RETENTION, SUCCESS, AND SATISFACTION

OF ENGINEERING STUDENTS

BASED ON THE FIRST-YEAR EXPERIENCE

by

LYDIA Q. PRENDERGAST

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ABSTRACT OF THE DISSERTATION

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A project-based course for first-year engineering students, called Engineering Exploration, was created an implemented with the goals of increasing retention, providing professional skills, increasing interest about engineering, and to aide in choosing an engineering major. Over 100 students have taken the course since its inception in Fall 2009. Retention rates, GPA, and opinions of engineering students have improved for the cohort of students who took the course. Minority retention however did not see a steady increase. Female persistence in engineering was also explored in this study. While beneficial for women, the course was not as beneficial for them as it was for their male counterparts. Women who took the course and subsequently recounted reasons for leaving as being primarily due to educational pursuits outside of engineering. Faculty

involvement in the first year was crucial in students' experiences choosing a major. Future goals are to offer the course to more students, continue to fine tune the curriculum to make it more beneficial, increase awareness to faculty members, create an engineering video library for tours and virtual problem solving, and to create a secondary project-based course in the second year, specific to particular engineering majors. In total, Engineering Exploration has proven to be a benefit to the first-year experience for engineering students.

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I. INTRODUCTION

There is increasing awareness and recognition in research that undergraduate engineering students' experiences are positively affected by a dynamic first year experience. An active learning environment and a positive first year experience produce strong indicators of success and increased retention rates in engineering (Felder, 2000; Besterfireld-Sacre, Atman & Shuman, 1998; Tinto, 1993). Studies show that engineering curricula that include a dynamic first year experience produce a positive shift in students' attitudes, expectations, and skill level in engineering and engineering related course work.

At Rutgers, School of Engineering (RU-SOE), the retention rate is approximately 55%, meaning only half of students who start out in an engineering major finish with an engineering degree from Rutgers. Similar to other universities, engineering retention and experiences at Rutgers are in need of improvement. A common place to begin an inquiry is in the first year. The first year engineering curriculum at RU-SOE contains very little engineering specific coursework. This may contribute to a loss of interest among the engineering first-year student body. Eighty percent of the credits (28/35) in the first year are arts and science courses, which are not directly related to engineering (Figure 1).

Figure 1. Standard first year engineering curriculum.
Freshman Year

160:159	Chemistry	3	160:160	Chemistry	3
160:171	Chemistry Lab	1	440:127	Computers for Eng'rs	3
355:101	Expository Writing	3	640:152	Calculus for Eng'g	4
440:100	Eng'g Orientation Lect	1	440:221	Eng'g Mechanics (Statics)	3
640:151	Calculus for Eng'g	4	750:124	Analytical Physics Ib	2
750:123	Analytical Physics Ia	2	______	Hum/Soc Elective	3
______	Hum/Soc Elective	3			

It is clear that mathematics, physics, chemistry, and other non-engineering courses are prevalent in the first-year curriculum. This leaves very little time for engineering coursework, for applying math and science to engineering, or for presenting engineering as the dynamic field that it is. Therefore, it is important to optimize the quality of the engineering coursework that is present in the first year. There are three courses (totaling 7 credits) that are taught by SOE in the first year. These three engineering courses are described as follows:

- **Computers for Engineers-440:127**, 3cr: Applied computer programming for engineers. 440:127 is directly related to Electrical/Computer and Mechanical Engineering, covering ~46% of the engineering students.
- **Engineering Mechanics-Statics-440:221**, 3cr: Applied physics. 440:221 is directly related to Civil and Mechanical Engineering, covering ~40% of the students in SOE.
- **Engineering Orientation Lectures-440:100**, 1cr: Introduction to the fields of engineering. 440:100 is a seminar style, attendance based, and pass/no-credit course. 440:100 is directly related to all engineering majors.

Standard engineering curricula typically contain basic mechanics, calculus, programming, and overall knowledge of the different engineering majors. The content of 440:127 and 440:221 apply directly to only a portion of the engineering majors. The Engineering Orientation Lectures course, 440:100, is applicable to all engineering majors. Due to the lack of engineering presence in the first year, an engineering course like 440:100. According to Ercolano (Ercolano, 1995), the format and content of this type of cornerstone course can reduce attrition. At Rutgers - School of Engineering, the curriculum of the Engineering Orientation Lectures course (14:440:100) has been essentially the same for decades and is in need of updating.

> ‘Three objectives seem to turn up in many of the efforts to reform the freshman orientation course: building “studenting" skills, instilling a sense of membership in the academic community, and generating enthusiasm for "doing" engineering. Pursuing these objectives, reform advocates say, will serve the general goals of keeping qualified students in engineering and improving their academic performance.’ (Ercolano, 1995 p. 26)

The development of these “studenting” skills and engagement initiatives falls directly in line with the ABET Engineering Criteria (ABET criteria, 2010) which indicate that along with traditional STEM conceptual and design related skills, engineering students must also develop professional skills.

The Engineering Orientation Lectures course (14:440:100) at Rutgers is delivered as a traditional seminar style course where a representative of each engineering department talks to the students about the major in a large lecture style format. Project-based courses are becoming increasingly prevalent in first-year engineering programs across the nation for the intended outcome of increased retention and success. (Ercolano, 1995; Ercolano, 1996; Tezcan & Nicklow, 2008; Sheppard & Jenison, 1997; Carlson & Sullivan, 1999).

Administrative and faculty buy-in is essential to the success of these new and reformed first year initiatives (Tinto, 1993; Richards & Carlson-Skalak, 1997). Akin to other universities, I attempt to address these issues at Rutgers by revamping the first-year introductory course (14:440:100) from a passive seminar course to an active learning experience (Pendegrass, Kowalczzyk, Dowd, Laoulache, Nelles, Golen & Fowler, 2001; Porter & Fuller, 1998; Kemppanian & Hamlin, 2009; Giralt, Herrero, Grau, Alabart & Medir, 2000).

The education of future engineers and scientists must evolve to match the needs of today's society. In response, I developed a new first-year project based introduction to engineering course, called Engineering Exploration. Engineering Exploration was implemented as a pilot course in fall, 2009. Using the ABET criteria and research in the filed as a guide, I designed the curriculum with the intention increasing retention, increasing success, helping students choose an engineering major, to get students excited about engineering, and to equip them with some professional skills. I have structured Engineering Exploration to be a dynamic learning experience and a discipline-based, project-based, and team-based course. Students are introduced to the various majors of engineering by completing discipline-based projects. I created the project descriptions based on a life-like situation, which is meant to give students a glimpse of what they will be doing as senior-level students, and as professionals in the field. Students will use independent and collaborative efforts to complete the projects, based on sound science and mathematics concepts. Students must learn to effectively work in teams, communicate scientific ideas, manage time, and maintain professionalism.

With this dissertation, my goal is to answer these research questions:

1. What is the relationship between enrollment in Engineering Exploration and retention? Why do women who have taken EE leave engineering?
2. What is the relationship between enrollment in EE and academic success?
3. What is the relationship between enrollment in EE and student satisfaction?

By exploring these questions in this dissertation study, I hope to find and document the extent of the beneficial elements that this reformed course provides in regards to the skills, attitudes, expectations, and retention of engineering students. With these findings, I will explore pedagogical and instructional content implications. Section II details the theoretical underpinnings, philosophies, and assessment tools related to this study.

II. REVIEW OF THE LITERATURE

In this section, there are three main questions or themes for which I will detail the theoretical underpinnings:

A. Why is this study being conducted?
    1. This study is being conducted in response to the need to provide students with the skills that are important in an engineering curriculum today;

2. to improve retention, success and satisfaction of engineering students;
3. to identify what role administrators and faculty need to play in order to achieve these goals.

B. How will the new course be taught and why?

C. Research Approach.

II.A Why is this study being conducted?

II.A.1 Evolution of Engineering Education

The philosophies of Engineering Education began to grow and drastically transform in the mid 1990's, valuing a more wholesome engineer. Surely the focus continues to include the traditional solidly rooted STEM skills, but also includes professional development skills such as: communication, teamwork, global and ethical awareness, and skills for life-long learning (ABET criteria, 2010). Summarized by Shuman et al., prior to the 1990's, the professional skills did not make ABET's list of requirements for engineering programs (Shuman, Besterfield-Sacre & McGourty, 2005). Prados, a leader in ABET's reform in the 90's, noted that ABET criteria in the 1970's and 1980's had become too rule-bound and rigid, focusing too narrowly on specific course requirements, credit hours, number of faculty, and the like (Prados, 1997). In 1996 ABET released a radically new set of criteria, called EC, 2000. (ABET criteria, 2010)These criteria have been updated and include the most recent objectives for the 2011-2012 accreditation cycle. Criterion 3 includes 11 specific outcomes. The first five educational objectives of Criterion 3 are the traditional STEM related skills:

> (a) an ability to apply knowledge of mathematics, science, and engineering;
> (b) an ability to design and conduct experiments, as well as to analyze and interpret data;
> (c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability;
> (d) an ability to function on multidisciplinary teams; and
> (e) an ability to identify, formulate, and solve engineering problems.

In addition to learning the foundations of design, helping future engineers master such professional skills as team work, leadership, and communication before they enter the workforce is key ("Criteria for accrediting,", 2011; Hall et al., 2008; "Ideas to innovation (i2i) laboratory"; Yalvac, Smith, Troy & Hirsch, 2007; Lengsfeld, Edelstein, Black, Hightower, Root, Stevens & Whitt, 2004). The focus of this study lies both in the acquisition and use of traditional skills as seen above, as well as in the professional development skills in Criterion 3:

> (f) an understanding of professional and ethical responsibility;
> (g) an ability to communicate effectively;
> (h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context;
> (i) a recognition of the need for, and an ability to engage in life-long learning;
> (j) a knowledge of contemporary issues;
> (k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

With these educational and developmental objectives on the radar, universities in the nation are charged with the responsibility of delivering the proper tools and scaffolding into their programs. (Diefes-Dux, Follman, Haghighi, Imbrie, Montgomery, Oakes & Wankat, 2004; "Ideas to innovation (i2i) laboratory"). Similarly to ABET’s radically reformed Engineering Criteria, at the turn of the century NSF also launched the Engineering Education Coalitions (EEC) aimed at innovating engineering education. The Engineer of 2020 states that there were mixed formal reviews of the effectiveness of these coalitions. (Borrego, Froyd & Hall, 2010; National Academy of Engineering, 2005). However, many individual participants of the EEC's had positive things to say regarding systematic changes that have been made at universities. One of the biggest impacts on attitudes, skills, and attrition was early introduction of engineering and design into the first two years of the engineering curriculum. (Ercolano, 1996; Hall, Cronk, Brackin, Barker, Crittenden, 2008; Tinto, 1993).

II.A.2 Factors Affecting Attrition

Tinto, Ercolano, and other earlier engineering educators were aligned and clear that the face of engineering education needed to change to keep students in the field and to give them the requisite skills for life in an engineering career (Ercolano, 1995; (Diefes-Dux, Follman, Haghighi, Imbrie, Montgomery, Oakes & Wankat, 2004; Ercolano, 1996; Tinto, 1993). Reforming the first year curriculum is a place where many universities start tackling these factors of attrition. (Tezcan et al., 2008; Hoit & Ohland, 1998; Porter & Fuller, 1998; Kemppainen & Hamlin, 2009). Assessment of the reform measures, whether it is an integrated curriculum, updated teaching methods, or a cornerstone course, has produced positive results in lowering attrition and increasing students' satisfaction with their career choice (Mendez, Buskirk, Lohr & Haag, 2008; Olds & Miller, 2004; Felder,

Felder & Dietz, 1998; Felder, Forrest, Baker-Ward, Deitz & Morh,1993; Felder, 1995).

Many of the initiatives reforming first year courses and curricula have yielded increased success (via higher grades). Yet, in some cases, attrition rates did not decline substantially enough. Research indicates that there are several factors that impact students' attitudes and efficacy beliefs in engineering which can, in the end, tip the scales in the students' decision to stay in engineering or leave. These factors include self-efficacy, self-confidence, race, gender, faculty interaction, high school preparedness, curricular rigor, academic performance, interest in other majors, etc. (Borrego, Froyd & Hall, 2010; Mendez, Buskirk, Lohr & Haag, 2008; Kilgore, Atman, Yasuhara, Barker & Morozov, 2007; Hutchinson, Follman, Sumpter & Bodner, 2006; Hutchinson-Green, Follman & Bodner, 2008; Meyers, Sillman, Gedde & Ohland, 2010). While it is clear that students leave engineering for a myriad of reasons, typically they leave early on in their education (Triplett & Haag, 2004; Myers et al., 2010; Lichtenstein, 2010).

Students' beliefs in their own abilities often take center stage in a rigorous and competitive discipline of engineering (Kittleson, & Southerland, 2004; Litzinger, Wise & Lee, 2005). Arriving on the same academic playing field as other students is essential in fighting self-doubt and allowing for a higher chance of success in academic courses (Fadali, Belasquez-Bryant & Robinson, 2004). Preparation in particular subjects, in particular math, adequate study skills, and the ability to transfer these skills from one platform to another (from math to physics for example) is a skill that engineers must possess in order to be savvy problem solvers (Gupta & Elby, 2010; Redish & Smith, 2008; Noeth, Cruce & Harmston, 2003). Certain characteristics like gender, ethnicity, and residential background, are often studied within retention and self-efficacy (Taraben & Roman, 2011; Hartman, 2006; Felder, Forrest, Baker-Ward, Dietz & Morh, 1993; Felder, Mohr, Dietz & Baker-Ward, 1994; Felder, Felder, Mauney, Harmin & Dietz, 1995). Additionally, several social pressures on women and underrepresented minorities (URMs) can cause attrition. These social pressures can include: isolation, sexism, racism, discrimination, cultural adaptation, lack of faculty/industry role models. These pressures can leave these typically at-risk students feeling unattached to the field of engineering (Li, Swaminathan & Tang, 2009; Lord, Camacho, Layton, Long, Ohland & Wasburn, 2009; Grandy, 1998).

Self-efficacy plays a particularly prominent role in retention of women and underrepresented minorities in engineering. Female students typically start college with a more negative attitude and lack of confidence in their abilities than their male counterparts, despite their comparable academic skills (Besterfield-Sacre, Moreno, Shuman & Atman, 2001; Bottomley, Rajala & Porter, 1999). Going forward from here, typically women transfer out of engineering earlier and with higher GPA than men. Women don’t believe in themselves as much as their male counterparts, despite their seemingly equal academic ability and higher levels of graduation. This phenomenon seems to then be attributed to women’s self-esteem and/or loss of interest issues (Hartman & Hartman, 2006). Of the women who stay in engineering, most times women have higher graduation rates than their male counterparts (Jenkins & Keim, 2004). We also know that there is a huge disparity between the number of male and female students who choose engineering as a major. With this information, universities can focus attention on recruiting more women to engineering. Once they are here, in order to keep women, we need to build their self-esteem and inspire them to be excited about the major. With Engineering Exploration, I hope to focus on the latter: helping to keep female students interested in engineering (Litzler, Lange & Mody, 2006; Hickey, 2011).

Conversely to female students, underrepresented minority students (African-American, Native American-Indians, and Hispanic students), start college with the highest regard for engineering out of all ethnic groups, despite possibly lacking adequate preparation in math and science subjects (Besterfireld-Sacre, Atman, & Shuman, 1998; Besterfield-Sacre, Moreno, Shuman & Atman, 2001). Although URMs may enter college with a higher regard for engineering than their white peers, they leave engineering at a higher rate. In addition to academic preparation, study skills, and self-efficacy issues, URMs who matriculate at predominately white schools are more apt to experience racism by their peers, instructors, administrators, etc. They are also more likely to experience social isolation, have to adapt to another culture, are less likely to get involved in social organizations and activities, and see fewer role models like themselves within the faculty (Li, Swaminathan & Tang, 2009; Grandy, 1998, Van Aken, Watford, & Medina-Borja, 1999; National Science Foundation, 2005). These struggles for URM's are serious and are not easily tackled by one course. While I hope to build up their self-confidence with Engineering Exploration, I feel that concerted efforts need to continue and be put in place to battle some of the external social pressures and ills.

Keeping students not only engaged in engineering course content, but also in their educational community can help strengthen a student's perception of where she fits and can contribute in the engineering world (Carlone & Johnson, 2007; Fouad & Singh, 2011; Kittleson, & Southerland, 2004; Purdue University). In general, women prefer collaboration work instead of competition (Haller, Gallaggher, Weldon & Felder, 2000). Hence, offering a course where students work together can be beneficial to female students. It is important to be aware that problems can arise in group work that can further disenchant female students. Awareness, expertise, interest on the part of the instructional faculty is essential (Richard & Carlson-Skalak, 1997). Research also shows that the type of delivery of information in the classroom has effects on students' attitudes about their major. We will review later that active learning environments are key to keeping students, particularly where attrition is a concern (Bernold, Spurlin & Anson, 2007; Braxton, Milem & Sullivan, 2000; Olds & Miller, 2004; Meyers, Sillman, Gedde & Ohland, 2010). I hope to begin to address several of the factors that affect retention and success in engineering by designing an innovative first-year course. The ideas and philosophies adopted in this course will hopefully carry over into other first-year courses and onto the remaining years of engineering education. Combatting self-efficacy, rote instruction, lack of academic community, and an early dynamic engineering curriculum takes a supportive and involved administration and faculty.

II.A.3 Administrative and Faculty Involvement

Engineering Education reform initiatives, like first-year cornerstone courses, new spaces, redesigned curricula, etc., are being designed to welcome, interest, and impassion students, as opposed to the century-old unwelcoming philosophies of weed-out courses and “look to the left, look to the right” speeches. Only with administrative and faculty support, are reform initiatives possible. Purdue University, perhaps the leader in Engineering Education, has a state-of-the-art facility and curriculum for first year engineering (Purdue University). Like Purdue, other universities around the country are adopting new practices, reforming their first year curricula (Dym, 2005; Cronk, Hall & Nelson, 2009; Ernst, Brickley, Bailey & Cornia, 2006; Froyd, 2005), writing new texts on how to teach engineering (Wankat, 1993; Ogot & Kremer, 2004), building new spaces for the first-year courses, and publishing many papers on the art and science behind delivering quality engineering education for today’s needs. Administrative and faculty buy-in is essential to their success (Tinto, 1993).

Faculty involvement of the curricular reform initiatives aides in the creation of a sense of fitting in and belonging to an academic community for the students (Richards & Carlson-Skalak, 1997; Meyers, Sillman, Gedde & Ohland, 2010). The faculty teaching the course is just as important as understanding how students learn in addition to what they learn (National Academy of Engineering, 2005; National Research Council, 2000; Tezcan, 2008). In designing the curriculum with retention in mind, it is crucial to have interested and welcoming faculty as much as developing an engaging curriculum. (Hoit & Ohland, 1998; Sheppard, 1997; Carlson, 1999; Felder, Felder, & Dietz, 1998). With an involved faculty at hand, universities can reform their first year courses in order to improve retention and the overall first year experience (Pendegrass, Kowalczzyk, Dowd, Laoulache, Nelles, Golen & Fowler, 2001; Porter, 1998; Kemppainen, 2009; Tinto, 1993).

II.B Focus on First-Year Experience

Now that we have reviewed the reasons why there needs to be some reform measures put into place, next we will see what the reform measures look like. There are several types of reforms and different elements that educators can choose for an institution of learning. In this section, we will explore three key categories of reform measures:

1. Engineering Design
2. Active Learning
3. Cornerstone Courses and other Reform
4. Choosing appropriate reform measures.

