Science Board, 2006a).

As an indicator of academic difficulties and confirmation of the NSF's conclusion, the percentage of college freshman engineering majors who reported the need for remediation in mathematics has increased since 1984, from 11.7% in 1984 to 14.0% in 2002 (National Science Board, 2006b). Between the years of 1992 and 2000, 20% of the freshmen who entered a doctoral institution took at least one remedial course (National Science Board, 2004). The student's decision to persist or change occurs during the first year of study at the college level. Often, this decision is based on successful completion of a gateway course (e.g., calculus) because the culture in these engineering courses tends to be quantitatively oriented (Gainen & Willemsen, 1995). Moreover, the knowledge gained from these quantitative courses is essential for the nation to compete successfully in today's global society (National Science Board, 2006a).

While the interest and retention of engineering majors have decreased, there appears to be stagnation in mathematical ability for 12th-grade students. Since 1969, the National Assessment of Educational Progress (NAEP) has yielded assessments in reading, mathematics, science, writing, social studies, and the arts among 4th-, 8th-, and 12th-grade students from public and private schools. Individual students or schools were not provided the results of these assessments; however, the United States Department of Education (USDOE) analyzed the NAEP student achievement data and published data trends for the nation and specific geographic regions. Furthermore, the USDOE disaggregated the NAEP data in order to study the academic achievement results in the content areas for specific groups of students (Livingston & Wirt, 2004).

The mathematics subtest of the NAEP assessed five different domains: number sense, properties, and operation; measurement; geometry and spatial sense; data analysis, statistics, and probability; and algebra and functions. Within their framework, problem solving, conceptual understanding, and procedural knowledge were integrated throughout each domain (Mitchell, Hawkins, Stancavage, & Dossey, 1999). Further examination of the 1999 NAEP average mathematics score for the nation revealed that the 9-year-old and 13-year-old participants continued to improve their scores each year, but the 17-year-old students' scores have remained stagnant since 1973 (Campbell, Hombo, & Mazzeo, 2000). Furthermore, 97% of the 17-year-olds achieved a level of 250 that indicated math proficiency in the four basic math operations and solving of one-step word problems. However, only 8% of all 17-year-old students scored at the 350 level indicating that they were capable of understanding and computing multiple step problems. These data indicated that nationally 92% of all 17-year-old students who took the NAEP test could not comprehend or solve multiple-step problems.

More promising results of students' ability to complete mathematics problems were found in a study by Mitchell et al. (1999). Using the same NAEP mathematics data, these researchers focused on the disaggregated data for students in 8th and 12th grade who took higher-level mathematics courses. These researchers found that 30% of advanced 12th graders correctly solved problems involving two or more steps. However, all of the students who comprised the disaggregated data group indicated on surveys that their mathematics courses included a heavy emphasis on problem solving skills. To support the findings of this NAEP study, of the 108,437 students who took the Advanced Placement Calculus AB exam in 1997, approximately 59% of them earned a passing score of three or higher on a 5-point scale. Nine years later, in 2004, the pass percentage was nearly equivalent (National Science Board, 2006b).

All of these findings, which have employed the NAEP data, indicate that many students lack proficiency when presented with mathematics problems that involve higher order thinking skills. Another indicator of mathematical achievement is the number of advanced mathematics courses taken at the high school level. Despite increasing percentages of advanced mathematics courses being offered at the high school level (i.e., 26.8% increase for statistics and probability and 13.4% increase for calculus since 1990), of the 2000 graduating class, only 5.7% of them completed a statistics and probability course, and 12.6% of the graduates completed a calculus course (National Science Board, 2006b). Courses, such as calculus, can open or close the gate for students interested in mathematical, scientific, or technological careers (Gainen & Willemsen, 1995).

The majority of high schools require 3 years of mathematics for graduation, which is referred to as midlevel curriculum. Since 1990, the average number of required mathematics courses has increased from 3.2 to 3.8; however, only 10% of the high school graduates in 2005 participated in a rigorous curriculum level where 4 years of mathematics was required. Thus, it is likely that a graduating senior would not be involved in formal mathematics courses for at least 1 year at the time of college enrollment (Shettle et al., 2007).

High school preparation severely limits their access to knowledge and the ability to solve real world problems. Often classroom instruction is delivered in the lecture format instead of explaining, illustrating, applying, or discussing. The emphasis on testing and rote memorization replaces application and generalization of the concepts. Consequently, the students lack the ability to analyze the presented material critically and tend to be unsuccessful in the quantitative courses (Gainen, 1995). This tendency to emphasize testing and memorization stems from the most recent elementary and secondary legislation.

