# An Analysis of the Effect of Cognitive Factors on Students' Attritions in Engineering: A Literature Review

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**Abstract**

Schools of engineering throughout the United States are currently experiencing high student attrition rates, which greatly concerns institutions of higher learning and the nation itself due to the significant need for well-qualified and prepared engineers. In response, a large number of studies have been conducted to solve the attrition puzzle. To gain a better understanding of engineering attrition, this paper provides a review of relevant empirical studies. This review aims to identify the effects of cognitive factors in both high school and college on engineering undergraduates' attrition behaviors. After careful examination, this paper discusses several conclusions that could help schools of engineering better predict their student retention.
**Keywords:** STEM, Engineering, Attrition, Retention

## Introduction

Over the past thirty years, higher attrition in engineering programs remains a trying issue for universities across the country. In 1975, attrition rates among engineering freshmen were only about 12 percent; by 1990, freshman attrition rates had doubled to 24 percent (Beaufalt, 1991). A National Center for Educational Statistics (NCES) longitudinal study of first-year science and engineering students in 1990 indicated that less than 50% percent of engineering students graduated from engineering programs within five years (Smith, 1996). By analyzing a database with records of 75,686 first-time college students matriculating in engineering from 1988 through 1998, Ohland et al. (2011) concluded that 61% of 73,154 students persisted to the eighth semester in engineering within six years(Ohland et al., 2011). Nationwide, 40%-60% of engineering undergraduate students switched to other majors before they graduate (Astin &Astin, 1972; Moller-Wong &Eide,1997; Seymour &Hewitt, 1997; Adelman,1998). The ongoing high attrition rates, combined with the declining engineering graduation rates, greatly concerns institutions and the nation due to the significant costs associated with the attrition phenomenon(Suresh, 2006).

As the number of engineering student graduates declines, the demand for technological and engineering workers is expanding, even in a weak economy. According to the U.S. Department of Labor, jobs requiring technical degrees were projected to grow at approximately three times the rate of occupations by 2009. An estimated 6 million job openings were projected

for technically trained workers between 1998 and 2008(Executive office of the president, 2009). Further, Jackson and Talent (2003) viewed the gap between the nation's growing need for scientists, engineers and its deficient production as a "quite crisis", that could "jeopardize the nation's pre-eminence and well-being" and "could reverse the global leadership Americans currently enjoy"(Jackson& Talent,2003). These statistics solidify the increased need for well-qualified engineers, but the college attrition numbers signify that there is a growing gap between the supply of qualified students and industry demand.

In response to this issue, many researchers (Besterfield-Sacre, Atman & Shuman, 1997; Brainard &Carlin, 1997;Burtner, 2005; LeBold &Ward, 1998; Leslie, McClure & Oaxaca, 1998; Levin &Wyckoff, 1991; Seymour & Hewitt, 1997; White, 2005; Zhang, Anderson, Ohland&Thorndyke,2004)conducted studies to identify the cognitive factors associated with engineering students' attrition behaviors. This paper aims to integrate the empirical findings and examine how these cognitive variables can predict engineering students' attrition. Moreover, upon examining these cognitive variables, this review will be able to provide educators and researchers with a better understanding of engineering students' high attrition rate. For the purpose of this review, the paper will focus only on undergraduate students in engineering.

## Study Methodologies

This review is conducted by examining scholarly literature as empirical evidence to identify the causes of engineering undergraduates' attrition issues in order to yield valuable insight for educators, policy makers and further research. The publications examined in this review were collected using education-related databases and search engines, such as Social Science Abstracts, ERIC, Education Abstracts, JSTOR, and ProQuest. Searches were conducted using key words pertaining to engineering, attrition, retention, persistence and higher education. Book chapters, technical reports, conference papers and online materials were also examined and included if relevant. Google scholar forward and backward searching were utilized to ensure comprehensive inclusion. The proposed time frame of this study is from 1980 to 2011.This study also used cross-refer databases from multiple disciplines, such as education, engineering education, sociology, psychology and economics to extract different views from various perspectives. Examining the methodologies of the primary sources of this review reveals the following break-down:

- 14 quantitative and 4 qualitative studies. 4 mixed quantitative and qualitative studies
- 12 single-institution and 9 multi-institution studies
- 10 cross-sectional and 5 longitudinal studies
- 18 mixed gender and 2 female-only studies
- The largest number of engineering undergraduate participants is 87,167(Zhang et al., 2004).
- The smallest number of participants is 108 (Lichtenstein, 2007).