II.B.1 Engineering Design

When one is thinking about creating or redesigning a first year introductory course, including a design component becomes an important factor (Ercolano, 1996; Carlson & Sullivan, 1999; Dym, Agogino, Eris, Frey & Leifer, 2005; Ernst, Brickley, Bailey, & Cornia, 2006; Froyd, Srinivasa, Maxwell, Conkey, & Shyrock, 2005). For example, Louisiana Tech University designed a two part project-based course series to introduce their first year students to engineering and engineering design (Cronk, Hall & Nelson, 2009). In this curriculum, the students use a highly structured manual as a step-by-step guide on how to proceed with and complete the project. At key points in the project, the manual presents relevant scientific topics, with which students must make important design decisions. The inclusion of these conceptual topics at strategic positions in the manual helps the students see what math/science concepts are used, and lead them to make crucial design decisions. Using this highly structured tool allows a single instructor to have a greater number of students (44) in the classroom. This style can be referred to as ‘cook-book’, where the curriculum is strictly pre-defined and students can follow it like a recipe. While this hands-on project oriented course is a marked improvement to the traditional passive lecture or seminar style course, the cook-book setup does not provide students with a sense of ‘why’ they are doing the activities nor does it allow them to develop a design model for themselves. Another tool that supports learning and the design process is the ‘need to know’ a particular step in the investigation or a concept underlying the investigation (Etkina, 2004; Prince & Felder, 2006). The ‘need to know’ concept falls under the umbrella of active learning, which is discussed further in the next section.

II.B.2 Active Learning

“I hear and I forget,

I see and I remember,
I do and I understand. ”
Confucius

Numerous initiatives at universities across the nation for first year intro-design courses take on several different formats, all which incorporate some form of active learning. Active learning is an instructional style where the student is actively engaged in her learning. (ABET EC2000, 2010; National Academy of Engineering, 2005; BSF Shaping the future, 1996). Educators and administrators want students to stay, be happy, and be successful. However, at the forefront, we need them to learn the concepts, skills, traits, etc. of an engineer. There is a science behind the method that information is learned in the brain (Zull, 2002; National Research Council, 2000). Zull summarizes the brain’s learning cycle as one that starts with a concrete experience and continues with reflection, developing an abstract idea or hypothesis, and on to active testing of this hypothesis. The process continues through this cycle as learning is taking place.

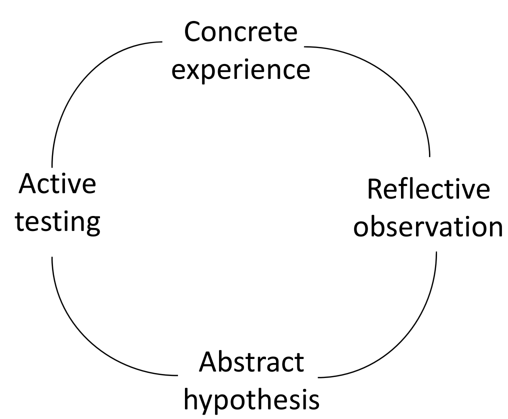


Figure 2. Learning Cycle of the Brain

Physics education researchers, Etkina and Van Heuvelen (Etkina & Van Heuvelen, 2001; Etkina and Van Heuvelen, 2007) have developed a discovery-based learning system for introductory physics, called Investigative Science Learning Environment (ISLE). In discovery-based learning, students must explain an observation, answer a question, etc. In the process, they ‘discover’ the underlying scientific phenomenon. In ISLE the student’s learning experiences mirror the ways scientists construct new knowledge and apply it. The ISLE learning cycle closely resembles the learning cycle in the brain, shown in figure 2. In order to construct a new concept or a mathematical relation, students move through a sequence of observation, idea construction, prediction, testing, reconciliation and back through the cycle (Kolb, 1984; Kolodner, 2003; Crismond, 2001). Learning is less likely to take place when the learner is passive and if the new information has little correlation to something already observed, known, or believed (Prince & Felder, 2006). Active learning is worthy of attention and inclusion into curricula because it forms new connections and paths in the brain, to allow learning to really stick, whereas traditional pedagogies are more easily forgotten. Cognitive science argues that people learn by fitting new information into existing cognitive structures in an active learning environment. In this regard, two renowned psychologists and cognivists, Piaget and Vygotsky, have developed theories concerning learning (Beveridge, 1997; Vygotsky 1997). Typically Piaget’s and Vygotsky’s theories on learning are viewed as divergent. However, in my opinion, both of their theories work together synergistically in education and learning.

Vygotsky’s theory of the Zone of Proximal Development posits that learning was primarily a result of problem solving and social interaction between more ‘novice’ and more ‘expert’ persons. This seems to go along with the student/teacher schema used in our educational settings. Collaborative efforts and group work also seems to borrow from this theory.

On the other hand, Piaget’s theories relating to learning can be summarized with: assimilation, accommodation, and reflective abstraction. Assimilation is where new information is interpreted into our existing schema (or way of thinking). Accommodation is where we modify our schemas in order to incorporate unpredicted information. Reflective abstraction is the ability to reflect upon prior knowledge, without the need of additional information, to arrive at new, higher-level of knowledge. Piaget also believed that certain types or levels of learning were based on the biological maturation, meaning that what a 3 year old can learn is different than what a 16yr old can learn. Discovery-based learning borrows a great deal from Piaget’s theories.

While Piaget’s and Vygotsky’s are different, I see them as working harmoniously in learning. Learning that begins with an active or social environment, scaffolded for age-appropriateness, facilitated by a more knowledgeable person, and used in conjunction with the individual construction of a scientific concept is where Vygotsky and Piaget’s theories work harmoniously in an educational setting. Individual acquisition of scientific concepts is compulsory in learning. Likewise, a social element early in and throughout the learning process is present in many of the methodologies used today that boost learning. ABET also deems conceptual knowledge acquisition and socialization in engineering education as necessary. These two elements in learning are explicitly and implicitly a part of ABET's Criterion 3: conceptual learning - 3a and 3b; socialization in learning - 3d, 3f, and 3g:

> 3a: an ability to apply knowledge of mathematics, science, and engineering;
> 3b: an ability to design and conduct experiments, as well as to analyze and interpret data;
> 3d: an ability to function on multidisciplinary teams;
> 3f: an understanding of professional and ethical responsibility;
> 3g: an ability to communicate effectively.

Many science departments across the country have also recognized the need for interactive engagement of students during learning and have developed curricula to replace the traditional lecture style curriculum ("Workshop physics," 2009; "Tutorials in introductory Physics"; NCSU Physics Education R & D Group, 2007; Kolodner, Crismond, Fasse, Gray, Holbrook, & Puntembakar, 2003).

"Tell me, and I forget.
Teach me, and I may remember.
Involve me, and I learn. "
Benjamin Franklin

Engineering educators, science educators, and cognitive behaviorists, and psychologists are taking different paths to the same destination (Etkina, Murthy, & Zou, 2006; Kolb, 1984; Prince & Felder, 2006; Beveridge, 1997; Vygotsky 1997, Lewis, 2006; Maltese & Tai, 2011; Seymour, 2002). Psychologists like Piaget and Vygotsky view learning as a function of biological maturation or social interaction. At the same time cognitive scientists see learning as fitting new information into existing cognitive structures. Science educators of today borrow from each of these ideas in that they view the learning process as something that starts with something active or social, then with some introspective cognitive processing using pre-existing knowledge to arrive upon new understanding of a scientific concept. It is the active and social elements used together with the individual processing and construction of a scientific concept where each of these theories works synergistically. Similarly, in order to keep our students happy and healthy academically, to be knowledgeable in engineering coursework, to be and successful in the major and professional field, our course curricula must evolve and provide students with a blend of various elements: an engaging academic environment, conceptual understanding of math and science concepts, professional skills, etc.

Engineering Education is a relatively new field in comparison to science and mathematics education. While seemingly green and rigid, the view of engineering education is in fact changing (Felder, 2004 Changing Times; Jaeger, 2008). Individual engineering faculty members are beginning to reform their pedagogies and methodologies in their courses (Jaeger, Bates, Damon & Reppy, 2008). Felder, a chemical engineering faculty and a key proponent of active learning in engineering, has utilized inductive pedagogies for decades from within the realms of the engineering curriculum. Felder’s substantial research and publications in Engineering Education offer usable strategies for curriculum design, day-to-day teaching strategies, instructor and program assessment, and overall support and encouragement in this field (Felder, 1995; Felder & Dietz, 1998; Felder, 2000). Felder highlights that the skills needed of engineers today have shifted over the decades. Engineering educators and administrators have the onus of providing students with the experiences necessary to reach industry’s current engineering needs (Woods, Felder & Garcia, 2000).

Educators and scientists across disciplines are now coming to the conclusion that a student who is active and engaged will learn better (Carlson; Etkina; Kolb; Felder; Brent, 2001). Inductive, reformed, and hands-on teaching methodologies as opposed to the traditional lecture style are the desired styles of today (Ercolano, 1995; Felder, Felder & Dietz, 1998; Felder, 2000; Smith & Sheppard, 2005; Dichter, 2001). Engineers, physical scientists, cognitive scientists, and educators are looking at learning with different lenses. However, the end result is unanimous in that learning takes place when the student is active and engaged. Educational reform that includes active learning is an involved process and comes in many formats.

II.B.3 Cornerstone Courses and Other Types of Reform

Reforming the first year engineering curriculum is the first and most obvious place to start for many institutions in the fight against attrition and dissatisfaction and to begin acquiring the needed professional skills. Engineers must be problem solvers, creative thinkers, and dynamic leaders in order to be successful in the profession (National Academy Press, 2005). Teaching and learning methods need to evolve to meet the needs of today’s times. Deductive teaching methods like lecturing (or chalk and talk), routine problem solving, etc. have been in place for centuries, and have been shown to be ineffective learning strategies (Tinto, 1993; Felder, Felder & Dietz, 1998; Hoit & Ohland, 1998; Etkina & Van Heuvelen, 2001; Lawson, 2009; Oh, 2010). Conversely, inductive pedagogies (including: guided inquiry learning, problem-based learning, project-based learning, case-based teaching, integrated curricula, cooperative learning, and just-in-time teaching) are likely to be more effective (Burton, 1999). Reforming engineering education in the first year can start from creating or revamping a single cornerstone course to integrating the entire first year curriculum. These and other reform strategies that aid in the acquisition of professional skills and the increase in retention will be reviewed in the remainder of this section.

Reform measures can come in many different formats. Some reform measures are: integrated curriculum, custom facilities, and engineering design. An integrated curriculum is one where math, science, engineering, and sometimes English courses are taught in an ‘integrated’ format. These courses may be taught together as combined courses, or taught separately, but with corresponding content (Carlson, 1999). For example, in a math course, vector addition may be introduced just prior to vectors in the physics course. Often in integrated curricula, the introductory engineering course spans all subjects (engineering, math, science, English, art, etc.). At the University of Colorado, the introductory engineering course provided students with a custom facility where real world engineering problems, design projects, and the expertise, technology, and physical apparatuses to solve these problems are available (Pendegrass, Kowalczyk, Dowd, Laoulache, Nelles, Golen & Fowler, 2001). Froyd and Ohland (Froyd & Ohland, 2005) have reviewed the term ‘integrated’ as it relates to engineering curricula, which has several different definitions. In all, an integrated engineering curriculum refers to the combination of disciplines concerning course content, learning outcomes, and/or projects.

Creating an integrated first-year curriculum or a custom facility is a major task that involves resources, personnel, and administrative buy-in. For some, these factors are not always available. Often universities start with the development of a cornerstone course in the first year. Cornerstone courses for first year engineering students in themselves can be designed in different ways. Steering away from the traditional lecture experience and leaning towards student engagement is where research suggests we should go with curriculum design of engineering courses. Cornerstone courses may include some other active learning strategies not mentioned above like, case-based learning, collaborative learning, discovery-learning, project-based learning, and problem-based learning.

As we saw in the previous section, discovery-based learning is where students must explain an observation, answer a question, etc. In the process, they 'discover' the underlying scientific phenomenon (Etkina & Van Heuvelen, 2001; Etkina and Van Heuvelen, 2007). Discovery learning engages the student in each step of learning, from observation, prediction, testing, and conceptual formation. Students can also answer conceptual questions in another reform measure called case-based learning. Case-based learning is where students analyze accounts of real world (or hypothetical) engineering related problems. In the process of analyzing this highly contextualized problem, an underlying scientific concept comes into play (Yadav, Shaver, & Meckl, 2010). In some instances, students work together in case-based learning. Collaborative learning is where students work in a group to solve a problem or project. Collaborative learning is often used in conjunction with case-based learning, project-based and problem-based learning. Often more than one reform measure is used in a curriculum.

Problem-based learning is where students work in teams on open-ended ill-structured problems in order to identify learning outcomes and needs. Instead of a traditional professor, who would provide ample un-contextualized information, the professor acts as a facilitator for the contextualized problem at hand. Solving this problem could be a pencil-paper activity, it could include working out logistical or technical issue, or it could include doing engineering related research to determine solutions (Dichter, 2001; Woods et al., 1997; Aglan & Ali, 1996). Project-based learning is where students (normally in groups) complete a project that is well-defined or ill-defined (Prince, 2006). The project is typically something tangible and must use a hands-on approach (Cronk, Hall & Nelson, 2009; Aglan & Ali, 1996; Giralt et al., 2000). Project-based learning can be very exciting for students. This excitement also comes with a price tag in that the projects themselves have a cost. Engineering educators must make an important decision when making pedagogical course decisions.

At Louisiana Tech University, as in many introductory courses, students work on projects in a group setting (Cronk, Hall & Nelson, 2009). Putting students into teams adds a level of complexity that can enhance the experience, if scaffolded appropriately (Felder, 2000; Felder & Brent, 2001; Vygotsky, 1997). In addition to designing a curriculum that is appropriate for a group, managing the dynamics of group work is challenging and complex (Johnson, Johnson & Stanne, 2000; Oakley et al., 2004; Smith et al., 2005). For courses like this, working on problems and projects go hand-in-hand with working in groups. Both of these methods lend to student engagement. Students in each team work together to identify: what they already know, what they need to know, and what resources are needed to acquire come up with a feasible solution. With problem-based learning, students could work independently, in pairs, or in groups.

There are a variety of reform measures from which to choose. Each educator at each institution of learning must make decisions that will help facilitate objectives and goals. At Rutgers, School of Engineering, I chose a combination of reform methods for a new cornerstone course.

II.B.4 Choosing Appropriate Reform Measures

As noted earlier, the current first-year introductory engineering course is a traditional lecture style seminar course. In response to the apparent need to update this course, I have reviewed the various learning methods and course structures. An integrated curriculum and a custom space are not plausible option currently at this institution, primarily due to budgetary constraints and the higher level organization of the engineering and arts/sciences schools at Rutgers University. Even under these types of constraints, it is possible to create a dynamic learning experience for first-year engineering students. I have implemented a pilot cornerstone first-year project-based design course. In order to provide students with a lasting dynamic hands-on experience, the curriculum includes project-based activities, scaffolded with active learning techniques. The discipline-based design projects introduce the various engineering majors to the students and incorporate design within engineering constraints. Students work in groups solving the semi-structured projects. Each project concludes with some form of communication, either oral, written, or both. I have structured the projects in a way that the students will need to utilize initiative, design, testing, analysis, cycle revision, communication, and teamwork. The students themselves will produce their own approach, rationale, design, and identify the concepts needed to solve the problem at hand, within a group setting. I incorporated these elements of design, projects, communication, group-work, active learning pedagogies, and engaging instruction into the course in order to address the concerns and needs relating to retention, academic success, satisfaction, and the engineering workforce. The expanded curriculum design will be further detailed in the Course Design section.

With any course, new or old, assessment is a necessary component to determine its value (Budny, LeBold, & Bjedov, 1998; Felder 2000). Developing and using updated pedagogies can be an exciting and challenging endeavor for educators. Out of the various methods, styles, and metrics, the end goal of them all is to increase student learning, provide students with the needed skills to be relevant and successful, to increase retention and passion for the field of engineering. When educators put their ideas into action, they need to assess the effectiveness. The following subsection will detail the research approach.

II.C Research Approach

This study examines attitudes, success, and retention using both quantitative methods qualitative methods. With the implementation of Engineering Exploration, which was guided by research on student learning, I now attempt to assess student learning using quantitative and qualitative measures (Etkina, Karelina, Murthy, Riubal-Villasenor, 2009). To understand the environment and the needs of the first year engineering students, the study uses the academic and the social lenses as they both may relate to students' academic performance, persistence, and opinions (Creswell, 2007; Besterfireld-Sacre, Atman & Shuman, 1997). The results of the study will contribute to the STEM education research community, and in this case, help develop a better first-year experience and promote student success, retention, and overall attitudes relating to engineering.

Investigating retention, success, and graduation rates are a standard quantitative standard practice used by universities (Budny, LeBold, & Bjedov, 1998; Takahira, Goodings, & Byrnes, 1998). At Rutgers, academic data for the approximately 100 students who have taken Engineering Exploration in the past three years and the thousands who have not will be statistically analyzed for academic success via overall GPA. Additionally, retention rates for these two cohorts will be included in the analysis. Lastly, success and retention rates as related to female engineering students will be reported. Graduation rates will not be included in this study as the first group of students who took Engineering Exploration has not yet graduated.

There are several types of assessment measures available to investigate engineering students' learning preferences, learning strategies, attitudes, and levels of persistence. Anson et al. (Anson, Bernold, Spurlin & Crossland, 2004) summarize some of the tools available in these areas. Learning preferences, learning strategies, and creativity are a very relevant element in relation to an engineering educational setting (Rosati, Dean, & Rodman, 1998; Felder & Brent, 2005; Charyton, 2009). In designing the course curriculum, I incorporated the variability of these student related traits by using several modes of delivering, representing, and assessment of the material (theoretical concepts, hands-on projects, simulations, problem solving, collaboration, team-work, communication, etc.) , I was able to address a range of the learning preferences and strategies in the curriculum in hopes to build on and develop students' pre-existing skills and to work on refining other less developed learning skills. I will investigate to what extent students stay in engineering (retention) and with what level of success (GPA). While some researchers look at learning styles and teaching pedagogies that address learning styles as retention tools, others look at students' attitudes as a measure of persistence. Some schools develop their own attitude assessment instruments, like Texas A&M and The University of Pittsburgh (Graham & Caso, 2002; Besterfield-Sacre, Atman, & Shuman, 1997; Besterfireld-Sacre, Atman & Shuman, 1998; Besterfield-Sacre et al., 1999; Burtner, 2005). There are some critics of these tools (Hilpert et al., 2008), however some these tools are widely used in attitude assessment. The review by Anson et al. of tools used to assess success in the first year found that first year students had few learning strategies, and that motivation, diligence, and self-discipline all link to success in the first year. In this study, I would like to find out what specifically in the first year curriculum and environment at Rutgers works and what does not. Instead of using an attitudes assessment or learning style assessment, I will interview students who have taken Engineering Exploration and those who have not. The specifics of the interviews will be discussed further in the Findings section.

With a theoretical framework and theoretical underpinnings well defined for this study regarding the inception of a new project-based cornerstone course, I will now provide a detailed course description, findings, and implications.

III. COURSE DESIGN

III.A Course Structure and Background

Engineering Exploration was designed for incoming first-year students to have a dynamic introduction to the various engineering majors, using group-work, projects, engineering design, and communication of conceptual ideas. One requirement that I chose to uphold for enrollment eligibility was that students must be in standard math and writing (non-remedial) for the engineering program (ie. calculus and college-level writing). All students in the class are in the standard physics and calculus courses (or have credit for them via Advanced Placement or transfer credit). By having students on a somewhat level starting point academically, the goal is to be able to find projects that are challenging, yet not too easy or hard for any student. The concepts used in the projects can be found in the standard calculus and physics textbook. Therefore, there is no additional textbook for this course. Instead, students must pay a lab fee for the course. The lab fee includes a toolkit (that they keep), and the cost of non-reusable project supplies.