The No Child Left Behind Act (NCLB) of 2001 mandated that all students, regardless of gender, economic status, racial classification, or disabilities, must reach proficient levels of academic achievement by 2013-2014. Furthermore, each school and system must meet adequate yearly progress (AYP) in order to avoid placement on specific states' needs improvement lists. In order to meet AYP, each school must have 95% or more participation in statewide assessments and meet or exceed the state's annual measurable objectives in curriculum content areas, including mathematics.

Mathematics requires fundamental knowledge of concepts and procedures; however, it requires critical and analytical thinking skills. These mathematical problem-solving skills allow the students to apply their fundamental knowledge in various contextual situations. Students need to practice problem-solving skills in real-life situations. By practicing these skills, the students can increase their engagement with the content of mathematics, increase their ability to think critically, and increase their performance on higher order cognitive questions (Mitchell et al., 1999; Wulf & Fisher, 2002). Based on these reasons, there is a need to prepare the students from lifelong learning where they can solve contextual problems. Thus, they will be prepared for the ever-changing society (National Academy of Engineering, 2005; Litzinger, Wise, & Lee, 2005; Wulf & Fisher).

Education must provide the next generation with a view of the engineering profession, and education must academically prepare those potential engineers for the world of tomorrow (National Academy of Engineering, 2005). Anthony, Hagedoorn, and Motlagh (2001) suggested problem solving and application skills would increase the likelihood of success in engineering (e.g., correlating the calculus and physics content). Litzinger and Marra (2000) defined the critical skills and attributes needed for lifelong learning as confident, flexible, logical, analytical, and self-aware. Unfortunately, traditional classroom instruction provides minimal preparation for inquiry-based learning or critical thinking during performance-based tasks. The learning experience should provide open-ended problems within a real-world context to give the students the opportunities to develop and practice these skills.

The nation must prepare students in K-12 education for tomorrow's demands in the workforce and society. With continuing advances in technology, students must have a solid foundation in mathematics to be productive members in their communities (National Science Board, 2006a). External forces of society, economy, and profession challenge the stability of the engineering workforce. This instability affects recruitment of the most talented students into the engineering profession (National Academy of Engineering, 2005). Students cannot begin to develop their intellectual capacities when they enter college at the age of 18. Hence, these demands will require developing their mathematical skills earlier in the formal education years (National Science Board; Wulf & Fisher, 2002). To improve mathematics education at the K-12 level, the curriculum should make the learning experiences more meaningful and introduce the essence of engineering (National Academy of Engineering).

The NSF recommends further research regarding teaching and learning mathematics. Using this research, K-12 educators should be provided with quality professional development to deepen their content knowledge and promote inquiry-based pedagogy in the classroom to advance higher order thinking skills. For the students, the NSF recommends student exposure to science, technology, engineering, and mathematics careers through activities (National Science Board, 2006a). Similarly, Gainen (1995) and Klingbeil, Mercer, Rattan, Raymer, and Reynolds (2005) recommend early intervention programs in high school and a strong emphasis on application and appreciation of mathematical inquiry to increase student success in quantitative courses.

Mathematics ability is the strongest predictor of success in the field of engineering (LeBold & Ward, 1988). A correlational study conducted by van Alphen and Katz (2001) with electrical engineering majors supports this notion. The researchers found that a strong relationship existed between admission to engineering and academic background. Likewise, Klingbeil et al. (2005) pointed to a lack of high school preparation as the most notable factor that influences success in engineering. Without a strong foundation in algebra, the doors are closed for subsequent mathematics courses (Edge & Friedberg, 1984; Klein, 2003).

Wilhite, Windham, and Munday (1998) investigated the effects of high school calculus and academic achievement variables on the undergraduate achievement in calculus I. The participants were selected as a stratified random sample from 1,542 calculus I students at the University of Arkansas. Of the 182 selected participants, a stepwise multiple regression was conducted to predict the final grade in calculus I. The researchers explained 29.9% of the variance in the calculus I final grade. The most significant predictor was ACT math scores followed by high school rank, age, and high school mathematics GPA. Similarly, a study conducted by Buechler (2004) found grades in the first-semester calculus course predicted student performance in the engineering core classes.

