The Effects of Informal Learning Environments on

Engineering Education

By

Michael Brown

A dissertation submitted to the

Graduate School of Education

Rutgers, The State University of New Jersey

in partial fulfillment of the requirements

for the degree of

Doctor of Education

Graduate Program in Science Education

written under the direction of

Dr. Eugenia Etkina, Chair

Dr. Ravit Duncan

Dr. Evelyn Laffey

New Brunswick, New Jersey

May 2019

Abstract of the Dissertation

The Effects of Informal Learning Environments on Engineering Education

By

Michael S. Brown Jr.

Dissertation Committee: Dr. Eugenia Etkina (Chair), Dr. Ravit Duncan, Dr. Evelyn Laffey

This mixed-methods grounded theory study investigates the development of engineering identity cultivated through engagement in informal learning experiences. In addition, the retention of engineering students and academic performance are investigated for connections to these learning environments. This is the beginning of work to identify best practices for engineering education outside of the formal undergraduate classroom experience. This research provides a framework for investigating the various factors that contribute to the success of low performing engineering students. The essential research categories to the study are (1) Informal learning Environments, (2) Engineering Identity, (3) Academic Performance, and (4) Retention. The tools used to investigate these categories include peer focus groups and the Academic Pathways of People Learning Engineering Survey (APPLES). APPLES is a research tool developed and used by the National Science Foundation-funded Academic Pathways Study (2010). It is designed to measure engineering students' educational experience, knowledge of the engineering field, and post-graduation plans.

The collected data on existing programs and activities- including summer bridge engineering programs, internships, coops, tutoring, study groups, mentoring, etc. – suggest that there are connections between the out-of-class commitments of students and their ability to identify with the engineering field. The study also offers performance and retention implications for our low performing engineering students. The research findings unpack salient features for

the most noted learning environments and their impact on engineering identity. Through this investigation, the researcher can make recommendations for services, programs, and experiences that can support at-risk students completing their engineering degree.

Dedication

This dissertation is dedicated to my children, **Nicholas** & **Nathan Brown**. You may not understand it now, but daddy is doing what he thought was impossible so that anything is possible for you. Never be afraid of a challenge or to do what seems hard, because you are your biggest obstacle.

This dissertation is also dedicated to the memory of my aunt (**Inez Harrison**), and my maternal grandparents (**Ollie & Alberta Harrison**). I pray I'm making you proud.

Acknowledgements

I want to first thank God for being a pillar for my family as I embarked on this journey. HE put me on this path, gave strength when I was weak, and offered guidance when I lost my way.

Diana Brown, my wife, my better half. Thank you for seeing the potential in me that I didn't see in myself. Your motivation made me want this for our legacy when I no longer cared to do it for myself. I love you and your unwavering support.

Alma Brown (Mom), Michael Brown Sr. (Dad), & Mikia Brown (Sister). Everything I am is because of you. I live to make you proud because that's what we do. Sacrifice, build, and do the best with the cards we've been dealt in life. The saga continues…

To my engineering education mentors, **Donald Brown**, **Dr. Ilene Rosen**, **Dr. Evelyn Laffey**, and **Dr. Lydia Prendergast**, I am forever grateful for your guidance, support, and perspective. There are tons of other people you could have chosen to adopt, but you chose me. Thank you for seeing something in me.

Candiece White, thank you for your consistent friendship and support during this journey. I lean on you for clarity and reason. Thank you for always being that voice.

To my **Office of Student Services** family**,** the amazing work that we do and our impact on students is the reason I chose to pursue this degree. Thank you for being there every step of the way. **Engineering Students,** you motivate me to be better at my craft and you deserve the best experience possible. Thank you for being my motivation and a constant reminder that you are the priority at this institution.

Finally, I want to thank Drs. **Eugenia Etkina**, **Ravit Duncan**, and **Evelyn Laffey** for all their guidance and support throughout this study. Thank you for placing your confidence in me and prioritizing the needs of our students. You are the true definition of concerned and caring educators.

Table of Contents

List of Tables

List of Figures

I. Introduction

Engineering departments at universities across the country provide services and implement programs to improve the performance and retention rates of undergraduate engineering students. Some examples of services and programs include peer tutoring, supplemental instruction, living-learning communities, summer bridge programs, and mentoring. Unfortunately, at Rutgers University many of these services go underutilized or are not available to the general student population. For example, in fall 2012, the engineering population consisted of 3492 students (2640 excluding first year and transfer students) and 17% of those students had GPAs below 2.4. But, for that academic year less than 8% of all students utilized tutoring, mentoring, and study group activities offered by the school of engineering (Rutgers SOE Fall 2012).

At the university, many of our engineering support structures are focused on underrepresented groups[1] and high achieving populations. While it is important to support special populations that have traditionally been underrepresented in the field, it is also important to raise awareness to the overall deficit that the engineering field is currently experiencing (Steve & Riordan 2012) and, therefore, extend support services to all engineering students to increase overall retention and graduation rates. U.S. jobs are growing fastest in the areas that require knowledge and skills in the areas of science, technology, engineering, and mathematics (STEM). The projected need for more STEM professionals coupled with the fact that underrepresented groups comprise an increasing proportion of the labor pool argue for policies, programs, and resources that support greater participation by all groups in STEM education and careers (May & Chubin, 2003, p. 27). For the aforementioned reasons, this study sought practices that encourage

[1] Underrepresented Groups in Engineering – Women, low-income/SES, ethnic minority including African-American/Black, Hispanic/Latino, and Native American.

enrolled students to identify with the engineering profession as well as supporting their persistence to graduation.

The goal of this research is to investigate the development of engineering identity cultivated through engagement in informal learning experiences. The targeted population is engineering students with senior year standing who have completed their freshman or sophomore year with a cumulative GPA of 2.4 or lower. These students have not been admitted as members of the honors program or the Equal Opportunity Fund (EOF). The overarching **research question** guiding this study is: To what extent does participating in informal learning environments[2] impact the development of engineering identity, as well as persistence and performance for generally admitted[3] students' who held GPAs of 2.4 or lower in their first or second year of undergraduate study?

1. Conceptual Underpinnings for the Study

Current research on retention practices explore the structure of support programs that aim to improve the performance of underrepresented populations in the undergraduate engineering curriculum of study. Some examples of these support programs include the Increasing Diversity in Engineering Academics Program at the University of Akron, the Meyerhoff Scholars Program at the University of Maryland, and the STEM Talent Expansion Program at Virginia Polytechnic Institute, which both focus on raising representation and performance of women, African Americans, and Hispanic students in engineering (Lam et. al 1997; Matanin et. al 2007). Transition

[2] Informal Learning Environments - Venues where academic, professional, and/or personal development takes place outside of the classroom to motivate students in engineering and offer engineering discourse.
[3] General Admits - Students not admitted into the Honors Academy or the Educational Opportunity Fund programs.

activities, study groups, tutoring, mentoring, workshops and financial incentives have been used to increase the average grade point average of participants and maintain six-year retention rates as high as 74%.

Some research emphasizes the development of academic programs for high performing students to encourage them to develop in the areas such as innovation and design. For example, these students at Rutgers University are classified as “outstanding” with combined math and critical reading SAT scores exceeding 1450. Researchers provide evidence that ‘honor program’ benefits for students include an elite education at a fraction of the price of more selective universities, smaller class sizes, special academic advising, honors residence halls, and other perks (Digby, 1999). Under the umbrella of the Rutgers School of Engineering ‘Honor’s Program’, students enter a community of like-minded peers to pursue scholarly research, specialized courses, and on occasion dual degrees. Upon graduation, honors students indicate higher satisfaction with their jobs than non-honors students (Sturgess & Fleming, 1994), and are more likely to complete graduate or professional school than non-honors students (Jahnke, 1976). In a study by Anne Rin (2005), students associated with honor community program models at Western Kentucky University experience an increase in ‘self-concept’ over their college years, over 81% of the junior and senior population aspire to pursue doctoral degrees, and results show significant differences in career aspirations between these students and the general admits.

Little research exists for retention support models that occur outside the classroom for low performing first and second year general admits to the undergraduate engineering programs. These students meet the admission guidelines for the School of Engineering, but do not meet the requirements for support programs for low-income/first-generation or honor program students. For the purpose of this study, low performing general admits are considered those achieving a 2.4/4.0

GPA or below, which consists of 15.03% of the Rutgers engineering population. This data is reported by Associate Dean Fred Bernath who is responsible for providing institutional data to our accrediting agency, the Accreditation Board for Engineering & Technology (Rutgers SOE Fall 2012).

The purpose of this mixed-methods grounded theory study is to examine informal learning environments to explore how they encourage or discourage student's identities as engineers. In addition, the retention of students at Rutgers School of Engineering and student performance are investigated for possible connection to these learning environments. The developed study is the beginning of work to identify best practices for engineering education outside of the formal undergraduate classroom experience. I approach this by examining how students define *engineering identity,* the *informal learning environments* that are available to support them in their engineering pursuits, and how they utilize them. These environments include, but are not limited to university-wide services and learning opportunities for targeted populations. By analyzing both quantitative and qualitative responses from students, I was able to uncover salient features for the most noted learning environments and their impact on engineering identity. Through this investigation, I was able to make recommendations for services and programs that can be implemented to support low performing engineering students using best practices from existing models.

2. Definitions of Key Terms

Informal Learning Environments: Interactions that occur outside of the credit-bearing classroom that engages students in the ongoing phenomenon of learning by participating in conversations and activities with peers or educators that result in knowledge creation. These interactions are student-centered, in contrast to the traditional teacher-centered pedagogy found in the didactic classroom. (Paradise & Barbara, 2009).

Engineering Identity: A student's sense of belonging to the engineering community. A stage theory of development that takes place over time impacted by numerous sources, both internal and external to the academic institution (Meyers et. al, 2012).

Engineering Retention: The number of students who remain enrolled from fall to fall. This number is typically derived from first-time, full time traditional day students, but can be applied to any defined cohort (Voigt & Hundrieser, 2008).

Engineering Persistence: The enrollment headcount of any cohort compared to its headcount on its initial official census date. The goal is to measure the number of students who persist term to term and to completion (Voigt & Hundrieser, 2008).

Low Performing Students: Students from the engineering population who have GPAs below a 2.4 in their first and/or second years of academic study (Rutgers SOE Fall 2012).

Academic Discourse: The engineering dialogue, language used, and format that facilitates communication in environments outside of the classroom (White & Lowenthal, 2011).

3. Statement of Problem

The need for engineers in this country is rising due to the growing need for innovation in science and technology. In order to maintain a competitive edge, the nation must strengthen its resources by developing a society that is STEM-literate and can provide the technological breakthroughs needed for the 21st century. In doing so, it is necessary to develop a diverse population of scientist and engineers. Diversity is an important issue because the ethnicity of the U.S. workforce is changing dramatically. (Galloway, 2008, p. 3)

Our nation's minority participation in the workforce is at an all-time high. It is projected that currently underrepresented minority groups will increase from 25% to approximately 48% of the workforce by 2050. Currently included in this significantly underrepresented group are African Americans, Hispanics, and Native Americans. U.S. jobs are growing fastest in the areas that require knowledge and skills in the areas of science, technology, engineering, and mathematics (STEM). The projected need for more STEM works coupled with the fact that underrepresented groups comprise an increasing proportion of the labor pool, argue for policies, programs, and resources that support greater participation by all groups in STEM education and careers. Currently STEM workers remain overwhelmingly white, male, and able-bodied while the available pool of talented women, minorities and persons with disabilities remains significantly underutilized (May & Chubin, 2003, p. 27).

Specializations within STEM fields vary by academic level. Engineering was among the most common STEM specialties at all levels of study in 2002-2003 (Kuenzi et al. 2006). The following are some crucial statistics regarding the state of STEM education in 2003:

- Of the 659,000 underrepresented minority high school students in 2003, only 26,000 (4%) met the requirements in math and science preparation to quality for admission to study engineering or technology on a collegiate level (Roach 2006).
- Underrepresented minority students only accounted for 15.9 percent of the students that attended collegiate engineering programs (Roach 2006).

- A third of white students and 42 percent of Asian-American students who started college as intended STEM majors graduated with STEM degrees by the end of five years. For underrepresented minorities, the five-year completion rates were much lower, Latino (22.1%), Black (18.4%), and Native American (18.8%) (Epstein 2010).

With the national completion rate of 55.9% and New Jersey averaging 61% in 2008, these statistics reflect a need for support in the area of academic development for all engineering populations especially those classified as underrepresented minorities (National Report Card 2008). All students in the general engineering population require this support to maintain their level of engagement in engineering and retain them in the STEM fields. The goal of this study was to investigate the informal learning environments that influence these retention rates and increase both minority and nonminority involvement at Rutgers School of Engineering.

4. Purpose of the Study (Research Questions)

This study was designed to evaluate the impact of out-of-class practices on engineering students' success. I used the students' voices to describe the extent in which informal learning environments affected the development of low performing, Rutgers engineering students' engineering identity, retention, and GPA. The primary research tools used were the Academic Pathways of People Learning Engineering (APPLE) survey and focus groups for the study. Details regarding the APPLE survey and focus groups are discussed in the methodology section of this document. The following research and essential questions were derived by the review of literature and influenced by my personal experiences as an engineering student, as well as an engineering educator:

Research Question: To what extent does participating in informal learning environments impact the development of engineering identity, as well as persistence and performance for generally admitted students' who held GPAs of 2.4 or lower in their first or second year of undergraduate study?

Essential Questions:

(1) What informal learning environments do engineering students use?

(2) How does discourse in these informal learning environments impact the identity of engineering students?

(3) How do these informal learning environments impact performance?

(4) How do these factors impact student retention?

II. Literature Review

A review of the literature reveals a body of knowledge developed from mostly quantitative studies or descriptive accounts of the structural components of informal learning environments. The existing literature was used to develop a theoretical and analytical framework to guide this mixed-methods study. The aim of this study is to use students' voices to better understand the role that informal learning environments play in the development of engineering identity and any consequential impact on retention/performance. In the following sections, I review literature on motivation and attitude factors effecting students' identities as engineers. Secondly, I explore literature related to out-of-class learning environments that support engineering students. Much of the research in these two categories is discussed as it relates to student performance and/or retention.

1. Engineering Identity

To address the national need for more engineers, innovation in engineering education is needed to support all students. According to Adams et al. (2011), we need to adopt strategies and tools for implementing multifaceted pedagogy to better understand complex engineering concepts. It is important that students explore connections between conceptual and procedural knowledge, as well as strive for structural connections. According to cognitive scientists, learning is an ongoing process of participation of an individual in a member of a community. (Lave and Wenger 1991) Such participation helps the individual develop a particular identity within that community. Gee characterizes identity as "the 'kind of person' one is recognized as 'being', at a given time and place" (Gee 2001, p. 99). Using this view of identity, engineering identity does not focus only on internalization of ones' self-perception of engineer. Instead, it captures how an individual presents one's self to the world and how the world recognizes an individual with respect to the engineering profession.

In the research study, I use students' voice to understand the link between developing engineering identity and retention. The false assumption is that those students fleeing from engineering are only lower performing and low skilled students. Researchers Besterfield-Sacre and Shuman (1997) conducted a study and their data provide evidence that this is not solely the case. While students with lower standing (2.0 or below) leave at higher rates, students leaving the undergraduate engineering program in good and poor standing had lower general impressions of engineering when they first started and low confidence in their engineering skills. Additionally, students who leave rated financial influences higher than intrinsic reason as a motivator for entering the field. Therefore, it may be beneficial to understand how students develop their identities as engineers and motivators for retention and attrition.

Some commonalities have also been found in those students who choose to persist and engage in engineering disciplines. Students who persist in the field of engineering commonly rank their impact on social good highest among motivating factors (Korte & Smith, 2007). Students find the field objective, logical, concrete and prefer its applied nature. Consequently, Korte and Smith were able to see more engagement and higher persistence in for those students exposed to engineering career options. From this exposure, participants in their study were able to develop accurate perceptions of what engineers do, their needed skills, and their own abilities to impact change. Some areas of discourse to develop this learning are uncovered by Matusovich et al. (2008) and include taking engineering classes, participating in campus activities, and completing internships. Trenor et al. in their 2008 study on underrepresented minority (URM) students hypothesized that student's sense of self and belonging contribute to positive learning experiences and eases transitions through college. In a later study by Matusovich et al. (2010) researchers were able to use Eccles expectancy-value categories, which have rich history of application in understanding career choices, to explain why students persist in engineering. The research shows that students choose to engage and persist in earning engineering degrees for reasons that connect to an ‘attainment value’. Eccles defines *attainment value* as how a task is important to one’s sense of themselves and who they want to be. Students with high attainment values also (1) rate highly the importance of relative costs (time, effort, and psychological price of succeeding) in their choices to become engineers, (2) have moderate to high interest levels, and (3) perceive the usefulness of engineering the same or decrease with time. In Figure 1, Matusovich et al. give us a synopsis of how this sense of engineering ‘self’ for students with both low and high attainment values.

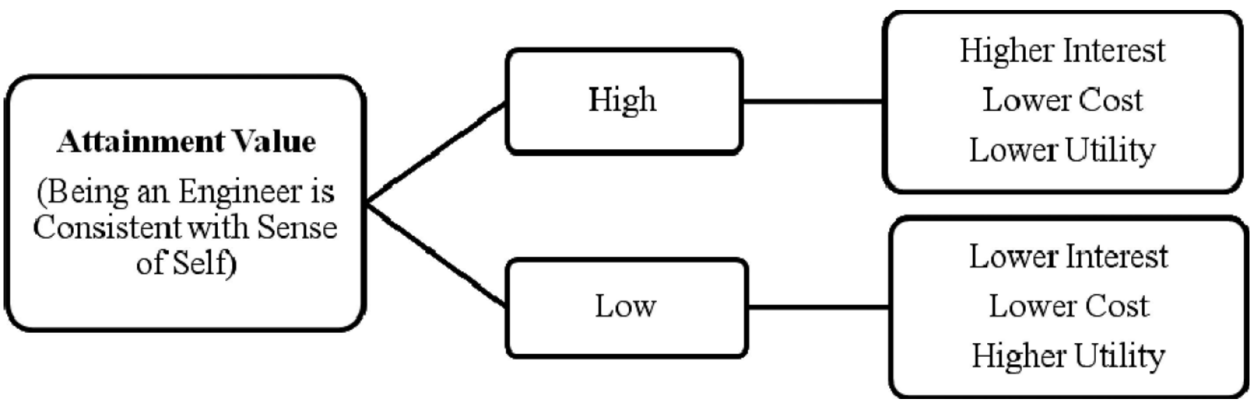

Figure 1: Relationships among value constructs showing the importance of attainment value

To understand the skills and habits we need to foster in our students, some researchers have developed Engineering Habits of Mind (EHoM) which many believe are the essential skills for the 21st century. A study by Lucas and Hanson (2016) gave a definition of these skills investigating how engineers think and act (p. 4). The six powerful learning dispositions classified were (1) system-thinking, (2) problem-finding, (3) visualizing, (4) improving, (5) creative problem-solving, and (6) adapting. A slightly different set of learning goals were originally offered by the National Academy of Engineering (Katehi, Pearson, & Feder 2009). They list (1) systems thinking, (2) creativity, (3) optimism, (4) collaboration, (5) communication, and (6) attention to ethical considerations as the key identifying factors in engineers that need to be enhanced. In both studies, the described skills are not unique to engineering but considered essential skills for citizens in the 21^{st} century. This information was created to help the education system develop learners who think and act like engineers. Through continuing longitudinal studies on these identifying characteristics, researchers are hoping to understand the impacts of engineering education on student engagement and retention, understanding of engineering, career aspirations, and technological literacy.

The described literature on identity implies that there are some similarities between students who persist in engineering. Some of those skills and habits are being fostered at the K12 and postsecondary levels to help students connect with the engineering field. Researchers hope that by understanding engineering identity, students reasons for being interested, how they gain exposure to the field, as well as their potential impact on change they can effect students' ability to persist in engineering.

2. **Informal Learning Environments**

Communities of practice are environments for students to practice and enhance their skills with their peers (Buysse et. al, 2003). They share three essential characteristics. First, the participants share a common culture and historical heritage that are usually displayed through shared goals and meaning. Secondly, communities of practice are situated within an interdependent system in which individuals are part or connected to something larger. Finally, every community of practice has a reproduction cycle, or an ability to regenerate itself.

Within engineering communities of practice, situated learning is essential (Johri & Olds, 2011). The situative perspective is broad and owes a debt to many scholars. It suggests that human knowledge arises conceptually through dynamic construction within a specific social context (Clancey, 2009). Furthermore, knowledge is socially reproduced and learning occurs though participation in meaningful activities that are part of a community of practice (Lave & Wenger, 1991), participation that is mutually constituted through and reflects our thinking and literacy skills (Gee, 1997).

Engineering communities of practice include shared inquiry and learning centered on issues, dilemmas, and ambiguity that emerge from actual situations in authentic practice settings. These experiences allow students to collaboratively examine immediate skills and competencies in a specific setting and explore alternative ways to solve problems for the professional setting (Buysee et al., 2003; Kuh, 1995). In this study I am interested in the connection between engineering identity and these communities of practice (informal learning environments), and whether they help low performing students persist in the engineering field and improve performance. The involvements that encourage engineering identity and/or allow students to engage in activities as a community of practice are referred to as informal learning environments.

