PREDICTING AND IMPROVING FIRST YEAR ENGINEERING STUDENT RETENTION THROUGH LEAN THINKING AND QUALITY MANAGEMENT CONCEPTS

Thesis
Submitted to
The School of Engineering of the UNIVERSITY OF DAYTON

In Partial Fulfillment of the Requirements for
The Degree of
Master of Science in Management Science

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December 2017
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ABSTRACT

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While the percentage of undergraduate engineering degrees awarded has increased over the past decade, it has been outpaced by the overall growth in bachelor degree attainment. With this, the amount of enrollment in engineering programs has increased, but still a significant number of engineering students choose to drop out or pursue other educational paths. Universities and policy makers are motivated to increase the retention of engineering students to graduation. This thesis explores the quantitative data that makes up a first year engineering student’s profile. The data is used to develop an ordinal logistic regression model to predict 2nd year student retention. Ideas to improve retention are discussed with a focus of applying Lean Manufacturing techniques in conjunction with the proposed prediction model.

Data from a college of engineering within a public land-grant research university is used to test for significance as indicators for freshman retention. Data used in this study is from 2010 and 2011 freshman engineering cohorts. Using collected student data, a prediction model is developed that assesses the probability of a first year engineering student either i) returning to engineering in their second year, ii) leaving engineering but remaining at the university, or iii) leaving the university altogether. Then, using concepts from lean manufacturing and quality management this prediction model is incorporated in a proposed engineering education quality
This study creates a prediction model to identify students that are likely to be: retained in engineering, switch majors out of engineering, and drop out of the university. This prediction model is then incorporated into the proposed engineering education quality management system to assist with identifying; where and when students may not persist in engineering curriculum, and ideas to promote student persistence using the prediction results.

**Keywords** engineering education, first year retention, quality management, lean concepts
Dedicated to my Mom who instilled in me at a young age the importance of learning and compassion.

To my Dad who encouraged me to be inquisitive and ambitious.

And to my wife who has always been my number one supporter of my graduate education and gave me my foundation to succeed.
ACKNOWLEDGEMENTS

My very special thanks to my advisor Dr. Kellie Schneider for giving me the opportunity to work on this interesting research in engineering student retention, a personal topic for me as a once academically dismissed engineering student. I am very appreciative of her positive attitude, her patience and time she spent helping me over the past few years, and her wealth of knowledge she has shared with me.

I would like to thank Dr. Furterer and Dr. Mykytka for the thoughtful advice and constructive critiques they’ve given me through the writing and development of my thesis.

I would also like to thank the University of Dayton Management Science graduate program as a whole. It has been an exciting, fun learning, challenging, and always engaging four years of my life. The way I imagine and analyze my environment around me has definitely changed for the better because of this experience. Specifically in this regard I would like to thank Dr. Mykytka for taking the time to talk to me on the phone over four years ago, and encouraging me to apply to the Management Science program at University of Dayton.
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A recent study indicates that approximately 57% of engineering students are retained from the start of their engineering education to graduation. [24] Other studies that have looked at engineering student retention show that approximately 43% of first year engineering students go on to graduate [2] and another study of first year engineering students at a single university by Honken & Ralston showed that after the first year of college only 76% of engineering students were retained. [13] This data shows that there is a potential problem that exists in the way the nation educates and trains future engineers, and the data shows that this problem likely begins during the first year of a student’s engineering education, as after the first year shows a significant drop in retention. This leaves a significant number of students who were interested in pursuing engineering education but decided to eventually leave.

Qualitative and quantitative study on the subject of engineering student dropouts observes that the problem of increasing first year engineering student retention has multivariate root causes. [18] Qualitatively speaking, students who leave engineering generally feel that they;

- Could not integrate into their school’s engineering culture,
- Are disappointed in themselves for failing,
- Feel overwhelmed and unprepared for engineering school,
- Are inadequately advised, and
• Experienced an unwelcoming culture at their engineering departments.

This conjunction of negative feelings and rejection, along with a loss of motivation to pursue an engineering education can lead to an ease of transition to another academic program or an exit from the university entirely. [18] From the authors’ own personal experience of being academically dismissed from an engineering program, this qualitative research carries weight in its relatability to that experience.

While this paper focuses solely on the retention of engineering students, the retention of college students is a concern that transcends all students pursuing a four-year degree. According to a report titled “Completing College: A National View of Student Attainment Rates - Fall 2008 Cohort” by the Project on Academic Success, the national graduation rate within six years of entering a four-year public institution was 48.4%, with 24.6% of students that left higher education with no degree or certificate. [30] Compounding these negative trends is the cost of higher education. According to the The College Board the cost of four year degree tuition at a public institution increased on average by 3.96% annually since 1985, while U.S. median family income increased during that same time period by an average of 0.57%. [17, 33] National data such as this has led the Obama administration to push for new higher education goals and accountability measures. The White House noted in their report that in 1990 the U.S. was 1st in the world for four-year degree attainment, and as of recently had fallen to 12th in the world. [12] One component of the White House’s plan to reform higher education is to create an annual scorecard for all higher education institutions to show data such as the average annual cost of attending, the median salary after graduation, and of the most relevance to this study, the Department of Education will incorporate the institution’s six-year graduation rate. [7]
2-1 The Importance of a STEM Education

The importance of an education rooted in Science, Technology, Engineering, and Mathematics (STEM), is a regularly debated issue within the United States. This debate transcends educational institutions, policy makers, think tanks, businesses, and students themselves. Broadly this debate can be summarized with the understanding of whether or not there is a demand for graduates of STEM programs that can or cannot be met by the current supply of STEM graduates, specifically engineering degree graduates. [6]

To help quantify data for this complex educational issue, The National Science Board (NSB) publishes the Science and Engineering Indicators Report a biennial report on the state of the overall science and engineering enterprise in the United States. [20] In 2014, Revisiting the STEM Workforce, a companion report to the Science and Engineering Indicators Report, showed that as of 2010 in the United States there are approximately 19.5 million people that hold at least one degree (bachelor’s or higher) in a STEM field. [20] The NSB’s report shows that as of 2010 there are as many as 16.5 million positions in the United States that require some level of bachelor degree training in STEM. Research conducted in 2011 showed that there potentially is as many as 26.0 million positions in the economy that require some level of bachelor degree training in STEM. [28] Along with the growing demand that employers are requesting of employees to have some bachelor degree level training in STEM fields, there is also a rising
concern that the current supply of STEM professionals is ageing, and potentially on the verge of retirement, which would have a direct effect on the supply of STEM professionals in the labor force. According to the last Science and Engineering Indicators report issued by the NSF in 2014, the proportion of individuals working in a STEM field over the age of 50 in 1993 was 20%, as of 2010 the proportion became 33%. [21] In conjunction of this growing ageing proportion of STEM workers, a newer iteration of the Science and Engineering Indicators report in 2016, the unemployment rate of STEM workers has remained below that of the national average at 3.8% for all STEM workers, 4.3% for college graduates, and 8.1% for the entire nation in 2013. [21] In terms of STEM worker wages, in 2014 the median STEM worker earned $81,000, which easily outpaced the national median earnings of $36,000. [21] The lower unemployment rate compared to all college graduates and all workers, combined with the higher salaries vs. national median earnings, and adding in the larger proportion of workers age 50 or older, indicates that the STEM workforce could be facing shortages in certain career fields in the near future. The STEM workforce itself has seen stronger than average growth since 1960 at 3% annually per year, outpacing the 2% annual growth that the overall labor force has experienced. In the indicators 2016 report, the authors cited that the Bureau of Labor Statistics forecasts the growth of STEM jobs in the U.S. at 15% between the years of 2012-2022, predicting future STEM occupation growth will continue to outpace the overall occupation growth of 11%. This confluence of factors builds a strong argument that the importance of a quality STEM education is a high priority for the continuing to grow the nation’s economy, promote and maintain a high standard of living, and fostering the research and development of new technologies. [21]

2.2 Modern Focus on Engineering Education

The modern need to foster a supportive culture of engineering education in the United States can trace its roots back to Vannevar Bush, and the history of the creation of the National
Science Foundation. During World War II there was great debate on how the United States should focus its scientific research resources. U.S. President Franklin D. Roosevelt commissioned Mr. Bush to study and report on how the government could support scientific study. [23] As the basis of this report a few major concepts were discussed. From President Roosevelt’s comments to Bush: “What can the Government do now and in the future to aid research activities by public and private organizations?” and “Can an effective program be proposed for discovering and developing scientific talent in American youth so that the continuing future of scientific research in this country may be assured on a level comparable to what has been done during the war?” [29] Following these comments Mr. Bush wrote a report called “Science: The Endless Frontier” to which Mr. Bush outlined the need for modern policy regarding STEM research to be guided by scientists themselves. From Mr. Bush’s report, he emphasized the need for scientific study as an essential means to improving our society by better healthcare, increased economic activity, and basic research stimulating and progressing new ideas. [28] This report eventually was used as the foundation to draft policy for the creation of the National Science Foundation. [23]

In relation to education the NSF’s explicitly stated goals include, “cultivate a world-class, broadly inclusive science and engineering workforce and expand the scientific literacy of all citizens” and to “support excellence in science and engineering research and education through a capable and responsive organization.” [22] Thus it can be ascertained that through the NSF’s leadership and other scientific organizations, there is a broadly stated goal to improve STEM education and promote STEM education research for the discovery of new ideas and progression of STEM education.