The purpose of this study was to determine if preparation in mathematics in high school is a significant prerequisite for success in engineering education at the collegiate level. Specifically hypothesized was that select mathematics subjects from the high school curriculum would be significantly related to achievement in collegiate quantitative subjects, a necessary condition for success in engineering education.

Methods

Participants

The College Freshman Survey: Engineering Form (Halpin & Halpin, 1996) was administered to a sample of 3,052 students who entered Auburn University from the fall semester of 2000 through the fall semester of 2004. Table 1 displays the frequencies for each admission year. Of these cases, 2,328 participants were selected for the study because their survey responses were matched with the grades and standardized scores provided by the University Planning and Analysis Office. The participants who have an intended engineering major included 1,901 (81.7%) were male, and 427 (18.3%) were female. Of these students, the racial classification of the group was 1,932 (83.0%) White, 259 (11.1%) Black, and 137 (5.9%) students who reported they belonged to other racial groups. The majority of the participants (54.8%) reported a masters degree as their highest education level they expected to attain.

When asked to describe the place where they lived before enrolling in college, 746 (32.0%) participants reported small town, 676 (29.0%) reported suburbia, 550 (23.6 %) reported large town, 181 (7.8%) reported big city, and 175 (7.5%) participants reported rural. The participants in this study represented 40 of the 50 U.S. States. For specifically, 1,646 (70.7%) reported Alabama as their home state. Nearly 60% of the participants reported their high school rank to be in the top 20% of the graduating class. The range of graduating class size was less than 50 to more than 500 students with a median of 200.

Table 1

Frequencies by Academic Year

	Entire Sample		Sample Cases	
Year	*n*	%	*n*	%
2000	609	20.0	466	20.0
2001	608	19.9	464	19.9
2002	626	20.5	453	19.5
2003	641	21.0	495	21.3
2004	568	18.6	450	19.3
Total	3,052	100.0	2,328	100.0

Measure

The College Freshman Survey (Halpin & Halpin, 1996), which consisted of 248 items, was the measurement tool used in this study. The beginning questions elicited demographic information, standardized test scores, and high school grades. For interest in high school courses, the participants rate their interest in each of the above subjects using a 4-point scale with 1, which denotes *Really Liked*, to 4, which denotes *Really Disliked*: algebra-calculus sequence, chemistry, physics, English, social studies, computer, and foreign language. The remaining questions (200 items) determine the importance of various subjects, rank of abilities, likelihood of various events, and agreement with various statements. The responses from these items were not utilized in this study.

Research Question

What is the relationship between high school preparation and quantitative grade point average in a pre-engineering curriculum at Auburn University?

Results

Descriptives for the grades and interest in the high school mathematics courses (i.e., algebra I, algebra II, geometry, trigonometry, and calculus) were assessed. For 292 cases, the participants only took the SAT. The SAT quantitative and ACT math scores are highly correlated (r = .79; p < .001). To linear equate the SAT quantitative and ACT math scores, a multiple regression analysis was conducted (Peterson, Kolen, & Hoover, 1989). The predicted ACT math score was used for the participants who only took the SAT. The mean score for the adjusted ACT math was 26.59 with a standard deviation of 4.22 and ranged from 15 to 36. For high school grades, the participants' responses range from 1, which represented *D+ or less*, to 7, which represented *A+*. The seven-point scale was used to empirically weight the responses in order to account for the class not being taken in high school and to differentiate between A+, A, and A-. Table 2 displays the means and standard deviations for grades for each high school mathematics course. Table 3 displays the intercorrelations with the predictor variables.

Table 2

Means and Standard Deviations for Grades for each High School Mathematics Course

	Grades	
Course	*M*	*SD*
Algebra I	5.65	1.38
Geometry	5.58	1.35
Algebra II	5.48	1.39
Trigonometry	5.00	1.59
Calculus	4.45	1.65

Table 3

Intercorrelations for the Predictor Variables

Variable	1	2	3	4	5	6	7
1. Adjusted ACT Math	--	.20**	.30**	.34**	.32**	.42**	.19**
2. Algebra I grade		--	.41**	.48**	.34**	.23**	.29**
3. Geometry grade			--	.55**	.40**	.32**	.28**
4. Algebra II grade				--	.52**	.41**	.41**
5. Trigonometry grade					--	.37**	.33**
6. Calculus grade						--	.28**
7. Interest in high school mathematics							--

Note: * p < .05; ** p < .01.