Informal learning environments can be more simply defined as the out-of-class experiences that students associate with their engineering learning: use of representations, alignment with professional practices, and emphasis on design. (Kuh, 1995; Johri & Olds, 2011). One learning venue that researchers such as Cox, Cekic, and Adams (2010) and Allie et al. (2009) emphasize for student learning are those outside of the university setting. These include cooperative, internship, and study abroad opportunities, which allow students to learn from the experiences of themselves and others. Through the theoretical lens of Vygotsky (1978), we can imagine these learning environments as a process of learning the dynamics of engineering through *multiple zones of proximal development.* A zone of proximal development defines the distance between current level of learning and the level that can be reached with the help of people, tools, and artifacts. Within these multiple overlapping zones, students navigate by different routes and at different rates. However, the push is toward upper levels of competence. These levels are changing as participants become increasingly independent at more advanced levels. Cox et al (2010) and Allie et al. (2009) were able to investigate environments like cooperative learning, internship, and study abroad opportunities and confirm they were involvements where students gain competence in their practice as engineers. As a result, these experiences offer positive contributions to conceptual learning, sense of self as engineers, leadership and problem solving skills.

It is beneficial for students to engage in off-campus, engineering-related activities because they provide real life experience. The following paragraphs focus on learning environments offered by colleges and universities. These environments cultivate the skills and leadership necessary for students to gain access to full-time, co-op, intern, and research positions as well as study abroad. The following subsections investigate literature on existing peer learning environments from a range of student populations.

2.2.1 Student Organizations

Korte (2007) describes informal learning as the most pervasive type of learning that occurs in organizations. Informal learning is characterized as non-structured, experiential, and not organized by people in authority (i.e., university administrators and faculty). The learning is driven by people's choices, preferences, and intentions. At the university level, student organizations provide a venue for informal learning to occur among students who share an identified interest. For example, the Engineers Without Borders (EWB-USA) organization gathers students interested in working with developing communities to design and implement sustainable engineering projects to improve their quality of life (Rutgers EWB-USA 2013). In student organizations like EWB-USA, a process occurs through which individuals acquire the behavior and knowledge required to participate. In this student chapter, project leads must become well versed in identifying needs of partnered communities, assessing the project location to create development plans, and implementing these plans while coordinating a team of peers. Typically, the mission of student organizations and the role that students play within them are aligned with their intrinsic interests, inherent qualities, and character.

Research has provided evidence that the frequency of use and value of student organizations vary by the demographic of the students. In a study by Chachra et al. (2009), the importance of these extracurricular activities for all genders peak during their junior year. Women rate the importance of these extracurricular activities significantly higher and engage in them at higher frequencies. Women are more likely to take on administrative leadership positions, while men's involvements tend to be engineering-related, such as hands-on design and building prototypes. Predominantly URM organizations provide levels of emotional support for academic achievement and persistence in engineering (Trenor & Archer, 2010). Through this study researchers found that student groups positively affect academic and career skills such as interview skills, time management, teamwork, and problem solving. Additionally, alumni and peers provide career guidance specifically for engineering, such as graduate school advising, research experiences, and internships. Student-run organizations have the potential to link students to particular communities through outreach and play a role in challenging institutional norms that limit the success of students (Maldonado et al., 2005).

2.2.2 Clustering

Another form of peer learning environments aimed at increasing engineering student retention is clustering. Clustering has shown positive outcomes because it promotes a high level of collaborative learning among groups of students with similar academic profiles. Some of these outcomes include improved academic performance, improved retention, enhanced student satisfaction with the learning experience, improved oral communication skills, and higher self-esteem are achieved (May & Chubin 2003, p. 35). Clustering students into laboratory, lecture, and discussion sections in their first year provides the opportunity for students to engage in collaborative learning through meaningful group study (Reichert & Absher, 1997; Gregg & Watford, 1996). Additionally, a study by Stough & Songeroth (1994) shows a direct correlation between the variety of learning strategies used by URM students, including study groups, and those students being "metacognitively" aware of learning strategies they have at their disposal. Results show that these students are ultimately more successful academically. Through this supportive environment, they can develop their confidence, strengthen study skills, and learn the value of collaborative study. May & Chubin (2003) discourage establishing "minority-only" course sections. Clustering has the added benefit of reducing the isolation of URM students, and minority-only sections can be counterproductive, marginalizing those students that they are designed to support.

Clusters of engineering students in living-learning communities report a more favorable college experience. Data show that students in living-learning communities are more likely to persist to graduation, to report fewer social problems, and to perform better academically (Kampe et. al, 2007). At Virginia Polytechnic Institute and State University, there are currently two living-learning communities for freshmen engineering students. The influence of participation in a living-learning community on GPA at that institution appears to have a notable positive effect in the first semester.

2.2.3 Mentoring

Mentoring is defined as "an intensive, one-to-one form of teaching in which the wise and experienced mentor inducts the aspiring protégé into a particular, usually professional way of life" (Good et al. 1998, p. 4). Mentoring is one strategy for increasing the retention of engineering students with low performance. By matching freshmen and upper-class students of similar academic, ethnicity, or interests, the mentors demonstrate by example that success can be achieved. They also work to encourage a sense of self-confidence among novice students. As a result of mentoring, students have shown improved interest in engineering, equality, and improved the climate in the classroom for URM students (Chesler & Chesler, 2002). The College of Engineering at Clemson University has run a proactive peer-mentoring program for incoming African American engineering majors. (Lasser & Snelsire, 1996) Over 9 years, the institution was able to raise the sophomore retention rate in the targeted population to 80 percent, a rate that exceeds that majority rate at Clemson. Approximately 55 percent of their African American students earned some degree, comparable to the majority overall graduation rate of 60 percent.

2.2.4 Tutoring

Having a network for identifying students in need of tutoring is important for engineering students. Reichert and Absher (1997) implemented a model that shows promise when these efforts are focused on freshmen classes in calculus, chemistry, physics, and computer programming. They recommend the structure for tutoring as walk-in study halls with paid tutors accessible during study hours. Many minority-engineering programs have mandatory study halls that are outlined in the student contract and are tied to the universities retention efforts (Landis, 1991).

In addition to benefitting the students being tutored, tutors also experience affective and academic benefits from their academic sessions. In the case of Auburn University where upperclassmen served a dual role as mentors and tutors for incoming freshmen, researchers found that tutors experienced the following academic and affective gains (Good et al. 1998): (1) Reinforcement and improvement of existing academic skills; (2) Learning strategies emphasized in problem-solving workshops transferred to mentors as readily as did their freshmen mentees; (3) Development of personal skills (communication, confidence, identity); (4) Balanced multiple identities (friend, tutor, confidante, teacher, parent, coach); (5) Increased sense of self awareness and personal understanding; and (6) Developed a role and sense of identity

2.2.5 Transition Activities

According to Reichert and Absher (1997), the goals of transition activities are to ease the shock of the rigorous workload and fast-paced classes for engineering students. Students not challenged academically in high school often experience shock and/or lacked specific courses important to engineering, such as physics. To some extent, all traditional aged college students' students venturing into this new transition experience shock. Sociology-based theories identify multiple factors that may influence that process such as: students' initial goals and commitments; their collegiate experiences, including their academic performance, extracurricular activities, and interactions with faculty, staff and peer groups; their relationships with people and communities outside of college; and their personal attributes and characteristics (Tinto, 1993;Weidman, 1989). Advisors maintaining ongoing contact with students throughout their "shock" semesters can be effective in helping traditional students recognize challenges and renegotiate strategies for their semester goals (Clark 2005).

To ease the shock of the engineering course load, Reichert and Absher (1997) suggest transition programs that can range from two weeks to an entire summer. In addition, the authors suggest workshops over the course of the first academic year. Potential topics include orientation to engineering disciplines, college survival skills, team building, problem solving, test-taking skills, leadership development, time management, and career development. The advantage of these programs is that students who are academically underprepared get a head start on what is required of them on a collegiate level. Transition programs have been found effective for URM students and have traditionally been designed to ensured success by increasing students' time and energy devoted to studying, time spent on campus, interaction with other students, interaction with faculty, and participation in student organizations (May & Chubin, 2003).

The second category of transition activity is freshman orientation. May and Chubin (2003) argue that the goal of these programs is to integrate freshman students into support groups early in their matriculation. In addition, these students should receive general information about the activities of professional engineers in each of the fields of engineering offered by the institution. Marra et al. (2000) use a more practical approach of engineering orientation by describing a first-year design course. The goals of such a course are to introduce the engineering design process for problem solving, demonstrate the importance of graphical, oral and written communication skills, and incorporate skill-oriented tasks into team design projects. The analysis suggests that the challenges natural in a project and team based curriculum provide the type of intellectual environment that stimulates students' natural progression toward more complex thinking. As a result of the out-of-class commitment required, it also fosters collaborative learning.

3. Literature Summary

The preceding sections discussed engineering identity research and some of the factors that contribute to students developing sense of self. In addition, I explored five informal learning environments that have shown to have impact on student performance and/or retention. While the nature of these informal learning environments and their impact on students are the primary focus of this study, an area I also hope to touch upon are where they are housed at the institution to impact their target populations. In most of the aforementioned research, the engineering learning environments are centered in the dean's office, which suggests that in order to be effective they should be coordinated there. This sends a message from the top to both students and faculty that the institution values the needs of students. In addition, collaborative learning requires space in which to work as a group. A study center component is defined as a physical location that becomes the central point for academic services (May & Chubin 2003). In addition to group study, this is the ideal location for tutoring and academic workshops. These are noteworthy suggestions to consider when packaging the informal learning environments found significant to engineering identity in this study.

With research suggestions on informal learning environments, I conducted a study to uncover those that engineering students connect to their engineering identity. I investigated whether student's identification of their engineering identity have ties to performance and/or retention in the curriculum. In the next section, I provide general background on focus groups, their use in educational settings, and their operational characteristics.

III. Conceptual Framework

This study examines the relationship between informal learning environments and engineering identity using a mixed methods approach. The framework I investigate them is guided by research in the following two constructs:

(1) Social theory on development of possible selves (Identity);

(2) Learning in educational settings that provide ‘discourse’, a primary means for the search for knowledge and scientific sense-making (Bransford et. al, 2000). (Learning Environments)

‘Possible selves’ represent individuals’ ideas of who they might become, who they would *like* to become, and who they are *afraid* of becoming. Thus, the theory of “possible selves” provides a conceptual link between cognition and motivation. (Markus & Nurius 1986) Possible selves represent significant hopes, fears, and fantasies. They are direct result of previous social comparisons in which the individual’s own thoughts, feelings, characteristics, and behaviors have been contrasted to those of others. An individual is free to create any variety of possible selves, yet the pool of possible selves derives from the categories made salient by the individual’s particular sociocultural, historical context and from the models, images, and symbols provided by the media and by the individual’s immediate social experiences. Past selves can also be possible selves, to the extent that they may define an individual again in the future. Development can therefore be seen as a process of acquiring and then achieving or resisting certain ‘possible selves’. For the purpose of this study, the ‘possible selves’ that our students are negotiating are their *engineering identity*.

My research attempts to draw stronger correlation between engineering identity and discourse in engineering learning environments outside the classroom. The framework guiding the study is that learning in engineering involves taking on the discourse of an engineering community, which is critically linked to the identity of being a member of that community. In social science research, discourse refers to certain ways of using language, acting, interacting, behaving, believing, and using tools, sign systems, and ways of thinking within a particular community (Gee 2001). Scholars who study the impact of college on students agree that engaging in discourse outside the classroom can contribute valued outcomes of college. For example, participation in extracurricular activities, living in a campus residence, and conversation with faculty and peers have been positively related to persistence and satisfaction and gains in such areas as social competence, autonomy, confidence, self-awareness, and appreciate for human diversity (Kuh 1995, p 34). My hypothesis is that engineering identities (or possible selves) are also developed through engaging in this discourse. I believe this is particularly true for our engineering students who were not strong academic performers in the classroom early in their college careers, but still persist to graduation. As an industry driven major, this also suggests that success for students pursuing an engineering degree may connect to the identities they perceive in their future careers. (Allie et. al 2009).

This study will contribute to the body of engineering education literature by identifying the out of class learning environments that cultivate discourse in engineering. Examples of these learning environments include workplace experience offered through internships, cooperative work, and study abroad opportunities. Additionally, it also includes the campus learning environments that allow students to develop academic skills, leadership skills, and gain hands on engineering experience. These learning environments offer students opportunities to engage in discourse about engineering. The goal of this research was to identify those environments that contribute to their sense of self as an engineer. The literature discussed suggests that students with high attainment values are more likely to be retained in the field of engineering, meaning that their roles as engineers are consistent with their sense of self. In this study I have identified the learning environments that contribute to students needs as engineers, but in addition I have looked at each of these environments to determine why students value you them, and how their involvement helps them work towards/or strengthen their engineering identity. Finally, I studied whether these involvements had any impact on retention and performance to help low performing students stay interested and connected to the engineering field.

IV. Methods

In this section I discuss the analytical approach that was used to collect data and answer my research question. The overarching goal of the study is to understand the extent that participating in informal learning environments impact the development of engineering identity, as well as persistence and performance for generally admitted students' who held GPAs of 2.4 or lower in their first or second year of undergraduate study. However, to reach this understanding four essential questions guided my data collection:

(1) What informal learning environments do engineering students use?

(2) How does discourse in these informal learning environments impact the identity of engineering students?

(3) How do these informal learning environments impact performance?

(4) How do these factors impact student retention?

In the following sections I discuss the participants, my role as the researcher in the study, and both the qualitative and quantitative tools used to conduct my study.

1. Participants

A purposeful sample was selected for this grounded theory study (Creswell 2012). Because I am interested in understanding the complexity of informal learning environments through the perspectives of engineering students, I recruited traditional-aged, full-time, undergraduate engineering students. Students had senior year standing in their engineering curriculum and completed their freshman or sophomore year with a cumulative GPA of 2.4 or lower. The major reason for using this group was that they had experienced academic hardship but still managed to persist through the engineering requirements. These students are currently taking their last set of required courses before graduation. The goal in gaining the perspectives of various points along their undergraduate experience was to capture the development of engineering identity, the range of learning environments used by the group, as well as successful patterns for students' with similar academic and demographic profiles. To recruit participants, I used my established relationship with the administrative deans in both the Office of Student Development and Office of Academic Affairs at Rutgers School of Engineering. These two offices handle a majority of the academic advising and professional development for the School of Engineering. Recommendations from academic deans in both of these offices were accepted for a diverse pool of students that fit the research criteria. In addition, the snowball sample technique was utilized to ensure adequate student participation.

I contacted 12 students before each of the four focus groups to request their participation in the study. Each focus group consisted of 4-6 students. Prior to reaching out to participants I crosschecked each student who was referred with a student list provided by the Administrative Engineering Deans to confirm engineering attendance and profile requirements. Each participant was be asked to complete a variation of the Academic Pathways of People Learning Engineering Survey (APPLES) and an IRB approved informed consent form prior to participation in the focus group (Appendix A: Apples Survey Design). Each videotaped focus group ranged from 45 minutes to 1.5 hours. After the collection of the five focus groups, I, the researcher, got the sense that the data was being saturated with consistent information from student participants. Therefore, as opposed to conducting additional focus group data, the protocol was minimally altered to conduct four interviews. The twenty focus group/interview participants are coded below:

Table 1: List of participants and focus groups

Data	Participants
Focus Group 1	WB, CA, AF, SR, & FR
Focus Group 2	BS, OJ, & AP
Focus Group 3	C1, C2, C3, & C4
Focus Group 4	RL, KM, & GR
Interview 1	I1
Interview 2	I2
Interview 3	I3
Interview 4	I4
Interview 5	I5

All students who were not able to participate in a focus group or interview were asked to complete the APPLE Survey. Fifty-nine students voluntarily participated in this data collection. Twenty of these students participated in both the focus group and survey, 39 only participated in the survey only (See table 2). The participants represent 23% of the available population for this study (260 total students).

Table 2: Number of participants in focus group and survey data collection.

Focus Group & Survey	**Survey Only**	**Total Participants**
20	39	59

2. Role of Researcher

As a graduate of the Rutgers engineering program, I have a strong interest in the subject area. I have relied on my ability to draw upon personal experiences as another analysis strategy for the study (Corbin & Strauss 2008). This analytical strategy involves drawing on those experiences to obtain insight to what participants are describing (pg. 80). In addition, my own undergraduate experience provides me with first-hand knowledge that allows me to understand the experience of participants. In the focus groups, this has helped to probe participants for descriptive input that hold value to the study. Within the analysis, this additional knowledge helped to uncover the structural differences between learning environments, the components of their engineering identity, and the relationships between them. Currently I am an education professional working for the school of engineering in the Office of Student Services. I have a vested interested in using this study to understand the needs of students, develop resources to enhance their student experience, and connecting them to services that will accommodate their personal, academic, and professional needs.

3. Quantitative Data: Academic Pathways of People Learning Engineering Survey (APPLES)

The Academic Pathways of People Learning Engineering Survey (APPLES) is a research tool developed and used by the National Science Foundation-funded Academic Pathways Study (APS). It is designed to measure engineering students' educational experience, knowledge of the engineering field, and post-graduation plans (Sheppard et. all 2010). The APS research questions by primary area are:

(1) Skills and Knowledge: How do students' engineering skills and knowledge develop and/or change over time?

(2) Identity: How do students come to identify themselves as engineers? How does student appreciation, confidence, and commitment to engineering change as they navigate their education? How does this in turn affect how these students make decisions about further participation in engineering after graduation?

(3) Education: What elements of students' engineering education contribute to changes observed related to skills, knowledge, and identity? What do students find difficult and how do they deal with the difficulties they face?

(4) Workplace: How do students and early career engineers perceive of their engineering future? What skills do early career engineer's needs as they enter the workplace? Where do they obtain these skills? Are there any missing skills?

The survey questions and responses associated to the above research questions can be found in Appendix B. The APPLES survey was administered to 59 students who were also asked to participate in a focus group. All of these students met the profile of the study being Rutgers School of Engineering who had a 2.4 or lower GPA during their freshman or sophomore year and are now in the final requirements of the engineering curriculum and were invited to take the survey even if they could not participate in the focus group.

4.3.1 Data Analysis:

There are 16 multi-item variables in the APPLES instrument. These variables potentially influence students' intentions to major in engineering and eventually, to continue studying or working in an engineering field. Each variable is assigned a Cronbach alpha score, a test of internal consistency of the individual items that comprise each variable. These scores measure the statistical reliability resulting from the similarity of individual item responses and represent the extent to which the items in a scale can be treated as measuring the same construct (such as skills). Generally speaking, Cronbach's alphas of .60 and higher are considered to be an acceptable level of internal consistency, although this threshold is arbitrary and an alpha value of .70 or above is preferable. Details regarding internal variables and internal consistency values (Cronbah Alphas) can be found in Appendix B.

In addition, nine single-item variables were used to describe the student experience and the APPLES demographic items (5) were used to characterize the survey respondents. These variables, descriptions, and rationale are found in Appendix C.

The quantitative data from this survey produced output related to the research question categories identified in Table 3:

Table 3: *APPLES Research Question Categories and Associated Variables*

Research Question Category	APPLES Core Variables
Skills	Confidence in Math and Science Skills
	Confidence in Professional and Interpersonal Skills
	Confidence in Solving Open-Ended Problems
	Perceived Importance of Math and Science Skills
	Perceived Importance of Professional and Interpersonal Skills
Identity	Motivation (Financial)
	Motivation (Parental Influence)
	Motivation (Social Good)
	Motivation (Mentor Influence)
	Extracurricular Fulfillment
	Intrinsic Motivation (Psychological)
	Intrinsic Motivation (Behavioral)
Education	Academic Persistence
	Curriculum Overload
	Financial Difficulties

	Academic Disengagement (Liberal Arts Courses)
	Academic Disengagement (Engineering)
	Frequency of Interaction with Instructors
	Satisfaction with Instructors
	Overall Satisfaction with Collegiate Experience
	Exposure to Project Based Learning Methods (Group & Individual Projects)
Workplace	Professional Persistence
	Knowledge of the Engineering Profession

4. Qualitative Data: Focus Group Interviews

The focus group environment allows participants to express their points of view without pressure to vote, choose, or reach consensus. Students targeted by focus group studies may need to share information and perceptions, and can provide valuable feedback and ideas from the synergy and interaction created within the session. In these sessions, the researcher takes a less directive and dominating role as moderator (when compared to traditional interview), so that attention is shifted from the interviewer to the group respondents (Van Aken, Watford, & Medina-Broja, 1999).

The objective of the focus group interview is to elicit qualitative information from a predetermined limited number of people. Van Aken et al. recommend that the objective is not to reach consensus, solve a problem, or make a decision. Focus groups are particularly appropriate when the goal is to explain how people regard an experience, idea, or event (pg. 335). This type of data collection is intended to be a one-time experience for the participants, who gather to share information in the group setting, after which is disbanded. The role of the moderator is critical to ensure a non-threatening environment that promotes self-disclosure and to assure relatively equal participation from all participants, who are generally strangers. For Krueger (2009), this ideal environment is achieved by three elements: (1) the selection of participants, (2) the nature of questioning, and (3) the establishment of focus group "ground rules". As a research methodology, focus groups often complement quantitative studies. The following describes a list of common characteristics of focus groups according to Krueger (2009):

- Qualitative data is obtained
- Comfortable, interactive, synergistic group discussion and sharing of ideas
- Group size is small enough for all to share insights, but large enough to gain a wide range of views
- The research plan contains focus groups in a series repeated with different people several times (minimum 3)
- Homogeneity within the group
- Group members are typically strangers or not well acquainted
- Roles needed: moderator and recorder
- Question design: The moderator makes questions appear to be spontaneous but in reality, he or she utilizes a carefully developed open-ended questionnaire in which respondents are able to choose the manner in which they respond. This set of questions is arranged in a logical sequence.

Krueger (2009) also describes situations where the use of focus groups is not advisable. (1) When the environment is emotionally charged and more information of any type is likely to intensity the conflict; (2) when statistical projections are needed; and (3) when the researcher cannot ensure the confidentiality of sensitive information.