Engineering Exploration is a 3 credit course and bears a grade, whereas the current course, Engineering Orientation Lectures, is a 1-credit pass/no-credit course. Taking Engineering Exploration would seemingly be a credit burden to students in an already packed and rigorous curriculum. Engineering Exploration is more work than the 1cr course. For these reasons, I was able to have Engineering Exploration approved to cover the 1cr course and cover 1 general elective (3cr). In essence, students who take Engineering Exploration (3cr) cover

4 credits in the curriculum. The curriculum includes 3 main projects, 2 mini-projects, 1 departmental tour, a few short activities, and assessments. The activities in the curriculum include: Data entry, calculations, and graphing (using Microsoft Excel); time management; and dean's information session. The projects and tour* encompass the following engineering majors: Civil, Mechanical, Industrial, Electrical, Biomedical, and Chemical*. At Rutgers, there are 8 engineering majors. The three majors not introduced by a project or tour are Bioenvironmental, Packaging, and Materials Science in Engineering. For these three majors, the departments are invited to give an interactive activity, demonstration, or presentation (15min. for the activity, 5 min. for questions). Unless or until we have suitable multidisciplinary projects and/or a customized laboratory space, there is not enough room in the syllabus or a proper physical space to complete a separate hands-on project in every major.

The goals of Engineering Exploration are to introduce students to the different engineering majors using engaging methodologies and to provide students with skills that they will need to be a successful engineer. The optimal situation would be to offer projects that were all multi-disciplinary, incorporating every engineering major by the end of the semester. Due to financial and physical space limitations, this option was not viable at the onset of the course. However, since the inception of Engineering Exploration, there have been some modifications and enhancements to the projects and activities. These changes were based on student feedback and new ideas. Due to the time limitation and the packed curriculum, some activities and projects are changed or removed from year to year. All of the project descriptions used in Engineering Exploration can be found in Appendix 2. A brief list of the projects that have been used in the course is as follows:

- Bridge construction: construct a bridge out of balsa wood to withstand highest load.
- Building construction: construct a building out of balsa wood and test to withstand earthquake like tremors (via unidirectional shake table).
- Circuit design: design a basic circuit with resistors to match specified design constraints.
- Reverse engineer coffee maker: students dissect a coffee maker to understand how it works as well as perform a heating efficiency test on two different models to test for best model (based on price and efficiency).
- Mousetrap racecar design: design a car powered by a mousetrap to go the fastest or furthest.
- Solar panel circuit design: design a circuit (resistors) that will optimize power output of a solar panel.
- Stress/strain data analysis: analyze stress strain data in excel to find the approximate modulus of elasticity value.
- Blood pressure analysis: collect real-time blood pressure data and analyze it in excel to determine typical BP and variables that affect it as they may relate to certain biomedical applications.

As mentioned, not all of these projects have been used every semester. The projects and activities have been fine-tuned each term based on student evaluations and instructor input. The course has also undergone a physical location shift. The evolution of the location, projects, and activities from term to term are featured in the next sub-sections, followed by a detailed description of one project.

III.B Project and Activity Pattern

As we have seen, the curriculum for Engineering Exploration takes considerable planning and effort. Each project in the course follows a similar pattern. There are a few days for concept processing and identification, design, construction, and analysis. Once a model has been constructed, the students test their models for proper fit and accuracy as specified in the project description. Each project is followed by some form of communication of ideas. The communication can be in the form of an oral presentation, technical paper, poster presentation, or short report. The semester has 28 class meeting days. The breakdown of projects and activities can be seen in Table 1. The information that is given in Table 1 is based on the fall 2011 course curriculum.

Table 1. Project and Activity Breakdown

Project	# days	Activity detail
Balsa Building project	3	Design, construction, analysis.
	1	Testing + department presentation
	1. 5	Student presentations
Data Analysis mini project (using Excel)	1	Data analysis
Presentation Skills	. 5	Presentation/activity by instructor
Team Meeting	1	
Circuits project	1	Concepts
	2	Design, construction, analysis
	2	Technical writing
	1	Poster presentation + department

		presentation
Academic Info Session	1	Information session, by Academic Dean
Chemical Engineering	1	Tour of Chemical Engineering Facilities
Blood Pressure mini project (using Excel)	1	Concepts and department presentation
	2	Data collection and analysis
	. 5	Technical report review and assessment
Time Management	. 5	Activity led by instructor
Department Presentations	1	Bioenvironmental, Packaging, Materials Science Engineering
Mousetrap Car project	1	concepts
	3	Design, construction, analysis
	1	Testing and racing
	2	Presentations + department presentation
Exam	1	Cumulative assessment of concepts
Total days	28	

In order to be able to complete all of the projects and activities in one semester, the curriculum and syllabus is considerably rigid. While the path to understanding the concepts, coming up with a design, and completing the project can vary from student to student, they (students) are required to complete certain aspects of each project within a specified time constraint. This time limitation is necessary by means of covering the syllabus, but also to expose the students to the concept of deadlines and constraints that they may face as practicing engineers.

Becoming a successful and healthy practicing engineer is the final goal. Each project is set within a life like situation. The reasons for this is to give the students a reason as to why they are about to learn about or solve a particular problem and secondly, to expose them to engineering-like scenarios that they may face as the progress through their education and into practice. An account of one of the projects is featured in the next section.

III.C Project Description

Earlier in the Project and Activity Breakdown section, I showed that the projects in this course all follow a similar layout. For each project, the students receive a description of a project or problem, which is written as a hypothetical authentic-like scenario. The reason for this contextualized description is to create a reason (an engineering reason) why they are going to perform the next tasks. Giving students a reason 'why' they will do a group of tasks engages the student, creating more pathways in the brain when thinking through a problem. This allows for an increased learning potential. A common term for this is 'a need to know' (Etkina, 2004). The contextualized description is in paragraph format, and takes between 3 and 5 sentences. The Mousetrap Car Project which involves students designing a car powered by a mousetrap that travels as fast as possible. Below I show the Mousetrap Car project (Figure 3).

Figure 3. Project description

Gasless Car Competition

Project Abstract:

- Greencorp Inc. is an environmentally friendly company that helps other companies to become more 'green'. Greencorp Inc. needs to design a wheeled vehicle to be used in production plants to transport products on an assembly line between stations as fast as possible. Greencorp Inc. is hosting a competition for Rutgers Engineers to construct a wheeled vehicle that travels with the greatest speed between two assembly line points. The vehicle is powered by a single mouse trap. The best product wins the competition and contract.

Constraints:

- Design and build wheeled vehicle capable of traveling solely powered by a single mouse trap. Once the car is released, no human intervention is allowed.
- The design may be modified using materials available in the classroom. The only part that must stay constant is the mousetrap itself.

Helpful terms: moment of inertia, torque, springs, friction, Newton's laws.

The contextualized description gives students a glimpse of the types of higher level projects that might be involved Mechanical Engineering. The students do not receive any formal introduction into what they need to do in order to solve this problem (ie. build a fast mousetrap car). In designing this vehicle, students will need to utilize physics concepts within engineering constraints. Borrowing from principles of problem-based and collaborative learning, in this semi-structured project, in groups, students are expected to make a self-assessment of what they already know, what they need to know, and where to go to find obtain information needed to solve the problem. In problem-based learning, the problems are typically ill-structured with several outcomes. In this course, due to time and physical constraints, the problems (or projects) in this course are semi-structured. There are expected several outcomes that students can use in their design, but they do not have to use any particular design element or any combination of design elements. Also, because the class is not held in a laboratory with relevant equipment, students' design decisions are constrained by the supplies that I provide. With these supplies, there are still several design modifications that the students can choose. I have also added some scaffolding to the projects by way of adding helpful terms. The addition of these terms and the inclusion of certain supplies are meant to help steer the students down the path of one or more possible design considerations. The students are expected to conduct individual and collaborative research and inquiry into car design and the physics concepts involved.

In a class period of 80 minutes on the first day of a project, say the Mousetrap car project, the class will start by the students receiving the project description and car kit in class (see figure. 4).

Figure 4. Mousetrap Car kit

The students (seated in their groups) are given time to review the project description and given materials. The wheels seen in this kit are removed prior to distribution, so as not to suggest a particular design element. Students can later browse through an assortment of wheels for their car design. Once they have read through the project, they can begin discussing their plan of action and researching concepts and strategies relevant to the project. Students are not told what is available or to what applications the supplies might pertain, but they are encouraged to survey the supplies and use anything that is available. At this time, they may also ask questions as to what supplies are available and browse through the available supplies (including: assorted wheels, strings, tape, balloons, rubber bands, etc.). From the beginning of class until this point is approximately 30 minutes. When students have a design idea in mind for their car, they must indicate what scientific concepts support this design decision. For example, if a student decides to use large diameter wheels, they can say that the moment of inertia is larger based on a larger wheel radius. Once a group has related all of their design decisions to a relevant scientific concept, a class aide or the instructor checks it, and they can begin building their car. Some groups begin building on the first day, by about 45 minutes or 1 hour into class, while others start on the second day. During the first day, there is no formal instruction. If any groups do not have their design and concepts approved, they are to finish the design and concepts for homework. On the beginning of day 2, there is a review of the commonly used concepts. The concept review, conducted by the instructor, lasts for approximately 20 minutes. The remainder of that day and the day after that is for students to build, test, and redesign if necessary.

Occasionally during the design process, students will request a material that is not available. Having prior knowledge of commonly used ideas relating to mousetrap car construction (Doc Fizzix - Mousetrap Powered Vehicles, 2004), I have attempted to include all supplies, within reason, for which students might ask. By the 3rd time the course was run, students did not ask for anything that was not already available in the stock of classroom supplies. In this way, students can conduct some self-guided inquiry during their engineering problem solving and design. Students can be seen in Figure 5 working on the Mousetrap Car project.

Figure 5. Mousetrap Car production

Often students start with a certain design decision, and end up changing or modifying it based on the outcome of the prototype, peer-input, or new discoveries. They then go back through the design cycle until they have reached their desired goals. With every design decision the students make, they must communicate their ideas and substantiate them with the supporting scientific principles, via oral presentations and technical papers.

III.D Communication

Communication of ideas is a key aspect to professional skills that are needed for today's engineer. In Engineering Exploration, students finish their project with an oral presentation and/or a technical report. The presentations and technical papers are the dominant form of assessment in this course. Figure 6 describes assessment as a part of the project write-up.

Figure 6: Written Assessment.

- Each team will have three attempts and only the best attempt will be considered.
- The team with the fastest speed traveled (over a 15’ distance) "wins". In case of a tie, the team traveling along the straightest line will win.
- Each team will make a group presentation describing project specifications, concepts, data, and conclusions that describe how it works, why it works, and physics/math involved.
- Each group member will write their own technical report detailing all of the information about this project, requirements, limitations, design modifications with relevant math/science concepts, pictures, diagrams, etc.

In both of the aforementioned modes of assessment, students must indicate the scientific concept that supports their design decisions. For example, if a student decides to use smaller wheels, she would need to indicate something relating to a direct proportional relationship between moment of inertia and radius of the wheel. Figure 7 shows an excerpt from a student’s technical paper (for a car built for distance).

Figure 7. Excerpt of a student technical paper.

Another factor that must be taken into account is the radius of the wheels. Deciding whether to use small wheels or big wheels comes from the physics. Moment of Inertia (I) is a measure of an object's resistance to changes its rotation. The equation for moment of inertia is found in Equation 4.
Equation 4: $I=mr^2$ (m is the mass and r is the radius of the circle)
Because this vehicle is designed to go the farthest distance, it has to have a wheel with a large radius. This is true for two reasons, the first is that with a bigger moment of inertia, the vehicle will not accelerate as fast, but rather for much longer than if it had a small moment of inertia. The second is that each time the axle makes a revolution so does the wheel. This means that the vehicle travels further with each turn of the axel if the circumference of the wheel is large. For these reasons, the next factor in building this car will be to use big wheels.

Technical writing and presentations are essential elements in the Engineering Exploration curriculum. Although, writing a technical report is a task that many incoming first-year students have never carried out, they will need to complete such a task in upper level engineering coursework, in their professional careers, and in graduate level coursework. In Engineering Exploration, the technical paper mirrors that of a scientific research paper. Because of the lack of exposure many students have in this area, I provide them with a guideline to follow when constructing the technical paper, via a rubric. The rubric for the paper includes the following sections: Abstract, Introduction, Concepts, Design and Constraints, Methodology, Results and Limitations, Conclusions. Technical Writing Rubric provides the students with a description of each section and grading (Table 2). The first time that a paper is assigned, the students must write each section of the paper step by step as they move through the project. Students first discuss and analyze each section of the paper in their groups first then together as a class.

Table 2. Technical Writing Rubric

Section (pp)	Areas to be covered	Ade-quate	Needs improve-ment	Inade-quate	Miss-ing
Abstract (¼-½ pg)	A condensed version of the main technical paper that highlights the major points covered (including the results), and reviews the writing's contents in abbreviated form. In the abstract, the reader should understand at a high level	15	11	7. 5	0

	everything that is contained in the main body of the paper.				
Intro-duction (½ to 1 pg)	A detailed description of the problem at hand.	10	7. 5	5	0
Concepts (1 to 3 pgs)	Write your paper as if a high school student (stranger to Eng'gExpl) was reading it and you did not know their level of expertise in the subject at hand (ex. physics/electricity). Describe well the math and science concepts used.	15	11	7. 5	0
Design and Constraints (½ to 2pgs)	Detail of your plan or design to solve this problem. If there are any constraining factors as designated in the project write-up, include them in this section.	15	11	7. 5	0
Results and Limitations (½ to 2pgs)	Describe the results and any limiting factors encountered while carrying out the project.	15	11	7. 5	0
Conclusions (½ to 1 pg)	Summary of the outcome of the project	10	7. 5	5	0

Grammar and Mechanics					
Tense	Technical papers are written in the passive tense, meaning you **cannot** use the 1st, 2nd, or 3rd person (no I, we, the group, our, one, etc.) Acceptable: "the solar panel was tested" vs. Unacceptable: "the group tested the solar panel"	10	7. 5	5	0
Font, format, and, cohesive-	12 font, double spaced. Figures, Diagrams, Charts labeled clearly and referenced in the text. Your paper should read fluidly. Each of the sections listed above	10	7. 5	5	0

ness	should be addressed and should be connected in your text. When you transition from one section to another, you should have some text leading into the next section. Always reread your paper; check for grammar, spelling, and cohesiveness.				
	TOTAL	100	75	50	0

The oral presentation also mirrors the technical report format. The oral presentation must include all elements of the technical paper, but in a summarized format. Students also receive a presentation rubric (Table 3). The presentation rubric does not contain a grading scale like the technical writing rubric. The reason for this is because presentations are graded in class by the other students. The time to grade is very quick, and hence a quicker schema was developed and is shown in the last line of Figure 20. However students should follow the full rubric when developing their oral presentation and slides.

Table 3. Presentation Rubric	
Adequate	▪ Goal (s) clearly stated. ▪ Math/Science concepts and methodologies used are correct and detailed properly. ▪ How goal was achieved is clearly stated. ▪ How do you know goal was achieved (assessment). ▪ Limitations. ▪ Topics and information learned (reflection). ▪ None of the presenters read verbatim. ▪ Transition between presents was smooth. ▪ Slides formatted properly: bullet points, efficient use of words, spelling/grammar correct.
Needs Improvement	▪ Goals are present but not completely clear. ▪ Math/Science concepts and methodologies used are incomplete and/or unclear. ▪ Incomplete assessment. ▪ Little or no reflection. ▪ Little to no limitations addressed.

	▪ Some of the presenters read verbatim from slides/notecards ▪ Transition between presenters needs some work. ▪ Slides may be wordy, poorly formatted, and/or unpleasing.
Inadequate	▪ Goal unclearly stated or not present. ▪ Math/Science concepts and methodologies used are incorrect or not addressed. ▪ No reflection. ▪ No limitations addressed. ▪ Transition between presenters was not smooth ▪ Presenters read verbatim from slides/notecards ▪ Slides present but do not match presentation parameters.
Missing	▪ No presentation.
Grading Schema: Slide Formatting-30 Slide Content-35Oral Presentation-35	

The culmination of the semi-structured project description, medium level of scaffolding, PBL (both problem and project based), team work, engineering design, and communication of ideas completes the life cycle of the basic curriculum of Engineering Exploration. This format is replicated several times throughout the semester. Allowing the students to have enough time to complete the majority of the work for these projects during class required a carefully planned syllabus. The 5 projects descriptions (3 main projects and 2 mini projects) follow this format. Appendices 2 and 3 provide the projects' description and the course syllabus.

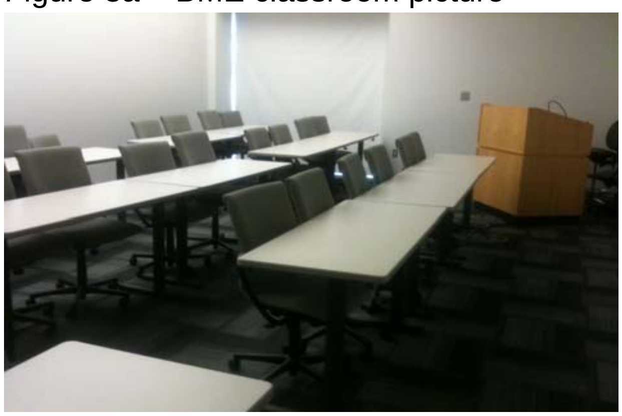
This new first-year project based course has been offered since the fall of 2009 with some successes, modifications, and some challenges. In the Findings section, I will review the methods used to measure these goals and the results. These findings will be followed by a discussion and future implications.

III.E Course Evolution

III.E.1 Location

Engineering Exploration has undergone some changes since the first time it was offered. These changes come in the form of location, projects, activities, resources, and instructional staff. The first section of Engineering Exploration was offered in the fall 2009 semester. Before the semester began, I surveyed the campus looking for a lab-like classroom space to use. Unfortunately, there was not one available. I was able to locate a classroom in the Biomedical Engineering (BME) Building that had rectangular tables, seating 4 students each, as seen in Figure 8a. I felt that the long rectangular tables were more conducive to collaborative project work than standard student desks.

Figure 8a – BME classroom picture



The classroom capacity of this room was capped at 30. A capacity of 30 worked fine for Engineering Exploration. As a first time offering the class, I wanted the numbers to be manageable. This made for a bit of a tight squeeze however as daily activities include supplies, collaboration, etc. Students often moved tables and chairs around in order to be able to work on projects in groups, Figure 8b.

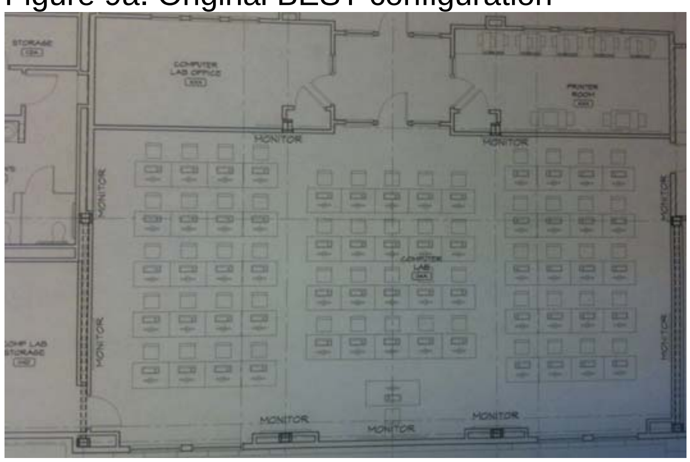
Figure 8b. EE students working
in BME classroom on the
Mousetrap car project

The classroom had a built-in projector, which was good for presentations. However it did not have Internet access at all. The lack of Internet in the classroom was a bit limiting when it came to researching topics relevant to the project. There was a nearby computer lab in the same building that the students were allowed to use. This solved the problem in part. However, this meant that I had to devise a monitoring process of the students' computer use and time in the computer lab. Another limitation to a non-laboratory space was that the projects that we could do in such a space were limited by what supplies could be brought in and taken out for each class. There was no running water, table tops could be easily damaged, carpeting, etc.