2-3 Challenges Specific to Improving Engineering Education

From the creation of the NSF and the nation’s focused priority of STEM education, researchers have been motivated to study new methods to improve engineering education, and
the barriers that exist that challenge institution’s ability to improve engineering education. A consistent barrier that has been researched in many studies is the overall dissatisfaction and low retention rate of undergraduate engineering students. In Astin’s book “What Matters in College, Four Critical Years Revisited”, Astin discussed that engineering students in relation to all other college students have the most dissatisfied attitudes in regards to their field of study. Astin’s study showed that engineering students reported lower levels of satisfaction compared to all other college students their curriculum and instruction, relationships with their faculty members, and the individual support services provided to the students. Astin later showed in more detailed engineering student research that 47% of freshman students who intend on studying engineering, actually graduate as engineers. [5] A positive engineering graduate trend has been the number of bachelor degrees awarded has increased year over year since 2007. Yoder, the author of the engineering graduating degree statistics noted that the number of freshman choosing engineering as a field of study only increased in 2014 by 1%, whereas the percentage of juniors and seniors entering engineering as a field of study increased by 8% and 6% respectively. [35] While there is no empirical evidence to conclude this, these increases of juniors and seniors choosing engineering may be related to a difficult economy for the students to find a job to which an engineering degree could provide a sense of stability for after college job placement. The increases could also be related to an overall higher level of maturity vs. the freshman students, which could lead to higher levels of persistence in engineering school.

2-4 Strategies for Student Retention

With the above discussion on the market analysis of the STEM labor force in the Importance of a STEM Education portion of this paper, it can be inferred that engineering student retention is a needed goal to be achieved for universities focused on the education and production of engineering professionals. With this in mind there have been numerous studies
and research devoted to the field of higher education student retention and this section of the paper will give an overview of leading student retention strategies. Seminal [31] research on modeling student retention conducted by Vincent Tinto revolved around studying individual characteristics related to educational persistence, such as the student’s social status, high school GPA, college GPA, and other important individual criteria, pioneered a methodology for creating a retention model in higher education to predict students’ persistence behaviors. [31] Tinto’s methodology focused on an input-output system that took a variety of individual attributes such as family background, and pre-college educational background as inputs, and then applied those inputs to the individual’s varying levels of educational attainment commitment, and the individual’s commitment to the educational institution. This part of the model is taken into account before the student enters the institution. Once the student is in the institution, Tinto’s model then applies the previous pre-institution inputs to factors that the individual faces in the academic and social systems of the institution. The factors of the academic system are the grade performance of the individual and the intellectual development of the individual. The grade performance can be defined as the tangible evaluation that the individual receives from the institution, whereas the intellectual development can be defined as the individual’s evaluation of the institution, with which Tinto [31] defined as an “intrinsic form of reward that can be viewed as an integral part of the person's personal and academic development.” Tinto noted, among others, [6, 2] in terms of grade performance, thatpersisters tend to achieve good grades, and in terms of intellectual development persisters tend to view their education as an experience of gaining knowledge and an appreciation of ideas, in contrast to a view of college as a means to acquire some sort of vocational development. The social system component of Tinto’s model focused on peer group interactions and social interactions with the institution’s faculty members. In discussing his model, Tinto explained some students could be very well
socially integrated, but a lack of institutional commitment could still lead to the student voluntarily leaving the university. This lack of institutional commitment could be from both the student not engaged or motivated by the perceived quality of instruction, or that the institution itself is lacking in the level of quality of instruction provided to the student. In both cases this leads to the student having decreased levels of commitment to the goal of graduating from the institution. This coincides with Tinto’s view that the student to be well socially integrated into the institution they must also have good social interactions with the institution’s faculty members, which is also a component of a strong commitment by the institution. Figure 1 visually describes the theoretical model of college dropout that Tinto [31] postulated the individual sets of processes that a student goes through before the final decision of dropping out of the institution. By dropout this can be defined as dropped out of the university entirely, or the student’s decision to transfer from one major to another.

![Figure 1 – Tinto’s Conceptual Model for Dropout from College [31]](image)

Tinto’s [31] study cited many academic sources that showed grade performance as being the most important predictor of an individual’s persistence in college. Astin [4] found that
engineering students are more likely to earn lower GPA’s than non-engineering students, Ohland, et. found that engineering students self-report a perception that their grades are lower compared to other majors, but in fact by Ohland, et.’s own data show that engineering students GPA’s are very similar to other majors. [24] If either are true, that engineering students do receive lower grades, or that engineering students perceive that they receive lower grades, that this is a significant level of anxiety that is placed on the engineering student and could likely lead to lower levels of the student’s perceived or actual social integration, and their perceived or actual level of institutional quality they are receiving.

Honken & Ralston showed with their data of first year freshman engineering students that 86% percent of those students who studied with other students were retained in the program, whereas 67% of students who did not study with others were retained in the engineering program. [13]

Honken & Ralston’s data supports the theory of student involvement developed by Alexander Astin. Astin defined student involvement as the “amount of physical and psychological energy a student devotes to the academic experience.” Astin described highly involved students as students who dedicate a substantial amount of their time and energy towards academic pursuits, mostly in the sense of amount of time studying and time spent on campus, in conjunction with a considerable amount of time and energy that a student dedicates to integrating in the campus’ social structures such as time spent with other students and faculty members. [3]

Astin reported the freshman students with the highest likelihood to feel satisfaction with their college environments were those that were already prepared academically in high school before entering college, students that came from well-off families, and are psychologically healthy. Astin reported that satisfaction was increased with students who
engaged with other students and faculty members, took courses related to their major, and had opportunities to participate with campus social and professional groups. Some factors that had a negative effect on student satisfaction were related to the student’s perception of how student-oriented the faculty was, how strong the student community is, and low student GPA. Astin also noted that engineering majors in particular had the most common levels of dissatisfaction with their college environments. Astin found that engineering students reported the lowest levels of satisfaction compared to all other majors in the areas of how student-oriented the faculty was, and students had the lowest levels of trust in the college’s administration. Coincidentally, Astin also found that majoring in engineering had negative effects on student’s GPA, and their likelihood to complete a bachelor’s degree. [4] This reported lower levels of student GPA and completion of a bachelor’s degree only confounds on the overall negative effects that lead to lower levels of student satisfaction. It is as if choosing a field of study in engineering already predisposes the student with factors for negative effects on student retention. Another study on engineering student retention by Felder, et al showed that there was correlation of freshman engineering students performance in an introductory chemical engineering course to their admissions index, SAT scores, GPA, grades in math, chemistry, and physics, and their freshman English grades. [11]

A recent study conducted by Meyer & Marx reported qualitative anecdotes from former engineering students who either transferred out of the engineering program at their university to another field of study, or left the university entirely. These anecdotes from the former engineering students reinforce Astin’s study on engineering students’ dissatisfaction with their curriculum. A recent study from 2014 by Meyer & Marx reported results on how students’ felt regarding their time spent in engineering school and the negative emotions that they felt navigating the engineering schools’ academic advising systems, overwhelming course workload,
feeling of a lack of prior preparedness and an overall sense of not feeling integrated into the engineering culture of the institution. The students who had recently left an engineering program in the Meyer & Marx study reported in contradiction to what might be expected based on Astin, and Tinto’s work [6, 35] that they had generally positive opinions on the level of quality instruction that they received from their engineering professors. All the students reported that in high school they received good grades, but three of the four stated that their high school preparation did not prepare them for the challenging coursework they were required of in the engineering department. All the students reported that they felt overwhelmed by the engineering coursework rigor and all did not feel that they integrated into the engineering department’s culture. All the students reported that due to the rigor of the engineering department’s academics felt a loss of motivation to study during their time in the program, which likely led to all the students reporting they received poor grades during their time in the engineering program. All the students felt that the engineering department at their institution had an unwelcoming culture. The general impression that these students had was that their engineering program had a weed out culture. This almost implies an adversarial relationship between the freshmen students and the faculty, and or the institution. Three of the four students in the study expressed a feeling of callousness by the engineering department advisors, but also admitted that the students themselves did not reach out to the advisors in a timely manner, with two of the students having already failed more courses than the department allows before contacting the advisors. Generally speaking all the students expressed a lack of knowledge or understanding of what it takes to become an engineer and had little understanding of what the engineering profession does post-graduation. Notably all the students held a feeling of respect for the engineering profession, and all the students expressed their desires to become engineers, with only one student reporting later a level of disinterest
toward engineering. [18] While Meyer & Marx’s study only focuses on four students and takes a qualitative approach towards the frustrations of an example engineering school dropout student, it does highlight and deeply discuss some prevalent concerns that have been discussed in engineering student retention literature. Meyer & Marx’s study shows good detailed examples of students that experienced the anxiety, disappointment, and frustrations with their engineering department’s institutions and the student’s own academic abilities, combined with a strong desire to become an engineer. These anxieties, disappointments, and frustrations add evidence of proof that there is a delicate balance of factors within the individual and the institution to achieve a harmonious system for the student and the institution. While an engineering education is very beneficial to the students that do go on to graduate, there is becoming a clear issue with how to prepare an engineering student so that they integrate fully into the idea of becoming an engineer, both academically and socially. As well a more proactive or predictive model is required for the engineering advisors who should be guiding these students and seeking the students best interests to retain these students in their prospective engineering programs.

In Tinto’s later work that reflected and reviewed the body of knowledge that existed in student retention methodologies and practices, Tinto opined that most universities had yet to successfully implement the researched knowledge of student retention into notable university student retention program results. [32]

2-5 Overview of Lean Thinking Concepts and Relatability to Higher Education

The concept of lean manufacturing began as a necessity in Japan’s post World War II economy that was decimated by the result of the war. With minimal resources and demand for goods, sparse producers were forced to invent new ways of thinking to produce goods. Popularization of lean thinking grew out of this constraint of resources, with a focus on
identifying and eliminating wastes in a given system. Within higher education this paper seeks to apply the lean thinking thought that a student not being retained in engineering is a form of waste, and can be identified in a manufacturing way as a “defective part”, created by a series of identifiable and predictable errors along the “production” process of educating a student.