I collected data on the experiences of engineering students by conducting four focus groups sessions consisting of 4-6 students. Each of these students were screened prior to participation to ensure they met the sample profile for the study. The goal of the focus group was to engage students discussing the informal learning environments that were significant to developing or reinforcing their engineering identity and those environments that have had impact on their retention and performance as engineering students. I asked the following question during a one hour focus group.

Focus Group Questions:

Identity - Possible Selves
1. Describe what it means to be an engineer.
2. How has your definition of what it means to be an engineer changed or stayed the same since you have become a student at Rutgers Engineering?
3. On a scale of one to ten, with ten being a professional engineer, where do you rate yourself? Why?
4. How did you choose your major?
5. After facing academic difficulty freshmen and/or sophomore year, why did you stay in the engineering field?
6. What attracted you to the field of engineering as opposed to other majors?
7. Can you describe the experiences in college that helped you figure out what type of engineering work or graduate study you will pursue after graduation?
8. What do you think will make you a good engineer?
9. What will make you a bad engineer?
Informal Learning Environments – Engineering Discourse
10. What are some of the things students do outside of class to learn how to be engineers?
11. What are the resources and involvements that help you with coursework, leadership, and professional development?
12. How do you generally learn material for classes?
13. Please describe the ways that academic resources were useful to you?
14. What resources did you find most beneficial in your time(s) of academic struggle?
15. Which resources would you have liked access, to that you did not have during your first and second year? Were these available at Rutgers?
16. Please describe the out of class resources and involvements that have not been useful to you.
17. Of all the non-academic communities you participated in (for example, sports, work, fraternities & sororities, church groups, volunteering, etc.), which helped you the most to engage in your engineering education? How did it help you?
Relationship: Identity & Informal Learning Environments
18. Some students report that they discover something about themselves by participating in out of class resources and involvements. Did you discover something about yourself?
19. Who have you turned to for course selection, academic guidance, or help understanding School of Engineering requirements?
20. Please describe the perspectives or realizations you gained about engineering from this guidance? How were they useful to you?

21.	How useful are engineering related jobs to your coursework or future plans? (I.e. Internship, research position, apprenticeship, etc.)?
22.	Did you have a mentor or become a mentor to help someone navigate the engineering program?
23.	What, if anything, did you discover about being an engineer from this relationship?
24.	Without any out-of-class involvement, are the resources offered in your classes enough to be successful in your coursework and future career plans? Why?
25.	Suppose a new student asked what they needed to do outside of class to learn how to be an engineer? How would you respond?

4.4.1 Data Analysis Method (1): Coding

After producing data files of the focus groups and interviews, the data were analyzed using an analytical model for studying the development of learning using videotape data developed by Powell, Francisco & Maher (2003). In this analysis framework, the data are the tapes allowing the researcher to make direct connections between observable behaviors and interpretations. Using their established criteria and particular ways of examining and analyzing video data the researcher was able to yield insights into explicit and implicit meanings of participants in an educational setting. (pg. 413) The analytic phases include the following sequence of seven interacting, non-linear phases:

1. Viewing attentively the video data
2. Describing the video data
3. Identifying critical events
4. Transcribing
5. Coding
6. Constructing storyline
7. Composing narrative

The tool for coding using this model was analytical software, Atlas Ti 7. During coding, I identified learning environments, student perceptions of themselves and these environments, and any captured emotions that exemplify significance or lack thereof. In addition to careful review of the tapes and identifying significant moments, these moments were transcribed and micro-analyzed as described by Strauss & Corbin (1998). This line-by-line coding allowed for categories, their properties, and relationships that take us beyond description (pg. 66).

Deductive coding is the process of coding qualitative data in which you start an analysis with codes in mind based on previous research or personal experience. The following deductive coding developed during my pilot study with this target population was used as a starting set of codes to analyze the focus groups. Inductive coding was used during the analysis of the qualitative data to saturate categories identified as well as identify new categories resulting from the collected data. Inductive codes will be described the data analysis portion of the report.

Deductive Codes:

Pro Identity – Learning environment encourages engineering involvement, engagement, and ideals for engineering self.
Con Identity – Learning environment discourages engineering involvement, engagement, and ideals for engineering self.
Significant – Student displays value in the learning environment and articulates evidence that suggest it encourages performance or retention. (Helpful, motivated, encouraged, guided)
Improvements – Students express a need for improvements in learning environments.
Insignificant – Students does not display value in the learning environment and articulates not using it as a performance tools.
Tutoring – one-on-one interaction with a student peer with goals to better grasp classroom content.

Mentoring - relationship in which a more experienced or more knowledgeable person helps a less experienced or less knowledgeable person.
Study-Support Groups – Groups organized by students to support one another in academic courses. This may be groups of students studying similar content or just supportive in study habits.
Organization affiliation – membership within an organization or group that encourages academic performance and engineering retention in its campus efforts.
Living Learning Communities – Residence halls devoted to engineering support and services. Students enroll in at least one common course.
Structured Study Group – study groups organized by instructional support program or departments to foster peer studying and support in a particular course of study.
Office Hours – individual or group subject review hosted by the course instructor or teaching assistant.
Academic Counseling – a student/staff relationship where a counselor (educator) works to provide academic, career, university access, and personal/social competencies. (Office of Student Development & Administrative Deans)
Departmental Guidance – Support provided to students from the department in their discipline of engineering.
Instructional Support Program – University unit with a mission of supporting engineering student academics. (Equal Opportunity Fund, Summer Bridge programs, Minority Engineering Programs, college preparatory programs)
Teaching Assistants – one-on-one time working with graduate students who are not instructors, but assistants for the professor. (These graduate students are typically recitation instructors.)
Apprenticeship Roles – internships, cooperative activities, research, or class projects that provide hands on exposure to engineering disciplines.
Site Tours – A brief tour of a company or institution that provides exposure to engineering activities and concept application experiences.
Career Development - Professional development services to help land full time, part time, cooperative learning and research opportunities. (Career services, resume building, business etiquette workshops)
Religion – religious rituals or involvements that reflect motivation for engineering regime.

Online Academic Resources – Resources available/utilized for academic support online. (Facebook, Sakai, Department Website, etc.)
Learning Environments – General reference to out of class learning environments.
Networking – Engineering related interactions outside of class or online with peers or engineering community to support learning or decision-making. (Excluded academic counselors and administrators) Not necessarily a support group because it may be a onetime encounter.

4.4.2 Inter-Coder Reliability – Percentage Agreement

The goal of this qualitative analysis is to identify and record objective characteristics of student experiences. Therefore, establishing reliability in the codes is vital. Using percentage agreement (also called simple agreement or crude agreement), I assessed the inter-coder reliability of the codes by having two coders categorize segments of video and/or transcripts. The goal in comparing the categorizations was to calculate a numerical index that describes the extent of agreement between coders. This index reflects a percentage of all coding decisions made by the pair of coders on which they agree. Percentage agreement takes values of .00 (no agreement) to 1.00 (perfect agreement). (Lombard et. al 2003). An acceptable level of reliability for the index was .70 and higher. After a brief training period and joint coding of 15 video segments, we achieved a coefficient of 0.81.

4.4.3 Data Analysis Method (2): Environment Relationships

This second phase of analysis involves taking the coding from the focus group and developing relationships among them. I used microanalysis to determine the relationship (or lack thereof) that exists between engineering learning environments and participants. Microanalysis is a method of analyzing focus group data by delineating which participants respond to each question, the order of responses, and the nature of the responses as well as the nonverbal communication used by each of the participants (Corbin & Strauss 2008). The first relationship sought is the relationship between learning environments and different populations of students. Corbin & Strauss (2008) call this type of analysis *Constant Comparisons* (p. 73). Using the method of comparisons sought to uncover any differences that exist in the population of students that utilize the varied types of learning environments. The structural components and attributes of the learning environment that students articulated were captured.

When analyzing the data, I noted the learning environments that students found significant to their performance and retention. Data microanalysis was used to identify these environments which required looking for the words and emotions that were expressed by participants. This is another analysis strategy identified by Corbin & Strauss (2008). According to the authors, "situations or events that are significant enough to be mentioned in an interview may provoke a range of emotions in participants…" (pg. 82). Within the data, I sought the descriptive language associated to the informal learning environments that suggest participants gain knowledge from the experience.

The focus group protocol asked students to articulate their experiences and their perceptions of the learning environments that help them perform well in engineering. The level of significance that the learning environment had on their engineering experience were based on their *naturalistic generalizations*. These were understandings that occur because of participants' interaction with the environments (Strauss & Corbin 1998, pg. 85). This study sought to understand their perceptions, how they developed, and whether these environments have positive or negative perceptions contribute to performance and retention. Potentially these constructed perceptions of the learning environments show patterns amongst the engineering students and help explain which environments are most effective. I also sought to understand if students' level of engineering identity had any correlation to the environments they chose to use (Lee & Andersen, pg. 196). The expectation was that these patterns would emerge within groups of students that share a commonality: such as, ethnic/racial group, socioeconomic status, performance levels, and/or engineering discipline.

5. Summary

The goal of this research is to investigate the development of engineering identity cultivated through engagement in informal learning experiences. Thus far, I have provided a framework for investigating the various factors that contribute to the success of low performing engineering students. The research categories for the collected data are (1) Informal learning Environments, (2) Engineering Identity, (3) Academic Performance, and (4) Retention. The tools that were used to investigate these categories include peer focus groups and the Academic Pathways of People Learning Engineering Survey (APPLES). The following table (Table 4) shows the data collection items that associate to the research categories being investigated:

Table 4: *Research question categories and associated data collection tools*

Research Category	**Data Collection Tool**	**APPLES Category/ Focus Group Question**
Informal Learning Environments	Focus Group	Focus Group Questions 4-17
Engineering Identity	APPLES Survey Focus Group	Identity Focus Group Questions 1-3
Academic Performance	APPLES Survey	Skills & Education
Retention	APPLES Survey	Education & Workplace

Prior research on existing engineering programs and activities offer models that show positive connection between the out-of-class commitments of students and their ability to identify with the engineering field. As mentioned during the literature review of this study, some of these out-of-class commitments include summer bridge engineering programs, internship, coop, tutoring, study groups, and mentoring. This study offers the opportunity to provide evidence of this relationship at Rutgers University as well as performance and retention implications for the low-performing engineering population.

.

V. Data Analysis & Results

The purpose of this mixed-methods grounded theory study is to examine the extent that participating in informal learning environments impact the development of engineering identity, as well as persistence and performance for generally admitted students who held GPAs of 2.4 or lower in their first or second year of undergraduate study. To determine the out of class experiences associated with these research categories I used both the APPLES survey and focus groups. Using these tools I was able to capture many aspects of the student educational experience outside-the-classroom. In this section of the study I present detail on the participants of the study as well as the captured data.

Presentation of Descriptive Characteristics of Respondents

I conducted the focus groups for this study during the 2013-2014 academic school year. In all, 59 students voluntarily participated in this data collection: male (32), female (26); American Indian (3), Asian (22), African American/Black (14), Hispanic (10), White (20); first generation (17), non-first generation (42); on-campus housing (42), off-campus housing (17). I had representation from 9 engineering majors: Bioenvironmental (1), Biomedical, (6), Chemical & Biochemical (11), Civil & Environmental (11), Electrical & Computer (8), Industrial & Systems (5), Material Science & Engineering (2), Mechanical & Aerospace (13), and Packaging (2). Of the 59 participants, 20 of these students participated in both the focus group and survey. More detailed description of the focus group participants is listed below in Table 5.

Table 5. Focus Group Participant Identifying Information

Participant	Major(s)	Graduation Year	GPA	Gender	Race	Session
WB	Electrical & Computer	May 2014	3.202	Male	White	1
CA	Mechanical & Aerospace Engineering	May 2014	3.254	Female	Hispanic/Latino	1
AF	Applied Science Engineering	May 2014	2.568	Female	Hispanic/Latino	1
SR	Electrical & Computer Engineering	May 2014	2.738	Female	Hispanic/Latino	1
FR	Civil & Environmental Engineering	May 2014	2.532	Male	White	1
BS	Chemical & Biochemical Engineering	May 2015	2.188	Male	White	2
OJ	Mechanical & Aerospace Engineering	January 2016	2.909	Male	Black/African American	2
AP	Electrical & Computer Engineering	May 2014	2.803	Male	Black/African American	2
C1	Industrial Engineering	January 2016	2.528	Female	Two or More	3
C2	Biomedical Engineering	May 2015	2.585	Male	White	3
C3	Chemical & Biochemical Engineering	October 2016	2.787	Female	Black/African American	3
C4	Biomedical Engineering	May 2015	2.585	Male	White	3
I1	Industrial Engineering	October 2015	2.039	Male	Asian	4
RL	Electrical & Computer Engineering	May 2016	2.320	Male	Black/African American	5
KM	Mechanical & Aerospace Engineering	January 2015	2.745	Male	Asian	5
GR	Civil & Environmental Engineering	May 2014	2.868	Female	Asian	5
I2	Mechanical & Aerospace Engineering	May 2015	2.592	Female	Black/African American	6
I3	Civil & Environmental Engineering	May 2015	2.699	Male	White	7
I4	Biomedical Engineering/ Anthropology	May 2015	2.742	Female	Black/African American	8
I5	Industrial Engineering	May 2015	2.942	Female	Hispanic/Latino	9

Research Questions

Participants in the APPLES survey and focus group were introduced to the purpose of the study. Following this introduction, they were then asked to provide responses to questions in their respective formats. These response provided guidance on the following research questions.

Research Question: To what extent does participating in informal learning environments impact the development of engineering identity, as well as persistence and performance for generally admitted students' who held GPAs of 2.4 or lower in their first or second year of undergraduate study?

Essential Questions: (1) What informal learning environments do engineering students use? (2) How does discourse in these informal learning environments impact the identity of engineering students? (3) How do these informal learning environments impact performance? (4) How do these factors impact student retention?

Analysis of Data

Two sets of procedures were used to analyze the data. The first set entailed inductive analyses of 9 focus groups/interviews which were in video data format. The second set of procedures was deductive and included statistical analysis of the data obtained by the APPLES survey. First, I present the categories of learning environments uncovered by the focus groups and relevant quotes from participants.

1. **Qualitative Data: Uncovering The Informal Learning Environments**

In this portion of the data analysis I describe the out of class environments that participants uncovered during their discussions in focus groups. When asked about learning environments that were experienced in their engineering college experience, student responses fell into four categories. These categories were *Peer Learning Environments*, *School of Engineering Hosted Environments*, External *Learning Environments*, and *Online Environments*. These themes emerged as the significant learning environments that had impact on the performance/skills needed to be a successful engineering student after facing points of difficulty in the curriculum.

Peer Learning Environments

Peer Study-Support Groups

Study groups were shown to be used by a majority of participants to gain a better understanding of engineering content and supplement the learning environments offered by professors (i.e. lectures & office hours). Participants saw value in study groups since peers are easily accessible and have different understandings of course content. Participant C1, C3, and C4 discuss their balance between studying alone and with study groups, they state,

> "C1: I just have a hard time getting to actual study groups and stuff. I remember when I was taking physics 2 and you could sign up for a mandatory study group. So we had to go and that helped me because I treated it like another class and could go over the things I didn't understand from class.
>
> C4: Yeah even informally, those are helpful. Talking to my friends in class is probably my most helpful out of classroom academic resource. Having two/three buddies in class that know what's going on is always super helpful.
>
> C3: That is why I prefer study groups to tutoring, because you have those people in your class who can get things that you may not get. I mean your tutor is not in your class so they don't necessarily know what your reviewing, what the professor said that you may have missed. So yeah, it's good to have those people from your class.

Students agreed that study groups provided an effective use of time and allowed peers to provide mutual contributions by sharing their methods of understanding. Students also saw value in working with peers to re-explain information they had studied. It reinforced their understanding and made it easier to apply. Participant AP discussed this in his statement,

> "AP: A resource that I tend to use often now that would have been really valuable to have freshmen year was 'people'. Having people to work with, people to discuss stuff with, people to study with. That took time because I didn't know anybody and I had to meet people to make me feel comfortable to work with. But yeah, I wish I could have come in and just had a group to study with from the start. …But I never meet up with a group unless I have prior knowledge. If I do that, it is just going to be a waste of time. Sometimes group members do not know what they are talking about and you just cannot up and believe everything that your peers say. The whole purpose of working in-group is to teach somebody and question others, and have people question you until you really understand what you are learning. "

While the design of the curriculum for engineering is competition-based, participants have an understanding that in order to make it through the engineering requirements they need to support one another through collaboration and not competition. As a result, participants discussed making great use of these academic support groups. Participant BS states,

> "BS: In organization that I'm in they have something called Achievers Plus where the older students go and study with the younger kids. And like, I think it's just its great that they offer the time for kids to come together and study. But getting together with people in my classes has been helpful for as long as I can remember. I remember freshman year the entire floor (Barr Hall – Engineering Dorm) would be out in the lounge working. We all had the same problems because we were all in the same classes. It's helpful using other people as a resource to learn certain things. "

Mentorship

Many students have peer and alumni mentors within the school of engineering. When asked about these mentors 71.1% mentioned that they were encouraged and/or inspired by them to study engineering. In addition to receiving guidance from mentors 62.6% of the participants frequently interacted with a faculty or academic advisor who they also encouraged and/or inspired them to study engineering. All participants expressed being involved in these relationships as the mentor and/or the mentee. They were found significant to encouraging student's performance, motivating students to pursue, and stay retained in the discipline. Even students with confidence in their ability felt the impact of mentorships. Participant FR states,

> "FR: Freshman year when I came in, I knew I could do engineering, but I was undecided on which branch I wanted to go into. But going to club meetings and interacting with upper classmen is what helped me decide. Being around those guys is what made me ultimately stay civil [engineering]."

Student saw value in the experiences of older classmen and looked to their guidance to understand how to prepare for courses and which courses to take. This was found impactful all the way through the engineering curriculum, freshmen thru senior year. Participant WB states,

> "Just having someone above you that has taken that course before you and saying, 'okay for the first exam this is exactly what you need to do and this is the cutoff here and don't worry too much about the first exam, you can pick yourself up' - so having someone older than me that has taken the courses in the program - I don't care who it is - just having someone basically shed a light on the course that I have had problems in has been a great help to me. Especially at the end, not really the beginning; towards my senior and junior year."

As a mentor students discussed how they were able to work with younger students from similar backgrounds to help them stay motivated in their difficult discipline. Participant C3 states,

> "I would call them my "mentees" but a lot of the minority/black engineers really look up to me. I have conversations and the come to me or advice. Sometimes you just have to give them the encouragement. I know it's hard. I know that teacher if rough. But you will be alright. I was there and made it this far so you can do that same..."

Through the focus group the investigator was able to uncover how students established these mentorship relationships. The majority of the participants mentioned student organizations as the initiator of the mentorship relationships. Participant FR discusses his interactions with his mentor freshmen year. They were pair up through the American Society of Civil Engineers (ASCE). He states,

> "FR: I feel like being a part of these organizations helped me communications-wise. Besides meeting your classmates outside the classroom your also get to meet upper and lower classmen to share experiences with what they've gone through. Advice on taking the FE exam or what to expect in the curriculum, trying to find job opportunities, figuring out what you plan on doing, what's everyday life going to be like after graduation. You get a wide range of students in the organizations. And for me it really helped me out freshmen year to be involved and learn off the upper classmen. Socializing within your branch of engineering really helps your engineering experience...And [Isaac] was my big brother coming into college so - I mean like I said I did a lot of things alone but that was after talking to [Isaac] and saying, 'what do you think about this'...And then I would go back to my room and I would study but it was after I asked the questions. And I think some students are afraid to reach out and ask questions."

Students saw values in a readily available resource that was knowledgeable about their chosen path. Participants agreed that all populations of students including undergraduate, transfers, and nontraditional students benefit from mentoring relationships. Participant AP states,

> "So that's why when I see transfer students or even underclassman, I tell them 'yo, if you need help scheduling, let me know'. Like this one girl, [Amanda] I kind rearranged her schedule a little bit, it was able to free up some time and have her still graduate on time. She has the semester off, doing an internship with NASA right now. My little brother, just squished the classes together a little bit and he's graduating in two years with a mechanical engineering degree. I mean I wish everyone knew it and that's why I'm adamant in telling people, 'yo - you know you can squeeze things together and having free time to do other things'. It's not just free time, you can pick up a co-op, you can pick up grad classes - you can do so much so get your bang for your buck. If you're going to pay for the whole semester, you may as well take some more classes"

While everyone did not have mentors for professional reasons, many students agree that this would have been an useful resource early on to know what they are aspiring towards and creating plans to achieve those professional goals. Participant CA states,

> "I would have liked to have an industry mentor. If you are assigned and you have that relationship with someone, you can get a lot out of it. Motivation from them seeing where they are or inspired to be where they are. Over the four years, you could have career advice and guidance on what to do along the way to ease your academic and professional experience. That would have helped. I did this by trying to network over time, but would have been nice to have something official."

The most influential relationships were those formed at the University, but some individuals found mentors in siblings and individuals outside of engineering. Participant I5 states,

> “I think my biggest mentor is my bother. He is one of those guys that were in my place and he motivates me. He knows how to motivate me. So he’s been through this struggle, and he is still jumping through hoops. He works for Verizon and government contacts, but everything he does has to be one point. So he’s big on making sure everything is done and done well. Making use of resources and networks. He pushes me to do that.

Participants went as far as to say that a peer-mentoring program mandated by the school of engineering for all students would go a long way to ensure students have the support and guidance needed in their curriculum. Participant C2 states,

> “A peer mentoring program at this school would definitely make a world a difference. And it would have to be a mentoring program where the upperclassmen are obligated - I mean they are always busy but like give benefits. For instance, like Starbucks - get a free coffee for you and your mentee if you come and do it. Because it’s like, yeah I said I would mentor you but then I get caught up in Senior Design and it’s just like, yo I don’t really have time to mentor you. So give like a couple of benefits for students having a mentor/mentee relationship.”