Including all of the pros and cons of the classroom space, I was very grateful to the Biomedical Engineering Department for allowing me to run my course in their space. While Engineering Exploration was underway in the BME classroom, a new computer laboratory (and smart classroom) was being built on the same campus (Busch campus) called the Busch Engineering, Science, and

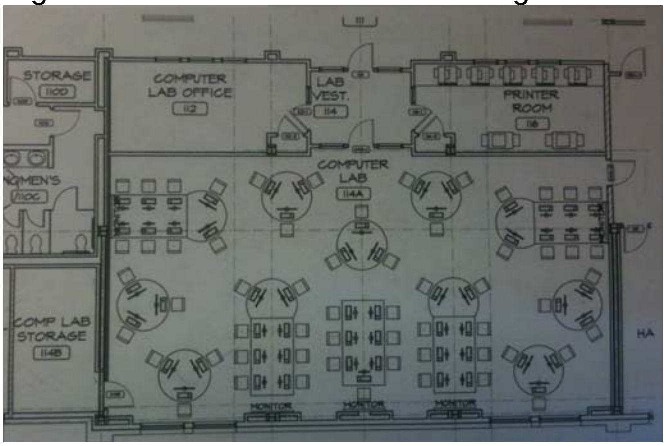
Technology Computer Center, B. E. S. T. ("BEST computing center," 2011). Because this computer laboratory was, in part, geared towards engineering students and engineering courses, as an Assistant Dean for the School of Engineering and as the director of this Engineering Exploration initiative, I was fortunate enough to have been included in the design process of the laboratory. The original design was going to include a standard rectangular row pattern of computer stations (Figure 9a).

Figure 9a. Original BEST configuration



After careful consideration of the needs of all individual student users and for the School of Engineering's instructional needs, the design for the lab was modified to incorporate more of a collaborative element. The rows of computer tables were replaced by circular and rectangular tables with large projection screens around the room (Figure 9b).

Figure 9b: Collaborative BEST configuration



After the lab was constructed and furniture in place, the final lab can be seen in Figure 9c and 9d. This new lab was chosen as the location for Engineering Exploration, which began in the fall 2011 semester.

Figure 9c. BEST Collaborative Computer Lab

Figure 9d. BEST Collaborative lab in use
by Engineering Exploration. Students and class-aide
are seen working on the Circuits project.

This new location is a marked improvement over the classroom space that was previously used. Since it is a computer laboratory and not a regular laboratory, projects are still limited to those for which supplies can be transported in and out daily, while not damaging any furniture or equipment. In the new collaborative computer lab, each student has their own computer workstation with internet access. Researching ideas, working on presentations and papers, etc. are now a breeze. Also, since it is a smart classroom, formal instruction and presentations can be broadcasted on each terminal and/or on the wall screens throughout the room. When it is time to work on projects, the all-in-one computers are easily shifted to allow for ample table workspace. There is a large storage closet in the room which we can use to store project supplies and equipment. This helps by not having to bring supplies from one building to another on a daily basis. An additional benefit is that this new space has a capacity of 47 students with ample free space. Having a manageable enrollment size is crucial in a project-based course like this one. However after the first semester in the new collaborative space, the instructional staff determined that we could accommodate more students in each section.

III.E.2 Enrollment

There are over 700 first year engineering students each year. During the summer prior to their first year, incoming first-year students who place into calculus (except Honors students) are contacted via email about the opportunity to take Engineering Exploration. Typically the response rate is around 200-300. The section sizes of Engineering Exploration have varied from 17 to 32. Out of the students who respond, a course roster is selected. Gender and ethnicity were considered in roster selection and group formation. Gender parity has been maintained in the course at almost equal proportions. Unfortunately, we are not able to accommodate a large percentage of students who want to take the course. Occasionally, within the first two or three class periods, a student may indicate that he or she does not want to continue with the course. In these cases, the student is removed from the course without a W, and replaced by another student. After the first two weeks of class, any student who does not want to continue with the course withdraws and receives a W. The number of withdrawals, failures, and replacements is small. Students typically work in groups of 4, except in cases where a student withdraws from the class, causing group size to be 3, or one group splits and members join other groups. The enrollment numbers for each semester can be seen in Table 4.

Table 4. Enrollment by semester

	Location	Enrollment	Withdrawals/ Failures
Fall 2009	BME class w/rectangular tables	1 section, 24 students	0
Fall 2010	BME class w/rectangular tables	2 sections, 48 students	1F
Spring 2011	BME Class w/rectangular tables	1 section, 17 students	1F
Fall 2011	BEST computer lab	2 sections, 48 students	3W, 1F
Fall 2012	BEST computer lab	1 section, 32 students	In process
Spring 2013	BEST computer lab	1 section, 21 (all female section)	TBD

When students are notified in the summer about Engineering Exploration, the response level is quite high. When I advertised the course for the Spring 2011 term, interestingly, the response level was much lower. In fact I was not able to fill the 24 available seats. In this semester, 17 students took the course. Initially I found the low enrollment very strange. The reasons for this are not known exactly. I attribute the decline in interest to a few factors: 1. Over 300 (out of 700) students have already taken the standard intro course. 2. Students are feeling the level of rigor of the engineering curriculum and do not want to commit to any ‘extra’ work. 3. Scheduling conflicts. 4. Some students are not doing well and are not eligible to take it, as I chose to implement a 2.0 GPA requirement for the spring course. I felt that students who are achieving below the minimum required not to be put on academic probation need to focus their efforts on the standard math and science courses. 5. Some other students may have decided what major they want already, and do not see the need to take a 3cr course over a 1cr course that requires no effort. Whatever the reasons, due to the decline in interest in the spring, I made the decision that while the course remains in pilot-phase and is optional, it would be offered only in the fall semester. This decision also allowed more time for review and curricular updates during the spring semester.

During the Fall 2011 semester in the new location, there were 2 sections of the course, each with 24 students. Both instructors agreed that they could handle more students in the course. Hence, for the Fall 2012 semester, the section size was increased to 32. This makes 8 groups instead of 6, as in previous terms. The day-to-day activities could perhaps go to even higher numbers, 10 groups (enrollment of 40 per section). One challenge we would face in the case of 10 groups is that it would be nearly impossible to fit all 10 presentations into the days that are allotted currently in the curriculum. Presentations and other forms of communication are key elements in the course’s design. While I would not like to see any of the communicational elements removed from the curriculum, enrollment management and curricular updates will continue to be considered and revised.

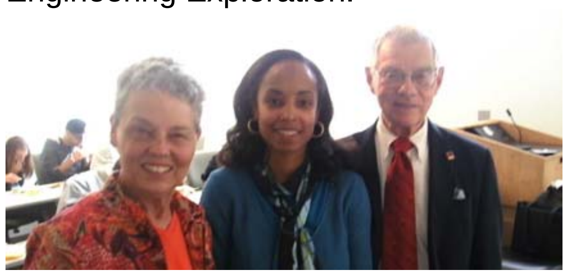
III.E.3 Projects, Activities, and Resources

Engineering Exploration has undergone several modifications since its inception. One of these changes is a modification of projects and activities. In an earlier section, the projects that have been used were outlined as follows:

- Bridge construction: construct a bridge out of balsa wood to withstand highest load.
- Building construction: construct a building out of balsa wood and test to withstand earthquake like tremors (via unidirectional shake table).
- Circuit design: design a basic circuit with resistors to match specified design constraints.
- Reverse engineer coffee maker: students dissect a coffee maker to understand how it works as well as perform a heating efficiency test on two different models to test for best model (based on price and efficiency).
- Mousetrap racecar design: design a car powered by a mousetrap to go the fastest or furthest.
- Solar panel circuit design: design a circuit (resistors) that will optimize power output of a solar panel.
- Stress/strain data analysis: analyze stress strain data in excel to find the approximate modulus of elasticity value.
- Blood pressure analysis: collect real-time blood pressure data and analyze it in excel to determine typical BP and variables that affect it as they may relate to certain biomedical applications.

At the onset of this course, the School of Engineering funded the course of the project supplies and instructional staff (except for myself). After the first term the course was offered, I was delighted when I was notified that a one of the School of Engineering's Development staff members secured an endowment for the Engineering Exploration initiative from an alumnus of the engineering program at Rutgers (Prendergast, 2009). The donor was given several initiatives to which he could support, and Engineering Exploration was chosen. I am very grateful to Steve and Julie Albertalli for their generosity and support. The husband and wife team visited Engineering Exploration during Fall 2010, Figure 10a/b.

Figure 10a. The Albertalli's visiting Engineering Exploration.



Left to right: Julie Albertalli, Lydia Prendergast, Steve Albertalli

Figure 10b. Steve Albertalli working with students on the Mousetrap Car project

With their support, I have been able to fund the courses expenses (personnel and project supplies). The projects in Engineering Exploration have evolved over the past few years. Below is a semester-by-semester evolution of the projects used in the course.

Fall 2009

During the Fall 2009 course, the students started with the Bridge project. This project was chosen as the first project in the semester because students can jump right into it on the first day and it is very interactive. Many students have done bridge building projects prior to entering college. While this activity is somewhat repetitive, it is also very familiar and perhaps offers a sense of comfortableness for the students. The difference however between what they may have had before and in here is that there is a strict time limitation and all of their decisions must be communicated to the class and instructor via an oral presentation. Presentations are often new to students when entering college. The winning bridge and group members are seen in Figure 11 after giving their presentation. During this semester, the students were also required to change group members for each project.

Figure 11. Winning group in the
Balsa Bridge project, Fall 2009

The next project for this semester was the Circuit Design project. The Circuit Design project is the most theoretical of the projects and includes a fairly long and involved technical paper as well as an oral presentation. For the third and final project, the class was split into two: one half of the class did the Reverse Engineering project, and the other half did the Mousetrap Car project. The choice was made the split the class so that another project could be completed in that semester, due to lack of time in the curriculum. Since not everyone was able to do both projects, one day each week, a group from each of the two projects would meet for 30 minutes and discuss all things related to their project with each other ('cross-training'). In essence, one group helped the other group learn their project and related concepts. With any formal review of concepts, all students were present. All students were responsible for the material covered in all of the projects.

There is one exam in the course, which was a cumulative assessment of the concepts learned and used in all projects. The final for this class was a technical paper on the last project and a presentation. The course was managed primarily via email. All course materials were circulated in class or sent via email. Another means of communication came by way of Facebook. I created a Facebook group for the class to join and use (Prendergast, 2009). Currently, there are 122 members. There is one assignment that runs throughout the semester where students had to post in the FB group about a global engineering topic. The main reason I decided to use Facebook as an online medium for this course is that I wanted to create a community of and for students who have taken this course. This gives them an avenue to communicate with each other about engineering, their courses, or other topic. Also, this gives me an avenue to contact all former Engineering Exploration students after they take the course and even after they graduate. In the long term planning, I would like to have Engineering Exploration alumni be featured guests in the course, take on a mentoring role to current Engineering Exploration students, be a corporate networking contact for the students, etc.

Fall 2010

Based on student feedback and curriculum planning, some of the projects and activities were modified for the Fall 2010 course. The anonymous end-of-course surveys included information that helped me to enhance the Fall 2010 course. Students indicated that they did not like switching group members for each project. They felt that they were just getting used to their group, and then had to switch. For this reason, I chose groups at the start of the semester and had them remain in these groups for the duration of the semester. Another comment that appeared often was that they wished they could have done more projects and that the class didn't get split for the last project. Now having experienced one semester, I was able to tweak the curriculum so that all students do all projects. I was also able to fit four projects into the semester. For the first project, instead of the students making a bridge, which most had done before, they now construct a building primarily made out of balsa wood. After consultation with the Civil Engineering Department, I was able to arrange the use of a shake table. The building is then put onto the shake table to see which group has the design that is best suited to withstand earthquake conditions. This project worked well and is still being used currently. A picture of a groups building that withstood the shake table is shown in Figure 12.

Figure 12. Balsa Building project.

The next project in the curriculum remains the Circuits project, unchanged. However, several students did note on the survey that while writing the technical paper that accompanies this project was very useful, it was quite a difficult task to complete as they had never done technical writing in the past. Based on that feedback, some additional scaffolding about technical writing was introduced into the curriculum. We spent more class time writing and reviewing sections of the paper to aide with this task.

Next, many students indicated that the Reverse engineering project was on the boring side. Finding an interesting Chemical Engineering project without a lab is an endeavor that I still have not completed. I removed the project and, with assistance and coordination from the Chemical Engineering Department, I added a tour of the Learning and Teaching facilities of Chemical Engineering. The Learning and Teaching facilities are primarily used by senior Chemical Engineers. The senior students help assist in the demonstration during the tour.

There is a student organization called the ChemE Car (an organization that builds a car powered by Chemical Engineering concepts and principles that competes with other schools nationally) gives a presentation and demonstration during this special tour (Figure 13). This feature is a great addition to the curriculum, especially in lieu of a project, and still exists in the curriculum today.

Figure 13. Senior ChemE students lead a tour of the Learning and Teaching facilities to EE students

Each year, I solicit the departments, for which I do not have a project, asking them for project ideas. During the Spring 2010, the Materials Science and Engineering Department gracefully responded with the Solar Panel project idea and relevant classroom supplies. This project includes some circuit design; hence it was inserted into the curriculum just after the Circuit Design project. Lastly, students complete the Mousetrap Car project. Previously, Career Services was brought into the class to perform a resume critique for the students. This year, the resume critique was proposed to the students to have done with Career Services as extra credit (out of class). Career Services instead did an in-class interactive interviewing session. Also, this semester, we used a course management program called Sakai instead of email. Course documents and assignments were submitted and retrieved via Sakai. Sakai also has other functions including grades, quizzes, forums, and more that were not used until the fall 2011 semester.

Spring 2011

The time period in between the fall and spring semesters is short. For this reason, the curriculum of the spring 2011 course mirrored the fall 2010 semester course exactly.

Fall 2011

One of the bigger changes in the Fall 2011 course is that the location switched to the new collaborative computer laboratory. Being in a space with internet access and having a workstation for each student allows for the use of additional technology. We used the course management tool Sakai more widely. In addition to document sharing, now grading, quizzes, and surveying functions are used. Also, Microsoft Excel is a very useful tool for engineers to know. With a workstation for each student, I made the decision to add the use of Excel into two new mini projects. The curriculum has always been quite tight. In order to accommodate new elements into the curriculum, some things had to be changed or removed. While we were fortunate to have the Solar Panel project, students commented on the end-of-class surveys that the Solar Panel project seemed like a second electrical engineering project. Therefore, in order to add some new elements, this project has been removed. I added two mini projects that involve data manipulation and analysis using Excel.

One of these mini projects is an extension of the Balsa Building project, specifically involving stress and strain calculations. The second mini-project relates to Biomedical Engineering. The idea of this project came from collaboration of the instructional staff and two class aides (Biomedical Engineering majors). In one of the junior BME courses, they complete some involved data analysis using Excel relating to blood pressure. The two class aides came up with an idea to create a toned down version of what they did in the junior course. I then embedded this idea into a life-like problem. The project can be seen in Appendix 2. As with all other projects, students must communicate their ideas. For the new BME project, students must create a short lab report (1-2 pages).

With the addition of these two mini-projects, the Career Services session is removed. Students are still offered extra credit if they get their resume critiqued by Career Services. During this semester, I created a course wiki with the goal of communicating to and among the students their ideas of what engineering is about (Prendergast, 2011). One highlight of this semester was that I hired a student who took the class in Fall 2009 as a class-aide. Students from the Fall 2009 semester were now juniors during Fall 2011. A few other former students were also interested, but had scheduling conflicts.

Fall 2012

The curriculum during fall 2012 is widely the same as the Fall 2011 curriculum. While I continue to update details of the projects, no major changes have been made to the projects. Some students did note in the class survey that while Engineering Exploration is a good class, it does involve a fair amount of work outside of class. The intended purpose of this course is not to overload the students any further than they already are. For this reason, I chose to consolidate one of the major out of class assignments (Circuits technical paper) into a group effort as opposed to an individual assignment. The instructional staff and I are hopeful that this is a beneficial change for the students and staff. The final technical paper that accompanies the Mousetrap care project remains an individual effort. Some students also noted that they felt often confused about what program to use at what time between Facebook, class wiki, Sakai, and email. In the fall 2012 semester, the wiki was replaced by a function in Sakai called Forums. Grades are completely being calculated in Sakai. We are hopeful that these changes streamline the process and aide students in focusing on the more important aspects of the course.

Spring 2013

In the upcoming spring 2013 semester, one section of Engineering Exploration is going to be offered to 20 first-year female engineering students that are a part of a new living/learning community program specifically for women in engineering ("Douglass women in engineering," 2011). This program will be described in more detail in a later section. Because there are fewer students in the course, it will not take as long to complete presentations at the end of each project. Therefore, there will be a day or two of extra some space in the curriculum. The curriculum of the course is intended to mirror the fall 2012 section, with a few minor changes due to the lower than normal enrollment and spare time. As the curriculum progresses term after term, so do the tools and supplies

III.E.4 Tools and Supplies

During the first semester the course was offered, all of the tools needed for the projects were purchased and put into a set of two toolboxes. The students could use the tools as needed throughout the duration of the semester. This process worked ok, however keeping track of the tools became an additional burden for the instructional staff. There were just a few tools that did not return to the toolbox at the end of the semester. A few of the tools were also broken during the course of the semester. Also, the notion of ownership of these tools (who for some have never used tools before) is meant to continue their drive towards engineering, solving or fixing problems, etc. into their lives. For these reasons, for the next courses, toolkits were purchased for each student. In lieu of a textbook, students were charged a lab fee of $40. The lab fee covers the cost of the toolkit (which they keep permanently) and for non-resuable project supplies. Examples of non-reusable supplies are glue, balsa wood, tape, balloons, sandpaper, etc. The toolkit contains most things that they will need to complete each project.

The contents of the toolkit can be seen in Figure 14, and are as follows:

- A document bag: used to hold all tools in the toolkit. This was chosen instead of a toolbox because the bag is flexible and can fit easily into a student's backpack for ease of transport. It is no larger than a textbook. This document bag is durable and sturdy.
- Safety glasses: protects the student from any flying objects, for example: a wood chip from the Balsa Building project. Providing students with their own pair reduces the spread of germs.
- A craft knife: used to cut the balsa wood in the Balsa Building project. It is also used in the Mousetrap Car project.
- A tape measure: used to measure lengths for the Balsa Building project and to measure distances in the Mousetrap Car project.
- A digital multimeter: used to measure the equivalent resistance in the Circuits project. It was also used in previous terms for the Solar Panel project.
- Multi-tip Screwdriver: used during the Mousetrap Car project.
- Needle-nose pliers: used during the Mousetrap Car project. (not shown in the picture)
- Electrical tape: used during the Mousetrap Car project.