As mentioned above, most of the studies examined in this review are quantitative studies; some are qualitative and mixed studies. Gender and race variables are not highlighted in this review in

order to get a whole picture of student attrition issues in engineering. The single-institution and multi-institution studies are well-balanced and not largely different by numbers. With this level of examination of these primary attrition studies, the findings of this review should be worthy of considerable confidence.

## Analysis of the Research

### Academic Ability during High School: High School GPA, SAT and ACT Scores

Based on the assumption that high school academic ability might partially account for the high attrition rate in engineering, a number of researchers conducted studies to track the effects of high school experiences on engineering students' leaving behaviors. Among them, high school GPA, SAT scores and ACT scores are considered as the main criteria to measure engineering students' college readiness. By examining these empirical findings, this paper will address the following questions:

1. Are high school GPA and SAT or ACT math scores associated with undergraduate students' academic outcome in engineering?
2. Can persistence be predicted by high school GPA, ACT and SAT scores?
3. What role do verbal scores in SAT or ACT play in shaping engineering students' academic performance and persistence?
4. Taken together, is the high school academic ability a cause of undergraduates' attrition in engineering?

#### 1. High school GPA and math scores (ACT, SAT): Overall, both variables combined can partially predict engineering undergraduates' academic success in college.

Zhang et al. (2004) conducted a comprehensive multi-institutional study about the relationships between high school academic characteristics and academic success measured by graduation rates. They analyzed the Southeastern University and College Coalition for Engineering Education longitudinal database using a multiple logistic regression model. In this analysis, a sample of 87,167 engineering students from nine institutions was analyzed. Zhang et al. (2004) found:1. High school GPA and math SAT scores were positively correlated with graduation rates for all universities where all data was available. 2. For six universities, a marked Odds Ratio of predicting graduation by high school GPA ranged from 2.12 to 4.47, which suggested that statistically, a one-point increase in high school GPA would increase the likelihood of graduation engineering by a factor of 2.12 to 4.47. 3) For all universities that included SAT math scores, SAT math scores correlated positively with graduation. Specifically, a ten-point increase in math SAT scores would result in a 3 to 8 percent increase in likelihood of graduation in engineering (Zhang et al. 2004).

These findings are also corroborated by several single-institutional studies. With a regression analysis of 48 minority engineering students at the University of Akron, Lam et al.

(1999) discovered that high school GPA was significantly correlated with graduation from the program, but ACT scores were not. However, both variables were significantly correlated with undergraduate GPA. Overall, high school GPA and ACT scores can explain 31% of the variance in college GPA (Lam et al., 1999). Bell(2008) surveyed 2, 276 engineering freshmen in Auburn University and revealed that ACT math scores, high school math grades and high school ranks, mediated the effects of non-cognitive factors, such as lack of confidence in academic ability or mathematical ability, on the college GPA in engineering. This predictive power of high school GPA also holds in pre-engineering programs. Levin and Wyckoff (1990) concluded that the variables best able to predict college GPA in a pre-engineering program were high school GPA, followed by algebra scores, gender, non-science points, chemistry scores, and reasons for choosing engineering (Levin &Wyckoff, 1990). To be consistent with previous research findings, French(2005) examined the engineering student success and persistence at a large Midwestern university and found that student pre-college variables, SAT math scores and HS rank, were significant predictors of college GPA, accounting for approximately 25% of the variance(French, 2005). A similar result was obtained by Kauffmann(2007), who examined the data of 27 engineering students at East Carolina University and discovered that high school GPA was a significant predictor for both entering classes and for the determination of college GPA after their first year(Kauffmann, 2007).In addition, high school GPA and SAT or ACT math scores affect the engineering undergraduates' performance of barrier courses. Suresh(2006)surveyed 594 engineering student at a Northeastern research university and noted that high school experience as measured by high school GPA and SAT math scores can greatly affect the grades engineering students earn in barrier courses. This hypothesis was proven true for calculus I and physics I during freshmen year. Similarly, by examining the data of 295 engineering students enrolled in a calculus course at a large Midwestern university, Mwavita (2005) found that high school GPA was the strongest predictor of engineering students' success in calculus, followed by ACT math scores and help-seeking behavior. Also, based on the quantitative analysis, high school GPA and ACT math scores can account for 40% of the variability in calculus success (Mwavita, 2005). Generally speaking, empirical research found that high school GPA and SAT or ACT math scores appear to positively affect engineering undergraduates' barrier course performance and college GPA, as well as graduation from engineering programs. However, the degree to which high school variables can predict the academic success in engineering still needs further analysis.