These data suggest that it is important to connect this population to an individual to help them make personal, academic, and professional decisions along their engineering journey. While students report this learning relationship between mentors and mentees as highly impactful on the engineering experience, many of them mention the need for it to be formalized from the school of engineering or discipline departments.

Tutoring

Tutoring was identified as an important learning environment to support learning and classroom performance. Peer tutoring is offered at a variety of locations around the campus for a variety of courses. Not all of the participants take advantage of tutoring services, but they all agree that tutoring is a viable service that supports students with academic difficulties. Participant I3 states,

> "Um, there's actually - I haven't taken advantage of it in a while but the OSD contacted me and I'm registered as one of the tutors. I have not been assigned anyone but my brother is tutoring three or four people...And then there's the MSLC - I send my residents to them sometimes and then yeah just knowing upperclassmen sometimes they pair people up. Like I generally do that with my underclassmen."

Participants agreed that freshman should strongly consider utilizing tutoring services especially if they are under prepared for the courses that they enter. Participant AP discusses some of the locations around campus to find these tutoring services,

> "I agree with you [OJ], learning center and office hours. I use to put those in my schedule just like my class schedule. Also, OSS tutoring, the one on one tutoring really helped me a lot. If it wasn't for that I don't think I would have been able to get through my first electrical engineering courses, or I would have had a lot more stress. Because study groups wasn't my thing I didn't know people and I wasn't' really into the student organization at first. So I had to go out of my way in class to talk to people, take initiative just to get them to work with me. But the one on one tutoring was assigned and it was perfect for me. It was like an hour of nothing but learning. I came prepared with questions and read the book to understand. It was constant learning. Sometimes instead of going to lecture I would just study myself and go to tutoring."

Student expressed difficulty with tutoring in that it has its limitations. The first limitation is that tutoring is not always offered for the engineering version of the fundamental courses (i.e. calculus, chemistry, physics, etc.). Therefore, tutors for the general courses are unfamiliar with some of the additional topics and applications of the student assignments. Also, there are limitations in the available tutoring areas. Participant I2 states, "I used tutoring freshman year. But I found - like I don't know. Like when you get higher they didn't have many tutors. Like more for the first two years."

For some of these same reasons certain participants did not see value in the tutoring services available through particular learning centers. Participant WB states,

> “When I was a freshman they told us about arcs studying. It was tutoring. I felt it was the worse place in the world to go for help. I do not know about you guys. When I was in freshmen year they always told us to go to tutoring in ARC and those guys just didn’t really help at all. I thought office hours were better. I went a couple of times and those kids didn’t really help.”

The preferred learning environment was office hours as opposed to tutoring because of the level of support they could provide for engineering students.

Living-Learning Communities

During the freshmen year of college students have the option of living in residence halls dedicated to engineering students. These students have access to their peers, organized study groups, tutoring sessions, and computer lab tailored to the needs of first year students. Our participants who lived in these communities their freshmen year found them significant to their performance in the engineering curriculum their first year. Participant I5 states,

> ““‘…having the RA that was in engineering really made a difference and to be able to live amongst a group of engineers put me a step ahead of people that didn’t leave in a Barr Hall at different universities. I feel like that was a unique quality that Rutgers possessed that not that many schools try to do. That changed the whole game for me to be able to walk out into the floor and be like, ‘I do not get this’ and someone would be like ‘I don’t get it either’. And to be able to meet in the common room and hash it out. Having that was a huge resource.”

According to this student the level of support experienced by having an engineering RA and peers to rely on for academic questions was significant. In fact one student attributed their retention in engineering to the engineering residence hall. Participant C1 states, “If I didn’t live in Barr I probably wouldn’t be an engineer right now”.

Participants who lived in the engineering dorms available on campus were asked about the component of this community that made it beneficial as opposed to living in other residence halls. They attributed the impact of this learning environment to the collaborative learning with peers from the same academic interest. Participant GR states,

> "Yeah, we'd be taking the same classes so we'd all be doing the same homework at the same time. We'd all be struggling together, we'd all figure out problems together. You'd be working as a team but you didn't realize it until looking back - like yeah we solved that problem together - that's really awesome."

Students were able to develop study group, mentors, and participate in workshops and programs to provide the learning experiences that contributed to their performance and retention in engineering.

Organization Affiliation

Students made many references to organizations they were affiliated with and the impact they had on their academics and establishing their place at the university. 86.4% of students were involved in engineering clubs and societies. Figure 2 below details the level of involvement from all study participants, most having some student organization participation.

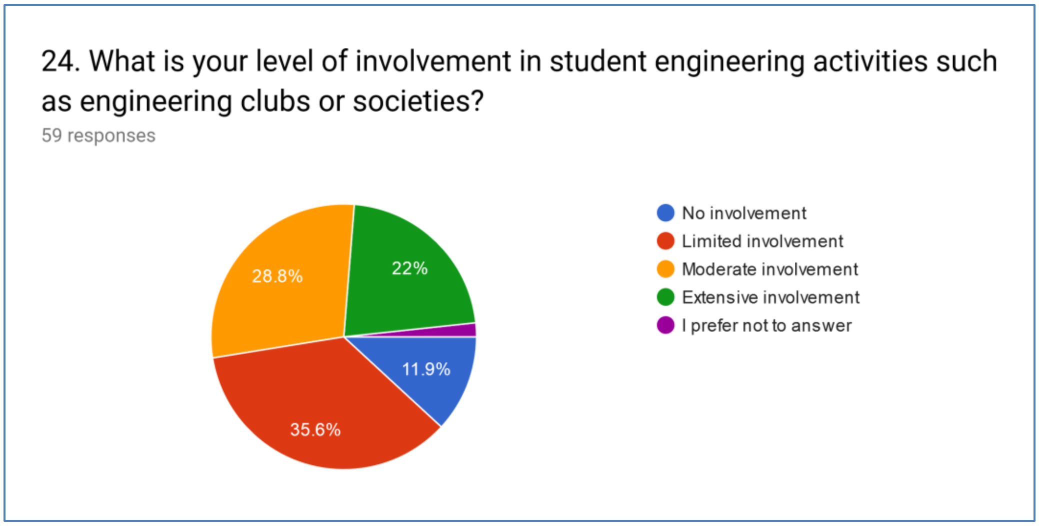

Figure 2: Student Organization Involvement

Participants from underrepresented groups placed a lot of emphasis on being involved in student organizations with other students that look like them and/or come from similar backgrounds. Models used by the Office of Student Services focus on developing a network and support for underrepresented groups including minority, women, low income, and first generation students in college. Participant C3 emphasizes that,

> "…organizations like MEET [Minority Engineering Educational Task], SHE [Society of Hispanic Engineers], and SWE [Society of Women in Engineering] are really good for networking and interacting with people who are going through things just like you."

Participants discussed the beneficial aspects of these organizations starting from the initial meetings where they are introduced to the organization. Participant I2 discusses how initial interactions help mold his understanding of engineering at the university. He states,

> "It would have to go back to my freshman year - the MEET program. At the Academic Institute. I came in thinking I was a hot shot - a 3.8 GPA, smart - and I'm thinking this engineering this is going to be a cake walk, just an extension of high school. And just hearing some of the stories from the people that have walked the ropes before me, it kinda just started to give me a new vision on how to look at things and attacking problems from their past experiences. So I guess for me that was the first transition in becoming an engineer."

Once in the academic year, student discussed the services that the organization provided to support personal, academic and professional development. Participants GR and FR discuss these services and the impact that they have had on her personal development,

> GR: “Well in my organization [Society of Women Engineers] we have personal development, professional development, and then fun stuff just to de-stress. So I find that from that from when I was younger I have changed - I’m more of a leader, I know what I want, I’m more confident so....”
>
> FR: “I feel like being a part of these organizations helped me communications-wise. Besides meeting your classmates outside the classroom your also get to meet upper and lower classmen to share experiences with what they’ve gone through. Advice on taking the FE exam or what to expect in the curriculum, trying to find job opportunities, figuring out what you plan on doing, what’s everyday life going to be like after graduation. You get a wide range of students in the organizations. And for me it really helped me out freshmen year to be involved and learn off the upper classmen. Socializing within your branch of engineering really helps your engineering experience….Freshman year when I came in, I knew I could do engineering, but I was undecided on which branch I wanted to go into. But going to club meetings and interacting with upper classmen is what helped me decide. Being around those guys is what made me ultimately stay civil [engineering].”

All students who participated in the focus group found their involvements in one or more organizations significant to their progress as engineers. These involvements were agreed to have supported their academics while in undergrad and created the networks for them to be reach the next level of their lives as well, whether it entails higher education or careers. Participant RL pins these organization involvements as the most important learning environment. He states,

> “For me, the single most important thing would be MEET [Minority Engineering Educational Task]. Starting freshmen year getting help with my classes and now going to things like the professional conferences has been helpful. Going to conference and just being able to talk to people has been a huge change. From freshman year I used to be shaking in my boots when I talk to people. Now I can present or talk to employers like it’s a normal conversation. Having people around to always support me and showing me what to do to improve as an engineer has been important.”

Peer Networking

Students attribute performance and retention in engineering to their ability to network with peers. Networking does not necessary have to take place in student organization or through relationships with mentors, but students see value in learning to interact with their engineering peers. Participant I4 discussed this skill of networking and that it is important know how to network with your peers. Participant I4 states “You have to learn how to network and talk to people outside of class and stuff”.

Participants mentioned the need to develop relationships and interact with peers in a way that is mutually beneficial. Participant BS discusses this in the following statement,

> “Going along with that, one thing that I am good at - ‘cuz I can’t think up problems and I can’t process the material...I don’t even know why I’m doing engineering, like what? [Jokes.] Um, but what I am good is organization and administration and stuff. Making sure that things are done on time. And the guy I study with, he at the other end of the spectrum. He picks things up in class but he’s completely disorganized. He’s going for his Ph.D. He’s one of those students, just kind of out of it. And I felt kinda guilty at first because he was always helping me, but then turning it around he’s taking a class that I already took and he was like, ‘yeah I wish you were in this class with me because then I’d be doing the homework and doing the assignments earlier and like actually doing it on time’. So I guess it’s a give and take.”

Overall students agreed that to be successful in engineering, most students needed to be active participants of social networks in their engineering discipline. This involves being involved in clubs and organizations, communicating with both upperclassmen and freshmen, and developing access to the resources peers can offer to ease the curriculum.

School of Engineering Hosted Learning Environments

Office Hours

Outside of class the only learning environment that students discussed that was supported by faculty was their office hours. This learning environment was agreed to highly impact student's performance in course work. Participant C2 discusses how this learning environment helps to reinforce what isn't learned in the classroom,

> "There is a lot that you learn in office hours that you don't learn in class. There is a lot that is explained better in office hours that you don't get in class. I have professors that, like, really do not explain fully until you get them in an office hours type of setting. So you can go to office hours and get that one on one or one on three and really sit there and get the explanation until you understand, hopefully."

Every student who participated in the study agreed that office hours are a learning environment that should be utilized by all engineering students who have trouble with material, especially freshmen students. Emphasis was placed on freshmen since many of them have not yet established their social networks and learning patterns. Students even offered rituals regarding how to use office hours they have found to be effective. Participant SR states,

> "I think if you read the book, pay attention in class, and go to the professor's office hours that you'll be more than prepared for anything that the class has - do the homework. Things like that...If it is a bigger class with like 200 people, definitely office hours. If there are only 20 people in a class they are usually more interactive, but I still go to office hours if I don't understand, just to make it a part of my schedule."

In this case participants in the focus group felt the learning environments offered by the professor (i.e. instruction and office hours) would be enough for certain populations of students if utilized in the right ways.

Participants also discussed difficulty utilizing this learning environment. While it would be great if all students had access to one on one questioning with the professor, the reality is there is not enough time in a day to give all students the individualized attention they need. Some participants offered recommendations in this area. Participant I4 states, “I feel for the professors though. They can’t teach all these kids. Some kids learn faster and stuff. I don’t really care, you just have to catch them at a good time. Like before the exams”. Here the participant suggests that while difficult, it is possible to gain the assistance if you are strategic and contact professor at good times.

The lack of one on one attention during office hours at the University may deter some populations of students from utilizing them. When asked if office hours and instruction were enough to do well in engineering, Participant C1 expressed not being shown enough attention in office hours in the following response,

> “No [all agree]. Those office hours aint nothing. Especially when have like 6 people on your back. I’m just one of those people. I don’t want you helping me and somebody else. That’s why I came here. That’s why I spend my time here. Because I want you to help me right now.”

Teaching Assistants

Students also identified one on one time with teaching assistants (TAs) as a viable resource for academic content. Unlike office hours with the professor, these students usually do not assign grades or teach the courses, but are fluent in the material to assist the students. Students suggest that they are less intimidated to work with TAs since they are more of a peer and have less impact on their overall grade. Participant I5 states,

> “I always find myself to do well in a class that has a TA because...I don’t know. For some reason, it seems always like you put the professor on this pedestal but the TA - I can ask them any question and not feel like it’s bad because we’re kinda like peers because they’re

> not a professor yet and they're a just a couple of years older than you. I'm not - um afraid to ask them questions that I wouldn't ask the professor."

Departmental Guidance

A few students were able to convey the importance of receiving academic support from the department staff outside of the classroom to assist them with requirements and guidance. The department personnel are most knowledgeable about the curriculum for students in their discipline. Participant CA was able to discuss how even the secretaries in these departments can be an important resource for academic guidance. She states,

> "Because the way I had to look at it was with [Allie] - who's amazing. She was the secretary of ME but now she's the secretary for the graduate director. But she knew the requirements like the back of her hand and knew how to do things like squeeze in grad classes - you could do that. Learning from her - yes everything is posted on the website but it's hard to navigate, especially for transfer students because if you don't take DMC which is a pre-req. for DMS which is a co-req. for senior design. And if they don't take DMC because they think it's just a junior course but really you can push off CADD and take DMC because if you don't take DMC you can't take DMS...and then you're trapped for another year because DMC is only offered in the fall."

For the identified engineering department students have a useful resource for curriculum guidance from direct sources in the department. Contrarily, students were not hesitant to mention their resistance to interact with the engineering departments because the departments tend to be a little more strict as spoken by Participant CA. Participants were able to identify improvements that could be made to the guidance offered by the engineering departments to better impact their learning. Participant OJ states,

> "I'm part of the Mechanical Engineering Advisory Board and I'm a representative in my class. Um, and we meet up like once a month to discuss things going on in the department. Like one thing they are trying to fix is, uh in mechanical engineering, students are assigned professors as advisors but when you go in the professors don't know the curriculum so it's basically useless. So they are trying to fix that and require the faculty to know the requirements."

Students appear to seek better guidance from the departments in their discipline and obtain more information than the guidance that is provided through the student handbook. By better preparing faculty on all engineering requirements students feel they can be more of a resource.

Academic Counseling

The majority of participants found that meetings with academic counselors and administrative deans are major factors in assisting engineering students to navigate the curriculum. Starting at the K-12 level students recalled important conversations with teachers and guidance counselors that drew connections between their academic performance and raised engineering as a career option. Participant C3 stated,

> "…I kind of remember someone in my family getting sick and I was like "Oh No, I wish there was a cure for that". So then I was like, okay, I want to do pharmaceutical stuff. And I use to tell my teachers, and then my parents use to be like "well you are always fixing everything in the house, you should be an engineer, you should go to school for engineering". Since you like to take things apart and put it back together. I was like "hey I never thought of that". So I told my teacher and she kind of blended the two ideas, and that's how I became a chemical engineer."

Once in the University settings most participants spoke about using academic counselors to help determine the services they should utilize in order to do well academically. Some of these services include those organized by both the engineering deans offices or uniform services offered at the university. Participant AF also stated, "I tell Dean Laffey I need help in a class and she has other people emailing her with the same concerns and she somehow groups us all together in small study groups".

Student overwhelmingly felt that the academic counselors and deans are their strongest resource for course selection and understanding their curriculum requirements. Students suggested that it is beneficial to routinely arrange time with engineering deans to keep track of courses taken, map out plans for courses, and draw connections between involvements and intermediate/long term goals (i.e., apprenticeship roles, full time job, and research). Participant I4 stated,

> "Definitely sit down with your dean freshman year. That's something I did that I was happy about. I actually mapped out my plan going through school, the classes I wanted to take. Um, getting acclimated to school - not taking to many hard courses at once..."

Students also discussed the connection that they felt to the academic counselors they worked with. Participants mentioned their ability to relate to academic advisors because of their familiarity with the courses, some of the staff members were students at the university and recently graduated, and overall most participants enjoyed working with advisors that were personable and able to assist in their personal endeavors. Participant I2 discusses a comparison between advising offices outside of the engineering school and his current advisor,

> "…I say that Rutgers Engineering is ahead of other schools in that sense because I uh worked for the Upward Bound program one summer and I tell 'em, 'I just popped in Dean's office and tell him one query with one professor or I might tell him a foreseen problem in the future that I didn't really know and turbulent weather or seas. And just like [Dylan] said that you can have that relationship. And most schools, they're like 'you can do that' and I'm like 'yeah, I go in and see him' and they're like 'our deans don't really do that'. He told me like what to do, who to see - that type of thing. I feel like [Rutgers] Engineering has a foot over other universities when it comes to that."

Participants also suggest that these academic counseling sessions may not necessarily need to come from higher authority at the university. Some students articulated having similar interactions with their peers to help understand the curriculum and how they can organize their schedules, but while highly useful, peer support isn't universal or systematic. Participant I1 discusses their interaction with a younger students who they helped understand the engineering curriculum to suit their needs,

> "Would he have known you can mix and match the curriculum so you can graduate in three years? Would he have known that if I hadn't pointed it out? Something like that - having upperclassmen is a huge, huge benefit. And I feel like a lot of my peers didn't have that."

Therefore, students discuss academic counseling coming from faculty, deans as well as other students. One participant discusses how the nature of the support provided by staff members and students is different. Participant I2 states,

> "Students can give you a raw and cut version of what engineering really is - the nitty gritty. Like if you took a senior student and paired him up with a few freshman and you just reflect back on the do's and don'ts. I think that would be very fruitful for the incoming students. But also - just the administration it's their job to put us in a direction where we could succeed so we should have access and one-on-one contact with them."

This was one of many students who saw value in academic guidance from those still going through the engineering curriculum. Participants also see the value in direction from engineering staff that observe best practices and can present all the available options offered by the institutions due to the rules and regulations of the department.

Most participants discussed academic counseling being significant to their performance and retention in engineering, but some also expressed difficulty obtaining the services because of lack of knowledge or exposure. Participant KM discusses how they initially navigated the engineering mainly from communication with peers,

> "I didn't even know we had it [set curriculum] when I first came. So for the first three years, I've been going off ear like what are you guys taking? Yeah I didn't know there was a set syllabus until I didn't know what to take now and I had to go in search of that information. But it wasn't like here's what you have to take. Maybe that's my own fault? But I just wasn't exposed to it. Like my first two semesters...the first one they picked and the second one I just went completely gung ho."

Some participants that utilized academic counselors discussed their relationships as necessary to fill a void in relationships they do not have. In response to why she considered the academic deans to be mentors Participant I5 states, "[they are] my friends, my parents, they are everything".

Through the focus groups students expressed that the level of academic support is not consistent for all populations of students and depends on the level of involvement a student has with advisors. Some of these counselors are also advisors to student organizations and oversee instructional support programs, which give them more access to certain students than others.

Instructional Support Programs

Support programs exist at the university to increase interest in engineering and support those that enter the field. Participants in the study were able to discuss some of their experiences with these programs and classify them as significant to understanding engineering content. Engineering programs exist from the Kindergarten through post-graduate levels. The two programs that were highlighted by participants during the study were the Governors School of Engineering & Technology and the Educational Opportunity Fund. While these programs service separate populations their ultimate goal is to increase students in the engineering pipeline and service there personal, professional and academic needs along that journey. Participant GR discusses her interaction with the “Governors School” and how it encouraged her engineering experience,

> “Working with governor school and being a project advisor for one of the projects. We did wind funnel technology dealing with wind turn binds and I didn’t know anything about it. I was given a book and I was told figure it out so the students know what they are talking about.

Governor School is an engineering exposure program for juniors in high school around the state of New Jersey. This position encouraged Participant GR to learn new engineering related concepts in a way that he could convey knowledge to others. By doing so, not only did the participant learn the content, but was able to transfer this information to others. In addition, they speak about their interactions with the students to complete the project,

> “Even though I didn’t go fully into the projects - I was able to see how the problems were set up and how the students approached the problems. They approached things from different angles than I would have approached them. I also have more experience than them in certain things and I think in that regard, like just working with the governor’s school and seeing how things were set up, I was able to think them out better.”

By observing engineering activities and projects participants convey being able to gain an understanding of engineering, problem solving and teamwork that can be transferred into the classroom and real world experiences.

Structured Study Groups

Structured study groups are distinguished from regular study groups because engineering staff initiate them. Students recognized this as an important learning environment since all students are not comfortable approaching their peers or asking for help. Participant AF discusses this in the following response regarding the impact of structured study groups,

> "Interviewer: So why are these study groups helpful?
>
> "To make sure you have someone to study with. Sometimes you can't find people. I don't know the people who are taking the classes I'm in. So I tell Dean Laffey I need help in a class and she has other people emailing her with the same concerns and she somehow groups us all together in small study groups."

While all students agree that study groups for important to student performance, they also agree that some students are hesitant to ask for help or initiate study groups. Therefore, this learning environment appears to assist those students in gaining the support they need through alternative methods.

Networking with SOE Faculty/Staff

Students consistently raised networking with faculty and staff a significant interaction. While networking with peers was found important to access resources and knowledge, students found the relationship with staff to be important for building perceptions and displaying work ethic.