Figure 14. Student Toolkit

There is also a set of classroom tools (contained in 2 toolboxes) that are not in the toolkit but are available for student use. These tools include: glue guns, thread, cordless drill, wire stripper, duct tape, small hand saw, extension cords, screwdrivers, hammer, adjustable wrench, etc. Additionally, there are project supplies such as: a set of wood boards and ceramic (for the floors and dead load of the balsa buildings), digital blood pressure cuffs, two sets of assorted resistors, 2 multimeters (for instructional staff use), assorted wheels, balloons, sandpaper, zip ties, mousetraps, dowels, etc. The majority of the tools were purchased from a local hardware store, Home Depot. The project supplies primarily came from an online and from an online educational supply store (KELVIN L.P., 2012).

Prior to the new location in Fall 2011 where there is a storage closet, all tools and supplies were brought in and out of the classroom daily. To aide with this, two AV-carts were purchased to transport and store these materials. The carts are stored in the storage closet, which his inside the classroom, and are still currently used to wheel out the supplies in and out of the closet. While the storage closet is available now, it is not equipped with cubbies or a suitable student storage area. It was therefore also useful to have a cardboard box available for each group to use to store their project materials from class to class. The tools and supplies needed for the semester have been fine-tuned over the semesters to make it most affordable and efficient for both students and the instructional staff, even when students and staff change from term to term. The curriculum, syllabus, and supplies are commonplace, accessible, and useable for people who choose to use this course. The student and professional instructional staff has changed from year to year. They have all been able to successfully adapt to the pedagogies and deliver a successful course to the students.

III.E.4 Instruction

Students encounter the math and science concepts needed to complete these projects in many high school courses and certainly in the math and science courses contained in the first and some in the second year of an engineering curriculum of these projects. The knowledge needed to be an instructor course is therefore not specific to any particular engineering major. The instructional pedagogies that were involved in the curriculum of this course are often counter-intuitive to a traditional engineering curriculum. Many current engineering professors are accustomed to the standard lecture style chalk-and-talk strategies. Training for this course is the easiest by observation. I have been fortunate thus far to be able to have a potential instructor observe the course in a term prior to when s/he becomes the primary instructor.

In Engineering Exploration, the instructional staff includes a primary instructor and class aides. Class aides are current engineering students who are in their junior year or above. Class aides can also be graduate students. Junior and senior-level engineering students that have a 3.0 cumulative GPA or higher are notified of the position. If interested, they apply and are interviewed. Students are also selected based on their major. For example, for the Circuits project, Electrical Engineering majors are considered. I chose to use a GPA marker for eligibility because in addition to using their expertise in their major, I also want to provide Engineering Exploration students with examples of other students who are succeeding well in the program. The class aides serve as academic and non-academic mentors to the students.

I was the primary instructor at the inception of this course. Even with the updated instructional strategies and project nature, the curriculum design of this course is one that is transferrable to others without much difficulty. Below I list the different instructors and their educational background.

- Instructor 1 (LP, myself) – holds a M. S. in Industrial Engineering. LP works as an academic dean for the School of Engineering, currently pursuing a Ph. D. in Engineering Education (via Interdisciplinary Studies).
- Instructor 2 (MB) – holds a M. S. in Industrial Engineering. MB is a staff member at Rutgers, and is pursuing a Ph. D. in Science Education. MB observed the course in fall 2009 then taught the course in fall 2010 and spring 2011.

- Instructor 3 (JD) – holds a B. S. in Civil Eng’g, and is pursuing a M. S. degree Civil Eng’g. JD was a class aide in fall 2009, fall 2010, and spring 2011. JD taught the course in Fall 2011 and Fall 2012.
- Instructor 4 (HB) – holds a Ph. D. in Chemical Engineering. HB is a faculty member from Chemical and Biomedical Engineering. HB is observing the course currently (Fall 2012), and plans to be the instructor in Spring 2013. The spring 2013 section of Engineering Exploration will be a part of a special women-in-engineering living-learning community.

The Douglass Women in Engineering Living-Learning Community is a new program where incoming female first-year students now have the opportunity to participate in a residential and academically focused engineering community ("Douglass women in engineering," 2011). In addition to these 20 students living in the same residence hall, they also participate in an academic component which includes, but not limited to, a 3-credit semester course on exploring engineering. Since I am already offering a course of this type, Engineering Exploration was chosen for this program and will be offered to the women participating in this program. The first semester that Engineering Exploration will be offered to the all-female section is Spring 2013.

Engineering Exploration is a course unlike most other courses in a standard engineering curriculum. The course takes ample planning, knowledge, and enthusiasm to run efficiently. A summation of the location, enrollment, instructors, and projects for each semester can be seen in Table 5. Following the summary of course logistics is a daily breakdown of projects and activities in one semester.

Table 5: Summary of Engineering Exploration Course Logistics

	Location	Enrollment	Instructional Staff (observed)	Projects
Fall 2009	Classroom w/rectangular tables	1 section, 24 students	LP+ Class Aides (MB)	Bridge, Circuits, Reverse Engineering, and Mousetrap Car.
Fall 2010	Classroom w/rectangular tables	2 sections, 48 students	LP+ MB+ Class Aides	Building, Circuits, Solar Panel, Mousetrap Car
Spring 2011	Classroom w/rectangular tables	1 section, 17 students	MB + Class Aides	Building, Circuits, Solar Panel, Mousetrap Car
Fall 2011	Collaborative computer lab	2 sections, 48 students	LP + JD + Class Aides	Building, Data Analysis, Circuits, Blood Pressure Analysis, Mousetrap Car
Fall 2012	Collaborative computer lab	1 section, 32 students	JD+ Class Aides (HB)	Building, Data Analysis, Circuits, Blood Pressure Analysis, Mousetrap Car
Spring 2013	Collaborative computer lab	1 section, 21 (female)	HB + Class Aides	Building, Data Analysis, Circuits, Blood Pressure Analysis, Mousetrap Car

IV. FINDINGS: RETENTION, ACADEMIC SUCCESS, AND STUDENT SATISFACTION

The findings detailed in this section address the following research questions in relation to Rutgers Engineering students' first year experience and Engineering Exploration:

1. What is the relationship between enrollment in Engineering Exploration and retention? Why do women who have taken EE leave engineering?
2. What is the relationship between enrollment in EE and academic success?
3. What is the relationship between enrollment in EE and student satisfaction?

These research questions will be addressed by standard retention and GPA inquiries along with interviews of engineering students.

IV.A Retention and GPA

In this study, I conducted a standard retention analysis in order to assess the extent that taking Engineering Exploration has on retention and GPA. The One, Two, and Three Year retention figures for the entire School of Engineering were obtained from the Office of Institutional Research (the university's official data generation office). The school-wide figures measured students who started in SOE and remained in SOE after one, two, and three years. Correspondingly, I calculated the 1, 2, and 3 yr retention figures for those students who took Engineering Exploration (EE). Engineering Exploration students are chosen from students who place at least into calculus, and who are not a part of the Honors Program. The data from the Office of Institutional Research includes Honors students and student who placed remedially in upon entering Rutgers. Retention of Honors students is tracked by the Honors Program Director. Over the past decade, retention of Honors students has averaged from 96-98%. In Fall 2011, out of 665 incoming first-year students there were 90 Honors students. Retention of remedially placed students is unfortunately not tracked. Average 1, 2, and 3yr retention of Honors students and for the entire student body is shown in Table 6:

Table 6: Retention of SOE, Honors, and EOF Students

Retention	SOE (N=520-750)	Honors (77-90)
1 yr	82.53%	>95%
2 yr	68.10%	>95%
3 yr	61.35%	>95%

Since we know retention of Honors students, the overall school retention rate, and the number of students placed remedially, we can see if honors students and remedially placed students skew the data in comparison to non-honors calculus placed students (like those who take Engineering Exploration. The non-honors calculus placed students will be called the 'standard' cohort. Using a simple weighted average calculation,

$$\frac{(90 \times .98) + 465x + 110y}{665} = .60$$

In this equation, x is the retention of standard cohort; and y is the retention of the remedially-placed cohort. The 3rd year retention rate of SOE is 61.35%, hence an estimated value of 60% was used above. For the sake of covering the case of a higher school retention rate, 70% was also considered as a scenario. The retention rate of the standard cohort is shown in Table 7 below for the two cases of SOE retention of 60% and 70%. One might expect that the retention of a remedially placed student would be lower than the school average. In order to account for this assumption along with others, I will use y values of 40%, 50%, 60%, and 70%, which are values that are below, equal to, and above the school average retention, the retention of non-honors calculus placed students would be 57%, 55%, 53%, and 50% respectively.

Table 7: Retention of Non-Honors/Non-Remedial Students

SOE Students	N=665	Reten-tion 1	Reten-tion 2	Reten-tion 3	Reten-tion 4
Honors	90	0.98	**0.98**	0.98	0.98
Remedial (y)	110	0.40	**0.50**	0.60	0.70
Standard (x) (SOE retention = .6)	465	0.57	**0.55**	0.53	0.50
Standard (x) (SOE retention = .7)	465	0.72	**0.69**	0.67	0.65

This would suggest that regardless of the retention of remedially placed students, retention of non-honors calculus is typically lower than the school average. In only one case (where remedially-placed retention is 40% and SOE retention is 70%), does the standard cohort retention rise above the school average. However in all other cases, the unknown retention of the remedially placed students will be offset by the much higher than average retention rate of the honors cohort. What can be drawn from here is that any positive shift in retention that is found for the Engineering Exploration cohort can be trusted as a positive shift. Any lower shift in retention will need further study.

In addition to the yearly retention rates, I included two sub-categories: gender and ethnicity. In this study, ethnicity is defined as a grouping of African-American, Hispanic, Latin, and Native-American. The 3yr retention figures for Engineering Exploration are only based on one section (the Fall 2009 course), as that was the first time the class was offered. The raw data can be found in

Appendix 4. A summary of the retention and gpa data is found in in Tables 8 through 12.

Table 8. Retention of SOE vs. EE			
Retention	SOE overall	EE overall	Change
1 yr	82.53%	89.58%	+7.05%
2 yr	68.10%	86.36%	+18.26%
3 yr	61.35%	80.21%	+18.86%

Table 9. Retention of SOE Female vs. EE Female			
Retention	SOE female	EE female	Change
1 yr	83.67%	91.70%	+8.03%
2 yr	69.28%	85.61%	+16.33%
3 yr	64.76%	82.58%	+17.82%

Table 10. Retention of SOE Minority vs. EE Minority			
Retention	SOE minority	EE minority	Change
1 yr	80. 10%	80. 31%	+0. 02%
2 yr	66. 47%	74. 07%	+7. 60%
3 yr	57. 95%	55. 56%	-2. 40%

Table 11. Retention of EE Male vs. EE Female			
Retention	EE male	EE female	Change
1 yr	87. 59%	91. 70%	+4. 11%
2 yr	83. 97%	85. 61%	+1. 64%
3 yr	77. 56%	82. 58%	+9. 02%

Table 12. Retention of SOE Male vs. SOE Female			
Retention	SOE male	SOE female	Change
1 yr	82. 38%	83. 67%	+1. 29%
2 yr	67. 89%	69. 28%	+1. 39%
3 yr	60. 72%	64. 76%	+4. 04%

The retention rates indicate for the overall analysis and for the sub-category analyses that that retention of the Engineering Exploration cohort was higher in all cases, with one exception. In figure 24, the 3rd year minority retention rate is lower than the school average. I am not certain if this is indicative of anything correlating to Engineering Exploration or if there is not enough data in the 3rd year cohort, as mentioned in the previous paragraph. Since Engineering Exploration appears to help most students, it is possible that reasons behind attrition for minority students may be different than non-minority students, and are not addressed in a course of this type. The possible reasons of attrition for URMs were discussed earlier in section II.A.2. As there is more data available, I will continue to analyze all cohorts, in particular the minority cohort.

The GPA statistics collected were as of May 2012 and include all students registered in the School of Engineering. The statistics for the cohort ‘All’ are all students in SOE, except those who took Engineering Exploration. The same cohorts were examined as in Retention, namely: all students, females, and minorities. The GPA results can be seen in Table 13.

Table 13: Cumulative GPA		
Cohort	Cumulative GPA	T-TEST
EE	3. 108	5. 33E-05
All	2. 885	
EE Female	3. 063	0. 163069
All Female	2. 935	
EE Male	3. 140	0. 000168
All Male	2. 874	
EE Minority	2. 946	0. 001005
All Minority	2. 625	

All students who take Engineering Exploration experience an upward shift in their cumulative GPA. However, for female students, the upwards shift is not statistically significant. While I was hoping for more of a shift for female students, this result is not surprising. Female students are more likely to leave a STEM major for reasons other than academics. The reasons that women leave are more popularly because of interest in other areas of because they have self-efficacy issues. What is also interesting is that although minority students did not experience higher retention, they did see a positive shift in grades. Hence, Engineering Exploration does aide in the success of minority students, but does not support enough their decision to stay.

Retention is a complex concept that includes many factors. In addition to grades and project oriented courses, there are other areas in the first-year curriculum that are important to students. In addition to the retention and GPA inquiry, I also conducted student interviews to document their views concerning what worked well for them and what concerns they had in their first-year college experience. The results of these interviews will be explored in the next sub-section.

IV.B. Student Concerns in the First Year

In order to understand better the opinions that students have concerning their first year in an engineering curriculum, I interviewed thirteen engineering students. Four students took the standard intro course (440:100), eight students took Engineering Exploration (440:125), and one student took the honors version of the intro course (440:191). From the interviews, some patterns did arise that would support the retention findings. There were four questions in particular that were most relevant to the academic experiences in the first year. These questions and a summary of the answers are found in Table 14. The entire interview protocol can be found in Appendix 5.

Table 14. Interviews

Question	Non-EE (440:100/191) cohort	EE (440:125) cohort
What changes would you make to the 1st yr curriculum?	4 out of 5 answered to revamp 440:100 to include projects, hands-on, dynamic academic experience, including instruction. The other talked about math courses/professors.	4 out of 8 noted liking the hands-on experience and projects, and wanting more of it. Others talked about wanting smaller class sizes, moving some core courses to the 2nd year, scheduling exams differently, learning more in high school.
Most valuable 1st yr course.	4 out of 5 listed Matlab (programming course).	7 out of 8 listed Engineering Exploration
Usefulness of the intro course in major selection	2 said it discouraged them. 2 said not useful. 1 said it helped (if they liked the lecturer).	4 said it helped. 3 said it supported existing choice
Skills learned from Intro	4 said none. 1 (440:191 cohort) said the	All 8 said ‘yes’ for one of these reasons: math/science

course.	course helped form study groups.	application to solve engineering problems, math/science concepts, work ethic, group work, time management, registration/scheduling, social/study network.

The students who did not take Engineering Exploration (440:100 and 440:191cohort) consistently indicated that they were looking for a more dynamic introductory course in the first year. The 440:100/191-cohort for the most part did not report getting anything useful out of their introductory course. When asked what changes they would make in the first year engineering curriculum (as an administrator, dean, or professor), a current engineering student, John J., talked about his experiences. John J is a student who switched out of engineering to economics and then switched back to engineering after one year. John J. commented the following:

> John J. (440:100):“I guess I would completely revamp the Engineering Orientation Lectures. Um, I don't think I got really much from them. Maybe, some of the information in the lectures is just completely outdated. I think that those, that class or that … that uh … I think it was called Introduction to Engineering in my year. Um, I think, I think there's newer examples that could be used to describe each major. I mean because all the lectures that I saw were outdated. They were really boring. I dreaded going to that class. It had minor factor in me making a decision to leave engineering. So, so it could've been a lot better. I had to speak to other people to come back to engineering and realize that there's much more than what was described in the engineering lectures. ”

What is particularly interesting here is that the student transferred out of engineering and back in. He notes that the course had only a minor impact on his decision to leave engineering, but also notes that in speaking to other people about the field of engineering (recharging his interest in the field), did he decide to come back. Had his first year introductory course been dynamic and up to date, perhaps this student would not have spent valuable time and money in another major. The course that this cohort found most valuable in their first year was the programming course. The programming course at RU-SOE uses the software language, Matlab, to solve engineering problems. While the format of that course is simply computer programming, it utilizes engineering decision making when determining what strategy to use to solve the problem.

Having a modern curriculum is certainly important and is a part of ABET's criterion. Engineering is an applied science, hence being able to view its' applications in physics, math, and chemistry in a current global setting is necessary. It is also crucial for educators to provide students with information in a way that they can learn and absorb the information. Students are asking for a dynamic engineering experience directly. Glen A, another student from the 440:100 cohort talks about wanting a project based environment in the first year.

> Glen A (440:100): "…the lectures (440:100) were somewhat informative but they were really boring. I would like to see a little more life examples or like . . I tried to get into the Engineering Exploration course. I think that should be offered to a lot more people. I think that should be offered to a lot more people because I felt like it would've been a better idea. I learn better in a project based environment so, and a lot of other engineering aspects are project based as well so. I feel that would've helped if we could maybe expand on that".

The majority of the students in RU-SOE take 440:100. Honors students get a different course, the honors version of the introductory course (440:191). This course, which is taught by the First-Year Dean, includes tours of each engineering department, activities on ethics, teaming, academic success strategies, creativity, and a non-major specific design project. The design project is based primarily on creativity. Students are to build something useful out of typical household items and materials. Examples of these household items include: cardboard, paper clips, tape, straws, etc. Although the honors students receive an enhanced experience in comparison to those that take 440:100, some still are looking for more. Victor R, an honors student, makes this claim for revising the first year curriculum.

> Victor R. (440:191): “More lab experience. Um, the-the first real lab experience for the things we learn in the first 2 years, maybe in the first 3 years I don’t know, I’m my schedule is strange, is mechanical engineering measurements and even that is so watered-down from what it, what I feel it should be. Like if the intro to engineering class were more a lab-based thing, even a basic lab where you get to do hands-on things with the equipment in each of the fields, so you have an idea of what you would be doing instead of just hearing about it. I feel like that would be the biggest improvement. ”

There were five students in the 440:100/440:191 cohorts that were interviewed. Out of these five students, four of them talked about wanting a more dynamic introduction to engineering, including projects, interesting content, dynamic content delivery, etc. Conversely, in response to the question about making changes to the first year curriculum, Engineering Exploration students talked about different things. Two of the students from Engineering Exploration, Henry K. and Maria L., talked about the importance of receiving a dynamic experience in the first year as being very important for them and all engineering students. Henry and Maria recount some of their experiences from Engineering Exploration as examples.

> Henry K. (440:125): “I would definitely make sure that people know um what they want to do in engineering. . . you telling as much about engineering as you want and you can tell me what I’m going to do, but that’s hands-on project like even though as a first year you can’t do what you’re going to do your senior year obviously but just the little things like uh you know like um experiments like just making a bridge maybe out of-seeing who can make the strongest bridge, whatever the case may be, but just showing like this is an idea of what you would do. And if you’re coming here just for money, just for the wrong reasons sometimes you lose sight, sometimes you won’t really-like why am I doing this? And you gotta show the fun of it.”

> Maria L. (440:125): “The first year curriculum is really like the core engineering classes and it’s kind of overwhelming I think coming in and taking all those at once. And it really doesn’t get into interesting like major-related classes really I guess until your junior year. So it’s a lot at once and you really have to sit back and think, is this really what you want to do? Because you don’t really have those interesting classes yet. But Engineering Exploration like really delved in with the projects and exploring them all and that really helped you see what you were getting into and helped you get past all these classes.”

Male or female, honors or standard student, it is apparent from these interviews, retention, and GPA inquiries, engineering students want and need some “engineering” in their first year. These things that they are looking for could have a direct impact on retention and success in engineering. In contrast to the 440:100 and 440:191 cohorts, the students who took Engineering Exploration felt positive about haven taken Engineering Exploration. They were able to get some academic, professional, and social benefits from the course. When they were asked about the things they would change in the first year curriculum, instead of talking about wanting hands-on projects, application, and more excitement in the first year, Engineering Exploration students recounted their positive experiences with Engineering Exploration, while some others talked about wanting smaller class sizes, rigor of courses, and the packed curriculum.