In the book, “The Machine that Changed the World” the authors set out to create an in-depth survey of the change in the Automotive Industry from mass production to lean production. Surveyed in this book was how an engineer at Toyota Motor Company, Taiichi Ohno widely considered to be one of the founders of lean production, implemented a system for managing defective parts. [34] Comparing and contrasting mass production and lean production systems in the viewpoint of product flow and quality inspection, a mass producers goal was to maximize yield or the number of finished vehicles compared to the planned amount of finished vehicles and quality, which was the final vehicle quality shipped to the customer. [34] This system of mass production allowed for the rework of a defective part in a separate area of the factory and encouraged the production line to never stop moving, which allowed for defective parts to be assembled to the vehicle and continue down the line. [34] In a mass production system this was okay because stopping a production line would force overtime labor costs on the factory, whereas a designated rework area in thought did not. [34] Ohno hypothesized that the mass production model was very wasteful because the first error eventually led to other errors in the production system and an increasing amount of work would then be required to correct the errors. [34] This can be translated to the system of higher education production in multiple ways. If the goal of the university is to award degrees based on a set of given expectations such as GPA, and coursework, then the student’s progress through the education production system is class by class, assignment by assignment a series of tasks whose end goal is to produce a degree. Therefore, just like a manufacturing system that has errors not being
corrected, which in turn produce more errors, the education system is the same. If a student receives a failing score and continues on progressing in their pursuit of an education, the errors incurred may not have been addressed and corrected.

To affirm this thought that a student is the product progressing through the educational production system, consider what is deemed successful and unsuccessful in the education production system. The student is judged quantitatively on GPA by class, semester, and overall. In this system GPA for each class affects the GPA for the semester and overall. Each positive or negative experience in GPA earned directly affects the quality of the student’s perceived performance. These grades are in effect the student’s measurement of a conforming or non-conforming “part”. In a mass produced system a non-conforming part would need repair and be sent to a separate rework station for processing to make the part conforming. In a lean system, a production worker would identify the part on the line as defective and if not fixable by the worker the line would be stopped so the production team could be gathered to problem solve a countermeasure. In a mass production system, these errors were perceived as random events with which workers were tasked with fixing each error and hope that the error would not occur again. In other words, no system was in place to ensure that these errors would not occur again. In the lean system problem solving is part of the system, but it is also a systematic approach to understanding the root cause of why the error occurred and creating a countermeasure to prevent the error from occurring later. The problem solving system that Ohno created for his production workers was called “the five why’s”, also known as a “why-why analysis”. Taking this concept and transferring it to an educational setting an ideal classroom would promote a culture of group problem solving, where students are engaging each other along with faculty to creatively solve problems together and learn the objective course material. This ideal lean concept to learning builds off of Tinto’s model of student retention. If students who are
struggling in class were learning in an environment that encouraged continuous improvement, these students would experience the factors Tinto concluded were positive to student retention. These students would see a learning institution that would show a commitment to the students’ success through problem solving the students difficulties and procedurally attempt to ensure the student’s success.

Genchi Genbutsu, clarifying with one’s own eyes, or going to the spot. [16] GPA cannot be the only metric with which a faculty member grades the student. Genchi Genbutsu as a concept is an idea of the system’s management of not only being at the spot of where work actually occurs to view, but to also know. [16] Through this philosophy of going to the spot, a problem can be identified and understood. In the context of higher education the faculty and the institution working to develop students should ideally know the students and the problems they encounter. Both academically and outside influences, that may affect their academic performance. Toyota Motor Company, well known globally for its collective contribution to the study of lean manufacturing and the creation of the Toyota Production System is often used as a benchmark for developing good processes. The following quote is attributed to a senior Toyota manager discussing Toyota’s process management strategy.

“Brilliant process management is our strategy. We get brilliant results from average people managing brilliant processes. We observe that our competitors often get average (or worse) results from brilliant people managing broken processes.” [15]

This manager’s comments echo the lean thinking culture that Toyota has instilled in their workforce to continuously improve processes through a well thought out system of process management and problem identification.
2-6 Overview of Management Science Concepts and Applications for Engineering Education

Management science is defined as “an approach to decision making based on the scientific method, makes extensive use of quantitative analysis.” [1] Management Science is an interdisciplinary field that consists of business, engineering, economics, mathematics, and behavioral sciences used to analyze and solve complex problems facing a variety of organizations. This paper seeks to use concepts and tools from the field of Management Science and apply it to engineering education and this section will detail the concepts and tools that may improve freshman engineering retention and to create an ideal quality system for an engineering university to apply to their curriculum.

2-7 Plan, Do, Check, Act Cycle

The Plan, Do, Check, Act Cycle is a management tool that can be used to create, document, analyze, and improve on processes. The PDCA cycle for short, has its roots in the scientific methodology conceptualized by Galileo in the 17th century and evolving into its current form from the work of Dr. Walter Shewhart and Dr. W. Edwards Deming during the 20th century. [19] The precursor concept before PDCA was the Shewhart cycle, created by Dr. Shewhart. The Shewhart Cycle described a three step management process of 1) Specification 2) Production 3) Inspection. [19] In Dr. Shewhart’s concept, the three steps can be analogized as the theorizing of a hypothesis, conducting an experiment, and testing the hypothesis. [19] The Shewhart Cycle was later refined into the PDCA Cycle for a seminar presentation to a group of Japanese managers and engineers in 1950 by Dr. W. Edwards Deming, who had helped Dr. Shewhart edit his book that discussed the Shewhart Cycle. [19] The usefulness of the PDCA Cycle is to create a repeatable process, perform the process, and improve on the process as improvements are identified. [19] PDCA can also be used to define a goal, set out an action to achieve the goal, check the results compared to the goal, analyze areas where the goal is not being achieved and
how to close that achievement gap, and finally implement those changes to re-try achieving the goal. [19] As defined and outlined by the American Society for Quality the PDCA method should be used by an organization if one of the below characteristics is required by the organization.

1. As a model for continuous improvement.
2. When starting a new improvement project.
3. When developing a new or improved design of a process, product or service.
4. When defining a repetitive work process.
5. When planning data collection and analysis in order to verify and prioritize problems or root causes.
6. When implementing any change. [25]

When an organization does wish to develop processes around the PDCA method the American Society for Quality outlines an ideal procedure for how to use the PDCA method in an organization.

1. Plan. Recognize an opportunity and plan a change.
2. Do. Test the change. Carry out a small-scale study.
3. Check. Review the test, analyze the results and identify what you’ve learned.
4. Act. Take action based on what you learned in the study step: If the change did not work, go through the cycle again with a different plan. If you were successful, incorporate what you learned from the test into wider changes. Use what you learned to plan new improvements, beginning the cycle again. [25]

2-8 Statistical Process Control, Continuous, and Continual Improvement

Statistical Process Control is a concept of collecting quantitative observations to measure the performance of a process from one period of time to the next. It has its roots in the field of statistics and specifically in terms of quality control can be credited with its development
by Dr. Walter Shewhart, also the founder of the Shewhart Cycle. Statistical Process Control or SPC for short has many tools to evaluate and measure processes, the first tool and probably most common is the use of Control Charts, created by Dr. Shewhart in 1924. [10] The use of control charts are to create a tool for how the process works at that moment of time, calculate control limits to determine where the process is out of control, observe and collect data from the output of the process, and compare against the control limits calculated from the typical process. [10] Observed data that falls outside of the control limits is analyzed to determine if it should be considered for study or not, and if so, what the assignable cause is that caused this observation to be outside its control limit. [27] Using the observed data collected from process measurements the concept of improving those processes has its foundation in continuous improvement and the concept of improving the system as a whole is considered continual improvement. For the proposed model in this paper it is important to distinguish between the two concepts. The PDCA cycle is the qualitative definition of why and what data the SPC model is collecting and PDCA should be used in both continual and continuous improvement concepts to document the goal or problem the process is aimed to achieve or resolve and to document to overall goal and plan to implement for a complete system.
3-1 Research Design

To create a predictive model for freshman engineering student retention, data was collected from two different freshman engineering cohorts at a public land-grant research university during the academic years of 2010-2011, and 2011-2012. Data that was collected from the cohorts were their gender, ethnicity, high school GPA, ACT scores for Math, English, and Composite. Furthermore, for each student, observational data was collected to determine if, the student was either (i) enrolled in the studied university engineering school, (ii) enrolled at the same university, or (iii) dropped out of the university at the beginning of their second year at the university. The data was analyzed using the Statistical Analysis software Minitab. In Table 1 below, is a data summary of the characteristics of the 2010 Freshman Engineering Cohort and some analyzed observations. The 2010 Freshman Engineering Cohort observed 518 total students, with ~80% male and ~20% female, consisting of 7 ethnicities and entering the university with an average high school GPA of 3.72. Of the 518 students that entered for the freshmen engineering program in 2010, 366 returned to engineering in their second year of college, 77 switched into other majors at the university, and 75 dropped out of the university. Within the second year retention data a slightly higher proportion of females switched majors out of engineering compared to males, and a slightly higher proportion of females dropped out of the university compared to males. The average fall GPA, or GPA at the end of the students’
first semester at the university was 2.9 and by spring or the students’ end students that returned to engineering in their second year at the university their average spring GPA was 3.12, compared to the students leaving the university with an average GPA of 1.81. All of the observed average university GPA’s are noticeably lower than the observed high school average GPA of 3.72, potentially indicating an adjustment of coursework expectations between high school curriculum and university curriculum.