Participants communicated that building a relationship with faculty staff gives them potential advantages a benefits which ranged from increased grades to recommendations for engineering related involvements and fulltime job positions. Participant C4 expresses some of these ideas in his statement about office hours,

> "I'm big on office hours. I love going. Not to suck up but like, if a teacher knows you they give recommendations. Even if kids say it sucks I'm there [laughs]. Yea, I'm trying to learn and get a recommendation. I have like 4 teachers to write recommendations right now. That's what they [office hours] are helpful for really getting time with the professor."

From the statement, we see that students see value in relationships for both academic and personal gain.

External Learning Environments

Apprenticeship Roles

Apprenticeships was the research code used to label internships, coops, research and other forms of hands on design projects outside the classroom. These environments were the single most mentioned environment to help students draw connections between their classes and the engineering profession. Fourty-four percent of students were involved in some undergraduate research at the university (Figure 3):

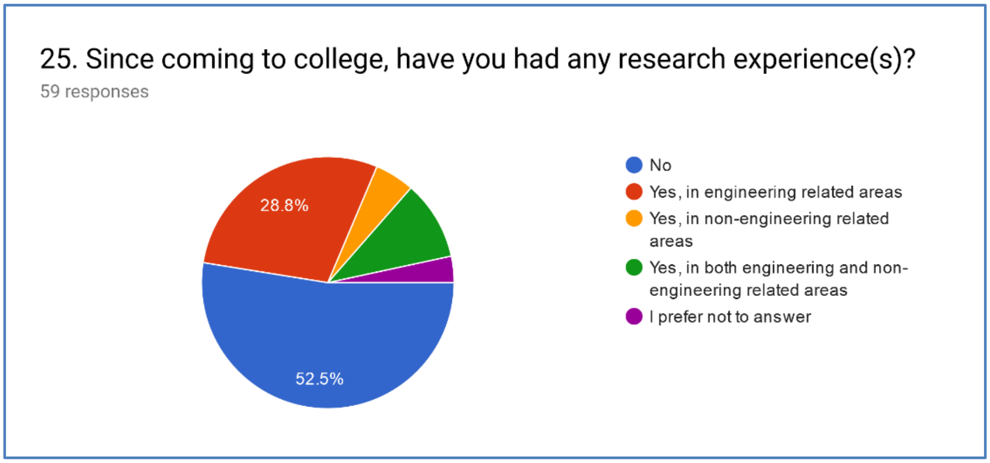

Figure 3: Survey results on research experience.

Over 66% of the students have had some exposure to the professional engineering environment by visiting, interning, or completing a coop at an engineering company, see Figure 4.

Figure 4: Survey results on professional engineering experience.

While these experiences are company-driven, it appears that it would be useful to create pathways to help students obtain professional experiences to increase retention in the engineering disciplines. To obtain these positions usually requires students to either have a strong GPA, leadership experiences, and/or work experience. All of the students in the study have struggled academically at some point in their first two years of engineering. This leaves us to assume that they were able to offset their GPA with leadership and work experience. Providing the development to help students in these areas in addition to academic performance may be instrumental to retaining our at-risk students.

Engineering students in the focus group frequently mentioned hands-on learning environments that occur outside of the classroom, and discussed their significance to understanding how to be an engineer. Apprenticeship roles are the settings where students practice applying engineering concepts to real world experiences. Participant I5 mentions how her current Industrial Engineering curriculum draws connections to these out of class experience through projects. Participant I5 states,

> "For example this semester I'm working with like 3 companies. I'm doing two engineering projects that ask me to do work with companies and do presentations and stuff like that. Which is good because we go for interviews they ask for stuff like that."

This participant articulates a connection between the undergraduate apprenticeship roles and its importance to landing full time positions after graduation. This participant also discusses how these roles outside of class help define engineering and helped determine whether it would be his career choice. Participant I5 states,

> "[I went] to Human Skill [company] for example and did some measurements and checked out the production line. And that was only my sophomore year. After that I knew I wanted to do industrial engineering because it was all ergonomics and supply chain which I found very interesting. And that class kind of just presented it as "this is what it is". Instead of reading it from a book it really helped me by seeing and doing it. And the team work was huge because you don't really get that in high school. Well I didn't get that in my high school [laughs]."

Participants also discussed the difference between learning information in the classroom and what they experienced in these roles. Participant SR states,

> "You get the hands on and the technical background when you are sitting in the classes. And then, I feel you get the real experiences from doing the internships and jobs. I was privileged to have 3 IT internships and those really help me out as far as understanding what being an engineer and getting the real world experience. I would say it's from being in class, getting the technical knowledge and seeing different ways to apply that every day."

Both the student that did and did not have apprenticeship roles saw value in these roles and their ability to provide deeper understanding of course material and develop the professional skills to land full time jobs after the undergraduate experience. Participant WB states,

> "I told one of my friends, who are both students, they have good internships. One for BP. I was like you're set. I was like that experience right there puts you ahead of all the seniors that have no experience. Experience is bigger than anything. That's what the companies are looking for.""

Most participants also agreed that the skills learned in these learning environments support the needs of the classroom. Therefore, by introducing students to apprenticeship roles early in the curriculum they agreed that knowledge and content for course could be strengthened. Participant OJ stated,

> ""… my first internship I got at a small mechanical engineering firm …11 employees, 15 million dollars in net gross per year. And I worked directly with the president of the company and everyday he sat down with me and did CADD drawings. And then we would go to the field and he would show me what I had to look for and to be honest with you his methodology was mostly to take the drawings and essentially to solve any problems I still use to this day and my internships have changed and grown. But definitely I feel like what I learned at that first internship is something I still use to this day."

This student emphasizes the not only the network that he established by being in this learning environment, but the knowledge he was able to transfer into classroom. Through the focus group the investigator was also able to uncover what types of skills student feel they gained from apprenticeship roles. Participant FR states,

> ""…the skills that I've developed, the social capital, networking, um professionalism - the internship I got was through my fraternity. I'm with the Department of Defense doing

> engineering work. I've been to the Middle East, Spain - um just beautiful experiences that I can't imagine getting otherwise. Um - public speaking. You just develop - it's amazing the growth you see when you put something into an organization. Um work, put the boot straps up, [laughs] really getting down and dirty. And that's closest thing to getting real world experience. Because they have budgets, they have deadlines - all things that you would see and do. But you're doing it for free. The experiences though are priceless.".”

In addition to developing classroom content the focus group participants suggest apprenticeship roles as another avenue to develop the transferable skills necessary to be a leader in all environments. Even participants who were not paid for their roles were able to see the value in the experience gained from hands-on experience.'

Hands On Projects/Design

Participants also discussed opportunities outside of class to engage in hands-on projects that were not required by their coursework. While difficult to obtain, internships, coops, and research positions serve as useful skill building activities. They help engineering students understand how to apply concepts to real situations. Participant RL makes the following statement regarding independent projects,

> "I developed a smart grid for the virgin island on my own because my family is from there. I always had a fascination with energy and renewable energy, and I'm also doing my minor in entrepreneurship So after I get some real world experience I want to start a business for this combining engineering with my entrepreneurship…But this stemmed from my imagination and wanted to design things. I started this idea before, but I'm looking to incorporate into my capstone."

Similar to apprenticeship roles, this learning environment appears to put engineering into perspective by showing students their place in industry and corporate environments.

Career Development

Students identified learning environments that supported career development of importance to retention and in the school of engineering. They discussed the need for learning environments that taught them how to be better students, but in this case, they emphasized the learning environments that prepared them for the workforce as well. Participants mentioned utilizing careers services as well as professional networking websites (i.e. Linkedin) to learn professional etiquette and maintain influential resumes. Participant WB discussed the type of information that would be emphasized in a comparison between himself and a conflict with another student. Participant WB states,

> "Try to stand out. You don't want to be that kid…You can get a 3.5…I remember this kid that asked me "what's your GPA"…and I was like "3.0" and he was like "3.5"…and I was like O were you ever president of an organization, have you ever ran events, co sponsored events, had internships I'm sure my resume looked better than his. Like do stuff that makes you stand out. Do stuff that makes you exceeds…puts you ahead of other people."

Community Service Activities

During the collection of data there were instances where students discussed the desire to use their design abilities to work with local or worldwide organizations and serve the needs of disadvantaged communities through engineering projects. These involvements appeared to connect to underlying engineering identity characteristics to have impact on society. Participant I4 states,

> "I'm a member of people to people international, I'm the president here. I've been in it for four years basically since I've gotten here. And that's just helped my growth overall as a person. You know we do a lot of hands on volunteer work. The purpose is to spread diversity, better yet embrace it. And having done that I've met so many different people and learned so much about other cultures. I've made great connections through all the networking opportunities and that's not even why I joined."

People to People and Engineers Without Borders were two service based organization that were discussed by participants. In most cases, students were involved in community service activities for both the engineering design and the ability to affect underserved communities.

External Networking

While in college students express value you in interacting with professionals outside of the engineering to give them leverage for job and positions after graduation. Participant I1 states,

> "I remember I went to this networking events for a bunch of like…top dogs at ESPN and when I was talking to one of them one of them asked me my major and he was like "oh….you're graduating" and I was like "not yet but I will "and he was like "Hey, as long as you graduate…that's good your set". And that made me feel good. I'll take that.."

Students in this focus group agreed that support and relationships with companies and institutions prior to graduation provide motivation to pursue goals and provide the guidance to achieve them.

<u>Online Learning Environments</u>

Online Academic Resources

Students communicated two types of online academic resources that were significant to their studies. The first set of resources were academic tracking resources to help monitor the classes taken, prerequisites and unfulfilled requirements. Participants discussed using these online tools in conjunction with advising meetings with deans and counselors. Participant I4 states,

> "I usually go through the check sheet and check off what I have taken by myself. Using it to figure out exactly what I need to take to graduate. I go to them when I need to know what class counts for what classes. Because that's class dependent and I want to make sure I am taking the right things to finish my requirements. I go to them [academic advisors] just to make sure everything is on point.""

Students emphasized that a motivating factor to finishing their degree is knowing their completion status along the journey. Therefore, these tools assist in that monitoring process.

Participants also found significance in using online resources such as videos and lectures to supplement the instruction learned in the classroom. Some of those resources mentioned by participants include Youtube, Wolfram and Kahn Academy. Participant GR states, "There are a lot of resources online too. Like if you Google how to do a problem or there's videos and lectures on like YouTube that show you how to do it." Therefore, online resources can also be used as a tool to support academic performance in students.

Online Social Networking

Another out of class environment that impacted student access to apprenticeship and engineering related learning environments were online social networks. Student discussed the majority of organization academic events being promoted using social networks and websites. They also discussed building their professional network and gaining access to apprenticeship and full time roles using social networking as well. Participant I2 states,

> "LinkedIn is kinda good actually. I heard about it at my internship a few summers ago… I don't know, as soon as I got on there I got connected to my bosses and all that. That's a good way to build your network with business people. Especially when you have a profile that really presents you in a businesslike manner like its suppose to its good. Actually when I leave I'm going to send a message to like 12 recruiters to see if they have any positions…"

While nothing is promised by being active on these online tools, students see value in having access to information and learning environments using web and Internet tools.

Summary

The preceding sections discuss the learning and nontraditional environments that students perceive to be significant to their performance as engineering students. The environments of particular interest were those that were outside of class, important during times of academic difficulty, and/or helped them understand what it meant to be an engineer. Tutoring, study groups, mentoring, academic counseling/coaching, online academic resources, apprenticeships, hand-on design, and organization affiliation were described as significant to those student experiences. While important, many also expressed concern about underclassmen being exposed to these resources. Many of the participants did not know these of these services and experiences until later in their academic careers. This is highly probable since they were not initially affiliated with an instructional support program or one of the schools target community groups (EOF/Honors).

2. Qualitative Data: Engineering Identity

Engineering identity is believed to relate to educational and professional persistence. In this portion of the data analysis we try to understand how students self-identify as engineers after being in circumstances where they did not perform well academically. In this study we particularly sought to (1) understand the characteristics and perceptions of engineering identity at Rutgers University as well as (2) the out of class learning environments that impact this identity.

While conducting focus groups, participants suggested variables that contribute to engineering identity. The first was the degree to which they have design and hands on experiences (Also supported by APPLE survey results). According to the students the more design and hands on experiences they had in their field, the more confident they felt identifying as engineers. When asked about experiences to help incoming students identify as engineers I4, states,

> "[To be an engineer]…find opportunities to apply what you are learning in class. Because all your comfort in engineering comes from the application or practicing engineering…Get an internship to understand how effective your problem solving skills are and working in teams. You need that experience and you're not always going to get it in class."

Lastly, they suggested that their engineering identity also includes their ability to show leadership, communicate, learn from failure, and maintain a work life balance. Some of these learning environments to help them build those skills are becoming tutors, mentors, being active in student organizations, and obtaining apprenticeship (internships, coops, and research).

Participants of this my study described these attributes unpacking what it means to be an engineer. There was a noteworthy conflict between two ideas that came from their descriptions. . The two ideas were "being" an engineer and currently identifying with the traits, or thought processes of an engineer. The second idea is that they were some where on this continuum of "becoming" an engineer and must gain a particular set of skills or experiences to obtain this title. The two perspectives on identity were shown in the language of the students. Below is an example of a student who described 'being' an engineer. From the description, he sees engineering in both academic and personal aspects of his life. He is not working to obtain the title of engineer, he already self identifies as an engineer because of his personal traits and the way he views his surroundings. Participant I1 states,

> "[To understand the information in classes] I go outside and think about what I've learned. It happens naturally. I feel like I'm a natural [finger quotes] engineer in that sense. Anything I do. Just today, I was looking at my pen writing and I was trying to figure out why my writing is so sloppy? Well what if I decrease the length to the point of this pen will I have more control. Even with small things like that. Cooking, cleaning, the way I'm mopping, doing dishes, when I make my bed. I do music production, I do recordings…I do all sorts of things and they come together because in my mind it is all the same thing. There is math, there is science, there is engineering in everything. Everything in this room was engineered. Even this pen.

> As an engineer you just have to look at everything at that depth, you know what I mean? ".

Other students describe themselves as *becoming* an engineer suggesting that they have not yet achieved their engineering identity and in the process of earning that title. These students perceive the skills, classes, and student experience as one of preparation to obtain engineering status. Participants KM an GR state,

> "KM: [On a scale of 1 to 10] I'd say I'm a 4 when it comes to being an engineer. I don't' think I do enough studying. When I study I don't think I study as well as I could, and I should consult the professors more"
>
> GR: I'd say I'm a 5/6. Because…we're given so many problems in our early classes in engineering to solve, but never told how to use them to understand how to apply them to problems later on. So for me I'm finally getting to the grove of it by it by doing senior design. Like your given this and you have to solve it. There no solutions to it and there are multiple was to solve it. But its your own engineering mentality to do it. So on a continuum I'm a 5/6 in progression to a 10."

While both categories of students were consistent in the skills and attributes associated with engineering identity, further studies may investigate whether these distinctions play a part in the academic decisions, out of class involvements, or the performance differences of those identities.

3. Quantitative Data: APPLES Survey Findings

In this section of the analysis I will outline the quantitative analyses performed based on the responses of 59 individuals who took the Academic Pathways of People Learning Engineering Survey (APPLES) survey. As mentioned in previous sections, there are 16 multi-item variables in the APPLES instrument. These variables potentially influence students' intentions to major in engineering and eventually, to continue studying or working in an engineering field. Each variable is assigned a Cronbach alpha score, a test of internal consistency of the individual items that comprise each variable. These scores measure the statistical reliability resulting from the similarity of individual item responses and represent the extent to which the items in a scale can be treated as measuring the same construct (such as motivation). Generally speaking, Cronbach's alphas of .60 and higher are considered to be an acceptable level of internal consistency These analyses are divided into 2 parts. In part I, the alpha reliability coefficients for each of the 4 main individual constructs, as well as sub-constructs. In part II, the correlations of each pair of constructs of interest (i.e., Identity (Motivation) and Academic Performance (Skills & Education, Identity (Motivation) and Retention (Education & Workplace)) are given.

5.3.1. Main Constructs

Below are the alpha reliability coefficients (Cronbach's alpha) for each of the constructs (Identity (Motivation), Skills, Education, & Workplace) based on the responses from the 59 individuals of the APPLES survey. The survey questions affiliated with each of the sub-constructs are listed as well.

- ***Identity (overall*** α ***=0.83)***

  1. Motivation: Financial (α=.79)

     - 9b. Reason: Engineers make more money than most other professionals
     - 9e. Reason: Engineers are well paid
     - 9g. Reason: An engineering degree will guarantee me a job when I graduate

  2. Motivation: Parental Influence (α=.81)

     - 9c. Reason: My parents would disapprove if I chose a major other than engineering
     - 9f. Reason: My parents want me to be an engineer

  3. Motivation: Social Good (α=.83)

     - 9a. Reason: Technology plays an important role in solving society's problems
     - 9d. Reason: Engineers have contributed greatly to fixing problems in the world
     - 9n. Reason: Engineering skills can be used for the good of society

  4. Motivation: Mentor Influence (α=.74)

- 9h. Reason: A faculty member, academic advisor, teaching assistant or other university affiliated person has encouraged and/or inspired me to study engineering1
- 9i. Reason: A non-university affiliated mentor has encouraged and/or inspired me to study engineering
- 9j. Reason: A mentor has introduced me to people and opportunities in engineering
- 10c. Agree/disagree: A mentor has supported my decision to major in engineering

5. Motivation: Intrinsic Psychological (α=.84)

- 9k. Reason: I feel good when I am doing engineering
- 9m. Reason: I think engineering is fun
- 9o. Reason: I think engineering is interesting

6. Motivation: Intrinsic Behavioral (α=.76)

- 9l. Reason: I like to build stuff
- 9p. Reason: I like to figure out how things work

- ***Skills (overall*** α ***=0.88)***

1. Confidence in Math and Science Skills (α=.78)

- 11d. Confidence: Math ability
- 11e. Confidence: Science ability
- 11g. Confidence: Ability to apply math and science principles in solving real world problems

2. Confidence in Professional and Interpersonal Skills (α=.87)

- 11a. Confidence: Self-confidence (social)
- 11b. Confidence: Leadership ability
- 11c. Confidence: Public speaking ability
- 11f. Confidence: Communication skills
- 11h. Confidence: Business ability
- 11i. Confidence: Ability to perform in teams

3. Confidence in Solving Open-Ended Problems (α=.70)

- 10a. Agree/disagree: Creative thinking is one of my strengths
- 10b. Agree/disagree: I am skilled at solving problems with multiple solutions
- 11j. Confidence: Critical thinking skills

4. Perceived Importance of Math and Science Skills (α=.74)

- 12d. Perceived importance: Math ability
- 12e. Perceived importance: Science ability
- 12g. Perceived importance: Ability to apply math and science principles in solving real world problems

5. Perceived Importance of Professional and Interpersonal Skills (α=.76)

- 12a. Perceived importance: Self-confidence (social)
- 12b. Perceived importance: Leadership ability
- 12c. Perceived importance: Public speaking ability
- 12f. Perceived importance: Communication skills
- 12h. Perceived importance: Business ability
- 12i. Perceived importance: Ability to perform in teams

- ***Education (overall alpha=0.80)***

1. GPA (Q35 – Single Item Variable)

- What is your cumulative grade point average?

2. Academic Persistence (Q7 – Single Item Variable)

- Do you intend to complete a major in engineering?

3. Curriculum Overload (α=.79)

- 18. How well are you meeting the workload demands of your coursework?
- 19. How stressed do you feel in your coursework right now?
- 20a. During the current year, how much pressure have you felt with course load?
- 20b. During the current year, how much pressure have you felt with course pace?
- 20c. During the current year, how much pressure have you felt with balance between social and academic life?

4. Financial Difficulties (Q34 - Single Item Variable)

- Do you have any concerns about your ability to finance your college Education?

5. <u>Academic Involvement—Liberal Arts Courses (α=.71)</u>

- 17a. Frequency: Came late to liberal arts class (reverse-coded)
- 17b. Frequency: Skipped liberal arts class (reverse-coded)
- 17c. Frequency: Turned in liberal arts assignments that did not reflect your best work (reverse-coded)
- 17d. Frequency: Turned in liberal arts assignments late (reverse-coded)

6. <u>Academic Involvement—Engineering-Related Courses (α=.79)</u>

- 16a. Frequency: Came late to engineering class (reverse-coded)
- 16b. Frequency: Skipped engineering class (reverse-coded)
- 16c. Frequency: Turned in engineering assignments that did not reflect your best work (reverse-coded)
- 16d. Frequency: Turned in engineering assignments late (reverse-coded)

7. <u>Frequency of Interaction with Instructors (α=.47)</u>

- 21a Frequency of interaction: Instructors during class
- 21b. Frequency of interaction: Instructors during office hours
- 21c. Frequency of interaction: Instructors outside of class or office hours

8. <u>Satisfaction with Instructors (α=.80)</u>

- 13a. Satisfaction: Quality of instruction
- 13b. Satisfaction: Availability of instructors
- 13c. Satisfaction: Quality of advising by instructors
- 13d. Satisfaction: Academic advising

9. <u>Overall Satisfaction with Collegiate Experience (Q15 - Single Item Variable)</u>

- ***Workplace (overall alpha=0.68)***

1. <u>Professional Persistence (Single Item Variables) (α=0.76)</u>

- Do you intend to practice, conduct research in, or teach engineering for at least 3 years after graduation? (Q8)
- Do you see yourself pursuing a career in engineering? (Q32)
- How likely is it that you would do each of the following after graduation: Work in an engineering job (Q33a)
- How likely is it that you would do each of the following after graduation: Work in a non-engineering job. (Q33b)

- How likely is it that you would do each of the following after graduation: Go to graduate school in an engineering discipline (Q33c)
- How likely is it that you would do each of the following after graduation: Go to graduate school in a non-engineering discipline (Q33d)

2. Knowledge of the Engineering Profession (Single Item Variables) α=0.19

- Before college, how much knowledge did you have about the engineering profession? (Q26)
- Since entering college, how much knowledge have you gained about the engineering profession? (Q27)
- How did you gain your knowledge about the engineering profession? (Q29)
- Do any of your immediate family members (parents, siblings) hold an engineering degree? (Q30)

To determine the reliability of the survey instrument it is sufficient to determine the reliability coefficient (in this case the Cronbach's alpha, α) for items within the survey that appear to be related and can be considered as one construct. Given that the Cronbach's alpha for each of the 4 main constructs above (i.e., identity, skills, education and workplace) is approximately 0.70 or larger, one can conclude that the survey instrument is reliable and internally consistent. {Note that two sub-constructs, specifically, "Frequency of Interaction with Instructors" and "Knowledge of the Engineering Profession" have very low alpha reliability coefficients (0.47 and 0.19, respectively), indicating that these may not be true constructs based on students' responses to these specific questions.}

5.3.2. Correlations Between the Main Constructs

The next step in the analysis is to understand the correlations between the main constructs of interest. The APPLES broke down engineering identity into the following categories that are connecting/motivating students to pursue this field: (1) Financial Influence, (2) Parental Influence,

(3) Social Good, (4) Mentor Influence, (5) Intrinsic Psychological, and (6) Intrinsic Behavioral. This survey suggests that if we can build how students feel in these areas, we can increase student's ability to connect with the major with a statistical reliability of 83% (alpha score).