The dependent variable of quantitative grade point average (GPA) in the pre-engineering curriculum was measured with at least two at quantitative courses in the pre-engineering curriculum at Auburn University. A quantitative course was defined as a college course whose conceptual foundation is based in mathematics (Gainen & Willemsen, 1995). Table 4 displays the courses from the pre-engineering curriculum which were considered quantitative courses in this study. The final letter grade in each quantitative course was coded using the four-point scale (i.e., A = 4, B = 3, C = 2, D = 1, F=0) and was averaged together to create the quantitative grade point average. The mean score was 2.33 with a standard deviation of 1.03. A bivariate correlation was conducted to determine the relationship between the quantitative GPA and pre-engineering GPA. A strong positive relationship existed between the GPAs ($r = .87$; $p < .001$).

Table 4

List of Possible Quantitative Courses in Pre-Engineering Curriculum

Course	Number
College Algebra	MA1000
Pre-Calculus Trigonometry	MA1130
Pre-Calculus Algebra Trigonometry	MA1150
Calculus I	MA1610
Honors Calculus I	MA1617
Calculus II	MA1620
Honors Calculus II	MA1627
Calculus for Engineering and Science I	MA1710
Calculus for Engineering and Science II	MA1720
Calculus III	MA2630
Calculus for Engineering and Science III	MA2730
Survey of Chemistry I	CH1010
Survey of Chemistry II	CH1020
Fundamentals of Chemistry I	CH1030
Fundamentals of Chemistry II	CH1040
General Chemistry I	CH1110
Honors General Chemistry I	CH1117
General Chemistry II	CH1120
Honors General Chemistry II	CH1127
Foundations of Physics	PH1000
General Physics I	PH1500
General Physics II	PH1510
Engineering Physics I	PH1600
Honors Physics I	PH1607
Engineering Physics II	PH1610
Honors Physics II	PH1617

Explanation of Quantitative GPA

After the initial descriptives and correlations, a multiple regression analysis was conducted using quantitative GPA as the dependent variable. Adjusted ACT math, high school mathematics course grades, and high school mathematics course interest were used as independent variables. The R^2 for the full regression model was .31 (F(7, 2264) = 143.10; $p < .001$). The most significant predictor of quantitative GPA was the adjusted ACT math score ($t = 15.47$; $p < .001$). Other significant contributors to the models were calculus grades ($t = 10.22$; $p < .001$), algebra II grades ($t = 3.76$; $p < .001$), trigonometry grades ($t = 3.71$; $p < .001$), and algebra I ($t = 2.01$; $p = .04$). Table 5 displays the summary of the full regression analysis including the zero-order correlations, semi-partial correlations, and structure coefficients for each predictor.

As a follow-up procedure, a series of univariate analyses were conducted with the Bonferroni post hoc for each significant high school mathematics course (i.e., algebra I, algebra II, trigonometry, and calculus) using quantitative GPA as the dependent variable. In general, the participants who reported that they made an A+ or A in a high school mathematics course tended to have significantly higher quantitative GPAs compared to the other grade categories. The participants who reported that they did not take a specific high school mathematics course tended to have significantly higher quantitative GPAs compared to the participants who reported poor performance in high school mathematics courses. The results suggest that successful performance in high school mathematics significantly affects performance in college quantitative courses. In addition, the exposure to the content in high school does not increase academic performance in college quantitative courses. Table 6 though Table 9 display the mean differences for each high school mathematics course by grade category.

Table 5

Summary of Full Regression Analysis for Variables Predicting Quantitative GPA (*N*=1,184)

Variable	*r*	*sr*	Structure Coefficient
Adjusted ACT Math	.46	.27	.84
Algebra I grade	.23	.04	.42
Geometry grade	.30	.03	.54
Algebra II grade	.34	.07	.62
Trigonometry grade	.32	.07	.58
Calculus grade	.42	.18	.76
Interest in high school mathematics	.19	-.01	.34

Note. $R^2 = .31$.

Table 6

Post Hoc Test Results: Mean Differences for Algebra I by Grade Category

	Mean difference						
Grade Category	A+	A	A- to B+	B to B-	C+ to C-	D+ or less	Did not take
A+	--						
A	.27**	--					
A- to B+	.65**	.38**	--				
B to B-	.83**	.56**	.18	--			
C+ to C-	.90**	.63**	.25	.08	--		
D+ or less	.74	.47	.09	-.09	-.16	--	
Did not take	-.03	-.29	-.67**	-.85**	-.93**	-.76	--

Note: * $p < .05$; ** $p < .001$.