## 2. Can high attrition be predicted by high school variables?

With the assumption above, researchers are particularly interested in whether high school variables can predict engineering undergraduate students' leaving behaviors. To answer this question, many studies were launched with differing results. To identify factors associated with science students' interest in studying science and in pursuing science careers, Astin and Astin(1992) analyzed the data of 27,065 science freshmen who entered 388 four-year colleges and universities. They used a longitudinal multivariate analysis to assess the impact of

background and college experience factors. Astin and Astin(1992) highlighted the significance of high school mathematical preparedness in engineering students' academic success and determined that students' entering level of mathematical and academic competency is the strongest and most consistent predictor of changes in students' interests or career paths (Astin &Astin, 1992).

Relying on a quantitative analysis of a sample of 87,167 engineering students from nine institutions, Zhang et al. (2004) found that the combination of high school GPA and SAT math scores can predict engineering students' persistence, but statistically a relatively small percentage, 12.6% (R2=0.126), was discovered. Levin and Wyckoff (1990) conducted research at Pennsylvania State University. They confirmed this conclusion, which determined that several non-cognitive variables, combined with high school grade point average and SAT scores, were predictive of freshman year persistence (Levin &Wyckoff, 1990). Moller-Wong and Eide(1997) and Burtner(2004) discovered two similar findings. Moller-Wong and Eide(1997) tracked 1151 freshman and transfer engineering students at Iowa State University and discovered that transfer credit, high school rank, ACT math scores, number of semesters of high school physics, and number of semesters of high school social science correlated positively with retention. Burtner (2004) revealed similar effects of high school GPA by examining the high school variables, first year performance, and attitudes and beliefs of 137 engineering students at Mercer University. This study noted that high school GPA was a critical factor in persistence

Seymour and Hewitt(1994)conducted an ethnographic study over a three-year period (1990-93) with 355 students in SME(Science, Mathematics, Engineering) majors drawn from seven universities. They found that that there were no real differences in the factors of high school preparation, ability, or coursework between students who remain and those who switch majors. Several studies (Jackson,1993; Hartman, 2006)also provided similar findings. Jackson(1993) surveyed 282 persisters and 198 non-persisters (leavers) at Michigan State University and found that even though SAT math scores correlated with persistence, high school GPA, high school science courses taken, and ACT scores produced no difference between persisters and non-persisters. At Rowan University, with an examination of 352 engineering students (319 persist and 33 leave), Hartman(2006)observed that persisters and leavers did not differ in terms of high school science and math courses and SAT math scores. Overall, there is a mixed result of the predictive power of high school variables on engineering students' attrition.

**3. SAT or ACT verbal scores: generally, findings show a negative effect of verbal score on academic achievement and persistence in engineering.**

After analyzing a sample of 87,167 engineering students from nine institutions using a multiple logistic regression model, Zhang et al. (2004) discovered that, interestingly, verbal SAT scores correlated negatively with graduation. Zhang et al. (2004) hypothesized that the negative correlation between graduation and SAT verbal may result from the fact that students with higher verbal skills are more likely to change majors from engineering and switch to other fields where verbal skills are more valued and more critical to success. Kauffmann (2007) also confirmed this

finding through conducting an analysis at the East Carolina University. Kauffmann(2007) found that the SAT verbal coefficient for predicting college GPA had a negative effect on retention. Also, Bell(2008) and Hartman(2006) provided confirmation of these findings. Bell(2008)surveyed 2276 engineering freshmen at Auburn University and found that those who did not return to the engineering program at the beginning of the second year of college had higher average SAT verbal and math scores than those who returned at the beginning of the second year but eventually left engineering. Hartman(2006)observed that students who left did have slightly lower high school science and mathematics grades and significantly higher verbal SAT scores(Hartman, 2006).These findings indicate that students with higher verbal scores are more likely to leave engineering.

**4. Is the high school academic ability a cause of undergraduates' attrition in engineering?**

It appears there is no unanimous agreement regarding whether or not a lack of academic ability in high school can result in the high attrition rates in engineering. However, an examination of the relationship between high school variables and undergraduate student outcomes has provided a deeper understanding of the causes of high attrition in engineering. Overall, engineering undergraduates' high school cognitive variables have positively affected students' educational outcome, such as college GPA and even graduation. The high school variables, such as high school GPA and standardized scores could be used to predict engineering students' academic success and retention. However, although high school variables have to be considered when studying engineering students' attrition, high school GPA and ACT/SAT score alone cannot predict attrition behaviors of engineering undergraduate students.