Using linear regression, I was able to explore and model the relationship between engineering identity and other constructs in the study. There is a moderate and positive linear relationship between *identity and academic performance*, and *identity and retention*.

Identity (Motivation) and Academic Performance (Skills & Education) - 0.55

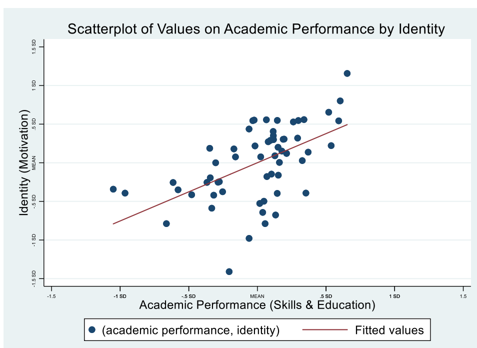

Figure 5: Identity Vs. Academic Performance

Identity (Motivation) and Retention (Education & Workplace) - 0.57

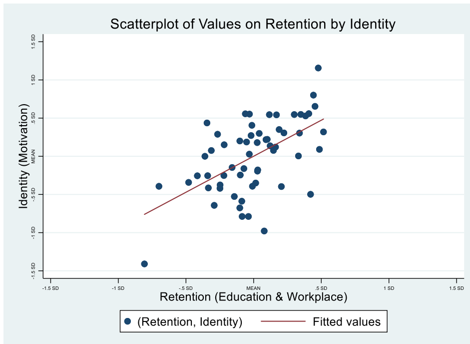

Figure 6: Identity Vs. Retention

There is a moderate and positive linear relationship between Identity and Academic Performance as well as between Identity and Retention. Each correlation is statistically significant ($p<0.05$).

- Below are the correlations between the sub-constructs of interest.
  - Identity (Motivation) and Skills - 0.53
  - Identity (Motivation) and Education - 0.33
  - Identity (Motivation) and Workplace - 0.56

There is a moderate and positive linear relationship between Identity and Skills as well as between Identity and Workplace. However, there is a weaker (and positive) linear relationship between Identity and Education. Each correlation is statistically significant ($p<0.05$).

Summary

Looking at the relationship between identity and academic performance we can expect students who have engaged in the practices to do well and perform well in their academic courses (Education) combined with the confidence in their STEM and problem solving abilities (Skills) will have strong engineering identity. The data analysis for this suggests that engineering identity is not strongly correlated to education factors alone (i.e., GPA, Academic involvement, Interaction with Instructors, etc.). In fact, these factors alone have a weak linear relationship to identity. The aspect that of academic performance that has the stronger linear relationship is the students confidence in math science skills and the perceived importance of these skills. This would explain why participants with lower GPAs still have strong engineering identity despite their performance on exams and other course assessments.

Engineering identity and retention variables also have a positive linear relationship. The stronger sub-construct in the retention variable were the workplace factors. This included student's interests in practicing engineering, pursuing engineering jobs, or conducting research. Those students who have hands-on experience or plans to practice engineering were found to have stronger retention values, which correlated to engineering identity.

Limitations of the Study

This study has several limitations that affect the reliability of the findings and their transferability to other settings. The most obvious is the relatively small number of participants from some engineering majors and ethnic groups at the university. In addition, Rutgers is known to provide high quality out-of-class learning opportunities that may influence patterns of involvement and this may differ across engineering institutions.

I emphasize positive qualitative and quantitative outcomes associated with identity and informal learning environments, but the results of these experiences were not uniformly positive. Many students talked about enduring difficulties and frustrations. For example, the challenge with student organizations is that the experience varies by organization and year. Unlike university departments who are systematic and provided consistency in services, students orgs can change focus from year-to-year varying by the interest and initiative of the yearly elected executive board.

The number, nature, and quality of the informal learning environments varied from one student to another. Therefore, the experiences these students associated with particular outcomes may not necessarily result in similar outcomes for other students who engage in comparable activities.

Lastly, reducing the spectrum of learning environments outside the class to 16 environments and 4 categories simplifies complex and evolving experiences. Presenting the words from students in written form masks nuances of meaning that are communicated clearly upon searing and hearing the student speak the words. Seeing the video recordings or listening to audio recordings evokes a measure of understanding that cannot be duplicated on the printed page.

VI. Interpretation of Findings, Conclusions, and Implications

In this chapter of the dissertation, I discuss the research findings and connect them to the research questions for the study and the literature in the field. Following are conclusions and implications for improvement in the engineering program. Lastly, I will address limitations of the study and conclude with suggestions for further research.

Research Question and Summary of Findings

The national engineering graduation rate (55.9%) still lags behind the overall college graduation rate of 60%. This issue is coupled with the challenge that the number of women and underrepresented minority students do not reflect their proportions in the general population. There is a need to understand what is keeping our engineering students in the field and identify the support we can offer for their academic, personal, and professional development. These students require support to maintain their level of engagement in engineering and retain them in the STEM fields. The goal of this study was to investigate the informal learning environments that influence retention and performance rates with the purpose of helping us understand how to increase participation in engineering for both minority and nonminority groups.

This study was designed to evaluate the impact of out-of-class practices on engineering students' success. The population was engineering students at Rutgers University. I used the students' voices to describe the extent to which informal learning environments affect the development of low performing, Rutgers engineering students' engineering identity, retention, and GPA. The primary research tools used were the Academic Pathways of People Learning Engineering (APPLE) survey and focus groups for the study. Details regarding the APPLE survey and focus groups are discussed in the methodology section of this document. The following research question was derived from the review of literature and influenced by my personal experiences as an engineering student, as well as an engineering educator.

> **Research Question:** To what extent does participating in informal learning environments impact the development of engineering identity, as well as persistence and performance for generally admitted students' who held GPAs of 2.4 or lower in their first or second year of undergraduate study?

To answer this research question I used a mixed method approach utilizing both quantitative and qualitative data. The mixed-method approach is based on my pragmatic assumption that collecting a variety of data can best illuminate the research problem and provide multiple data sources for triangulation of research findings.

My findings suggest that it is important to start the discussion with engineering identity. Based on my data analysis, engineering identity is related to two investigated variables: *academic performance* and *retention*. I will discuss the relationships between those variables first because they have helped me identify the informal learning environments that have the most noted impact on the participants in my study. In Table 6 I summarize the relationship between *identity, academic performance, and retention* based on my data analysis. Additionally, I have listed the informal learning environments that I found significant in my research areas.

Table 6: *Research question categories and associated discussion points*

Research Category	**Discussion Points**	**Implications**
Engineering Identity	Positive linear relationship between identity and *academic performance* with key sub-variable: *skills*.	Focus on fostering confidence in STEM skills, interpersonal/professional skills, and the perception of those skills.

	Positive linear relationship between identity and *retention* with key sub-variable: *workplace*.	Focus on plans for workplace, research, and hands on experiences to increase professional persistence
Academic Performance - Informal Learning Environments	Study Groups Tutoring Online Resources Student Organizations	Create/collaborate with university units that emphasize these four learning environments to positively affect academic performance and strengthen identity.
Retention - Informal Learning Environments	Apprenticeship roles/hands-on Mentoring Holistic Advising Student organizations	Create/collaborate with university units that emphasize these four learning environments to positively affect retention and strengthen identity.

Engineering Identity

Analyzing engineering identity has been instrumental for understanding engineering learning environments as well as their impact on retention and academic performance. In this section, I discuss engineering identity and the variables with which the identity has positive linear relationships. As mentioned in the quantitative data analysis, I used the APPLES survey to investigate identity. Based on the survey the influence on the identity can be broken down into six categories: (1) Financial Interest, (2) Parental Influence, (3) Social Good, (4) Mentor Influence, (5) Intrinsic Psychological, and (6) Intrinsic Behavioral. These categories explain this variable with 83% reliability. The tool developed by Sheppard et al. at the Center for Advancement of Engineering Education at the University of Washington reliably shows that if we can build students connectedness to engineering in these six areas, we can improve their engineering identity (Sheppard et. al, 2010).

Using linear regression, I was able to model the relationship between engineering identity and other constructs in the study. What I found is that there was a moderate and positive linear relationship between (1) *identity and academic performance*, and (2) *identity and retention*. These linear relationships were described in the quantitative data analysis and referenced graphically in Figures 5 and 6.

Based on my correlation test between *identity* and *academic performance,* there was a positive linear relationship between students with high engineering identity and their academic performance. Academic performance included subcategories for both *education measures* and *skills* in the APPLES survey. Therefore, my prediction based on this relationship was that students with strong identity should (1) have a history of doing well in their courses and should have frequent academic involvement with instructors (Education Variable), and (2) have perceived confidence in their STEM, problem solving abilities, and communication skills (Skills Variable). However, after analyzing *academic performance more closely*, I found that *engineering identity* has a weak correlation to the education factors (i.e., GPA, Academic involvement, Interaction with Instructors, and Frequency of interaction with instructors.) Surprisingly, despite having a 2.4 GPA at some point in their first two engineering years, my study participants were not less motivated to be engineers. They still maintained their desire to do social good and contribute to fixing world problems. In addition, possible financial gains from going into the technology field continued to motivate them to pursue engineering. These students did not lose interest in building things and understanding how things work as a result of poor assessments in the classroom.

The sub-construct in *academic performance* that showed a stronger relationship to *engineering identity* included students' confidence in STEM skills, professional/interpersonal skills, and the perceived importance of these skills. All of the participants struggled with performance during the first or second year of the curriculum; however, the students who identified most with engineering were confident in there STEM skills and understood why those skills were relevant to their major. The same was true for their professionalism and interpersonal skills. Students with confidence in their leadership, communication, and business skills showed higher engineering identity. Based on this assessment I hypothesize that we can help these students maintain interest in pursuing engineering by offering opportunities for them to apply STEM and interpersonal/professional skills in informal environments. The ability to practice these skills in a controlled environment separate from their academic course load would help them understand the importance of the skills and build confidence using them.

In short, while investigating the relationship between engineering identity and performance in engineering I found that identity had weak correlation to grades and in-class academic involvement (education). Identity had strong correlation to confidence in STEM and professional/interpersonal skills (skills). While my study does not show a need for both education and skill variables to increase identity, prior STEM research connects in-class academic involvement and confidence in STEM. For example, a study by Springer et al. (1999) analyzed 39 studies of small-group learning. In their analysis, incorporating small group learning into classrooms and positive attitudes/confidence in STEM helped students perform well. Another example comes from a quantitative literature review of college chemistry achievement where nearly all 37 studies show that for high performers, there is a positive relationship between involvement in active learning classrooms and student attitudes towards science skills (Bowen 2000).

In both of these examples, students involved in active learning classrooms correlated to better grades, higher confidence, and positive perception of their abilities in STEM. Active classroom involvement is fostering positive attitudes and confidence in STEM skills. Unlike these studies driven by performance, engineering identity and participants' level of academic involvement in the classroom are not connected. However, identity and the confidence/perceived importance of their STEM skills (skills variable) are correlated. These feelings towards their STEM skills are not being fostered in the classroom, therefore, they must be coming from somewhere. The participants in this study seem to get affirmation of their abilities from places outside of classroom. This supports my investigation on informal learning environments and the reasons they are important to the college experience.

Researchers Besterfield-Sacre and Shuman (1997) conducted a study on poor performing students and concluded that students with confidence in their engineering skills are more likely to be retained. Therefore, it is reasonable to suggest that by strengthening engineering identity we should also positively impact retention.

In my study I found that engineering identity and retention variables also have a positive linear relationship. Studies by Matusovih et al. in both 2008 and 2010 support this finding. They found positive correlations between retention and their developed 'attainment value', a measure of identity. Attainment value was measured by how a task is important to one's sense of themselves and who they want to be. In my study, identity is measured by students sense of self as well as extrinsic and intrinsic motivators. Identity was then tested for a correlation with retention variables, which included participants' plans to enter the engineering workplace, their knowledge level of engineering, education factors, and STEM skills. Similar to the previous section, education variables had weak linear correlation to engineering identity. The '*Knowledge of the engineering profession'* sub-construct was not statistically reliable in explaining the *retention* variable (α=0.19). The remaining sub-construct in the retention variable were the professional persistence variables. These variables included student's interests in practicing engineering, pursuing engineering jobs, or conducting research. This sub-construct had strong linear relationships to engineering identity. Participants who have hands-on experience or plans to practice engineering were found to have higher engineering identity. This concludes that the degree of workplace experience, having a professional plan, and/or graduate school plans affect engineering identity.

These relationships between identity, academic performance, and retention variables suggest that if we increase student's confidence in engineering abilities and experience in the engineering field we can improve engineering identity. By doing so, we should also see improvements in retention. Findings from the focus groups also support this claim. The participants suggested variables that contribute to engineering identity. The first was the degree to which they have design and hands on experiences. According to the students, the more design and hands on experiences they had in their field, the more confident they felt identifying as engineers. This conclusion is supported by a study conducted by Prendergast (2013) whose results show that design based classes enhance the undergraduate experience by improving retention rates, GPA, and overall opinions about their time in the program. Participants in my study also suggested that their engineering identity additionally includes their ability to show leadership, communicate, learn from failure, and maintain a work life balance. In the following sections I discuss the out-of-class learning environments that affect these targeted areas for academic performance and retention.

Academic Performance – Informal Learning Environments

This study results show that the variables that have the most impact on academic performance are those that connect to confidence in STEM, professional, and interpersonal skills.

By strengthening students in these areas we can develop students with stronger engineering identity, which has positive implications to retention. In this section, we identify the informal learning environments that participants describe being most significant to building confidence and helping them see the importance of the named skills.

Peer and structured study groups were commonly used learning environment for students to practice their academic skills in a safe space. In most cases these study groups were either self-led or peer led offering less emphasis on assessments and more focus on learning the concepts to do the coursework independently. These student-driven sessions allow students to identify the important concepts in the class, work on the concepts they do not understand, and eventually solving problems. After going through this process with their peers, they learned the importance of the concepts to the overall class and practiced these skills to become confident. Though the process of working with a team and effectively communicating their ideas they have also practiced their professional/interpersonal skills.

Students have to be highly motivated and strong willed to get through the engineering curriculum, especially during times of academic struggle. In many cases students are not as academically prepared in high school or are not accustomed to learning independently. In these cases, participants suggest turning to peers, but often preferred a content expert that is also a peer. *Tutoring* offers this accommodation, and for this population it was common for them to use tutoring over a period as opposed to a one-time service. When describing this resource the students preferred one-on-one tutoring to have a consistent person that understands their ability, as opposed to "drop-in" tutoring which could have them working with a new person every time. During these tutoring sessions students can get practice with open-ended questions, gain immediate feedback on their math/science approaches, and are encouraged to communicate their approach for the tutor to follow. All of these are all factors that contribute to the academic skills needed within engineering. Having an assigned tutor seems feasible since most students describe knowing their class difficulties before the start of the semester.

A common theme for students struggling academically is a willingness to use online academic resources. Many of the students attributed their lack of performance in classes to poor instruction. Poor instruction included a number of things, teaching theory without offering practical examples; incomplete examples and/or skipping steps during instruction; skipping important sections of the textbook; spending excessive time on tangent topics; rushing through key topics; and poor communication or language barriers in the classroom. All these challenges forced students to seek outside resources to teach themselves. They recognize their preferred style of instruction in the classroom and in many cases that level of instruction was not being used. With the vast amount of information on the internet, many turned to online resources to re-learn information covered in their classes. By doing this, they felt more confident in the material because they were taught the information in a meaningful way that resembled their experiences in K-12. The aspects of online resources they mentioned enjoying were (1) the convenience and flexibility engaging with the resources, (2) greater learning as a result of the detail in the instruction that was comparable to the textbook and (3) completed examples with both diagrams and computation. The challenge students mentioned is finding these resources for upper level classes, but for most of the first two years of the curriculum, students were able to find these resources. Some participants suggested Rutgers offer online recitations or recorded sessions that are tailored to their courses and available for reference as needed. These resources should not replace current classroom resources, instead, they should provide supplemental learning material similar to the use of non-Rutgers online resources currently.

The last learning environment that linked identity and academic skills were student organizations. All engineering student organizations on campus are student led. Therefore, they cater to the needs and interest of the general body membership. This appears to be the reason they intentionally target tutoring, mentorship, and school resources to help students navigate engineering. The feelings about student involvement in this study were consistent with research that student organizations offer emotional support for academic achievement and persistence (Trenor & Archer, 2010). In addition to academic support, many participants in the study attributed their professionalism and apprenticeship experiences to the access offered as members of the student organizations. Some of the examples include national and regional conferences, alumni networks, and leadership experience. This web of experiences enhances confidence in STEM through the academic resources. Student orgs also enhance professional and interpersonal skills by providing leadership experiences on campus and developing the skills to obtain apprenticeship roles.

Retention – Informal Learning Environments

The ultimate goal of this study was to help increase connectedness for students from at risk populations and help them remain in the field for their undergraduate degree. There students were on the verge of graduation, but held GPAs below a 2.4 during their first or second year of the curriculum. I found strong positive correlations between professional persistence (retention variable) and identity. This retention variable tells us that those participants who have a plan to pursue engineering after graduation identified more with engineering and were more likely to remain in the field. The out-of-class learning environments that connected to professional persistence included: *apprenticeship roles/hand-on experiences, mentoring, and holistic advising.*

Over 66% of the students in this study had some exposure to research or professional engineering environment. Research included experiences with professors at the University and typically initiated by the students making contact with professors. Industry experiences included visiting, interning, or completing a coop at an engineering company. These experiences are controlled by companies, not the institution, but the data from participants encourage creating pathways to help students obtain professional experiences. Obtaining both research and industry positions usually requires students to either have a strong GPA, leadership experiences, and/or work experience. All of the students in the study have struggled academically at some point in their first two years of engineering. This leaves us to assume that they were able to offset their GPA with leadership and/or work experience. Providing the development to help students in these areas may be instrumental to retaining our at-risk students. In additional to professional development, students were also challenged with access to these opportunities, which suggests pipeline programs and activities to offer exposure to engineering may help these students gain them and ultimately stay retained.

Students valued the *mentoring* experiences from their predecessors in engineering. In many cases they would prefer to follow the guidance of these students or alumni to their faculty and advisors. They were able to connect with individuals that have been through similar experiences and come from a similar background. Results from this study suggest that mentoring programs and activities should include exposure to engineering industry and higher education. Working with their mentors to identify career options and set professional engineering goals can have strong implications to engineering identity and retention. Laser & Snelsire (1996) implemented a peer-mentoring program called the Program for Engineering Enrichment and Retention. They were able to raise first year retention rates to eighty percent for their target at risk population using a proactive mentoring approach. Students in this mentoring program were primarily from minority and first generation backgrounds but had on average 0.5 GPA higher than their non-participating peers and a 20% higher graduation rate. In my study, some mentorship relationships were mandated by student organizations, but for most participants the mentor/mentee relationships are self-initiated. Therefore, if we can formalize these connections to peer mentors for at-risk students using approaches like proactive mentoring, we may be able to positively affect decisions to stay in engineering after experiencing times of academic difficulty and professional uncertainty.

Fifty-three percent of the students that participated in this study were first generation college students. They are the first generation in their families to navigate the university typically without the support of their parents because they do not have the experiences to support them. Thirty percent of students enrolled at Rutgers are first generation and low income students (RU-1st). There are some unique issues with this population, which includes but are not limited to high attrition rates, financial challenges, lack of guidance on resources in college, and unique personal challenges. These issues help us understand the emphasis that participants of this study placed on *advising*. While calling these advisors "academic advisors or counselors", many of their interactions with these individuals were parental and holistic in nature. While guiding students through the academic curriculum, the advisors were also supporting students though challenges with personal well-being, mental health, physical disabilities, finances, and academics. Most important to this study, advisors were also drawing connections to the academic and professional experiences students needed to achieve their long-term academic and professional goals. By being on an individualized path, students who used holistic advisors were able to work with these advisors over time to make decisions that affected their identity and retention.

In some cases, students attributed holistic support to particular instructional support programs that used this advising approach. The two programs discussed were the Educational Opportunity Program, which services low-income first generation college students. The other being students in the Honor Academy. Students are assigned to these programs according to admission criteria and have an identified set of advisors that provide a heightened level of support to maintain engagement in engineering and holistically approach their needs. While none of the participants were EOF or Honors Academy students, 65% of the participants utilized advisors from those programs to navigate the engineering curriculum.