> Mandy T. (440:125 female) “We're doing hands on stuff more. So it kinda helps you think like, first of all it helps to see if you're good at it. And second of it all it helps you see you know could I see myself doing something like this or whatever. I mean the projects are kinda easier than like an actual engineering project would be in that discipline. But it's still like you kind of get some kind of an idea at least. I feel like, if I was just doing the lectures I wouldn't have learned anything about you know what I could be doing.”

> Gary M. (440:125): “Smaller class sizes for general classes and then more advanced screening on TA’s. If I were to make a change I would change the uh, the-the general classes such as your physics and Matlab and make them smaller. I know you, I know there’s recitation for that, but I a smaller lecture would be better. More ah and I know this is difficult since everyone has to take it, but I definitely think that would be better. I just think the ah interaction with the professor would be better.”

Professor-student ratios are usually higher at the college level than in high school. This transition can be a complicated time for many students. Funding and budgeting constraints often make universities battle with professor-student ratios. Even with ratios being what they are, the quality of interaction between students and professors is very important. For first year students, the content of the lecturers’ talk and the sentiment conveyed appears to be crucial in students’ decisions and attitudes about their choice of major. When asked about the usefulness of 440:100 to their choice in major, all four students interviewed (who took 440:100) talked about their impression of specific majors, the presenters, and the impact that it had on their choice of major.

> John J. (440:100 switched out of engineering to economics and then switched back to IE after one year): “Yes, I had already decided on industrial and I think that the lecture kind of discouraged me from industrial even though I was kind of already excited about it. But I think that the lectures discouraged me from doing engineering in general.”

> Henry X (440:100): “I mean, people that showed up to talk to us about different types of engineering … are dry. It’s like if you want to show others

> what this engineering is about, you should approach it in a very attractive way, instead of saying this is what it is and this is how I like it. But you're not saying anything about how other people might find interest in it. You know. I think it was dry. . . I decided on chemical way before they even started introducing. (Interviewer: Did it become any more attractive after they talked about it?). . . Oh no no no. I think that guy almost ruined it for me."

> Gary A (440:100): "It was one lecture a week for like an hour twenty. Especially for industrial engineering, I really liked the lecture because uh I forgot who the professor was but he came in, he gave us an exercise to do in class, saying, "all right try to make this system the most efficient possible. Like find the efficiencies of these systems. " I felt that was a good insight to like what I would be doing in the future. And so I really like that lecture, like the -- that's another reason I chose industrial engineering because I liked how they presented the material to me and I actually understood it really well. So I felt that was a good choice of me to go to."

> Winnie N (440:100 female): "Well because of that class I got to speak with (inaudible) faculty from the environmental sciences department and that made me not choose environmental science. So um but I wasn't thinking about materials because I don't think the lecturer was really good. I think like my interests in each of the majors depended on if the lecturer was like engaging or not."

Faculty interaction and enthusiasm appears to place high on the list when choosing a major is concerned. This is especially important when considering populations with a greater risk for leaving engineering. One high-risk group is female students. While retention figures for female students did increase after taking Engineering Exploration, some women did choose to leave engineering. I was able to speak to a some women who left and some who stayed to understand better their experience in the School of Engineering at Rutgers.

IV.C Women Attrition

Out of the 5 interviewees in the 440:100 and 440:191 cohorts, 4 of them were male. Even with an interview response rate, this is quite representative of the overall population in engineering. The field of engineering traditionally has higher male enrollment than female. Female enrollment rates in engineering programs are generally between 15-25%. Female retention in engineering is often a topic that is studied, as is the case in this study. A female engineering student from the 440:100 cohort, Winnie N., was asked the question about making changes in the first-year curriculum. While she did not talk about the introductory course directly, (instead, her focus was on the physics program), she did directly say that on top of the courses being difficult that there was no application and no excitement relating to the rigorous coursework. She stated that the lack of luster and application in the first year had a direct impact on some of her female peers' decisions to leave engineering.

> Winnie N, (440:100): "I would make it more project oriented actually because um I know in analytical physics, I was talking to my roommate a lot about what we do and she said they don't really do a lot of like the cool activities that we do in-I know in other universities um I have friends that are in engineering at other universities and they have a lot more project oriented um just like a-just like a class that they actually do things, like apply. Which I think is important cause um a lot-freshman year a lot of the people in my floor, because I lived in an all engineering dorm and they were girls like, like my floor was all girls and I would say like maybe half of them switched to like bio because we were like mostly biomedical and they just switched to bio. Because they didn't like physics, they didn't like um-MatLab was way too hard for them and they felt like they weren't getting enough help in that and just like the whole thing was overwhelming. They weren't seeing how they could apply it, basically. So they were just getting overwhelmed by like all the stuff that you needed to know to apply and not seeing the application I guess? And they became really discouraged and dropped it. And I mean they could have done it for other reasons, but um I guess if they were more ways for them to see like that they can like just push through the academics for a while and then, then the cool stuff starts happening. They would have stayed."

Students change majors for a myriad of reasons. In engineering, female students leave engineering at a lower percentage rate than men (see Figures 8 and 9). In comparison to their male counterparts, women tend to leave engineering more for reasons other than poor grades. Female students tend to leave because other majors are more interesting to them, for fear of getting poor grades, or for lack of confidence in their abilities (self-efficacy). Out of the 58 women who have taken EE, 10 of them have left engineering. The 10 left for the following reasons:

- 2 academic dismissals.
- 3 left Rutgers University willingly.
- 5 transferred to an arts/science major within RU.

One of the five students who transferred to an arts/science major is planning on coming back to engineering. She stated that she left for fear of poor academic performance, which was in part due to non-academic issues.

> Josie E. (440:125): “I left SOE because I was afraid that I would completely fail, a lot was going on during spring semester that affected my school work. Then once I transferred out I realized that there was nothing else that I really wanted to do once I really read up on BME and what it means. I think it just took a little longer than everyone else for me to realize what I really wanted.”

It is essential to note that during the semester that Josie E. took Engineering Exploration, there was no Biomedical Engineering project. In engineering, females tend to cluster to majors more closely related to life sciences (Biomedical, Chemical, and Bioenvironmental). I was aware of this during the creation of the course, but was not able to find a suitable project in these fields, primarily due to not having a lab space. I have since added a mini-project in BME. The evolution of the projects was discussed earlier in the Course Evolution section.

Research indicates that female students in engineering are less likely to leave engineering because of poor grades. Usually there are other factors involved in their decision to leave. One female student, Carrie V., who took Engineering Exploration, did fine with her academic coursework in her first year. Yet, she later transferred to an arts and science major. In her first semester, Carrie earned a 3.281 GPA. In her second semester, her grades dropped to a 2.306. This is the semester where she took Engineering Exploration. In the interview Carrie indicated that in her second semester, when her grades dropped, she was pledging to a fraternity. Carrie spent one more semester taking engineering courses (2.939 GPA); then she began her migration to another curriculum. Carrie was obviously capable to do the engineering coursework. When asked why she left, she indicated that her interests were elsewhere.

> Carrie V (440:125): “Um, so, even when I first enrolled in the School of Engineering, I was a little bit hesitant. Um, I was always like alright in math and science and that kind of stuff. But it wasn’t ever really my favorite. So I guess like every semester when I was in engineering, I contemplated whether I wanted to be there. Um, and after a while, I was kind of like well…I’m not really enjoying it that much, and I’m not necessarily very good at it. And I really feel like this is one of those things where you really need to be one or the other: you have to really love it or you have to be really good at it. So I decided to transfer to do something that I enjoyed more.”

Carrie’s GPA skyrocketed in the Spring 2012 when she took all non-eng’g courses (3. 867 GPA). When asked if there were any changes she would make to the first year curriculum that would have made her more inclined to stay in engineering, she noted the Engineering Exploration was a factor that pushed her to stay. Carried had actually already taken the standard course (440:100) in the preceding fall semester.

> Carrie V: “I definitely think EE was a really fun and interesting class. It definitely…. ummm…I don’t know…it was really appealing. Um, because my first semester, I already took Engineering Orientation. Um, so I just took Engineering Exploration because I actually thought it would be really interesting. Um, and I definitely think that was a step in the right direction. Um, just because all of the other freshman courses are very…. . they’re not like very, um, engaging. Um, so I feel like that was , that was really good. Um, but I’m not sure what else, um, can be done with that…If anything, it (Engineering Exploration) would’ve convinced me more to stay. But, I guess it wasn’t that much of a factor that it actually made me stay. But I definitely think it would help…I definitely think it plays a role…just because it makes you so much more knowledgeable about engineering and what you’ll be doing later in the field rather than what’s in texts and stuff.”

While Carrie liked Engineering Exploration, she ultimately left. She feels more confident in the coursework in her new major, and has time to do some extracurricular activities now that she does not have such rigorous courses. Carrie was doing well in the engineering curriculum prior to her decision to leave. This leads me to believe that self-efficacy may have played a role in her decision to leave. Her engineering experience does not go without merit. She notes that she was able to get an internship at an engineering organization in part because of the time she spent in the engineering curriculum.

> Carrie V (440:125): “I, I like it a lot (her new major). Um, I think that I’m a really practical person, uh, is why I originally chose engineering. Um, but I think economics is a good balance between the two. Like being practical and something that I enjoy more. Um, and um, I don’t know, I guess I’m a little bit better at it. Um, so it gives me more time to do other things. Like, I’m an RA now, um and like I have an internship. Actually my…like I don’t really regret my experience in engineering, like my, me having been in the engineering school actually helped me get the internship that I have now. Cause I’m working at IEEE (the Institute of Electrical and Electronics Engineers). So it’s definitely not, I wouldn’t label it as a negative experience.”

From these interviews and the retention and GPA inquiries, it is clear that Engineering Exploration is a positive addition to the engineering curriculum for the general population and also for women. While it is still offered, the curriculum will continued to be updated and enhanced wherever possible. The future of the course is uncertain. I do hope to continue offering the course. I will offer a discussion and future implications in the next section.

IV.D Limitations

In all experiments and studies that are conducted in research, there exist limitations. The sample size of the Engineering Exploration cohort is relatively small, particularly where female and under-represented minority students are concerned. The scope of this study is to begin the dialogue and to develop a baseline of statistics that can be further investigated. Future study needs to be done as the sample size increases. A second limitation in this study is that enrollment in Engineering Exploration begins by choosing a roster out of students that self indicate as interested in taking the course. It is possible that Engineering Exploration students are better prepared than the average student body. In order to look at student preparation, I compared SAT scores of Engineering Exploration and of the entire SOE student body in Table 15.

Table 15: SAT Comparison – EE vs. SOE

	M-SAT	CR-SAT	TOTAL SAT
Avg SAT Eng’g Expl	664	568	1231
Avg SAT SOE	666	578	1243
T-test	0.88210	0.32194	0.54028

The average SAT scores of Engineering Exploration is actually slightly lower than the general student body, however not statistically significant. Next, I would like to compare the representation of at-risk students. When comparing the percentages of female and under-represented minorities, Table 16, Engineering Exploration has a higher representation of at-risk groups than the overall student body.

Table 16: Gender and Ethnicity Representation – EE vs. SOE

	EE	SOE
Female	40%	17%
Male	60%	83%
White	40%	46%
Asian	26%	35%
URM	34%	15%

Lastly, pre-existing motivation and attitudes in the Engineering Exploration cohort may contribute to the findings. Engineering students were given a survey called the Pittsburgh Freshman Engineering Attitudes Assessment (PFEAS) (Besterfireld-Sacre, Atman & Shuman, 1997). The survey contains questions spanning over several areas. The results of the survey indicated that there was no attitude difference between Engineering Exploration and the general student body.

Table 17: PFEAS Results - EE vs. SOE

	Overall	Perception	Career	Jobs	Society	Math	Exact	Family	Subject	Ability	Compatible	Group work	Study Habits
T-Test	0.75	0.58	0.15	0.80	0.56	0.73	0.35	0.62	0.68	0.96	0.48	0.79	0.30
EE	3.48	4.30	3.24	3.32	3.78	3.22	3.35	2.68	3.69	3.84	3.72	3.14	3.47
SOE	3.49	4.26	3.31	3.35	3.71	3.25	3.47	2.61	3.73	3.84	3.64	3.17	3.57

The SAT, gender/ethnicity representation, and attitudes assessment results show in part that Engineering Exploration students are no different than any other student in the School of Engineering. Motivation may be a difficult quality to quantify. In a future study, I will look at how the 200+ students interested in the course fare in relation to retention, GPA, and satisfaction in comparison to Engineering Exploration students.

DISCUSSION AND FUTURE IMPLICATIONS

V.A Retention

For my professional goals and for this study, I created a first-year project based course from the ground up based on principles of STEM education research in order to meet the needs of a 21^{st} century engineering curriculum (Ercolano, 1996; Hall, Cronk, Brackin, Barker, Crittenden, 2008; Tinto, 1993). Engineering Exploration has proven to be a positive addition to the educational experience for undergraduate engineering students. Retention rates, GPA, and opinions of the students all indicate that Engineering Exploration fills a gap that is needed to help produce productive engineers Ercolano, 1995; Pendegrass, Kowalczzyk, Dowd, Laoulache, Nelles, Golen & Fowler, 2001; Porter & Fuller, 1998;. The retention analysis shows that Engineering Exploration students stayed at a higher rate. The increase in retention jumps drastically by the second year, from a 7% increase after the first year to an 18% increase after years two and three. The 3-year retention rates need further inquiry as there is only one section from Fall 2009 (N=24) contributing to the 3-yr retention data.

The retention effects are similar for women who take the course. The increase of retention rates for women jumps from 8% in the first year to 16% and 17% in the second and third years, respectively. Whether students take

Engineering Exploration or not, female retention rates are always higher. This is in agreement with STEM research that posits that women's retention rates are higher than males' (Hartman & Hartman, 2006). While female retention is higher than male retention, the percentage of change for women is not as high as the percentage of change for men. These figures indicate that Engineering Exploration has slightly more beneficial results for male students over female students. I would venture a guess that the lack of projects in the engineering majors that are typically more popular among women (Chemical, Biomedical, and Bioenvironmental) is a part of the reason for women's retention increase not being as high as their male counterparts (Besterfield-Sacre, Moreno, Shuman & Atman, 2001; Bottomley, Rajala & Porter, 1999). A mini-project in Biomedical Engineering was added to the curriculum starting in the fall 2011 semester. This will be investigated in a future study. Engineering Exploration appeared to have little to no impact on minority students. Further research into this must be done to determine what the needs of this URM population are and how they may be addressed in a first-year course of this type. It is possible that the needs of minority students may need to be addressed in a forum other than a first-year project based course (Li, Swaminathan & Tang, 2009; Grandy, 1998, Van Aken, Watford, & Medina-Borja, 1999; National Science Foundation, 2005). However, Engineering Exploration did appear to help URM's by the increase in GPA.

V.B GPA

Two of the goals of Engineering Exploration are to help increase retention and success. We have looked into the retention figures. The GPA analysis shows that male students and minority students who take Engineering Exploration experience a statistically significant positive shift in their GPA. Female students' GPA were slightly higher, but not statistically significant. While I am not completely happy with this finding, I am not surprised. Existing STEM research shows that female students in STEM majors typically have a higher GPA than their male counterparts. The data in this study is in line with that assertion. STEM research also shows that female students tend to leave for reasons other than academics (Hartman & Hartman, 2006; Besterfield-Sacre, Moreno, Shuman & Atman, 2001; Bottomley, Rajala & Porter, 1999). The two female students who I interviewed who left SOE indicated that they left for fear of failure (self-efficacy) or because of other interests. For female students, the greatest effect of a course of this type would be to counteract remnants of self-efficacy and to exhibit the profession of engineering as an attractive one. I will continue to search for enhancements to the course that will benefit the female engineering population at least as equally as it benefits male students.

V.C Student Concerns

The retention and GPA analyses were supported by the opinions of the engineering students. I was very interested in hearing the opinions of all of the students who I interviewed. The general consensus from all of the students that I heard from is that the first year curriculum needs to be adorned, from curriculum to faculty to enthusiasm (Richards & Carlson-Skalak, 1997; Meyers, Sillman, Gedde & Ohland, 2010). Along with retention and success, an introductory course, like Engineering Exploration, is also meant to help students choose a major. The experience that students have with the faculty members that are involved in introducing students to a major play a key role in students' choice. Students report that dry and uninteresting interaction with faculty actually discouraged them from a particular major or from engineering in general (Hoit & Ohland, 1998; Sheppard, 1997; Carlson, 1999; Felder, Felder, & Dietz, 1998). Engineering needs to be presented to the students as an attractive and interesting field. With Engineering Exploration, I hope to meet this goal. However, to make a real impact, the course will need to be offered to more students.

V.D Engineering Exploration Comparison to Other Reform

A common measure the researchers use to quantify the success of reform initiatives comes in the form of retention. Other institutions have instituted first-year reform measures with increased retention results. I will compare the percentage increase along with the actual retention figures of four institutions. I designed the curriculum of Engineering Exploration to include a combination of reform measures. The three institutions used in the comparison each have some elements of reform that are common to that of Engineering Exploration. At the University of Florida (Hoit & Ohland, 1998), their lecture course was converted in a laboratory format where students rotate to different labs/projects in the various majors. They reported 3 and 4 year retention increases from 34% (lecture course) to 51% (lab course). Their percentage increase is similar to that found in this study, however their overall retention rates are much lower than at Rutgers, as Rutgers' 3-yr retention rates are 61% (lecture) and 80% (Engineering Exploration). The new lab course at the University of Florida, while a marked improvement, still contained a fair amount of traditional instruction, leaving the students less engaged than they could have been.

At the University of Denver, the Engineering and English departments collaborated and linked an Engineering Concepts course with a Critical Writing course in order to be in line with communication abilities that are noted in EC 2000 (Lengsfeld, Edelstein, Black, Hightower, Root, Stevens & Whitt, 2004). This linkage is also a pedagogical element that I used in Engineering Exploration, where the two of the projects conclude with a comprehensive technical paper. At the University of Denver, this course linkage resulted in a huge 30% increase in 1^{st} year retention from 53% to 83%. Two and three year rates were not given. Faculty at University of Denver noted the reasons behind huge retention increase to be student engagement and community development. Their results are remarkable for their institution. Their percentage increase in the first year is much higher than what was found in this study (30% vs. 7% increase). However their overall retention is still below our figures: 83% vs. 90%. It would be interesting to see their 2yr and 3yr retention rates for comparison. Engineering Exploration appeared to have a larger impact on retention in the 2^{nd} and 3^{rd} years.

At the University of Massachusetts at Dartmouth, their reform measure was to integrate the first year curriculum to include conceptual information, team-work, active learning, and a technology oriented space (Pendegrass, Kowalczzyk, Dowd, Laoulache, Nelles, Golen & Fowler, 2001). They experienced a 21% first year retention rate increase, from 62% to 83%. The results here are similar to the other universities mentioned in that the percent increase is higher than this study, but the actual retention rate is not as high as in this study.

Institutions across the nation that have implemented reform measures to increase retention, success, and student satisfaction are commendable. In many cases, it is important to look past the first year in order to determine longer term effects. When comparing Engineering Exploration to these other institutions, it seems clear that the effects of Engineering Exploration spanning past the first year are substantial. It is unclear if the effect was the same at other institutions. I would attribute the marked increase in retention, especially in the 2nd and 3rd year retention rates for students who took Engineering exploration to the design of the curriculum, in particular, the combination of active learning methods used. Engineering Exploration not only exposes students to the various fields, but also provides students with the academic and professional skills needed to succeed in a rigorous engineering program. I will continue to work with the administration to foster a better future for engineering students.