Table 7

Post Hoc Test Results: Mean Differences for Algebra II by Grade Category

	Mean difference						
Grade Category	A+	A	A- to B+	B to B-	C+ to C-	D+ or less	Did not take
A+	--						
A	0.35**	--					
A- to B+	0.71**	0.35**	--				
B to B-	0.93**	0.58**	0.22*	--			
C+ to C-	1.13**	0.78**	0.43**	0.20	--		
D+ or less	1.25**	0.89*	0.54	0.32	0.11	--	
Did not take	0.31	-0.05	-0.40	-0.62	-0.83	-0.94	--

Note: * $p < .05$; ** $p < .001$.

Table 8

Post Hoc Test Results: Mean Differences for Trigonometry by Grade Category

	Mean difference						
Grade Category	A+	A	A- to B+	B to B-	C+ to C-	D+ or less	Did not take
A+	--						
A	0.27**	--					
A- to B+	0.86**	0.59**	--				
B to B-	1.03**	0.76**	0.17	--			
C+ to C-	1.19**	0.92**	0.33*	0.16	--		
D+ or less	1.17*	0.90	0.31	0.14	-0.03	--	
Did not take	0.69**	0.42**	-0.17	-0.34**	-0.50**	-0.48	--

Note: * $p < .05$; ** $p < .001$.

Table 9

Post Hoc Test Results: Mean Differences for Calculus by Grade Category

	Mean difference						
Grade Category	A+	A	A- to B+	B to B-	C+ to C-	D+ or less	Did not take
A+	--						
A	0.34**	--					
A- to B+	0.66**	0.32**	--				
B to B-	0.99**	0.65**	0.33**	--			
C+ to C-	1.28**	0.94**	0.62**	0.29	--		
D+ or less	1.96**	1.62**	1.30**	0.97**	0.69*	--	
Did not take	1.09**	0.75**	0.43**	0.10	-0.19	-0.87**	--

Note: * $p < .05$; ** $p < .001$.

Discussion

Based the results of this study, ACT math scores were the most significant predictor of quantitative GPA according to the bivariate correlation, semi-partial, and structure coefficient. This significant contribution supports the findings of LeBold and Ward (1988). In addition to ACT math scores, the grades earned in the high school calculus course was a statistically significant contributor to the regression model. The post hoc tests revealed significant differences in quantitative GPA based on grade categories. The participants who earned an A+ in calculus had quantitative GPAs at least 1.00 higher compared to those participant who earned a B and lower. Similar mean differences were seen with algebra II and trigonometry. Algebra I, algebra II, trigonometry, and calculus were also statistically significant predictors, which support the significant findings of LeBold and Ward and Wilhite et al. (1998).

The nature of science, engineering, and mathematics college courses tends to be quantitatively oriented, and calculus tends to serve as the gateway course for academic success within these majors according to Gainen (1995). Therefore, mathematical ability is considered a critical factor for achieving success in engineering because it serves a foundation for the science curriculum (Heinze et al., 2003). Based on the findings of this study, the College of Engineering and K-12 educational systems should increase their awareness of the relationship between high school mathematical preparation and academic success in the pre-engineering curriculum. Future research should examine mathematics curriculum in order to develop mathematical skills at the secondary level so the students will be better prepared for the quantitative courses within the pre-engineering curriculum and other quantitatively-oriented professions.

References

Anthony, J. M., Hagedoorn, A. H., & Motlagh, B. S. (2001). *Innovative approaches for teaching calculus to engineering students*. Paper presented at the ASEE Annual Conference, Albuquerque, NM.

Buechler, D. N. (2004). *Mathematical background versus success in electrical engineering*. Paper presented at the ASEE Annual Conference, Salt Lake City, UT.

Campbell, C. M., Hombo, C. M., & Mazzeo, J. (2000). *NAEP 1999 trends in academic progress: Three decades of student performance*. Washington, DC: U.S. Department of Education, Office of Education Research and Improvement, National Center for Education Statistics. Retrieved January 20, 2005 from http://nces.ed.gov/pubsearch/pubsinfo.asp?pubid=2000469.

Edge, O. P., & Friedberg, S. H. (1984). Factors affecting achievement in the first course in calculus. *Journal of Experimental Education, 52*, 136-140.