Table 1 - Freshman Class of 2010 Engineering Cohort

<table>
<thead>
<tr>
<th>Category</th>
<th>Value</th>
<th>Proportion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Students</td>
<td>518</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>417</td>
<td>80.50%</td>
</tr>
<tr>
<td>Female</td>
<td>101</td>
<td>19.50%</td>
</tr>
<tr>
<td>Ethnicities</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>Average HS GPA</td>
<td>3.72</td>
<td></td>
</tr>
<tr>
<td>Returned to Engineering in 2nd Year</td>
<td>366</td>
<td>70.66%</td>
</tr>
<tr>
<td>Switched Majors</td>
<td>77</td>
<td>14.86%</td>
</tr>
<tr>
<td>Dropped Out</td>
<td>75</td>
<td>14.48%</td>
</tr>
<tr>
<td>Switched Majors - Males</td>
<td>61</td>
<td>14.63%</td>
</tr>
<tr>
<td>Switched Majors - Females</td>
<td>16</td>
<td>15.84%</td>
</tr>
<tr>
<td>Dropped Out - Males</td>
<td>59</td>
<td>14.15%</td>
</tr>
<tr>
<td>Dropped Out - Females</td>
<td>17</td>
<td>16.83%</td>
</tr>
<tr>
<td>Average Fall GPA</td>
<td>2.9</td>
<td></td>
</tr>
<tr>
<td>Average Spring GPA</td>
<td>2.93</td>
<td></td>
</tr>
<tr>
<td>Number of Students with GPA’s below 2.0 at 1st Year End</td>
<td>27</td>
<td>5.21%</td>
</tr>
<tr>
<td>Average Fall GPA of Students Returning to Engineering</td>
<td>3.18</td>
<td></td>
</tr>
<tr>
<td>Average Spring GPA of Students Returning to Engineering</td>
<td>3.12</td>
<td></td>
</tr>
<tr>
<td>Average Fall GPA of Students Leaving University</td>
<td>1.66</td>
<td></td>
</tr>
<tr>
<td>Average Cumulative Spring GPA of Students Leaving University</td>
<td>1.84</td>
<td></td>
</tr>
</tbody>
</table>

In Table 2 below, is a data summary of the characteristics of the 2011 Freshman Engineering Cohort and some analyzed observations. The 2011 Freshman Engineering Cohort observed 666 total students, with ~83% male and ~17% female, consisting of 7 ethnicities and entering the university with an average high school GPA of 3.67. Of the 666 that entered the freshman engineering program for 2011, 457 returned to engineering in their second year of college, 94 switched into other majors at the university, and 115 dropped out of the university. Within the second year retention data a higher proportion of males switched majors out of engineering compared to females, and a higher proportion of males dropped out of the...
university compared to females. The average fall GPA, or GPA at the end of the students’ first semester at the university was 2.85 and by spring or the students’ end of their second semester was 2.85, showing no improvement from fall to spring. For the students that returned to engineering in their second year at the university their average spring GPA was 3.22, compared to the students leaving the university with an average GPA of 1.81. All of the observed university GPA’s are noticeably lower than the observed high school average GPA of 3.67.

Table 2 - Freshman Class of 2011 Engineering Cohort

<table>
<thead>
<tr>
<th>Category</th>
<th>Value</th>
<th>Proportion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Students</td>
<td>666</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>553</td>
<td>83.03%</td>
</tr>
<tr>
<td>Female</td>
<td>113</td>
<td>16.97%</td>
</tr>
<tr>
<td>Ethnicities</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>Average HS GPA</td>
<td>3.67</td>
<td></td>
</tr>
<tr>
<td>Returned to Engineering in 2nd Year</td>
<td>457</td>
<td>68.62%</td>
</tr>
<tr>
<td>Switched Majors</td>
<td>94</td>
<td>14.11%</td>
</tr>
<tr>
<td>Dropped Out</td>
<td>115</td>
<td>17.27%</td>
</tr>
<tr>
<td>Switched Majors - Males</td>
<td>81</td>
<td>14.65%</td>
</tr>
<tr>
<td>Switched Majors - Females</td>
<td>13</td>
<td>11.50%</td>
</tr>
<tr>
<td>Dropped Out - Males</td>
<td>103</td>
<td>18.63%</td>
</tr>
<tr>
<td>Dropped Out - Females</td>
<td>12</td>
<td>10.62%</td>
</tr>
<tr>
<td>Average Fall GPA</td>
<td>2.85</td>
<td></td>
</tr>
<tr>
<td>Average Spring GPA</td>
<td>2.85</td>
<td></td>
</tr>
<tr>
<td>Number of Students with GPA’s below 2.0 at 1st Year End</td>
<td>86</td>
<td>12.91%</td>
</tr>
<tr>
<td>Average Fall GPA of Students Returning to Engineering</td>
<td>3.22</td>
<td></td>
</tr>
<tr>
<td>Average Spring GPA of Students Returning to Engineering</td>
<td>3.15</td>
<td></td>
</tr>
<tr>
<td>Average Fall GPA of Students Leaving University</td>
<td>1.59</td>
<td></td>
</tr>
<tr>
<td>Average Cumulative Spring GPA of Students Leaving University</td>
<td>1.81</td>
<td></td>
</tr>
</tbody>
</table>

Comparing and contrasting the 2010 freshman engineering cohort to the 2011 freshman engineering cohort there are some similarities that are somewhat expected, and differences that are somewhat surprising. The similarities between the two cohorts are how close the proportion of males and females are in the freshman engineering cohorts, roughly 80/20 split respectively. The high school GPAs, percentage of freshman engineering students retained, average fall and spring GPAs, and the GPAs fall and spring of students returning to engineering, and leaving the university are also similar in averages or proportions. The noticeable differences between the 2010 cohort and the 2011 cohort are in the increased proportion of students in the
2011 cohort that have a GPA of below 2.0 after the 1st year, a gender proportional decrease in the number of females switching majors and dropping out, and an increase in the proportion of total students dropping out of university.

3-2 Model Development

In this work, we seek to develop a predictive model of first year engineering student retention. The response for this model is categorical; students are identified as either being (1) retained in engineering, (2) retained at the university but majoring in something other than engineering, or (3) not retained, i.e. not enrolled at the university at the beginning of the second year. Since the response is categorical, an Ordinal Logistics Regression analysis was conducted to analyze multiple factors that are believed to be important predictors for second year retention. The coding scheme shown in Table 3 was used to quantify the following predictors: gender, ethnicity, second year retention, whether a student passed or failed a particular course, and the grade associated with a particular course. Initially, 12 factors were included in the predictive model. These factors are summarized in Table 4.

Table 3 - Coded Database Legend

<table>
<thead>
<tr>
<th>Gender</th>
<th>Code</th>
<th>Ethnic Group</th>
<th>Code</th>
<th>Grading</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>1</td>
<td>African American</td>
<td>1</td>
<td>A</td>
<td>1</td>
</tr>
<tr>
<td>Female</td>
<td>2</td>
<td>Asian</td>
<td>2</td>
<td>B</td>
<td>2</td>
</tr>
<tr>
<td>Student 2nd Year Outcome</td>
<td>3</td>
<td>Caucasian</td>
<td>3</td>
<td>C</td>
<td>3</td>
</tr>
<tr>
<td>Returned to Engineering</td>
<td>1</td>
<td>International Student</td>
<td>4</td>
<td>D</td>
<td>4</td>
</tr>
<tr>
<td>Switched Majors, Remained at University</td>
<td>2</td>
<td>Hispanic</td>
<td>5</td>
<td>F</td>
<td>5</td>
</tr>
<tr>
<td>Dropped Out of University</td>
<td>3</td>
<td>Native American</td>
<td>6</td>
<td>Withdrawal</td>
<td>6</td>
</tr>
<tr>
<td>Student Pass or Fail Data</td>
<td>1</td>
<td>Two or More Ethnicities</td>
<td>7</td>
<td>No Response</td>
<td>7</td>
</tr>
<tr>
<td>Pass</td>
<td>1</td>
<td>Audited</td>
<td>8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fail</td>
<td>2</td>
<td>No Data</td>
<td>3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Unlike linear regression models which predict the actual values of the response variable, logistic regression models result in the development of a link function which is used to compute the probability associated with each level of the response variable. For our model, the response variable has three possible outcomes; Let \( \pi_1 \) denote the probability of being in Category 1 (retained in engineering), \( \pi_2 \) denote the probability of being in Category 2 (retained at the university) and \( \pi_3 \) denote the probability of being in Category 3 (left the university). The log model is used to determine the probability of a student being in each category as follows:

\[
\pi_1 = \frac{\exp(\text{Const}_1 + \beta_1 x_1 + \ldots + \beta_k x_k)}{1 + \exp(\text{Const}_1 + \beta_1 x_1 + \ldots + \beta_k x_k)} \\
\pi_2 = \frac{\exp(\text{Const}_2 + \beta_1 x_1 + \ldots + \beta_k x_k)}{1 + \exp(\text{Const}_2 + \beta_1 x_1 + \ldots + \beta_k x_k)} \\
\pi_3 = 1 - (\pi_1 + \pi_2)
\]

where \( x_1, x_2, \ldots, x_k \) are the values of the predictors variables, and \( \text{Const}_1, \text{Const}_2, \beta_1, \ldots, \beta_2 \) are determined through ordinal logistic regression analaysis. The Minitab results in Table 5 show that whether or not a student passed their fall math class (FA1_Math1_Pass), a student’s grade

<table>
<thead>
<tr>
<th>Predictor</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ETHNIC_GRP_CD</td>
<td>Self Reported Student Ethnicity by Group</td>
</tr>
<tr>
<td>FA1_Math1_Pass</td>
<td>University reported pass or fail for Fall math course taken by student</td>
</tr>
<tr>
<td>SP1_Math1_Pass</td>
<td>University reported pass or fail for Spring math course taken by student</td>
</tr>
<tr>
<td>SP1_GPA</td>
<td>Student’s GPA reported by university for Spring year 1</td>
</tr>
<tr>
<td>AMATH</td>
<td>University recorded student’s ACT score for math</td>
</tr>
<tr>
<td>ACOMP</td>
<td>University recorded student’s overall ACT score</td>
</tr>
<tr>
<td>AENGL</td>
<td>University recorded student’s ACT score for english</td>
</tr>
<tr>
<td>HSGPA</td>
<td>Student’s reported high school GPA</td>
</tr>
<tr>
<td>SEX</td>
<td>Student’s reported gender</td>
</tr>
<tr>
<td>FA1_Math1_Grade</td>
<td>University recorded student’s year 1 Fall math grade</td>
</tr>
<tr>
<td>FA1_GPA</td>
<td>Student’s GPA reported by university for Fall year 1</td>
</tr>
<tr>
<td>SP1_Math1_Grade</td>
<td>University recorded student’s year 1 Spring math grade</td>
</tr>
</tbody>
</table>
in their fall math class (FA1_Math1_Grade), and a student’s grade in their spring math class (SP1_Math1_Grade) are not statistically significant at an alpha level of \( \alpha = 0.10 \).