V.E Future of Engineering Exploration

Cornerstone courses like Engineering Exploration have proven to be an asset to an institution's retention, success, and satisfaction at other institutions, similarly to what has been found at Rutgers University (Tezcan et al., 2008; Hoit & Ohland, 1998; Porter & Fuller, 1998). I would support and encourage expanding this course to all first year students. In addition to writing grants, expanding Engineering Exploration to the entire first-year will involve substantial financial support from high level administration. I will continue to revise and enhance the curriculum to make the experience the most beneficial for the students who take it. In addition to modifying or finding new projects, shortly after this study, I plan to create a video library of engineering related topics. One topic will be a virtual tour of each engineering department and of senior design courses. It is not feasible logistically to take the students on a tour of each department. However with a virtual video library, all students would have the opportunity to see each department. Another feature of the video library will be to create a portfolio of experiments and problems that elicit various concepts and components that relate to each engineering major. Professor Eugenia Etkina of the Physics Education department at Rutgers has created such a library for Physics (Etkina, 2001). Creating these virtual experiments can also help the current situation of not having a real lab space. Experiments can be conducted and videotaped in labs where most students do not have access. Accompanying projects or problems can be created and available for student use. I plan to start the video library in the spring 2013 semester.

My ultimate goal is to expand Engineering Exploration to the entire first year class, making it compulsory. In order to offer this course to over 700 first-year students, a plan to create a dedicated engineering lab space, dedicated instructional staff, and resources must be considered. In long-term planning, I would like for an Engineering Exploration II to be created in the second year, where students can continue the design based project work when they are in a major. At the same time, many current engineering faculty could benefit from some training, even informally to update their teaching style and course materials. Transforming an entire engineering faculty in the near future is an unrealistic goal. However, reaching a portion of the faculty, providing them with metrics and tools to use is a great start. I would like to take on projects like these to make the undergraduate experience for engineering students more beneficial, productive, and appealing. These long-term goals can only happen with support from the administration. The culture of education needs to trickle from the top down for change to be realized.

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V. APPENDIX

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Appendix 2a: Civil

Seismic Disasters

Project Abstract: Earthquakes have devastated nations for centuries. In 2010, there was a rash of earthquakes that had crippling effects. In January, a quake, with a 7.0 magnitude on the Richter scale, utterly overwhelmed Haiti with destruction. Chile was rocked by the 8.8 magnitude earthquake in February. The California-Mexico area was shaken with a 7.2 earthquake.

In preparation for an earthquake, the local township has announced the Seismic Building Competition for the best building design, and you are invited to compete.The winner receives the best Engineer of the Year award.Construct a model building that is mechanically and structurally sound. The structural integrity of the building will be determined by the maximum seismic disturbance that the building is able to support.

Project Design: The task for your team is to design and build a 5 story building with bracing for provided dead, live, and earthquake loading. The structure that withstands the maximum seismic disturbance wins the contest.

Each team of 4 will construct a five-story building prototype made of balsa wood. Groups should acknowledge the following scale: 12 ft. actual height = 6 in. project height. Structures should be constructed to a height of 30 inches, with a 4 inch minimum floor height. A unidirectional earthquake shake table, with dimensions of 18 in by 15 in and a capacity of 50 lb, will be used for structure testing.

Model Dimensions and Details

- Building Plan Dimensions = 12 in x 12 in (outside-to-outside)
- Total building height = 30 in
- Diaphragms (floors) = 12 in x 12 in
- Columns = 1/4 in x 1/4 in cross section. Built-up rectangular columns ½ in x ¼ in can be allowed at the **corners** if necessary. Interior edge columns are acceptable using allocated materials.
- Columns =1/4 in x 1/4 in cross section
- Braces = 1/8 in x 1/8 in cross section. Braces can be diagonal, cross, v-shaped, inverted v-shape, other design, or non-existent.
- Base plate = 15 in x 15 in x 1/4 in should be fixed to the base of the structure. The base plate will also attach the structure to the shake table using mechanical clamps.

Assessment

Each project will be evaluated in terms of the maximum acceleration or 'shake' that the structure is able to support without failure, and on the oral presentation. Each team member should keep record of project specifications (prototype/real structure), concepts used, and conclusions which should be included in the presentation.

Appendix 2b: Stress/Strain and Excel

Engineering Exploration: Data Analysis Project
Rutgers University is currently building new apartments on Livingston campus. In the plans for the building the structural engineer specified that the contractor must use A36 steel beams. A few days after the plans were released; the contractor said that he got a great deal on a bunch of steel from “some guy”. The engineer was skeptical that this new steel would have the same properties as what he originally specified, so he enabled the help of Rutgers Engineers! The Civil Lab did a tension test on a sample of steel and got the following results but had an emergency with an exploding concrete mixer and now needs your help to analyze the data.

Load (kip)	Elongation (in.)
0	0
1.50	0.0005
4.60	0.0015
8.00	0.0025
11.00	0.0035
11.80	0.0050
11.80	0.0080
12.00	0.0200
16.60	0.0400
20.00	0.1000
21.50	0.2800
19.50	0.4000
18.50	0.4600

Specified Data:
Diameter - . 503in
Gauge Length – 2. 00 in
Yeild- 36 ksi
E- 29,000 ksi
Rupture Stress- 58 ksi

Plot the stress-strain diagram and determine approximately the modulus of elasticity, the yield stress, the ultimate stress, and the rupture stress. Then compare your results to the ones originally specified by the structural engineer and give them a suggestion of whether or not the new steel can be used. Write a technical report that details goals, findings, and your analysis.

(Example: [http://higheredbcs. wiley. com/legacy/college/philpot/0470044381/mecmovies/index. html](http://higheredbcs.wiley.com/legacy/college/philpot/0470044381/mecmovies/index.html))

Appendix 2c: Electrical
Electrical and Computer Engineering

- Demo-activity (light a light bulb with 2 wires and a battery).

- Reconstruct the above set-up* and other listed below via an on-line simulation. Answer questions (http://phet. colorado. edu/en/simulation/circuit-construction-kit-dc):
  - battery+bulb*
  - battery only
  - battery+resistor

Questions
- On the simulation, identify items on simulation:current, voltage, resistance
- Why do balls go faster when there's no bulb/resistor?
- What does a bulb/resistor do in the circuit?
- Find a diagram of simple series and parallel circuits (with only resistors).
- Make simple, series, and parallel circuits. Use Ammeter, Voltmeter
- What happens to current with 1 resistor vs 2 in series?
- What happens to current with 1 resistor vs 2 in parallel?
- What happens to voltage with 1 resistor vs 2 in series?
- What happens to voltage with 1 resistor vs 2 in parallel?
- Predict the brightness of the bulbs in these 4 cases. Then make the circuits with bulbs and test your prediction.

- Based on your knowledge of the elements in a circuit, using an analogy, relate each element to the elements of people running on a track. You can modify the set-up of the track to make it relevant.

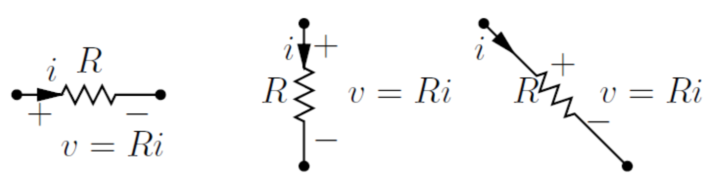
Parts of an electric circuit	Parts of a system: people running on a track
Moving Electrons	
Battery	
Connecting wires	
Light bulb	Hurdle
Light bulbs in series, bulb dimmer	
Light bulbs in parallel, bulb brighter	
Batteries in series, bulb brighter	
Batteries in parallel, bulb same brightness	

- Construct the following two scenarios on the simulation software and on a breadboard with actual resistors and a multi-meter. Ensure that your configurations are equivalent by measuring resistance and current.
  - Two resistors in series.
  - Two resistors in parallel

- Read the following conceptual text relating to your new knowledge of circuits.

Conceptual Background
Our aim in this project is to design a simple interfacing circuit. Before we introduce the design project and a method of achieving our design goal, we need some background information. The needed background and the details of design are given below step by step. At first, we need to learn a property of a resistor, namely that it presents what is known as electrical resistance to a flow of current. For this reason, often the words ‘resistor’ and ‘resistance’ are used interchangeably. Once we learn about resistance, we proceed to learn how two resistances connected in series can be thought of as one equivalent resistance. Similarly, we will learn how two resistances connected in parallel can be thought of as one equivalent resistance. These concepts will then lead us to a simple design problem.

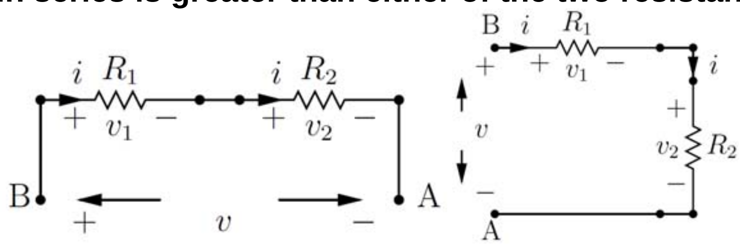
Step 1: (Concept of Resistance and Ohm’s law) A resistor is a two terminal element used almost in every electrical circuit. It presents resistance to the flow of an electrical current. The value of resistance is measured in Ohms whose symbol is Greek letter Omega, Ω . Ohm’s law states that v = Ri where v is the voltage in Volts across the resistance R and i is the current in Amperes through R. The figure below depicts a common representation of a resistance in a circuit.



Resistance is akin to friction. Often friction is considered as an undesirable element. In automotive travel, friction presented by the road surface is the cause of loss of energy since it opposes the motion (or flow) of the vehicle. On the other hand, icy roads with no friction or reduced friction can be dangerous. You may have experienced that it is difficult to control the motion of a vehicle on icy roads. The lesson here is that a controlled amount of friction, and similarly resistance in electrical circuits or elsewhere is indeed desirable. An appropriately controlled flow of current is the goal of all circuit designers. Circuit elements including resistance values are designed properly to control the flow of various currents in a circuit.

Step 2: (Two resistances interconnected in series) Figure below shows the interconnection of two resistances in series. As seen in the Figure, one terminal of the first resistance is connected to one terminal of the second resistance so that the current, i, flowing in both the resistances is the same. The other two terminals one from each resistance form the external terminals of the connection. One can view both the resistances interconnected together in series as one equivalent resistance. Then, the equivalent resistance between the terminals A and B is given by: $R_{Eq} = R_1 + R_2$. (Because $v = iR_{Eq} = v_1 + v_2 = i\,(R_1 + R_2)$.)

The above equation says that two resistances interconnected in series is equivalent to a single resistance having a value as the sum of two resistances, $R_{Eq} = R_1 + R_2$. **Note that theequivalent resistance of two positive resistances in series is greater than either of the two resistances.**

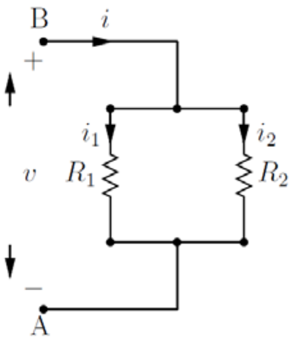


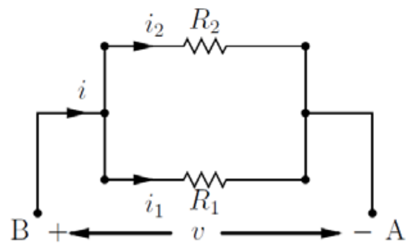
Step 3: (Two resistances interconnected in parallel) Figure below shows the interconnection of two resistances in parallel. As seen in the Figure, a pair of two terminals one from each resistance are connected together to form a node or a joint terminal, and similarly another pair of two terminals one from each resistance are again connected together to form another node. Both of these nodes form external terminals. In this case, the voltage v across each resistance is the same, however a current i flowing into a node divides itself into two parts i_1 and i_2. One can view both the resistances interconnected together in parallel as one equivalent resistance. Equivalent resistance of two resistances interconnected in parallel (that is, the resistance between the terminals A and B) is given by

$$\frac{1}{R_{Eq}} = \frac{1}{R_1} + \frac{1}{R_2} \quad \Rightarrow R_{Eq} = \frac{R_1 R_2}{R_1 + R_2}. \qquad \text{(Because } i = \frac{v}{R_{Eq}} = i_1 + i_2 = \frac{v}{R_1} + \frac{v}{R_2}.\text{)}$$

The above equation says that two resistances interconnected in parallel is equivalent to a single resistance having a value equal to the product of two resistances divided by their sum, as noted in the equation above. **Note that the**

equivalent resistance of two positive resistances in parallel is less than either of the two resistances.

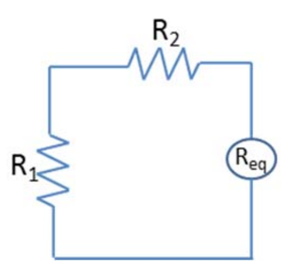
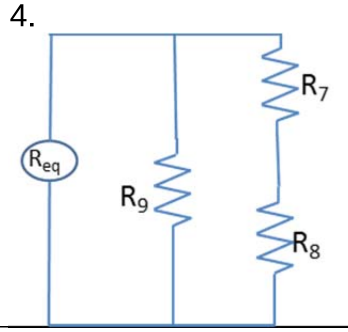
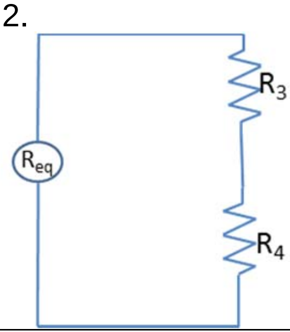




Two resistances interconnected in series as in Step 1 and similarly two resistances interconnected in parallel as in Step 2 form the basis of our design problem.

Guided Classroom problems:
Solve R_{eq} for these circuits where:

R_1= 50Ω	R_2= 2kΩ	R_3= 40Ω	R_4= 3kΩ
R_5=10Ω	R_6= 75Ω	R_7= 20kΩ	R_8= 15Ω
R_9= 35Ω	R_{10}= 100Ω	R_{11}= 95Ω	R_{12}= 20Ω

1. 	4. 
2. 	

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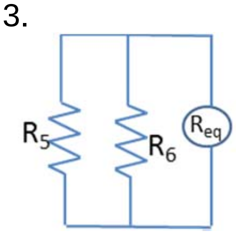
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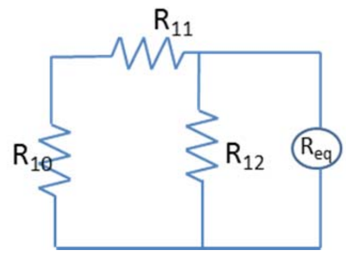
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(the next page is the main project)

What's Inside the Black Box?

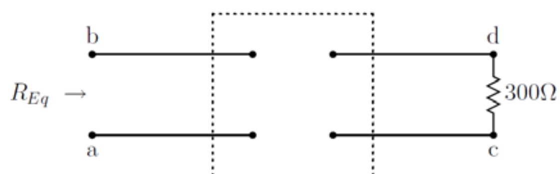
Based on materials given by Professor Pedda Sannuti

Project Abstract

Comvision is the largest cable company that supplies cable services to commercial buildings. In many commercial buildings built in the past, cable tv service is run from an outdoor antenna to several locations in the building. The standard cables used in the past were 300Ω cables. However, recent TVs have a 50±10Ω cable connection. If the resistance of incoming cable does not match what the TV cable connection requires, ghosts of previous images will linger on the TV screen making it impossible to watch the TV. One obvious solution to the problem is to replace all the 300Ω cables in the building cables that are 40Ω or 60Ω. This is expensive. A smart solution is to design an interfacing circuit between the 300Ω cable and the TV. Comvision is hosting a competition for the best circuit design. The best design wins the contract and receives a permanent job offer from Comvision.

Project Design

Consider the figure given below where the dotted box represents the interface between the cable and the TV. It contains the interface circuit. The terminals 'a' and 'b' are to be connected to TV and the terminals 'c' and 'd' are to be connected to the cable coming from an outdoor antenna. Assuming that the interface box is already connected to the cable coming from an outdoor antenna, the resistance of 300Ω between the terminals c and d is the equivalent resistance of the cable.



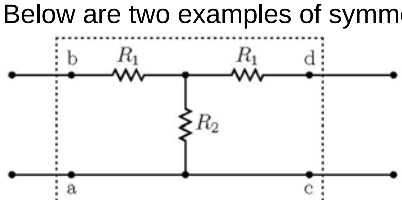
Block Diagram

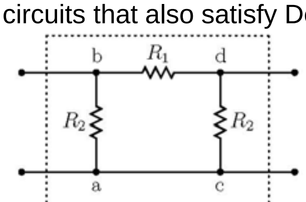
The mathematical design problem can then be expressed as follows: Design the interface circuit that should be in the dotted box such that the equivalent resistance REq between the terminals 'a' and 'b' is 50Ω.

Design Constraint 1: The terminal b cannot be interconnected to terminal d, They need to be distinctly different. The terminals a and c can be interconnected.

Design Constraint 2: The circuit designed need to be symmetrical. This implies that looking at the layout of the circuit either from the terminals a and b to the right or from the terminals c and d to the left must be the same. Such a symmetrical circuit allows us to connect either end of it to the cable, while the other end is connected to the TV. Each team must pick one of the designs shown below.

Below are two examples of symmetrical circuits that also satisfy Design Constraint 1:





Homework

Read 3 project papers and summarize main points. This assignment is to be included in the technical paper and will not be collected separately.

ord

Appendix 2d: Biomedical/Excel

Biomedical Engineering and Excel/Data Analysis

Abstract:
Your employer, University Pharmaceuticals Inc., has developed a new drug for college students to help counteract the “freshman fifteen”. The FDA will not approve their drug for fear that it will raise the blood pressure of its users over acceptable limits. UPI is looking for baseline blood pressure readings of college students while not on the drug. Later UPI plans on comparing the data collected from this class to the data of students who have taken the new drug to ensure the safety of their product to the FDA.

Furthermore, you are looking to impress your boss and instead of just coming back with a control blood pressure (students sitting and resting), you are going to collect additional data to test other conditions that affect blood pressure (i. e. lying down, caffeine, physical activity, and gender). By attaining this data, you will get a better idea of the ranges and conditions of what “normal” blood pressure will be.

HW prior to Class 1 (you will be given a quiz before data collection):

1) What is a blood pressure (systolic, diastolic)? What are factors at that affect it? How can it be manipulated? Give physiology behind the blood pressure.
2) Overview of Blood Pressure Monitors: How they work? What are the key elements of the device itself? What is better manual or automatic? Accuracy vs. Precision

Go to Sakai and download the Excel template under BME Project. Record all data on this file and when complete upload to dropbox. All data must be taken in one class period and be done on <u>left arm.</u>

Experiment 1: Control (Every group will do this)
Each student will take another individual’s blood pressure. Go in a circle until an individual’s blood pressure is attained 3 times. Then average (on Excel!). This will take into account of precision of blood pressure machines and take into account variations that may occur.

Experiment 2: Relaxation (2 Groups)
Each student will go into a “relaxed” position, lying down. After 2 minutes measure the blood pressure of each student. Wait 2 minutes. Repeat 3 times.