**Academic Ability during College: Barrier Courses and College GPA**

Barrier courses typically have the highest rate of failures or withdrawals, which have been referred to as gatekeeper courses, gateway courses, and sometimes barrier courses (Adelman, 1998). Based on the previous research and analysis, calculus, physics and statistics are generally accepted as the barrier courses for most engineering students (Suresh, 2006). Other than high school variables, a great number of researchers have considered barrier courses and college GPA as the reasons for engineering undergraduates' leaving engineering majors and switching to other disciplines. This assumption seems reasonable based on two facts: (1)failure of the barrier courses by undergraduate engineering students could result in their departure from engineering; (2)the higher attrition rate usually occurred during the freshmen year when barrier courses are normally taken. In this section, we will address the following three questions:

1. Can barrier courses cause the high attrition rate in engineering?
2. Could college GPA in engineering predict undergraduates' persistence?
3. Overall, are college cognitive variables the cause of the high attrition rate among engineering undergraduates?

**1. Barrier courses appear to contribute to students leaving engineering.**

Seymour and Hewitt (1997) conducted an ethnographic study with 355 students in Science, Mathematics and Engineering(SME) majors from seven universities and discovered that many engineering students reported feelings of being pressured by the heavy work load of barrier courses. It was noted that the barrier courses we reviewed as important factors when students switched to other fields (Seymour &Hewitt, 1997). To statistically identify the magnitude of the required science courses' effect on engineering student retention, Zhang et al.(2004) analyzed a database of all engineering student demographics, courses and graduation data at the University of Florida. After examining 20 science courses in three major areas (mathematics, physics and chemistry), they came to two conclusions. First, among these 20 science courses, only six of the core science courses showed a predictive effect on retention. A student's grade in each of these courses was positively correlated with his odds of retention in the engineering program. Among these predictive courses, the most influential were General Chemistry labs and the first General Chemistry lecture. Calculus 1 and 2 fell behind the chemistry courses, while the first Physics lab was the only course among the Physics group which showed predictive value. Their second conclusion was that among the remaining fourteen core courses, a student's grade had no statistically significant effect on retention in engineering(Zhang et al. 2004). In keeping with this finding, an analysis of 1,666 engineering midshipmen at the United States Naval Academy conducted by Kristof(2002) observed that the first semester academic performance and pre-calculus scores are the two greatest predictors of graduating(Kristof, 2002). Also, Marra et al. (2007) and Ohland et al. (2004) discovered similar findings. Marra et al. (2007) surveyed 120students who left engineering and noted that course grades were the second most important factor in a student's decision to transfer(Marra et al. 2007). Ohland's (2004) analysis of student data at Clemson University showed that when students took Calculus I in the second semester instead of in the first semester, student retention rates significantly improved in engineering(Ohland et al., 2004). Overall, based on the analysis above, it appears that barrier courses can affect engineering students' engineering attrition. Also, the scores of some barrier courses could potentially be a variable in predicting students' retention and graduation.

**2. College GPA can account for a fraction of undergraduates' attrition.**

With an examination of past, present and future factors associated with persistence in engineering, Jackson (1993) surveyed 480 engineering students (282 persisters and 198 non-persisters) at Michigan State University. The analysis revealed that the best predictor of engineering persistence for both sexes was college GPA. Persisters were more successful in the engineering program than non-persisters in terms of GPA. Gender differences were also observed. For female students, the two best predictors of engineering persistence were freshman GPA and expected salary. For male students, freshman GPA and goal uncertainty (negatively) predicted persistence (Jackson, 1993).

Several studies also provided confirmation of these findings. With an analysis of 1,666

engineering students at the United States Naval Academy, Kristof (2002) identified that the single greatest predictor of graduating with an engineering degree is first semester academic performance(Kristof, 2002). To evaluate the impact of the freshman engineering courses on retention, Budny(1998)studied the historical engineering student data for a 28-year period and found that there is a direct correlation between graduation and first semester GPA(Budny, 1998). French(2005)found that engineering students' GPAs had significant positive effects on student persistence in engineering(French, 2005). After examining the data of 352 engineering students, Hartman(2006) reported that the significant difference between students who leave and students who stay was their GPA at Rowan University. Similarly, Lebold and Ward(1988) also indicated that the best two predictors of engineering persistence were the first and second semester college grades and cumulative GPA (Lebold &Ward, 1988).