**Table 5 - Ordinal Logistic Regression Minitab Output for All Student Predictors**

<table>
<thead>
<tr>
<th>Predictor</th>
<th>Coef</th>
<th>SE Coef</th>
<th>Z</th>
<th>P</th>
<th>Odds</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Const(1)</td>
<td>3.96480</td>
<td>1.35762</td>
<td>2.92</td>
<td>0.004</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Const(2)</td>
<td>5.36580</td>
<td>1.37384</td>
<td>3.91</td>
<td>0.000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ETHNIC_GRP_CD</td>
<td>-0.23006</td>
<td>0.092713</td>
<td>-2.48</td>
<td>0.013</td>
<td>0.79</td>
<td>0.66, 0.96</td>
</tr>
<tr>
<td>FA1_Math1_Fail</td>
<td>-0.072265</td>
<td>0.475813</td>
<td>-0.15</td>
<td>0.880</td>
<td>0.93</td>
<td>0.57, 2.36</td>
</tr>
<tr>
<td>FA1_Math1_Pass</td>
<td>-0.081155</td>
<td>0.420791</td>
<td>-0.19</td>
<td>0.847</td>
<td>0.91</td>
<td>0.57, 2.36</td>
</tr>
<tr>
<td>SP1_Math1_Pass</td>
<td>-0.981350</td>
<td>0.420791</td>
<td>-2.33</td>
<td>0.020</td>
<td>0.47</td>
<td>0.16, 0.86</td>
</tr>
<tr>
<td>SP1_GPA</td>
<td>0.415772</td>
<td>0.144880</td>
<td>2.87</td>
<td>0.004</td>
<td>1.52</td>
<td>1.14, 2.01</td>
</tr>
<tr>
<td>AMATH</td>
<td>0.085654</td>
<td>0.0518718</td>
<td>1.65</td>
<td>0.099</td>
<td>1.09</td>
<td>0.98, 1.21</td>
</tr>
<tr>
<td>ACORP</td>
<td>-0.145899</td>
<td>0.0845037</td>
<td>-1.68</td>
<td>0.093</td>
<td>0.88</td>
<td>0.72, 1.02</td>
</tr>
<tr>
<td>AENGLISH</td>
<td>0.0926793</td>
<td>0.0561841</td>
<td>1.65</td>
<td>0.099</td>
<td>1.10</td>
<td>0.98, 1.22</td>
</tr>
<tr>
<td>NSGPA</td>
<td>-0.499976</td>
<td>0.396925</td>
<td>-2.33</td>
<td>0.020</td>
<td>0.41</td>
<td>0.19, 0.87</td>
</tr>
<tr>
<td>SEX</td>
<td>-0.686510</td>
<td>0.282525</td>
<td>-2.30</td>
<td>0.021</td>
<td>0.50</td>
<td>0.28, 0.90</td>
</tr>
<tr>
<td>FA1_Math1_Grade</td>
<td>-0.174404</td>
<td>0.158475</td>
<td>-1.10</td>
<td>0.271</td>
<td>0.84</td>
<td>0.62, 1.15</td>
</tr>
<tr>
<td>FA1_GPA</td>
<td>0.638557</td>
<td>0.209044</td>
<td>3.02</td>
<td>0.003</td>
<td>1.83</td>
<td>1.25, 2.83</td>
</tr>
<tr>
<td>SP1_Math1_Grade</td>
<td>0.0986069</td>
<td>0.164023</td>
<td>0.57</td>
<td>0.568</td>
<td>1.10</td>
<td>0.80, 1.51</td>
</tr>
</tbody>
</table>

Through a process of eliminating from the regression model predictors that were not statistically significant at an alpha level \( \alpha = 0.10 \), the final model that has all predictors at an alpha level of \( \alpha \leq 0.10 \) is shown below in Table 6.
To create a prediction for any given student that determines the probability of a first-year engineering student returning to engineering school in their second year, the constant, Const(1) and predictor coefficients are used to determine the value of $\pi_1$ as shown below:

$$
\pi_1 = \frac{1 + \exp(\text{Const}(1) + \text{SEX}_n \ast \text{SEXCoeff} + \text{ETHNICGRP}_{CDn} \ast \text{ETHNICGRP}_{CDCoeff}
+ \text{HSGPAn} \ast \text{HSGPAcoeff} + \text{AMATH}_n \ast \text{AMATHcoeff} + \text{ACOMPn} \ast \text{ACOMPcoeff}
+ \text{AENGLn} \ast \text{AENGLcoeff} + \text{FA1MathGrade}_n \ast \text{FA1MathGradecoeff}
+ \text{SP1GPA}_n \ast \text{SP1GPAcoeff}))}{1 + \exp(\text{Const}(1) + \text{SEX}_n \ast \text{SEXCoeff} + \text{ETHNICGRP}_{CDn} \ast \text{ETHNICGRP}_{CDCoeff}
+ \text{HSGPAn} \ast \text{HSGPAcoeff} + \text{AMATH}_n \ast \text{AMATHcoeff} + \text{ACOMPn} \ast \text{ACOMPcoeff}
+ \text{AENGLn} \ast \text{AENGLcoeff} + \text{FA1MathGrade}_n \ast \text{FA1MathGradecoeff}
+ \text{FA1GPA}_n \ast \text{FA1GPAcoeff} + \text{SP1Math1Pass}_n \ast \text{SP1Math1PassCoeff}
+ \text{SP1GPA}_n \ast \text{SP1GPAcoeff})}
$$
To create a prediction for any given student that determines the probability of a first year engineering student leaving the engineering school in their second year but remaining at the university, the constant, Const(2) and predictor coefficients are used to determine the value of $\pi_2$ as shown below

$$
\pi_2 = \frac{\exp(\text{Const}(2) + SEX_n \cdot SEX_{Coef} + ETHNIC \cdot GRP \cdot CD_n \cdot ETHNIC \cdot GRP \cdot CD_{Coef} \\
+ HSGPA_n \cdot HSGPA_{Coef} + AMATH_n \cdot AMATH_{Coef} + ACOMP_n \cdot ACOMP_{Coef} \\
+ AENGL_n \cdot AENGL_{Coef} + FA1_{Math \ Grade_n} \cdot FA1_{Math \ Grade_{Coef}} \\
SP1_{GPA_n} \cdot SP1_{GPA_{Coef}})}{1 + \exp(\text{Const}(2) + SEX_n \cdot SEX_{Coef} + ETHNIC \cdot GRP \cdot CD_n \cdot ETHNIC \cdot GRP \cdot CD_{Coef} \\
+ HSGPA_n \cdot HSGPA_{Coef} + AMATH_n \cdot AMATH_{Coef} + ACOMP_n \cdot ACOMP_{Coef} \\
+ AENGL_n \cdot AENGL_{Coef} + FA1_{Math \ Grade_n} \cdot FA1_{Math \ Grade_{Coef}} \\
+ FA1_{GPA_n} \cdot FA1_{GPA_{Coef}} + SP1_{Math1 \ Pass_n} \cdot SP1_{Math1 \ Pass_{Coef}} \\
SP1_{GPA_n} \cdot SP1_{GPA_{Coef}}))}
$$

A third and final outcome, a prediction formula to determine the probability of any given first year engineering student leaving the engineering school in their second year and leaving the university, $\pi_3$ is listed below.

$$
\pi_3 = 1 - \sum \pi_1 + \pi_2
$$

Since we are interested in determining the most likely outcome for each student, we can let $X$ be a discrete random variable that corresponds to a student’s retention. Note that $x \in \{1, 2, 3\}$. Therefore we can compute the expected value of $X$ as follows:

$$
E(X) = \sum_{i=1}^{3} x_i f(x_i) = 1 \cdot \pi_1 + 2 \cdot \pi_2 + 3 \cdot \pi_3
$$

### 3-3 Model Evaluation and Validation

Below in Table 7 is an example of the output of the prediction model for one student. This example student’s background consisted of a Male Caucasian, HSGPA of 3.05, ACT scores of 26 Math, 23 English, and 24 Composite, a “C” for FA1_Math_Grade, 2.636 GPA for FA1_GPA, received a failing grade for SP1_Math_Pass, and a 2.5 GPA for SP1_GPA.
The output in Table 7 shows using the prediction model there is a 76.87% probability that based on this student’s predictors that they will return to engineering in their second year of college, with a 16.23% probability that they will remain in the university but in a different major, and a 6.9% probability that they will leave the university entirely. The expected value $E(X)$ is calculated by taking the sum product of $p(ENGR)\cdot 1 + p(UNIV)\cdot 2 + p(GONE)\cdot 3$, which is respective of how the data was coded to apply $1=ENGR$, $2=UNIV$, $3=GONE$. Using the calculated $E(X)$ value, the $E(X)$ integer is the rounded up or down to the closest integer of $E(X)$. This is to determine the most likely decision outcome of remaining in engineering, changing majors, or dropping out of the university. The Observation category is the observed result of what path the student chose in their second year, in this example the student chose to return to the university and continued to study engineering. Abs $E(X)$ Integer-Observation shows the absolute error of $E(X)$ Integer subtracted by the observed result. $E(X)$-Observation is the subtraction of the expected value minus the observed value, and for analysis purposes the Abs Error is the absolute value of $E(X)$-Observation.