Implications & Further Work

As an educational institution for engineering students, we should constantly look at the support offered to help students excel academically, succeed professionally, and improve their connectedness to the engineering field. By conducting this study focused on engineering identity, retention, and academic performance, we were able to identify the learning environments that help our most at students successfully continue their studies at Rutgers University. Those environments that had the strongest impacts were s*tudy groups, tutoring, online academic resources, student organizations, apprenticeship roles, mentoring, and holistic advising*. Individually these services are effective to improve the engineering student experience, but no one support service is effective for all of our students. The same support is not always needed for the duration of the college experience. This is why I believe we see ‘networks’ of these environments being effective. Examples of these networks include instructional support programs, living-learning communities, retention centers, and retention courses. One or more of these options may be effective improving the identity, retention, and performance for our population.

My next step after this study is to investigate the best system to package all of these services in a way that is mutually beneficial to both Rutgers University and our at-risk students. This population is unique because they cannot be identified until they have had poor performance at the university. However, once identified, I believe we can create a community of students that receive resources until graduation. Following the development of this community resource, we can then investigate its effects on identity development, retention, and academic performance compared to a control group of students who do not become members of such community. While studying this resource I will also continue to investigate best practices for each of the individual learning environments. Best practices for this sample of engineering students can inform the individual services that are offered at engineering institutions like Rutgers School of Engineering. My hope is that by offering quality models of support, we can achieve improved academic performance, 100% retention, and full connectedness to engineering for all students who do not have the resources and support system to get through the engineering pipeline.

References

1. Adams, R., Evangelou, D., English, L., de Figueiredo, A., Mousoulides, N., Pawley, A., et al. (2011). Multiple perspectives on engaging future engineers. *Journal of Engineering Education, 100*(1), 48-88.
2. Allie, S., Armien, M. N., Burgoyne, N., Case, J. M., Collier-Reed, B. I., Craig, T. S., et al. (2009). Learning as acquiring a discursive identity through participation in a community: Improving student learning in engineering education. *European Journal of Engineering Education, 34*(4), 359-367.
3. Besterfield-Sacre, M., Atman, C. J., & Shuman, L. J. (1997). Characteristics of freshman engineering students: Models for determing student attrition in engineering. *Journal of Engineering Education-Washington-, 86*, 139-150.
4. Bransford, J. D., Brown, A. L., & Cocking, R. R. (2000). *How people learn* Washington, DC: National academy press.
5. Buysse, V., Sparkman, K. L., & Wesley, P. W. (2003). Communities of practice: Connecting what we know with what we do. *Exceptional Children, 69*(3), 263-277.
6. Chachra, D., Chen, H. L., Kilgore, D., & Sheppard, S. (2009). Outside the classroom: Gender differences in extracurricular activities of engineering students. *Frontiers in Education Conference, 2009. FIE'09. 39th IEEE,* pp. 1-6.
7. Corbin, J., & Strauss, A. (2008). *Basics of qualitative research: Techniques and procedures for developing grounded theory* Sage.
8. Corbin, J., & Strauss, A. (2008). *Basics of qualitative research: Techniques and procedures for developing grounded theory* Sage.

9. Cox, M. F., Cekic, O., & Adams, S. G. (2010). Developing leadership skills of undergraduate engineering students: Perspectives from engineering faculty.
10. Creswell, J. W. (2012). *Qualitative inquiry and research design: Choosing among five approaches* Sage.
11. Fernandez, M. J., Trenor, J. M., Zerda, K. S., & Cortes, C. (2008). First generation college students in engineering: A qualitative investigation of barriers to academic plans. *Frontiers in Education Conference, 2008. FIE 2008. 38th Annual,* pp. T4D-1-T4D-5.
12. Gee, J. P. (2000). Identity as an analytic lens for research in education. *Review of Research in Education, 25*, 99-125.
13. Good, J. M., Halpin, G., & Halpin, G. (1998). The affective and academic benefits for mentors in a minority engineering program.
14. Gregg, M., Hirschfeld, D., & Watford, B. (1996). Student retention strategies gender clustering. *American Society for Engineering Education Annual Conference Proceedings,*
15. Hermond, D. (1995). Measuring the retention strategies of a minority engineering program: A service quality perspective. *Journal of Engineering Education-Washington-, 84,* 395-400.
16. Johri, A., & Olds, B. M. (2011). Situated engineering learning: Bridging engineering education research and the learning sciences. *Journal of Engineering Education, 100*(1), 151-185.
17. Kampe, J., Edmister, W., Stimpson, M., Matanin, B., Martin, A., Brozina, C., et al. (2007). Ac 2007-2367: Freshman engineering living-learning communities at virginia tech.
18. Katehi, L., Pearson, G., & Feder, M. (2009). The status and nature of K-12 engineering education in the United States. *The Bridge*, *39*(3), 5-10.

19. Korte, R., & Smith, K. (2007). Portraying the academic experiences of students in engineering: Students' perceptions of their educational experiences and career aspirations in engineering. *Proceedings of the American Society for Engineering Education,*

20. Krueger, R. A. (2009). *Focus groups: A practical guide for applied research* Sage.

21. Kuenzi, J. J., Matthews, C. M., & Mangan, B. F. (2006). Science, technology, engineering, and mathematics (STEM) education issues and legislative options.

22. Kuh, G. D. (1995). The other curriculum: Out-of-class experiences associated with student learning and personal development. *The Journal of Higher Education*, , 123-155.

23. Lam, P. C., Doverspike, D., & Mawasha, P. R. (1997). Increasing diversity in engineering academics (IDEAs): Development of a program for improving african american representation. *Journal of Career Development, 24*(1), 55-70.

24. Landis, R. B., & National Action Council for Minorities in Engineering (US). (1991). *Retention by design: Achieving excellence in minority engineering education* National Action Council for Minorities in Engineering.

25. Lasser, S. J. S., & Snelsire, R. W. (1996). The case for proactive mentoring for minorities in engineering. *Frontiers in Education Conference, 1996. FIE'96. 26th Annual Conference., Proceedings of, , 2.* pp. 767-769 vol. 2.

26. LOMBARD, M., SNYDER-DUCH, J. E. N. N. I. F. E. R., & BRACKEN, C. C. (2002). Content Analysis in Mass Communication. *Human Communication Research*, *28*(4), 587-604.

27. Lucas, B., & Hanson, J. (2016). Thinking like an engineer: Using engineering habits of mind and signature pedagogies to redesign engineering education. *International Journal of Engineering Pedagogy (iJEP), 6*(2), 4-13.

28. Maldonado, D. E. Z., Rhoads, R., & Buenavista, T. L. (2005). The student-initiated retention project: Theoretical contributions and the role of self-empowerment. *American Educational Research Journal, 42*(4), 605-638.

29. Marra, R. M., Palmer, B., & Litzinger, T. A. (2000). The effects of a First-Year engineering design course on student intellectual development as measured by the perry scheme. *Journal of Engineering Education, 89*(1), 39-45.

30. Matanin, B., Waller, T., Kampe, J., Brozina, C., & Watford, B. (2007). A STEP in the right direction: Student transition to engineering program. *ASEE Annual Conference and Exposition, Honolulu, HI,*

31. Maton, K. I., Hrabowski, F. A., & Schmitt, C. L. (2000). African American college students excelling in the sciences: College and postcollege outcomes in the Meyerhoff Scholars Program. *Journal of Research in Science Teaching*, *37*(7), 629-654.

32. Matusovich, H., Streveler, R., Loshbaugh, H., Miller, R., & Olds, B. (2008). Will I succeed in engineering? using expectancy-value theory in a longitudinal investigation of students' beliefs. *Proceedings American Society of Engineering Education Annual Conference and Exposition,*

33. Matusovich, H., Streveler, R., & Miller, R. (2010). Why do students choose engineering? A qualitative, longitudinal investigation of students' motivational values. *Journal of Engineering Education, 99*(4), 289-303.

34. May, G. S., & Chubin, D. E. (2003). A retrospective on undergraduate engineering success for underrepresented minority students. *Journal of Engineering Education-Washington-, 92*(1), 27-40.

35. Olson, S., & Riordan, D. G. (2012). Engage to excel: Producing one million additional college graduates with degrees in science, technology, engineering, and mathematics. report to the president. *Executive Office of the President,*

36. Prendergast, L. Q. (2013). *Retention, success, and satisfaction of engineering students based on the first-year experience* (Doctoral dissertation, Rutgers University-Graduate School-New Brunswick).

37. Reichert, M., & Ahsher, M. (1997). Taking another look at educating african american engineers: The importance of undergraduate retention. *Journal of Engineering Education-Washington-, 86*, 241-254.

38. Rinn, A. N. (2005). Trends among honors college students: An analysis by year in school. *Prufrock Journal, 16*(4), 157-167.

39. Roach, R. (2006). Under construction: Building the engineering pipeline. *Diverse: Issues in Higher Education, 23*(2), 4.

40. Sheppard, S., Gilmartin, S., Chen, H., Donaldson, K., Lichtenstein, G., Eris, Ö., et al. (2010). Exploring the engineering student experience: Findings from the academic pathways of people learning engineering survey (APPLES). *Center for the Advancement of Engineering Education Technical Report: CAEE-TR-10-01,*

41. Stough, L. M., & Songeroth, M. S. (1994). Minority students who persist: A three-year study of undergraduate engineering majors.

42. Tinto, V. (1987). *Leaving college: Rethinking the causes and cures of student attrition*. University of Chicago Press, 5801 S. Ellis Avenue, Chicago, IL 60637.

43. Trenor, J. M., Grant, D. R. S., & Archer, E. (2010). The role of african american fraternities and sororities in engineering students' educational experiences at a predominantly white institution. *Frontiers in Education Conference (FIE), 2010 IEEE*, pp. T4G-1-T4G-6.

44. Trenor, J. M., Yu, S. L., Sha, T., Zerda, K. S., & Waight, C. (2008). The relations of ethnicity to female engineering students' educational experiences and college and career plans in an ethnically diverse learning environment. *Journal of Engineering Education*, *97*(4), 449-465.

45. Van Aken, E. M., Watford, B., & Medina-Borja, A. (1999). The use of focus groups for minority engineering program assessment. *Journal of Engineering Education-Washington-*, *88*, 333-344.

46. Vygotskiĭ, L. L. S. (1978). *Mind in society: The development of higher psychological processes* Harvard university press.

47. Allendoerfer, C., Wilson, D., Bates, R., Crawford, J., Jones, D., Floyd-Smith, T., ... & Veilleux, N. (2012). Strategic Pathways for Success: The Influence of Outside Community on Academic Engagement. *Journal of Engineering Education*, *101*(3), 512-538.

48. Brawner, C. E., Camacho, M. M., Lord, S. M., Long, R. A., & Ohland, M. W. (2012). Women in Industrial Engineering: Stereotypes, persistence, and perspectives. *Journal of Engineering Education*, *101*(2), 288-318.

49. Eliot, M., & Turns, J. (2011). Constructing Professional Portfolios: Sense-Making and Professional Identity Development for Engineering Undergraduates. *Journal of Engineering Education*, *100*(4), 630-654.

50. Weidman, J. (1989). Undergraduate socialization: A conceptual approach. *Higher education: Handbook of theory and research*, *5*, 289-322.

51. Springer, L., M.E. Stanne, and S.S. Donovan (1999). "Effects of small-group learning on undergraduates in science, mathematics, engineering, and technology: A meta-analysis." Review of Educational Research 69(1): 21-51.

52. Bowen, C.W. (2000). "A quantitative literature review of cooperative learning effects on high school and college chemistry achievement." Journal of Chemical Education 77(1): 116.

Appendix A:

Academic Pathways of People Learning Engineering Survey

Academic Pathways of People Learning Engineering Survey (APPLES)

For best viewing results, please maximize your browser.

Questions Marked With A * Are Required

* Required

1. What Rutgers school are you currently attending for your undergraduate degree? *

Mark only one oval.

- School of Engineering
- College of Nursing
- Edward J. Bloustein School of Planning and Public Policy
- Ernest Mario School of Pharmacy
- Mason Gross School of the Arts
- Rutgers Business School
- School of Arts and Sciences
- School of Communication and Information
- School of Environmental and Biological Sciences
- School of Health Related Professions
- School of Management and Labor Relations
- School of Public Health
- School of Social Work
- I prefer not to answer
- Other:

2. What is your current academic standing? *

Mark only one oval.

- First Year
- Second Year
- Third Year
- Fourth Year
- Fifth Year
- Sixth Year
- Graduate Student
- I prefer not to answer
- Other:

3. When you entered this institution were you: *

Mark only one oval.

- A first-time college student
- Returning or non-traditional college student
- A transfer student from a two-year institution
- A transfer student from a four-year institution
- A transfer student from an institution that participates in a 2+2 engineering program
- I prefer not to answer

4. What were you most interested in majoring in when you first came to Rutgers? *

Mark only one oval.

- Arts and Humanities
- Engineering
- Math and Natural Sciences
- Physical Sciences
- Social Sciences
- I prefer not to answer
- Other:

5. What is your current major or first choice of major? *

Mark only one oval.

- Applied Sciences in Engineering
- Bioenvironmental Engineering
- Biomedical Engineering
- Chemical and Biochemical Engineering
- Civil and Environmental Engineering
- Electrical and Computer Engineering
- Industrial and Systems Engineering
- Material Science and Engineering
- Mechanical and Aerospace Engineering
- Packaging Engineering Program
- I prefer not to answer
- Other:

6. What is your second choice of major or second major/minor? *

(Mark one or N/A if not applicable)

Mark only one oval.

- Applied Sciences in Engineering
- Bioenvironmental Engineering
- Biomedical Engineering
- Chemical and Biochemical Engineering
- Civil and Environmental Engineering
- Electrical and Computer Engineering
- Industrial and Systems Engineering
- Material Science and Engineering
- Mechanical and Aerospace Engineering
- Packaging Engineering Program
- Computer Science
- Arts and Humanities
- Math and Natural Sciences
- Physical Sciences
- Social Sciences
- N/A
- Undecided
- I prefer not to answer
- Other:

7. Do you intend to complete a major in engineering? *

Mark only one oval.

- Definitely not
- Probably not
- Not sure
- Probably yes
- Definitely yes
- I prefer not to answer

8. Do you intend to practice, conduct research in, or teach engineering for at least 3 years after graduation? *

Mark only one oval.

- Definitely not
- Probably not

- Not sure
- Probably yes
- Definitely yes
- I prefer not to answer

9. I am interested in knowing why you are or were studying engineering. Please indicate below the extent to which the following reasons apply to you: 0 - Not a Reason 1 - Minimal Reason 2 - Moderate Reason 3 - Major Reason

Technology plays an important role in solving society's problems

Mark only one oval.

0 1 2 3

Not a Reason Major Reason

Engineers make more money than most other professionals *

Mark only one oval.

0 1 2 3

Not a Reason Major Reason

My parent(s) would disapprove if I chose a major other than engineering *

Mark only one oval.

0 1 2 3

Not a Reason Major Reason

Engineers have contributed greatly to fixing problems in the world *

Mark only one oval.

0 1 2 3

Not a Reason Major Reason

Engineers are well paid *

Mark only one oval.

0 1 2 3

Not a Reason Major Reason

My parent(s) want me to be an engineer *

Mark only one oval.

0 1 2 3

Not a Reason Major Reason

An engineering degree will guarantee me a job when I graduate *

Mark only one oval.

0 1 2 3

Not a Reason Major Reason

A faculty member, academic advisor, teaching assistant or other university affiliated person has encouraged and/or inspired me to study engineering *

Mark only one oval.

0 1 2 3

Not a Reason Major Reason

A non-university affiliated mentor has encouraged and/or inspired me to study engineering *

Mark only one oval.

0 1 2 3

Not a Reason Major Reason

A mentor has introduced me to people and opportunities in engineering *

Mark only one oval.

0 1 2 3

Not a Reason Major Reason

I feel good when I am doing engineering *

Mark only one oval.

0 1 2 3

Not a Reason Major Reason

I like to build stuff *

Mark only one oval.

0 1 2 3

Not a Reason Major Reason

I think engineering is fun *

Mark only one oval.

0 1 2 3

Not a Reason Major Reason

Engineering skills can be used for the good of society *

Mark only one oval.

0 1 2 3

Not a Reason Major Reason

I think engineering is interesting *

Mark only one oval.

0 1 2 3

Not a Reason Major Reason

I like to figure out how things work *

Mark only one oval.

0 1 2 3

Not a Reason Major Reason

10. Please indicate how strongly you disagree or agree with each of the statements: (1) - Disagree Strongly (2) - Disagree (3) - Agree (4) - Agree Strongly

Creative thinking is one of my strengths *

Mark only one oval.

1 2 3 4

Disagree Strongly Agree Strongly

I am skilled at solving problems that can have multiple solutions *

Mark only one oval.

1 2 3 4

Disagree Strongly Agree Strongly

A mentor has supported my decision to major in engineering *

Mark only one oval.

1 2 3 4

Disagree Strongly Agree Strongly

11. Rate yourself on each of the following traits as compared to your classmates. I want the most accurate estimate of how you see yourself. (1) - Lowest 10% (2) - Below Average (3) - Average (4) - Above Average (5) - Highest 10%

Self confidence (social) *

Mark only one oval.

1 2 3 4 5

Lowest 10% Highest 10%

Leadership ability *

Mark only one oval.

1 2 3 4 5

Lowest 10% Highest 10%

Public speaking ability *

Mark only one oval.

1 2 3 4 5

Lowest 10% Highest 10%

Math ability *

Mark only one oval.

1 2 3 4 5

Lowest 10% Highest 10%

Science Ability *

Mark only one oval.

1 2 3 4 5

Lowest 10% Highest 10%

Communication skills *

Mark only one oval.

1 2 3 4 5

Lowest 10% Highest 10%

Ability to apply math and science principles in solving real world problems *

Mark only one oval.

1 2 3 4 5

Lowest 10% Highest 10%

Business ability *

Mark only one oval.

1 2 3 4 5

Lowest 10% Highest 10%

Ability to perform in teams *

Mark only one oval.

1 2 3 4 5

Lowest 10% Highest 10%

Critical thinking skills *

Mark only one oval.

1 2 3 4 5

Lowest 10% Highest 10%

12. How important do you think each of the following skills and abilities is to becoming a successful engineer? (0) - Not Important (1) - Somewhat Important (2) - Very Important (3) - Crucial

Self confidence (social) *

Mark only one oval.

1 2 3 4

Not Important Crucial

Leadership ability *

Mark only one oval.

1 2 3 4

Not Important Crucial

Public speaking ability *

Mark only one oval.

1 2 3 4

Not Important Crucial

Math ability *

Mark only one oval.

1 2 3 4

Not Important Crucial

Science ability *

Mark only one oval.

1 2 3 4

Not Important Crucial

Communication skills *

Mark only one oval.

1 2 3 4

Not Important Crucial

Ability to apply math and science principles in solving real world problems *

Mark only one oval.

1 2 3 4

Not Important Crucial

Business ability *

Mark only one oval.

1 2 3 4

Not Important Crucial

Ability to perform in teams *

Mark only one oval.

1 2 3 4

Not Important Crucial

13. Please rate your satisfaction with this institution on each aspect of campus life listed below. Mark 0 (N/A) if you do not have experience with this aspect. (0) - Not Applicable (1) - Very Dissatisfied (2) - Dissatisfied (3) - Satisfied (4) - Very Satisfied

Quality of instruction *

Mark only one oval.

0 1 2 3 4

N/A Very Satisfied

Availability of instructors *

Mark only one oval.

0 1 2 3 4

N/A Very Satisfied

Quality of advising by instructors *

Mark only one oval.

0 1 2 3 4

N/A Very Satisfied

Academic advising *

Mark only one oval.

0 1 2 3 4

N/A Very Satisfied

14. During the current school year, what portion of your classes have used the following teaching methods? (0) - None (1) - Very Little (2) - Less than half (3) - About half (4) - More than half (5) - All or Nearly All

Individual Projects *

Mark only one oval.

0 1 2 3 4 5

None All or Nearly All

Team Projects *

Mark only one oval.

0 1 2 3 4 5

None All or Nearly All

15. Please rate the overall quality of your collegiate experience so far: *

Mark only one oval.

- Very Dissatisfied
- Dissatisfied
- Satisfied
- Very Satisfied
- I prefer not to answer

16. Think about the engineering, math or science classes you are taking/have taken during the current school year. Indicate how often you: (0) - Never (1) - Rarely (2) - Occasionally (3) - Frequently

Came late to engineering class *

Mark only one oval.

0 1 2 3

Never Frequently

Skipped engineering class *

Mark only one oval.

0 1 2 3

Never Frequently

Turned in engineering assignments that did not reflect your best work *

Mark only one oval.

0 1 2 3

Never Frequently

Turned in engineering assignments late *

Mark only one oval.

0 1 2 3

Never Frequently

17. Think about the liberal arts classes (not engineering, math, or science classes) you are taking/have taken during the current school year. Indicate how often you:

Came late to liberal arts class *

Mark only one oval.

0 1 2 3

Never Frequently

Skipped liberal arts class *

Mark only one oval.

0 1 2 3

Never Frequently

Turned in liberal arts assignments that did not reflect your best work *

Mark only one oval.

0 1 2 3

Never Frequently

Turned in liberal arts assignments late *

Mark only one oval.

0 1 2 3

Never Frequently

18. How well are you meeting the workload demands of your coursework? *

Mark only one oval.

- I am meeting all of the demands easily
- I am meeting all of the demands, but it is hard work
- I am meeting most of the demands, but cannot meet some
- I can meet some of the demands, but cannot meet most
- I cannot meet any of the demands
- I prefer not to answer

19. How stressed do you feel in your coursework right now? *

Mark only one oval.