Felder, R. M., Forrest, K. D., Baker-Ward, L., Dietz, E. J., & Mohr, P. H. (1993). A longitudinal study of engineering student performance and retention: I. Success and failure in the introductory course. *Journal of Engineering Education*, *82*, 15-21.

Gainen, J. (1995). Barrier to success in quantitative gatekeeper course. In J. Gainen, & E. W. Willemsen (Eds.), Fostering student success in quantitative gateway course. *New Directions for Teaching and Learning, 61*, 1-3.

Gainen, J., & Willemsen, E. W. (Eds.). (1995). Fostering student success in quantitative gateway course. *New Directions for Teaching and Learning, 61*, 1-3.

Halpin, G., & Halpin, G. (1996). *College freshman survey: Engineering Form*. Auburn University, AL: Auburn University.

Heinze, L. R., Gregory, J. M., & Rivera, J. (2003). *Math readiness: The implications for engineering majors*. Paper presented at the Frontiers In Engineering Conference, Boulder, CO.

Klein, D. (2003). A brief history of American K-12 mathematics education in the 20th century. In J. M. Royer (Ed.), *Mathematical cognition* (pp. 175-259). Greenwich, CT: Information Age Publishing.

Klingbeil, N. W., Mercer, R.E., Rattan, K. S., Raymer, M. L., & Reynolds, D. B. (2005). *The WSU model for engineering mathematics education*. Paper presented at the ASEE Annual Conference, Portland, OR.

LeBold, W. K., & Ward, S. K. (1988). *Engineering retention: National and institutional perspectives*. Paper presented at the ASEE Annual Conference, Portland, OR.

Litzinger, T. A., & Marra, R. M. (2000). *Life long learning: Implications for curricular change and assessment*. Paper presented at the ASEE Annual Conference, St. Louis, MS.

Litzinger, T. A., Wise, J. C., & Lee, S. H. (2005). Self-directed learning readiness among engineering undergraduate students. *Journal of Engineering Education, 94*, 215-221.

Livingston, A., & Wirt, J. (Eds.). (2004). *The condition of education 2004 in brief*. Washington, DC: US Department of Education, Office of Education Research and Improvement, National Center for Education Statistics. Retrieved January 20, 2005 from http://nces.ed.gov/pubsearch/pubsinfo.asp?pubid=2004076.

Mitchell, J. H., Hawkins, E. F., Stancavage, F. B., & Dossey, J. A. (1999). *Estimation skills, mathematics-in-context, and advanced skills in mathematics: Results from three studies of the national assessment of educational progress 1996 mathematics assessment.*

Washington, DC: U.S. Department of Education, Office of Educational Research and Improvement (NCES 2000-451).

National Academy of Engineering. (2005). *Educating the engineer of 2020: Adapting engineering education to the new century*. Washington DC: National Academies Press.

National Science Board. (2004). *Science and engineering education indicators 2004*. Arlington, VA: National Science Foundation.

National Science Board. (2006a). *America's pressing challenge – Building a stronger foundation: A companion to science and engineering indicators 2006*. Arlington, VA: National Science Foundation.

National Science Board. (2006b). *Science and engineering education indicators 2006*. Arlington, VA: National Science Foundation.

No Child Left Behind Act, 20 U.S.C. § 6301 et seq. (2001). Retrieved January 20, 2005 from http://www.ed.gov/policy/elsec/leg/esea02/index.html.

Peterson, N. S., Kolen, M. J., & Hoover, H. D. (1989). Scaling, norming, and equating. In R. L. Linn (Ed.), *Educational measurement* (3rd ed.) (pp. 221-262). New York: Macmillan Publishing Company.

Shettle, C., Roey, S., Mordca, J., Perkins, R., Nord, C., Teodorovic, J., Brown, J., Lyons, M., Averett, C., & Kastberg, D. (2007). *The nation's report card: America's high school graduates.* Washington, DC: U.S. Department of Education, National Center for Education Statistics (NCES 2007-467).

van Alphen, D. K., & Katz, S. (2001). A study of predictive factors for success in electrical engineering. Paper presented at the ASEE Annual Conference, Albuquerque, NM.

Wilhite, P., Windham, B., & Munday, R. (1998). Predictive effects of high school calculus and other variables on achievement in a first-semester college calculus course. *College Student Journal, 32*, 610-615.

Wulf, W. A., & Fisher, G. M. C. (2002). A makeover for engineering education. *Issues in Science and Technology, 18*(3). Retrieved May 7, 2007 from http://www.issues.org/18.3/p_wulf.html.