In Table 8, a summary of the number of students for both 2010, and 2011 engineering cohorts is categorized into three categories of Returned to Engineering, Switched Majors, and Dropped Out. This data is shown for both what was observed in the three paths that students chose, and the number of students that is expected by the prediction model for each of the three paths.
In the final column is a calculation of the percent error for each path for each engineering cohort and a calculation of percent error using the sum of students who switched majors and dropped out of the university. The percent error is calculated to show how close the expected value created by the prediction model is to the observation. The error for students who returned, labeled under Returned to Engineering is reasonably low, 3.01% and 2.41%, for 2010 and 2011 cohorts respectively. Percent error for students who switched majors but remained in the university, labeled under Switched Majors, is 78.67% and 91.49%, for 2010 and 2011 cohorts respectively, and the percent error for students who dropped out of the university, labeled under Dropped Out is 62.34% and 65.22% for 2010 and 2011 cohorts respectively. The error for Switched Majors and Dropped Out students is noticeably high and shows that the prediction model is not accurate when measuring these two categories independently. The percent error for the sum of the categories Switched Majors and Dropped Out is 7.24% and 5.26% for 2010 and 2011 cohorts respectively. The percent errors for students Returning to Engineering and the sum of Switched Majors and Dropped Out show that the error is reasonable and that the prediction model is fairly accurate in predicting which students will be retained to engineering in their second years and which students will leave engineering, either through changing their major or leaving the university altogether. In the context that the percent error is low when predicting the students that will return to engineering in the second year and the percent error is high for students that likely will switch majors or drop out, this result is reasonably acceptable. It would be ideal to predict each of the three paths with a low
amount of percent error, but is acceptable if the engineering department’s goal is to maximize the retainment of freshman engineering students to only engineering curriculum.

In Table 9 the prediction results of different student path outcomes are summarized. For the 2010 Engineering Cohort a total of 353 students were accurately predicted with 298 accurately predicted for students who were retained in engineering and 55 students accurately predicted to switch majors or drop out of the university. For student outcomes that were inaccurately predicted there was a total of 165 students. Of the total 165 students inaccurately predicted, 40 students were inaccurately predicted to either switch majors, or drop out, 57 students were inaccurately predicted to stay in engineering, and 68 students were predicted to leave engineering but ultimately chose to stay in engineering for their second year. The 57 students that were predicted to stay in engineering but chose to leave engineering or the university may represent a natural turnover of students that try engineering school, are good at the coursework but for some reason or another decide that engineering school is not for them. The 68 that were predicted to leave engineering but chose to stay meets the study’s goal of retaining first year engineering students but it is of concern because this subgroup of student’s Fall GPA is 2.29 and Spring GPA is 2.26, which is by academic standards considered average and nearing poor.
Table 9 – Summary Prediction Results for Engineering Student Cohorts

<table>
<thead>
<tr>
<th></th>
<th>2010 Engineering Cohort</th>
<th>2011 Engineering Cohort</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Number of Students</td>
<td>518</td>
<td>666</td>
</tr>
<tr>
<td>Number of Students 2nd Year Path</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Accurately Predicted</td>
<td>353</td>
<td>460</td>
</tr>
<tr>
<td>Number of Students 2nd Year Path</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Accurately Predicted. Result -&gt;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Retained to Engineering</td>
<td>298</td>
<td>384</td>
</tr>
<tr>
<td>Number of Students 2nd Year Path</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Accurately Predicted. Result -&gt;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Switched Majors or Dropped Out</td>
<td>55</td>
<td>76</td>
</tr>
<tr>
<td>Number of Students 2nd Year Path</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inaccurately Predicted</td>
<td>165</td>
<td>206</td>
</tr>
<tr>
<td>Number of Students 2nd Year Path</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inaccurately Predicted, but Retained</td>
<td></td>
<td></td>
</tr>
<tr>
<td>to Engineering</td>
<td>68</td>
<td>73</td>
</tr>
<tr>
<td>Number of Students 2nd Year Path</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inaccurately Predicted</td>
<td></td>
<td></td>
</tr>
<tr>
<td>to Either Switched Major or Dropped</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Out. Result -&gt; Switched Majors or</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dropped Out</td>
<td>40</td>
<td>71</td>
</tr>
<tr>
<td>Number of Students 2nd Year Path</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inaccurately Predicted</td>
<td></td>
<td></td>
</tr>
<tr>
<td>to be Retained in Engineering. Result</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-&gt; Switched Majors or Dropped Out</td>
<td>57</td>
<td>62</td>
</tr>
</tbody>
</table>
CHAPTER 4
DISCUSSION

The goal of this study is to identify a systemic process through Lean Thinking methods that can be implemented to benefit engineering students by fostering an engineering education culture that encourages social integration among students and an institutional commitment to those students. Using Lean Thinking as an educational model a strong focus would be placed on the quality of the overall product (students), continuous improvement of the education institution, and a respect for people (students, faculty, administration, institution stakeholders).

To evaluate how to create this ideal system an analysis of the data is conducted. Attribute data is collected for each student that participated. Attributes included gender, ethnicity, grade point average (GPA), Intro to Engineering I final grade, midterm grade of Intro to Engineering I, percent of classes attended, high school GPA, math, English, and composite ACT scores.

4-1 An Engineering Education Quality System

To summarize all of the above discussed parts into a theoretical proposed system for engineering education, this section will detail how a quality system could be constructed for an engineering curriculum. To build the framework for this model a school district in New York State, Pearl River, will be used as the foundation for this system. Pearl River School District was chosen because it was awarded in 2001 by the National Institute of Standards and Technology (NIST), the Malcolm Baldrige National Quality Award. [26] Along with the Pearl River School District as an example to building an engineering curriculum quality model case study,
framework will also be derived from the NIST’s Baldrige Excellence Framework for Educational Organizations. To be awarded this quality award a U.S. organization must have a system that does the following:

1. Ensures continuous improvement in overall performance in delivering products and/or services
2. Provides an approach for satisfying and responding to customers and stakeholders

Source: National Institute of Standards and Technology [9]

The Baldrige Excellence Framework for Educational Organizations identifies the seven below criteria to benchmark an organization’s objective's accomplishments.

1. Leadership
2. Strategy
3. Customers
4. Measurement, analysis, and knowledge management
5. Workforce
6. Operations
7. Results

The Baldrige framework goes on to state that it is believed these values and characteristics are found in high performing organizations and should be incorporated into an organization’s quality culture.

1. Systems perspective
2. Visionary leadership
3. Student-centered excellence
4. Valuing people
5. Organizational learning and agility
6. Focus on success
7. Managing for innovation
8. Management by fact
9. Societal responsibility
10. Ethics and transparency
11. Delivering value and results

Source: National Institute of Standards and Technology (NIST) [9]

The above criteria from the Baldrige Excellence Framework for Education Organizations is very similar to the seven ISO 9000 Quality Management Principles. ISO 9000 is considered a benchmark for defining the processes required for any kind of quality system. The seven principles from ISO 9000:

1. Customer Focus
2. Leadership
3. Engagement of People
4. Process Approach
5. Improvement
6. Evidence-based Decision Making
7. Relationship Management

Source: American Society for Quality [14]

Using the above criteria and organizational values along with Tinto’s model for student retention and the quality system Pearl River School District implemented [35, 37, 38], we can create a proposed organizational philosophy for the ideal engineering curriculum’s quality system. The proposed engineering curriculum quality system outlined in this paper will discuss two types of quality structures within the quality system, being that of;
1) the policy management of the university and the department and how the system conforms to those requirements and;

2) the daily departmental goals and procedures that are required in the operation of an engineering education organization. While both of these are equally important, the focus of this paper’s discussion will be mainly on the daily aspects of a quality system.

4-2 Organizational Philosophy – Using a systems perspective, the university’s engineering department will seek to create an innovative, student centric engineering curriculum that focuses on the retainment, success, and an inclusive community for all students. The department will maintain a high level of student’s quality in accumulated engineering knowledge, with equally high quality expectations of the lasting intrinsic value of the engineering education conferred on students and alumni alike. The department will actively improve curriculum based on measurements, analysis, and feedback from the department’s customers – faculty, students, and community. The engineering department will foster an educational community of faculty, advisors, administrators, and students to create a social support network within the department that will drive student social integration, a key characteristic for student retention. The engineering department will aim to maximize a balanced scorecard of measurables in student satisfaction and social integration with the department/university, student academic performance, and concurrently seeking to provide a reasonable total program cost to the student and university. With every improvement, the department will seek to compare its current position with best in class peers.
Planning – As outlined in the engineering department’s Organizational Philosophy the department will seek to achieve three goals with thorough planning by the department’s key stakeholders.