- No stress
- Moderately low stress
- Moderate stress
- Moderately high stress
- High stress
- I prefer not to answer

20. During the current school year, how much pressure have you felt with each of the following? (0) - No Pressure (1) - Moderately Low Pressure (2) - Moderate Pressure (3) - Moderately High Pressure (4) - High Pressure

Course load (amount of course material being covered) *

Mark only one oval.

1 2 3 4 5

No Pressure High Pressure

Course pace (the rate at which the course material is being covered) *

Mark only one oval.

1 2 3 4 5

No Pressure High Pressure

Balance between social and academic life *

Mark only one oval.

1 2 3 4 5

No Pressure High Pressure

21. During the current school year, how often have you interacted with your instructors (faculty, teaching assistants) in your engineering, math, or science classes (e.g. by phone, e-mail, IM, or in person)? (0) - Never (1) - Rarely (2) - Occasionally (3) - Often (4) - Very Often

Instructors during class *

Mark only one oval.

0 1 2 3 4

Never Very Often

Instructors during office hours *

Mark only one oval.

0 1 2 3 4

Never Very Often

Instructors outside of class or office hours *

Mark only one oval.

0 1 2 3 4

Never Very Often

22. Some people are involved in non-engineering activities on or off campus, such as hobbies, civic or church organizations, campus publications, student government, social fraternity or sorority, sports, etc. How important is it for you to be involved in these kind of activities? *

Mark only one oval.

- Not important
- Somewhat important
- Very important
- Essential
- I prefer not to answer

23. How often are you involved in the kinds of non-engineering activities described above? *

Mark only one oval.

- Never
- Rarely
- Occasionally
- Frequently
- I prefer not to answer

24. What is your level of involvement in student engineering activities such as engineering clubs or societies? *

Mark only one oval.

- No involvement
- Limited involvement
- Moderate involvement
- Extensive involvement
- I prefer not to answer

25. Since coming to college, have you had any research experience(s)? *

Mark only one oval.

- No
- Yes, in engineering related areas
- Yes, in non-engineering related areas
- Yes, in both engineering and non-engineering related areas
- I prefer not to answer

26. Before college, how much knowledge did you have about the engineering profession? *

Mark only one oval.

- No knowledge
- Limited knowledge
- Moderate knowledge
- Extensive knowledge
- I prefer not to answer

27. Since entering college, how much knowledge have you gained about the engineering profession? *

Mark only one oval.

- No knowledge
- Limited knowledge
- Moderate knowledge
- Extensive knowledge
- I prefer not to answer

28. How much exposure have you had to a professional engineering environment as a visitor, intern, or employee? *

Mark only one oval.

- No exposure
- Limited exposure
- Moderate exposure
- Extensive exposure
- I prefer not to answer

29. How did you gain your knowledge about the engineering profession? (Mark all that apply) *

Check all that apply.

- From being a visitor
- From being a co-op student or intern
- From being an employee
- From a family member
- From a close friend
- From school-related experiences (i.e., a professor or class)
- I prefer not to answer
- Other:

30. Do any of your immediate family members (parents, siblings) hold an engineering degree? *

Mark only one oval.

- No

- Yes
- I prefer not to answer

31. Do you see yourself continuing in an engineering major? *

Mark only one oval.

- No - I am NOT majoring or planning to major in engineering
- Yes
- I prefer not to answer

32. Do you see yourself pursuing a career in engineering? *

Mark only one oval.

- Definitely not
- Probably not
- Not sure
- Probably yes
- Definitely yes
- I prefer not to answer

33. How likely is it that you would do each of the following after graduation? (0) - Definitely Not (1) - Probably Not (2) - Not Sure (3) - Probably Yes (4) - Definitely Yes

Work in an engineering job *

Mark only one oval.

0 1 2 3 4

Definitely Not Definitely Yes

Work in a non-engineering job *

Mark only one oval.

0 1 2 3 4

Definitely Not Definitely Yes

Go to graduate school in an engineering discipline *

Mark only one oval.

0 1 2 3 4

Definitely Not Definitely Yes

Go to graduate school outside of engineering *

Mark only one oval.

0 1 2 3 4

Definitely Not Definitely Yes

34. Do you have any concerns about your ability to finance your college education? *

Mark only one oval.

- None (I am confident that I will have sufficient funds)
- Some (but I probably will have sufficient funds)
- Major (I have funds but will graduate with significant debt)
- Extreme (not sure if I will have sufficient funds to complete college)
- I prefer not to answer

35. What is your cumulative grade point average? *

Mark only one oval.

- A or A+ (i.e., 3.9 or above on a 4.0 scale)
- A- (3.5-3.8)
- B+ (3.2-3.4)
- B (2.9-3.1)
- B- (2.5-2.8)
- C+ (2.2-2.4)
- C (1.9-2.1)
- C- or lower (less than 1.5)
- I prefer not to answer

Your sex: *

Mark only one oval.

- Female
- Male
- I prefer not to answer

37. What is your racial or ethnic identification? (Mark all that apply) *

Check all that apply.

- American Indian or Alaska Native
- Asian or Asian American
- Black or African American
- Hispanic or Latino/a
- Native Hawaiian or Pacific Islander
- White
- I prefer not to answer
- Other:

How old are you? *

Mark only one oval.

- 17 or younger
- 18-19
- 20-23
- 24-29
- 30-39
- 40-55
- Over 55
- I prefer not to answer

39. Are you: *

Mark only one oval.

- ○ A U.S. Citizen
- ○ A Permanent Resident of the U.S.
- ○ Other:

40. Were you born in the United States? *

Mark only one oval.

- ○ Yes
- ○ No

41. Did one or more of your parents/guardians immigrate to the United States? *

Mark only one oval.

- ○ Yes
- ○ No

42. Is English your first language? *

Mark only one oval.

- ○ Yes
- ○ No

43. Are you a first-generation college student (first in your immediate family to attend college)? *

Mark only one oval.

- ○ Yes
- ○ No

44. Are you enrolled primarily as a: *

Mark only one oval.

- Full-time Student
- Part-time Student

45. Which of the following best describes where you are living now while attending college? *

Mark only one oval.

- Dormitory or other campus housing
- Residence (house, apartment, etc.) within walking distance of the institution
- Residence (house, apartment, etc.) within driving distance of the institution

46. Would you describe your family as: *

Mark only one oval.

- High Income
- Upper-Middle Income
- Middle Income
- Lower-Middle Income
- Low Income

47. What is the highest level of education that your mother completed? (Mark one) *

Mark only one oval.

- Did not finish high school
- Graduated from high school
- Attended college but did not complete degree
- Completed an Associate degree (AA, AS, etc.)
- Completed a Bachelor degree (BA, BS, etc.)
- Completed a Masters degree (MA, MS, etc.)
- Completed a Doctoral or Professional degree (JD, MD, PhD, etc.)
- Don't know or not applicable

48. What is the highest level of education that your father completed? (Mark one) *

Mark only one oval.

- Did not finish high school
- Graduated from high school

- Attended college but did not complete degree
- Completed an Associate degree (AA, AS, etc.)
- Completed a Bachelor degree (BA, BS, etc.)
- Completed a Masters degree (MA, MS, etc.)
- Completed a Doctoral or Professional degree (JD, MD, PhD, etc.)
- Don't know or not applicable

49. Of the twenty-three design activities below, please put a check mark next to the SIX MOST IMPORTANT. *

Check all that apply.

- Abstracting
- Brainstorming
- Building
- Communicating
- Decomposing
- Evaluating
- Generating alternatives
- Goal setting
- Identifying contraints
- Imagining
- Iterating
- Making decisions
- Making trade-offs
- Modeling
- Planning
- Prototyping
- Seeking information
- Sketching
- Synthesizing
- Testing
- Understanding the problem
- Using creativity
- Visualizing

50. Are you a School of Engineering Equal Opportunity Fund (EOF) Student? *

Mark only one oval.

- Yes
- No
- I'd prefer not to answer

51. Is there anything you want to tell us about your experiences in engineering that we haven't already asked you about?

Appendix B:

Internal Consistency of Multi-Item APPLES Variables (Cronbach's Alphas)

Variable and Constituent Items	APPLES2 Cronbach's Alpha
1. Motivation (Financial)	**0.81**
Engineers are well paid.	
Engineers make more money than most other professionals.	
An engineering degree will guarantee me a job when I graduate.	
2. Motivation (Parental Influence)	**0.83**
My parents would disapprove if I chose a major other than engineering.	
My parents want me to be an engineer.	
3. Motivation (Social Good)	**0.77**
Technology plays an important role in solving society's problems.	
Engineers have contributed greatly to fixing problems in the world.	
Engineering skills can be used for the good of society.	
4. Motivation (Mentor Influence)	**0.77**
A faculty member, academic advisor, teaching assistant or other university affiliated person has encouraged and/or inspired me to study engineering.	
A non-university affiliated mentor has encouraged and/or inspired me to study engineering.	
A mentor has introduced me to people and opportunities in engineering.	
A mentor has supported my decision to major in engineering.	
5. Motivation (Intrinsic, Psychological)	**0.75**
I feel good when I am doing engineering	
I think engineering is fun	
I think engineering is interesting	
6. Motivation (Intrinsic, Behavioral)	**0.72**
I like to build stuff	
I like to figure out how things work	
7. Confidence in Math and Science Skills	**0.80**
Confidence: Science ability	
Confidence: Math ability	
Confidence: Ability to apply math and science principles in solving real world problems	
8. Confidence in Professional and Interpersonal Skills	**0.82**
Confidence: Self confidence (social)	
Confidence: Leadership ability	
Confidence: Public speaking ability	
Confidence: Communication skills	
Confidence: Business ability	
Confidence: Ability to perform in teams	

Variable and Constituent Items	APPLES2 Cronbach's Alpha
9. Confidence in Solving Open-Ended Problems	**0.65**
Creative thinking is one of my strengths	
I am skilled at solving problems with multiple solutions	
Confidence: Critical thinking skills	
10. Perceived Importance of Math and Science Skills	**0.80**
Perceived importance: Math ability	
Perceived importance: Science ability	
Perceived importance: Ability to apply math and science principles in solving real world problems	
11. Perceived Importance of Professional and Interpersonal Skills	**0.82**
Perceived importance: Self confidence (social)	
Perceived importance: Leadership ability	
Perceived importance: Public speaking ability	
Perceived importance: Communication skills	
Perceived importance: Business ability	
Perceived importance: Ability to perform in teams	
12. Curriculum Overload	**0.82**
How well are you meeting the workload demands of your coursework?	
How stressed do you feel in your coursework right now?	
During the current year, how much pressure have you felt with course load	
During the current year, how much pressure have you felt with course pace	
During the current year, how much pressure have you felt with balance between social and academic life	
13. Academic Disengagement (Liberal Arts Courses)	**0.75**
Came late to liberal arts class	
Skipped liberal arts class	
Turned in liberal arts assignments that did not reflect your best work	
Turned in liberal arts assignments late	
14. Academic Disengagement (Engineering-related Courses)	**0.71**
Came late to engineering class	
Skipped engineering class	
Turned in engineering assignments that did not reflect your best work	
Turned in engineering assignments late	
15. Frequency of Interaction with Instructors	**0.70**
Instructors during class	
Instructors during office hours	
Instructors outside of class or office hours	
16. Satisfaction with Instructors	**0.79**
Quality of instruction	
Availability of instructors	

Variable and Constituent Items	APPLES2 Cronbach's Alpha	APPLES1 Cronbach's Alpha
Quality of advising by instructors		
Academic advising		

Single-Item APPLES Variables and Related Items

17. Academic Persistence
Do you intend to complete a major in engineering?
18. Professional Persistence
Do you intend to practice, conduct research in, or teach engineering for at least 3 years after graduation?
Do you see yourself pursuing a career in engineering?
How likely is it that you would do each of the following after graduation: Work in an engineering job
How likely is it that you would do each of the following after graduation: Work in a non-engineering job
How likely is it that you would do each of the following after graduation: Go to graduate school in an engineering discipline
How likely is it that you would do each of the following after graduation: Go to graduate school in a non-engineering discipline
19. Exposure to the Engineering Profession
How much exposure have you had to a professional engineering environment as a visitor, intern, or employee?
20. Knowledge of the Engineering Profession
Before college, how much knowledge did you have about the engineering profession?
Since entering college, how much knowledge have you gained about the engineering profession?
How did you gain your knowledge about the engineering profession?
From being a visitor
From being a co-op student or intern
From being an employee
From a family member
From a close friend
From school-related experiences
From other
Do any of your immediate family members (parents, siblings) hold an engineering degree?

21. Exposure to Project-Based Learning Methods	
	During the current school year, what portion of your classes have used the following teaching methods? Individual projects
	During the current school year, what portion of your classes have used the following teaching methods? Team projects
22. Extracurricular Involvement (Engineering and Non-Engineering)	
	Importance of non-engineering activities on or off campus
	Involvement in non-engineering activities
	Level of involvement: Student engineering activities such as engineering clubs or societies
23. Research Experience	
	Since coming to college, have you had any research experiences in engineering and/or non-engineering areas
24. Financial Difficulties	
	Do you have any concerns about your ability to finance your college education?
25. Overall Satisfaction with Collegiate Experience	
	Rate the overall quality of your collegiate experience so far

Apples Demographic Items

26. Student Characteristics	
	What school are you currently attending?
	Gender
	Racial or ethnic identification
	Age
	Housing: which of the following best describes where you are living now while attending college?
27. Academic Status	
	What is your current academic standing? (freshman, sophomore, junior, senior, 5th year senior, graduate student, other)
	When you first entered this institution, were you: (first-time, returning, transfer student)
	Full-time/part-time student?
	What is your cumulative grade point average? [GPA Index]
28. Academic Interests and Majors	
	What were you most interested in majoring in when you first came to university?
	What is your current major or first choice of major?
	What is your second choice or major or second major/minor?
29. Citizenship, Immigration and Cultural Status	
	Citizenship status (U.S. citizen, permanent resident of U.S., other)
	Were you born in the U.S.?
	Did one or more of your parents/guardians immigrate to the U.S.?
	Is English your first language?
	Are you a first generation college student?
30. Socioeconomic Status	
	Would you describe your family as low, lower middle, middle, upper-middle, or high income?
	Highest level of education mother completed
	Highest level of education father completed

Appendix C:

Definitions and Rationale Behind the Apple Survey Variables

APPLES Variable	Variable Description and Rationale
1. Motivation to Study Engineering: Financial	Motivation to study engineering due to the belief that engineering will provide a financially rewarding career. Astin (1993) found that engineering majors frequently reported that the "chief benefit of college is making money." Seymour found that the belief "science, mathematics and engineering career options and rewards are not worth the effort to get the degree" influenced the decision to leave engineering (Adelman, 1998; Seymour & Hewitt, 1997). This variable was borrowed from the Pittsburgh Freshman Engineering Attitudes Survey (PFEAS) (Besterfield-Sacre et al, 1995; 1997).
2. Motivation to Study Engineering: Parental Influence	Motivation to study engineering due to parental influences. Astin found that having a father who is an engineer was an indicator for engineering as a career choice (Adelman, 1998). However, Seymour and Hewitt's findings (1994, 1997) suggest that men leaving science and engineering majors are those most likely to have followed a "family career tradition" into science and engineering fields. This variable was borrowed from the PFEAS.
3. Motivation to Study Engineering: Social Good	Motivation to study engineering due to the belief that engineers improve the welfare of society. Since Astin (1993) reported that engineering majors frequently voiced the belief that "individuals can't change society," it is relevant to investigate whether this motivation variable is a persistence factor. Also, Nicholls et al. (2007) reported that non-STEM students were more likely to be motivated by influencing social values than STEM students. Thus, students who leave engineering might respond more strongly to this variable than the ones who stay. This variable was borrowed from the PFEAS.
4. Motivation to Study Engineering: Mentor Influence	Motivation to study engineering due to the influence of mentor(s) while in college. Schuman et al. (1999) suggested that students who drop out of engineering do not seek counseling services that are offered by the institutions.
5. Motivation to Study Engineering: Intrinsic Psychological	Motivation to study engineering for its own sake, to experience enjoyment that is inherent in the activity. This variable is a modified version of the intrinsic motivation subscale of the Situational Motivation Scale (SIMS) (Guay, Vallerand, & Blanchard, 2000).
6. Motivation to Study Engineering: Intrinsic Behavioral	Motivation related to practical and hands-on aspects of engineering, e.g., "I like to figure out how things work," "I like to build stuff."
7. Confidence in Math and Science Skills	Math and science skills refer to proficiency in science, critical thinking, real-world problem solving, and computation. Engineering majors frequently reported "growth in analytic and problem-solving skills" during their undergraduate careers in Astin (1993). Besterfield-Sacre (1995, 1997) also identified "low confidence in basic mathematics, science, and engineering skills" as a characteristic of engineering students who did not persist. Burtner (1994) identified confidence in math and science ability as a predictor for short and long term persistence in engineering.

8. Confidence in Professional and Interpersonal Skills	Professional and interpersonal skills refer to proficiency in business, communication and teamwork. The variable explores the relationship between self-efficacy and persistence in engineering education. Seymour identified "feeling discouraged/losing confidence due to low grades in early years" as a persistence factor (Seymour & Hewitt, 1994; 1997). Seymour's findings are relevant to all three variables that are associated with self reported confidence.
9. Confidence in Solving Open-Ended Problems	Level of confidence in the ability to engage problems with multiple solutions. Although there is agreement that practicing engineers solve open-ended problems, it is not clear whether engineering curricula successfully prepare students to tackle such problems (Dym, 2005).
10. Perceived Importance of Math and Science Skills	Perceived importance of math and science skills, as measured by Variable 7, in becoming a successful engineer.
11. Perceived Importance of Professional and Interpersonal Skills	Perceived importance of professional and interpersonal engineering knowledge and skills, as measured by Variable 8, in becoming a successful engineer.
12. Curriculum Overload	Level of difficulty in coping with the pace and load demands of engineering-related courses. Seymour identified the level and the large volume of work required in the engineering curriculum, coupled with the rapid pace at which the information must be absorbed, to be a strong persistence factor (Seymour & Hewitt, 1994; 1997). Adelman (1998) reported that although the engineering major credit loads are not significantly higher than those of other majors, engineering students "perceive overload because of the high ratio of classroom, laboratory, and study hours to credit awarded."
13. & 14. Academic Involvement (Liberal Arts, Engineering Related Courses)	Frequency of events signaling disengagement or lack of involvement from engineering and non-engineering courses. Seymour found that a lack of or loss of interest in science, mathematics and engineering, as well as a belief that non-engineering majors offer a "better education," were both persistence factors (Seymour & Hewitt, 1994, 1997). Thus, lower involvement in engineering courses, while remaining engaged in non-engineering courses, might be a precursor to leaving engineering. On the other hand, disengagement from both engineering and non-engineering courses might be a precursor to leaving college. This variable was borrowed from the Your First College Year (YFYC) survey (Higher Education Research Institute, 2010b).
15. Frequency of Interaction with Instructors	Frequency of interactions with faculty and teaching assistants. Seymour found "poor teaching by science, mathematics, and engineering faculty" to be a strong persistence factor (Seymour & Hewitt, 1994; 1997). Strong correlation between student-faculty interaction and college GPA and retention have been reported (French, 2003). Also, engineering faculty often rely heavily on TAs in order to carry out teaching responsibilities, who might lack adequate teaching experience, which may also be a persistence factor. Furthermore, a significant percentage of TAs in engineering are foreign students, and experience difficulties in classroom management and communication (Seymour & Hewitt, 1994; 1997). This variable was borrowed from the PFEAS.

16. Satisfaction with Instructors	Level of satisfaction with interactions with faculty and teaching assistants.
17. & 18. Persistence in Engineering (Academic, Professional)	This variable is defined as two dimensions: "academic persistence" is graduating with an undergraduate engineering degree, whereas "professional persistence" is an intention to practice engineering for at least three years after graduation. Although the second is contingent on the first, not all students who graduate with an engineering degree practice engineering.
19. Exposure to the Engineering Profession	Level of exposure to professional engineering environments as a visitor, intern, or employee.
20. Knowledge of the Engineering Profession	This variable addresses various dimensions that contribute to knowledge of the engineering profession including self-assessed gains in understanding the field from before college and since entering college. Sources that contribute to students' perceptions of engineering through direct interactions (as a visitor, co-op, intern, employee), family members or peers, and other related experiences are also identified. Several studies have documented the influence of parents, particularly fathers, on their children's career choices, especially women (Assessing Women in Engineering Project, 2005; Hellerstein & Morrill, 2010; Leppel, Williams, & Waldauer, 2001).
21. Exposure to Project-Based Learning (a. Individual Projects, b. Team Projects)	Level of exposure to project-based learning (PBL) pedagogies in courses. The majority of engineering students enjoy courses which utilize project-based learning methods (Dym, 2005). Recent ABET requirements have resulted in an increase in design courses in engineering curricula, which are often taught using PBL approaches.
22. Extracurricular Involvement (Engineering and Non-Engineering)	Astin (1993) found that engineering majors reported low satisfaction with student life, including participation in extracurricular activities. Tracking the perceived importance of extracurricular activities in concert with the frequency of involvement in extracurricular activities allows us to place the level of involvement in its proper context.
23. Research Experience	Reflects whether a student has had experience during in a college doing engineering and/or non-engineering research.
24. Financial Difficulties	Level of comfort with financing college expenses. Seymour found having financial difficulties to be a persistence factor (Seymour & Hewitt, 1994; 1997).
25. Overall Satisfaction with Collegiate Experience	General satisfaction with the overall quality of the college experience. This question is asked at the end of the survey to obtain a Gestalt-like judgment. Continued dissatisfaction with the overall college experience is hypothesized to result in low persistence.