To investigate the role of grades in engineering students' decisions to leave engineering and their choice of a destination major, Ohland et al. (2004) studied a database of nine institutions containing records of undergraduate students from 1987 to 2002. This study indicated that (1)poor performance is not the primary reason students leave engineering; many engineering students left engineering with GPAs above 3.0; (2)students leaving with low GPAs are more likely to select business while students with high grades are more likely to choose natural science majors; (3)interestingly, those engineering students switching to education and social science were from all GPA levels(Ohland et al. 2004). Consistently, Seymour and Hewitt(1997)showed that there is little difference in academic ability between the students who graduate and those who do not. Female students often leave Science, Mathematics, and Engineering (S.M.E.) majors with grades as high or higher than the grades of male students who remain(Seymour &Hewitt, 1997).

Further, it appears that a fraction of students left because of loss of interest rather than lack of ability. White(2005)surveyed 357 underrepresented minority engineering undergraduate from 15 universities using a binominal logistic regression and found that while three variables (feelings, learning and difficulty) were statistically significant, only feelings were substantively significant; in particular, persistence increased 80.9% for each 1-unit increase in feelings and only 9.9% for learning. Moreover, White (2005) discovered that the most frequently cited reasons for departure from engineering students was loss of initial interest and the development of greater interest in another field. Consistent with this finding, Brainard and Carlin(1998), conducted a six-year longitudinal study of 672 undergraduate women majoring in science or engineering at the University of Washington. They noted that the primary reason female engineering students switched was a loss of interest in science and engineering and an attraction to another field (Brainard &Carlin, 1998). Generally, the previously-mentioned studies determined that freshman GPA is an important predictive factor for engineering students' attrition. Therefore, it is worth noting that loss of interest can also account for the leaving behaviors of engineering students.

**3. College cognitive variables are at least one of the variables that can affect students' switching decisions.**

Taken together, college GPA and barrier courses are closely related to the leaving trends of engineering students. Overall, students' performance in barrier courses affects their decision to stay or leave engineering, especially those students who have difficulty passing the courses. Further, it is generally accepted that students' attrition behaviors can be partially predicted by freshman GPA. On the other hand, a portion of engineering students left engineering due to a loss of interest instead of low GPA.

## Conclusion

The high attrition rates among engineering freshmen, combined with declining engineering graduation rates, have greatly concerned institutions of higher learning and the nation. Therefore, it is necessary and meaningful to identify the cognitive factors associated with engineering students' attrition behaviors through a careful examination of previously-conducted empirical works. After examining the empirical studies described above, the first conclusion is that high school GPA and admission test scores, especially math scores, appear to be predictive of engineering students' academic performance in college, particularly college GPA and graduation. Further, as Astin and Astin (1992) stated, high school variables can also predict engineering students' switching behaviors. Interestingly, several findings observed a negative effect of high SAT or ACT verbal scores on engineering students' retention, which may merit further studies in the future. Overall, college cognitive variables measured by college GPA and barrier courses seem closely related to students' attrition behaviors. Specifically, barrier courses have a predictive power related to students' attrition; however, not all introductory courses in engineering have this function. Further, it is generally accepted that students' attrition behaviors can be partially predicted by freshmen GPA, though a portion of engineering students left engineering due to a loss of interest, not their GPA.

These findings indicate that schools of engineering may be able to improve student persistence by helping students succeed in barrier courses and retaining student interest in engineering fields. Higher education administrators in engineering may consider determining best practices to increase student interest in engineering, such as undergraduate research opportunities and other hands-on learning activities that have been shown to increase retention rates. Further, they may consider revising barrier courses to aid students in receiving passing grades or increase tutoring services for such courses. Academic advisors and faculty members can also aid in persistence through mentoring and providing additional student support. This paper is limited to determining the predictive factors of student attrition and retention in engineering through examination of relevant research studies. A similar paper outlining the best practices for ensuring student persistence in engineering could also be considered. Regardless, more research is needed to quell the increasing attrition rates in engineering, especially given the ever-increasing need for well-qualified engineers in the constantly expanding global technology market.

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## Acknowledgments

This work was supported by a grant from the National Science Foundation (#ANT-0424589).

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