1) Maximizing and improving student satisfaction and social integration.
2) Provide and improve through benchmarking services offered to students.
3) Prepare students to the best of their abilities and at the best of the department’s commitments for STEM and STEM related careers.

With the three goals in mind of maintaining and improving year over year an engineering education program the department’s key stakeholders will create its planning using data collection from:

1) Student planning documents for each semester.
2) Student surveys on academic and social integration.
3) Student academic performance and predictions of student academic performance.
4) Faculty surveys for improvement ideas.

This aligns with the department’s mission:
The engineering department will support student social integration within the department/university, student academic performance, and develop future functioning engineers in conjunction with engineering community, and state requirements.

4-4 Data Management – The engineering department will collect individual student’s data in the categories of High School GPA, ACT scores for English, Math, and Composite score, student’s gender and ethnicity, semester by semester GPA and overall GPA, class by class GPA, and pass/fail in classes. This set of data is used in prediction Formulas 2, 3, and 4 to help determine which students will likely persist in engineering, and which students likely need assistance in their engineering studies. The prediction formula is then used in the prediction model, Model 1 to forecast individual students predicted paths and report these predictions internally to faculty, advisors, and administration.

Individual data is collected on students through self-reported surveys at intervals in the student’s academic career from before the student enters the engineering department, to post semester reviews and class circles during class’ semesters. This qualitative data can be used to create support services for students and seek to make improvements as student learning styles change.

4-5 Involvement – The engineering department promotes and encourages the inclusion of all stakeholders to have their voices heard in the planning, data and process management, and data collection within the engineering department’s production.

Using the student’s predicted paths from Model 1 the engineering department should contact students that are close to, failing, or have failed main engineering courses like math and discuss where the student’s problems are occurring. In this discussion key topics and plans to correct student problems should be documented and made available to the student, the student’s advisor, and the faculty that the student is currently studying under. If the student
chooses not to continue in the engineering program, or cannot meet the program’s specific GPA, or course grades, the student will be given notice of academic dismissal, along with a requested meeting to discuss what had happened with the student’s performance, and paths to return to the engineering department, and other support systems like voluntary student affinity groups for students with similar situations.

Students who are proceeding well in the engineering program but not exceptionally, GPA 2.0-3.0, and have predictions to either switch majors or drop out should also be contacted by the department to search for means to increase academic performance, and to help ensure student retention through discussing problems, offering department support services such as tutoring or social activities, and career counseling to help set expectations for the work engineers do.

During real time data collection on student’s performance students should be aware of common trouble indicators like consistently poor grades on assignments, and tests, feelings of a lack of commitment to their studies, or to the program that they are in. Ideally the best means to communicate these trouble indicator themes would be through the use of standard documents that students already receive such as syllabi, or as cover pages to exams or assignments.

The department will also measure the registration status of students on-going from one semester to the next and check for students who appear to be late or delaying registration, prioritizing importance on the students that are predicted to leave the university or switch majors. These students the department will automatically contact via email or text, depending on the student’s agreed upon method of contacting, to request a time to discuss with an advisor any barriers to registration that the student may be facing. These conversation’s key points will
also be documented and shared with the student, advisor, and faculty members the student has classes with or had classes with.

4-6 Process Management – For the operations that occur within the engineering department, the department will create a disciplined and detailed set of processes as part of its process management strategy. The faculty, advisors, and administration with feedback from those stakeholders along with students and the engineering community will develop these processes. The department processes will be actively reviewed to ensure that expectations are being accomplished, and any shortcomings to expectations be identified and the department stakeholders conduct root cause analyses to countermeasure shortcomings. The engineering department’s processes, real time data (besides confidential data), and identified problem root causes and countermeasures will be publicly shared within the department and among stakeholders.

4-7 How to Collect the Data Needed for a Quality System? – This is very difficult because customer satisfaction can be tough to quantify and the voice of the customer is not exactly easy to hear. Also in higher education, there are multiple customers at any given time. It can be considered conceptually that students are customers in the context that when they graduate from the university they have certain expectations for the types of jobs that are available to them due to the work, prestige, and education/skills obtained at their university. However, students can also be the product or the products processor at different given points of time in different contexts. For example when students complete a homework assignment, a test, or a final exam, the students are the processors of the work that needs to be accomplished. At the same time students could be considered the customer from the aforementioned concept of education/skills obtained in the course of study. Of course in the terms of a graduated student they would be no longer classified as a student but as an alumni at that point, so there
are two unique identifiers of the student and product of the students processed activities being a graduated student. A noted disclaimer to these proposed concepts is that while students could perceive themselves as customers, they can also be perceived as the processors in many scenarios not described in this paper. This is another point supporting the argument for thorough and documented processes setting the expectations for responsibilities in a high quality learning environment.

From Dr. Deming’s book “Out of the Crisis”, Dr. Deming discussed quality and the perception of quality by the consumer of a product or service, specifically noting the difficulty on measuring the quality of teaching. Dr. Deming, noted an example from his experience:

“Example: Another publishing house was preparing a new edition of its widely used series (elementary readers). One of us, asked to consult, objected in detail to the blandness of the stories proposed. The company’s vice-president in charge of textbooks confessed that he, too, thought that the stories would bore young readers, but he was obliged to keep in mind that neither children nor teachers buy textbooks: school boards and administrators do.” [8]

This is an interesting example that is maybe not so applicable to higher education but interesting in its own sense that the end user of the textbook, children and teachers, have no influence on the decision-making in a core function of their education, and in the teacher’s case, how they perform their job. This is a delicate balance in the realm of engineering education in that the faculty member must conform to a standard of curriculum that is required by the university, the accrediting body that accredits the engineering program, or even regulatory requirements. The type of data collection an ideal engineering education quality system would want to collect to inform decision makers of problems to solve or ideas to improve the engineering education system within the university.
To build on this concept Dr. Deming proposed the “three corners of quality” a triangle diagram that shows three critical quality measurements.

“1) The product itself; 2) the user and how they use the product; 3) instructions for use of the product and training of the customer” Deming noted that not one corner of quality by itself determines the quality of the system, but the sum of all the three parts does. [8] Below in Figure 3 is Dr. Deming’s three corners of quality.

![The Three Corners of Quality](image)

**Figure 3 – The Three Corners of Quality [8]**

Applying Dr. Deming’s three corners of quality concept to engineering education, it can be translated as the following.

**The Product** – As Dr. Deming outlines above the product is the producers tests of the product, and the users experience of the product in service. For the use of engineering education, engineering education at most institutions has been on-going for many decades, so the tests of the service has been on-going and can be reflected upon. Tests of new changes in the engineering department’s processes can be experimented on a small scale test through using individual classrooms or students as tests.

**Training of Customer Instructions for Use** – In the engineering education context of this corner of quality philosophy it can be translated as the training and education of students in the
engineering curriculum, and the preparation of converting engineering students into practicing engineers once they graduate from the engineering curriculum. In Dr. Deming’s philosophy of this quality corner’s concept Dr. Deming focused on the expectations that the customer would come to expect from the service the organization is providing. Conceptually this can be applied multiple ways. The engineering student’s expectations for the result of when they graduate, what types of jobs are expected based on their individual performance, and the student’s expectations of engineering coursework rigor and time commitments. Both the long term in the time it takes to complete an engineering program and the more granular levels of the time it takes to complete individual assignments and study for exams.

**The Customer and the Way they Use the Product** – For an engineering education department this is a measure that is difficult to qualify or quantify while the student is in the department. Some methods that could be used are to survey students who are pursuing internships during their engineering schooling and the employers the internship students work with. This would give a voice to how the curriculum is preparing students for engineering work and how employers perceive the curriculum’s quality in educating and training students. Another survey could be conducted for students that are alumni of the engineering department to understand how the department influenced them, and how they are using their engineering education at different intervals of time in their post student careers. For example, 1, 3, 5, 10, 15, 20, 25, and 30 years outside of graduation.

**4-8 Semester-by-Semester Data Collection**

To gather real time semester data and post semester data the engineering department should utilize a data collection method of recording all grades from each course for any assignment or exam into a master database. This will allow trend analyses to be conducted and control charts for visual management to be created. When problem trends are identified the
idea generation to create countermeasures to those problems can be conducted either on a one-on-one basis with the course instructor, or student’s advisor and the student. In some instances if the course is experiencing multiple students with problems in the course a quality circle, or essentially a group of students could be formed within the class to discuss the problem and how to improve the course as the course is being conducted. The group of students working on resolving a problem within the course should be voluntary and can include students struggling in the course and succeeding. The group should be able to consult with the instructor on improvement ideas and problem countermeasures.

When a problem is identified in the course, a student, faculty member, advisor, or group of students can create a problem statement and why-why analysis to assist in solving the identified problem. A why-why analysis example using freshman engineering student retention is outlined below:

**Problem:** xx% of freshman engineering students are leaving the engineering program to switch to another major that is not engineering or are leaving the university entirely.

1. **Why did the student leave engineering school?**
   - Student had poor grades and was academically dismissed.

2. **Why was the student academically dismissed?**
   - Student’s GPA had fallen below the university’s required achievement level.

3. **Why did the student’s GPA fall below the university’s required achievement level?**
   - Student’s math class grades were failing grades.

4. **Why was the student’s math class grades failing grades?**
   - The student’s exam grades in the math classes were as a whole failing exam grades.

5. **Why did the student receive failing grades on their math exams?**
- The student spent much time studying for the exams but could not cover the entire amount of material that was to be tested on.

**Root cause:** potentially multivariate, the student may not have learned the necessary studying habits, ethic in high school to be prepared for college level math. The student may have many other obligations outside of the classroom. The student may have been doing poorly on every homework assignment and never learned by the end of the semester the skills or concepts needed to be successful in that class.

Once a why-why analysis is completed the faculty member and the students could then “go to the spot” of the problem. Depending on the problem being studied this could be students and faculty conducting exit interviews with the students that are leaving, checking each other’s homework for errors and recommending how to study these topics, or weekly/monthly reviews on how to improve course delivery and assignment schedules/workload and content, among other recommendations.

This is just one example of a why-why analysis demonstrating the possible reasons why a student may be leaving a freshman engineering program. There are many opportunities along the course of a student’s first and hopefully second semesters in engineering school to identify problems and root causes to those problems. This line of thinking is in the foundation of the PDCA method. Based on the results from the prediction model developed in this study of freshman engineering student retention, faculty members, students, administrators, advisors, and essentially anyone involved in the processes of freshman engineering curriculum can use the predictor factors as study for identifying students that may have difficulty in being retained in engineering.

One method to use these prediction factors is for the university to continuously be reviewing the student’s data as they are entering and exiting different stages of the engineering
curriculum. As the students are entering university and therefore starting the freshman engineering curriculum, observation data for ACT scores and high school GPA’s could be used to identify students that exhibit prediction factors of those who drop out or switch majors. For students that are in the process of completing a semester’s worth of engineering coursework, studying the observations of individual student’s performance in every assignment and exam, which leads to the results of the student predictors in GPA, individual course grades, and passing or failing in a math course. Using the prediction model outlined in this paper an engineering department can use the individual student predictions to do a first year check of each student and forecast what outcome the department believes the student will have in their second year of study. A simple method the engineering department can use to help increase retention would be to use the prediction data for students predicted to change majors or drop out of the university. If these students are predicted in those two categories and additionally some of those students have not yet signed up for any engineering courses for the following semester the engineering department could attempt to contact those students and discuss the reasons why the student had not registered for engineering coursework., what barriers the student is experiencing to their registration within engineering. To visually and quantitatively track and analyze these student results in real time different types of quality control charts could be used. Within student evaluation observations specification limits could be used based off of university goals and prediction model data to determine where trouble issues are or students having difficulty progressing. In addition to creating control charts to observe where problems are occurring, control charts could also be devised to show how many students are predicted to end up in a certain result and track the changes on a semester to semester basis.
Lack of altruism was noted by Astin as a common characteristic that engineers possess, which can cause difficulty to study social interactions between the students and an ideal university’s intended goal of creating a social network that promotes the students to be helping one another to learn subject matter, and socially integrating the students into the university, proposed by Tinto. This study did not focus on those social interactions or observed means to foster more social connectivity. A future study could focus on the individual social connections of individual students and study the correlations, if any, between those connections and their academic performance. Along with a study on students’ social connections and their academic performance, creating a means to integrate student social investigations into a engineering education quality system and utilize lean tools to promote the improvement of that social system.

Upfront, before all of the prediction attributes are collected a study could be conducted to help determine predictions of freshman engineering retention using data before students begin their engineering coursework. As found by Felder, et al, Tinto, and Astin there are correlated links to the performance of students in high school carrying over into their college performance. An upfront prediction would help engineering schools better understand and prepare resources required for higher education engineering departments, which in turn would help to create evenness in the amount of students beginning and completing an engineering
degree program. This upfront prediction could be included as part of an engineering education department’s quality system to assist with choosing the correct students for acceptance into the university’s engineering department. Not discussed in this study is the amount of students or reasons why a student would start and stop their engineering education even though that student is qualified and is predicted to persist in engineering. There was no data collected on these students who are qualified and predicted to continue in engineering but resulted in leaving the engineering program. This type of study into those qualified predicted students maybe would have a qualitative not a quantitative reason for not persisting in engineering, of which such a study would need to conducted in the sociological and psychological reasons for those students not persisting. A thorough quality system would also want to account for reliability which is not completely considered or reflected upon in this study. A future study should attempt to calculate the individual reliability of the processes proposed in the engineering education quality system, the reliability of the prediction model proposed in this study, and the overall reliability of the entire engineering education quality system proposed.
CHAPTER 6

CONCLUSION

The purpose of this study sought to create a prediction model that could be used to identify first year engineering students who are likely to change majors or drop out of their university. This study also sought to develop a quality system for an engineering department to use to ensure the retention of those first year students all the way into completion of the engineering program. With a measurable amount of accuracy, this study created a prediction model, which could identify students that were likely to be retained in engineering, switch majors out of engineering, and to drop out of the university. This prediction model that was created was then incorporated into the engineering education quality system proposed to identify where and when students may not persist in engineering curriculum and ideas to promote persistence using the prediction results.
REFERENCES


[27] “Quality Glossary Definition: Continuous Improvement.” Continuous Improvement, ASQ, asq.org/learn-about-quality/continuous-improvement/overview/overview.html.


A. Tools for Data Collection

To ensure a good systems thinking approach to an engineering departments operation data would need to be collected at regular intervals so that the engineering department would have an on-going current status of the engineering department’s current operating performance. The first initial tool of data collection that could be used is to measure the incoming freshman engineering student’s potential engagement with engineering curriculum and the university itself through a student entrance survey. While this survey would be self-reported, it could be a mandatory requirement in curriculum that has an Introduction to Engineering class for freshman or could be a component of another freshman-engineering course like Technical Writing. An example of how the survey could be developed is below:

B. Freshman Engineering Entrance, Semester Completion, and Exit Survey Examples

Freshman Engineering Entrance Survey

Objective: To ensure and better enhance the quality of instruction that the engineering department delivers to students the engineering department requests students to complete the below survey to gain those insights to promote continuous improvement of the department. By completing this survey you are benefiting yourselves by conveying where you are academically and how well you may adjust to the rigors of engineering and the change that accompanies starting an engineering program, both of these characteristics are well established attributes of students who persist and are successful in higher education. Your answers to this survey are
confidential with the department faculty and advisors, who may contact you afterwards to
discuss further in person. Please try to keep your responses short and succinct to allow for a
quicker analysis. If you have something more in-depth that you would like to discuss please
inform your advisor or a faculty member.

Questions

1. Why do you want to be an engineer?

2. Are you proud of your acceptance to the university? To be studying at the university’s
   engineering program? Why?

3. Do you have any connections to the engineering program or the university? (ex. Another
   student you know attending, met with faculty member, alumni, etc.)

4. Do you feel you have or will have strong social connections at the university?

5. What was your least and most favorite course in high school? Why? Please provide 1 or
   2 examples.

   What do you expect to be your least and most favorite course you will take in
   engineering school?

Post Semester Completion Survey

Objective: Similar to Freshman Engineering Entrance Survey.

Questions

1. Reflecting on your entrance survey, do you still have the same reason(s) as to why you
   want to be an engineer? If different from your previous expectations, how have they
   changed?

2. Are you proud of the work you do in your engineering coursework? What makes you
   feel the most proud? Where do you think you can improve?

3. Are you satisfied with the courses you are studying? Do you find them engaging?
4. Is engineering school what you thought it would be? If different from your expectations, how so?

5. What is your least and most favorite course so far in your engineering coursework? Why?

6. Who is your favorite professor or instructor so far? Why?

7. Do you feel you have strong social connections within the engineering department? Or the University? Please describe the connection you have to both.

8. How often do you meet or discuss with your advisor? Are the meetings helpful?

9. Do you want to continue studying as an engineer? Are you considering another major or leaving the university?

10. Are you proud of the engineering department and the work it does?

11. Is there any improvement theme you would like to see the engineering department to consider?

**Engineering Alumni Survey (Varying Time Intervals)**

**Objective:** To ensure and better enhance the quality of instruction that the engineering department delivers to students the engineering department invites alumni from the engineering program to complete the below survey to gain those insights to promote continuous improvement of the department. Your answers to this survey are confidential with the department faculty and advisors, who may contact you afterwards to discuss further by phone, email, or in person.

**Questions**

1. What was your engineering major?

2. Are you proud of the work you did in your engineering degree experience?

3. Are you satisfied with the content and rigor of your engineering coursework?
4. Did you find the engineering coursework engaging? Do you now find the study of engineering engaging?

5. Is engineering school what you thought it would be? If different from your expectations, how so?

6. What was your least and most favorite course in your engineering coursework? Why?

7. Who was your favorite professor or instructor in your engineering coursework? Why?

8. Did you feel you had strong social connections within the engineering department? Or the University? Please describe the connection you had to both.

9. How often did you meet or discuss with your advisor? Were the meetings helpful?

10. Are you proud of the engineering department and the work it does?

11. Is there any improvement theme you would like to see the engineering department to consider?

Eventually random sampling could do these surveys once a baseline is established for a range of various responses. Random sampling of students and alumni would reduce the workload on analyzing surveys.

**Student Engineering Program Plan Example**

Much like a project management plan or a system-engineering plan, having a student create a plan for how to accomplish completing their degree with their advisor’s input could be beneficial. Projects that require a large time commitment and resources typically create some plan to ensure on time completion within a budgetary limit. Below is an example of how an engineering degree plan could be created for incoming freshman engineering students.

**Engineering Degree Plan**

**Name:**

**Program of Study:**
Class Level:

Course Load (Full or Part-time):

Coursework Completed:

Coursework Remaining:

Upcoming Semester Coursework Plan:

Expected level of time commitment by week for each course in upcoming plan:

Process Map of Overall Degree Plan:

This engineering degree plan should be updated every semester the student is attending the university and any problems identified if a student fails a course or finished the preceding semester with a course grade of C or worse, which indicates the student is having difficulty with the course material. Upfront expectation should be relayed to the student to document and communicate an expected level, maximum, and minimum level of time weekly needed by the student to help ensure successful completion of the course.