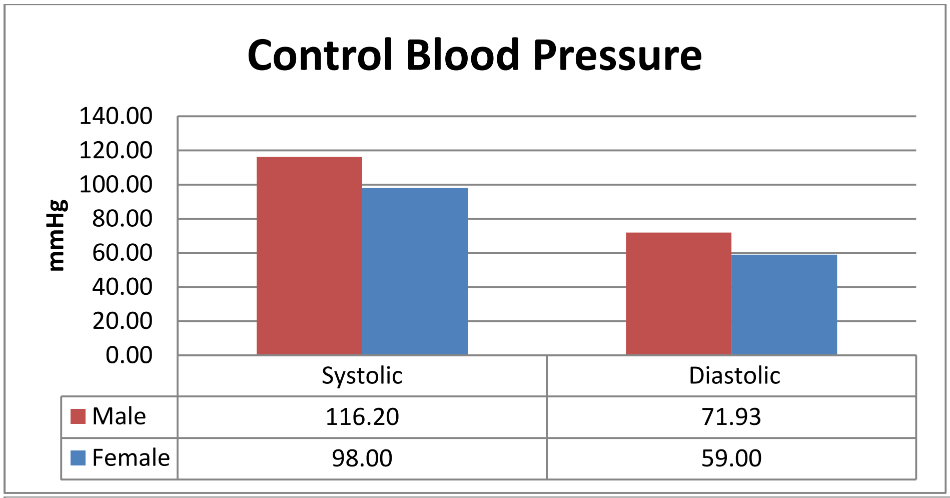
Experiment 3: Physical Activity (2 Groups)
Each student will perform jumping jacks for 60 seconds and then take BP/HR. Rest for 3 minutes.

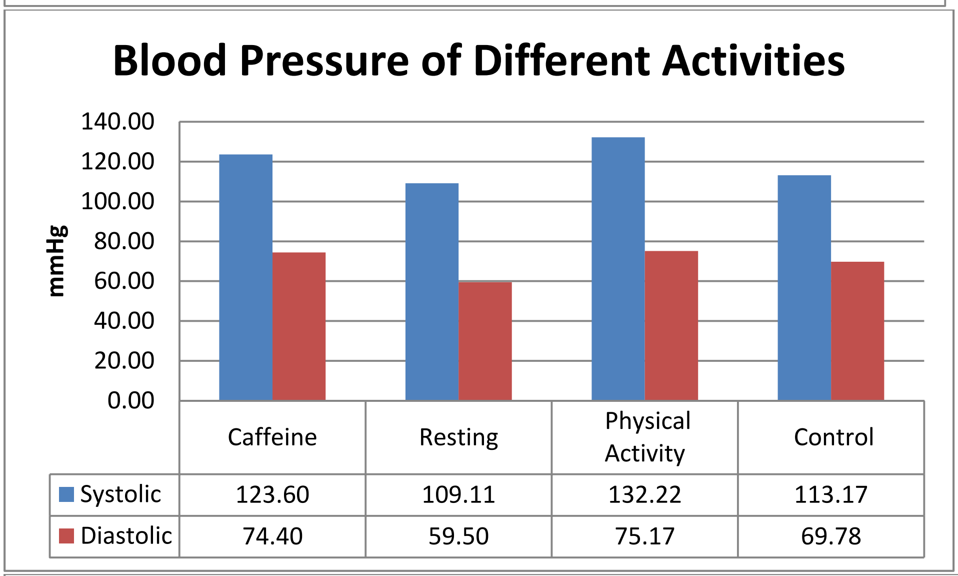
Repeat (jacks, BP measurement, rest) three times. Remove the cuff after each measurement.

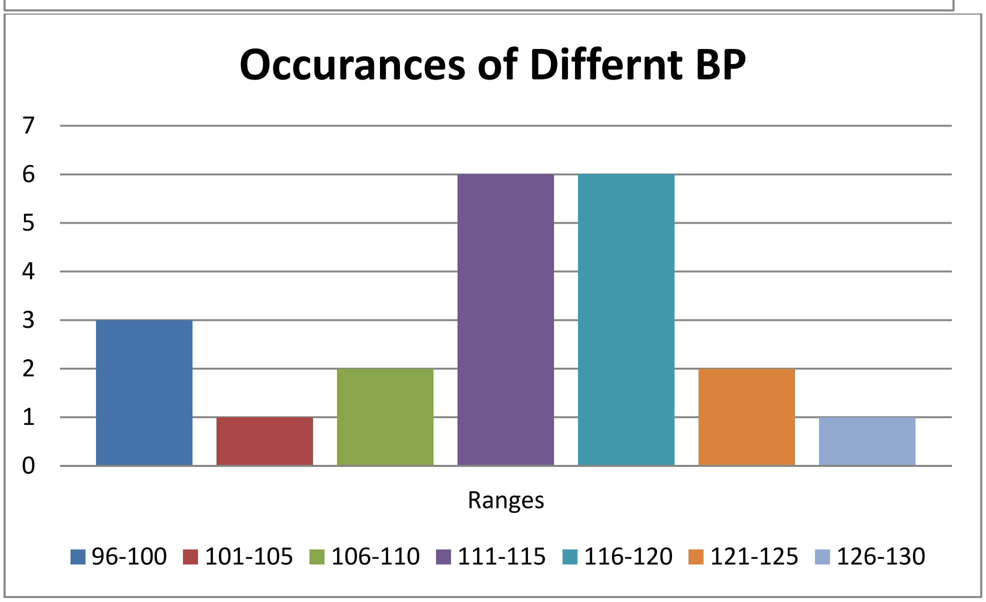
Experiment 4: Caffeine (2 Groups)
Each student will drink 1 can of caffeinated soda within 2 minutes. Wait 5 minutes. Take BP 3 times in 2 min intervals, removing the cuff each time.

Report:
See page below

Graphs:
- Bar graph of average male systolic/diastolic vs. female data
- Bar graph of average systolic/diastolic for each of the experiments
- Bar graph of all systolic control data based on occurrences in different ranges
- See examples of required graphs below.


Control Blood Pressure
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
mmHg
Systolic
Diastolic
Male
116.20
71.93
Female
98.00
59.00


Blood Pressure of Different Activities
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
mmHg
Caffeine
Resting
Physical Activity
Control
Systolic
123.60
109.11
132.22
113.17
Diastolic
74.40
59.50
75.17
69.78


Occurances of Differnt BP
7
6
5
4
3
2
1
0
Ranges
96-100
101-105
106-110
111-115
116-120
121-125
126-130

Lab Report Requirements

The purpose of a lab report is to convey to the reader the following:

- **What are the goals of this experiment**? Not everyone is interested in this report; the reader may be browsing for a specific topic and doesn't want to waste time with a poorly identified report.
- **How it was performed**. This is done to allow others to repeat the experiment and verify the results.
- **Results**. A good report will give the reader the most information with the least effort. This is done with sharp graphs and tables with units and labels given. Raw data (as taken during the experiment) must be included in the report to help diagnose experimental or computational error.
- **Conclusion**. Each reader may not have the time to sit down and draw their own conclusions for multiple reports.

Short Lab Report Format

1. Cover Sheet – Containing the following information:
   a. Experiment Title
   b. Your Name
   c. Course Name, Section Number
   d. Date Experiment Performed, Date Report Submitted
   e. The report is to be *stapled* or otherwise securely bound (or submitted on Sakai).

2. Introduction – Similar to Overview or Description of Experiment – Limit 4 sentences/bullets.
   a. Describe the experiment: the specimen used (ex. Arm…), the important equipment used, type of test performed, the manner in which the measurements are made (procedure), and the information obtained (ex. Blood pressure, heart rate…)

3. Data and Results
   a. **Raw Data**. This section consists of the actual data collected during the experiment with no computational modification (for the entire class). In case of error, it is important to offer the reader a way to verify your calculations. The raw data should be presented in neat, clearly labeled, tabular form. (No calculations should be seen)
   b. **Figures**. Include simple sketches to aid the reader in understanding the test. Draw how the specimen was oriented (ex. How cuff was attached and location of arm during test).
   c. Modified Data. Data that has been manipulated. Clearly state assumptions and equations used. (ex. Averages and any calculated data that is needed for the graphs in the Results section)
   d. Sample Calculations. Offer the reader sample calculations stating all information that led to the result. For example: $\sigma = P/A$, where σ = stress, psi; P = load applied, lbs; and A = cross sectional area, in^2. (Show average calculation samples)

4. Results
   a. Figures and Summary Tables. This section contains the "meat" of the experiment. Present only final answers and end results of the experiment. (ex. Table of averages and any important data)

b. **Graphs**. – A graph should present the results to a person who doesn't want to read the whole report. Graphs must be sharp and easy to understand and should include:

- Graphs should show data in a similar way as shown in assignment

<u>5.</u> Conclusions

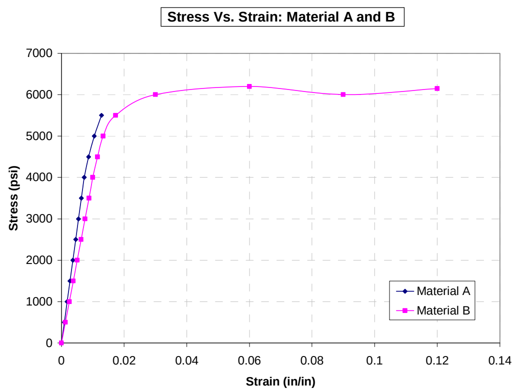
The conclusion is not the same as results.

a. Answer, "What does it mean?" What factual statements can be made from the graph?

Address questions you answered for homework. (Do not "re-answer them")What test has the most effect on blood pressure, etc. . .

**Review the plots and talk about the significance in relation to population with hypertension, pharmaceutical industry, devices industry, food industry.

(see Civil Engineering example below)



For example consider the graph above of stress vs. strain for two materials in axial tension, Material A and B. Study the graph and note the following factual observations:

1. Material A has a higher Young's Modulus, as evidenced by a steeper curve.
2. Material B has a higher ultimate strength.
3. Material B is more ductile; its total strain capacity is higher.
4. Material B is tougher; the area under the stress-strain curve is greater.

These true statements are starting points for a good conclusion. Each is a topic sentence in a paragraph. Quantitative results or other evidence from the test may support each statement. For example, "the Young's modulus for this material is 29000ksi because it looks like steel" is not acceptable.

b. Discuss the implications of the statements.

*A good conclusion saves the reader time. Given the time the reader could study the graph and draw similar conclusions. But it's the experimenter's job to do that studying for the reader.

Appendix 2e: Mechanical/Industrial

Gas-less Car Competition
by Lydia Prendergast

Project Abstract:

- Greencorp Inc. is an environmentally friendly company that helps other companies to become more ‘green’. Greencorp Inc. needs to design a wheeled vehicle to be used in production plants to transport products on an assembly line between stations as fast as possible. Greencorp Inc. is hosting a competition for Rutgers Engineers to construct 2 versions of a wheeled vehicle (one that travels with the greatest speed between two assembly line points, and one that travels the greatest distance). The vehicle is powered by a single mouse trap. The basic design costs $6. Any modifications come at an additional cost and weight; costs of materials to be purchased can be referenced from www.kelvin.com or from another source. The best product wins the competition and contract.

- Once the vehicle design is complete, Greencorp Inc. must determine the Cartesian coordinates of a new factory to manufacture these vehicles. The vehicles will be used in plants of five companies, each with their own demand for the vehicle.

Project Design Specifications:

- Design and build wheeled vehicle capable of traveling solely powered by a single mouse trap. Once the car is released, no human intervention is allowed.
- The design may be modified using materials supplied. The only part that must stay constant is the mousetrap itself.
- Determine the most optimal place to build a factory to build the vehicles. The companies buying the vehicles are located in the capital cities of the states indicated in the chart below. The optimal location will be where the distance to travel between companies is minimized keeping the demand in mind. The coordinates of the company sites are obtained using the latitude and longitude and translated into miles with respect to lat-long of (0, 0). The company sites and demands for each company are as follows (demand in millions pounds of the vehicle).

State	Arizona	California	Texas	North Dakota	New Jersey
Demand	300	900	1000	50	1000

- $X = (x,y)$ denotes the location of the new facility
- $P = (a_i,b_i)$ denotes the location of existing facility i, $i = 1,\ldots,m$
- w_i denotes the weight (or demand/flow) associated with travel between the new facility and existing facility i
- $d(X,P_i)$ denotes the distance between the new facility and existing facility (described by the distance calculations)

$$Minimize \quad f(X) = \sum_i w_i d(X, P_i)$$

- Helpful terms: Moment of Inertia, Torque, Squared Euclidean distance, Manhattan (rectilinear) distance, Chebyshev distance, Euclidean distance. Weighted center method may not be used for this project.

Assessment:

- Each team will have three attempts and only the best attempt will be considered.
- Version 1- speed: The team with the fastest speed traveled (over a 15’ distance) "wins". In case of a tie, the team traveling along the straightest line will win.
- Version 2-distance: The team with the longest distance “wins”. In case of a tie, the team traveling along the straightest line will win.
- Identify at least 1 professor at Rutgers University who has research interests in car design. Make at least one relation of the research to your project.
- Each team will make a group presentation describing project specifications, concepts, data, and conclusions that describe how it works, why it works, and physics/math involved.
- Each group member will write their own technical report detailing all of the information about this project, requirements, limitations, design modifications with relevant math/science concepts, pictures, diagrams, etc.
- The presentation and technical paper will be your final exam. Further details about the paper will be provided to you.

Appendix 3: Syllabus

Albertalli Engineering Exploration - 14:440:125, Fall 2011

	Section 1	Section 2
Time/Location	Monday and Wednesday 12:00-1:20, BEST Computer lab	Tuesday and Thursday 12:00-1:20, BEST Computer lab
Textbook	Standard Calculus and Physics texts.	
Lab Fee	$40 non-refundable fee ($25 toolkit, $15 lab fee), due on the first day of class (cash or money order only). If a student obtains a tool kit from a previous student, the course fee is $15. Each student must have their own toolkit.	
Wiki	http://engineeringexploration. wikispaces. com/	

Class	Activity	Homework and Notes
#1 Sec 1: 9-7 Sec 2: 9-1	Class Surveys Project 1: Balsa building Sketch the building and construct	HW:Bring in a sketch of the building design to class.
#2 Sec 1: 9-8 Sec 2: 9-6	Project 1: design, building, analysis	HW: Begin presentation. Bring presentation to class on laptop or email. Read, summarize main points of earthquake paper, making 1+ connection to your project and include in your ppt presentation.
#3 Sec 1: 9-12 Sec 2: 9-13	Project 1: design, building, analysis Presentation review	HW: Finish presentation. Post in the class wiki (http://engineeringexploration. wikispaces. com/) about Civil Eng'g. Definition, job posting, questions or response. Every student must make 2 posts on the wiki-majors over the semester (not both in the same major). Some RU Career Inforhttp://careerservices. rutgers. edu/CareerHandouts. shtml
#4 Sec 1: 9-14 Sec 2: 9-15	Project 1: Presentations	HW: Fill out schedule grid for class, work, HW, etc. Bring to next class. Have 2 questions prepared for the Civil Eng'g presenters.
#5 Sec 1: 9-19 Sec 2: 9-20	Project 1: Presentation wrap-up and Structure testing. Civil Eng'gdept presentation. Dr. Najm, Dr. Gucunski	Note: Decide on a dedicated time to meet with group out of class once per week. Write a group contract.
#6 Sec 1: 9-21 Sec 2: 9-22	Team Meeting #1.	Finish group contract. Download and review Data Analysis project.
#7 Sec 1: 9-26 Sec 2: 9-27	Presentation Skills:How to make a presentation using Eng'g disciplines (ppt, excel,	HW: Work on data analysis. Present your findings at the end of next class.

	word), what to include, slide formatting, how to collect and analyze data, etc. Project 1b:Data Analysis Activity	HW: Post in the class wiki (http://engineeringexploration. wikispaces. com/) about ChemEng'g. Definition, job posting, questions or response. Every student must make 2 posts on the wiki-majors over the semester (not both in the same major). Some RU Career Infor/http://careerservices. rutgers. edu/CareerHandouts. shtml
#8 Sec 1: 9-28 Sec 2: 9-29	Project 1b:Data Analysis Activity	HW: Download and review ECE project 3. Bring hard copy to next class.
#9 Sec 1: 10-3 Sec 2: 10-4	Department Tour: Chemical Eng'gdept tour EN-C115.	Extra Credit:Get your resume critiqued at Career Services for extra credit. Critiqued resume must be signed/dated by Career Services.
#10 Sec 1: 10-5 Sec 2: 10-6	Project 3: Circuit design. Background info and activity. Outline of tasks, group member functions	HW: Work on project 3, algorithm, theoretical calculation, phet simulation
#11 Sec 1: 10-10 Sec 2: 10-11	Project 3: Circuit design: design, building, analysis, concepts. Check theoretical calculation. Build circuit.	HW: Write Introduction and Concepts sections of a lab report for this project; bring 3 hard copies of the intro to next class (hard copy only). Complete Equivalent Resistance problems.
#12 Sec 1: 10-12 Sec 2: 10-13	Project 3: Peer review of Intro/Concepts sections. Build/Test Circuit Concept reinforcement	HW: Write a methods and results sections. Study for quiz.
#13 Sec 1: 10-17 Sec 2: 10-18	Quiz:Equivalent Resistance Project 3: Finish building and testing. Packaging Eng'g presentation	HW: Write remaining sections of paper. Bring 3 copies of Conclusions and Abstract to next class (hard copy only) HW: Post in the class wiki (http://engineeringexploration. wikispaces. com/) about Electrical/Computer Eng'g. Definition, job posting, questions or response. Every student must make 2 posts on the wiki-majors over the semester (not both in the same major). Some RU Career Infor/http://careerservices. rutgers. edu/CareerHandouts. shtml
#14 Sec 1: 10-19 Sec 2: 10-20	Project 3: Peer review of Conclusions and Abstract sections.	HW: ECE paper due next class (SAKAI) HW: work on poster presentations (print out PPT slides to be taped to wall as a poster)
#15 Sec 1: 10-24 Sec 2: 10-25	Project 3: ECE poster presentation ECE paper due (SAKAI) ECE dept presentation.	HW: Make your schedule for next semester and bring it to class. Also have one question prepared about any academic topic/issue. Post in the class wiki (http://engineeringexploration. wikispaces. com/) about Materials Science Eng'g. Definition, job posting, questions or response. Every student must make 2 posts on the wiki-majors over the semester (not both in the same major).

		Some RU Career Infor/http://careerservices. rutgers. edu/CareerHandouts. shtml
OCTOBER 26 is the Last Day to drop a class via webreg w/a W (Engineers can drop classes w/a Dean until Nov 21)		
#16 Sec 1: 10-26 Sec 2: 10-27	-Academic calendar and Info session (Dean Prendergast) -Everything you wanted to know, but were afraid to ask.	
#17 Sec 1: 10-31 Sec 2: 11-1	Time Mgt Activity Presentation: MSE department	HW: Post in the class wiki (http://engineeringexploration. wikispaces. com/) about Biomedical Eng'g. Definition, job posting, questions or response. Every student must make 2 posts on the wiki-majors over the semester (not both in the same major). Some RU Career Infor/http://careerservices. rutgers. edu/CareerHandouts. shtml
#18 Sec 1: 11-2 Sec 2: 11-3	Project 3:BME Activity (data collection and definitions)	HW: Technical paper rewrite due next class. Submit via sakai only.
#19 Sec 1: 11-7 Sec 2: 11-8	Project 3:BME Activity (data analysis) ECE PAPER DUE (rewrite), VIA SAKAI ONLY	HW: Complete Data Analysis Assignment.
#20 Sec 1: 11-9 Sec 2: 11-10	Project 3: BME assessment (in class individual Excel assessment with a written summary paragraph BME dept Presentation	HW: Read paper on 21st century Engineering. Research and define each (14) global topics listed in the paperOnline assignment. Post 2 question and 2 responses per topic in Rutgers - Engineering Exploration FB group.
#21 Sec 1: 11-14 Sec 2: 11-15	Project 4: Car - design, building, analysis	Hw:Concept building/reinforcement
#22 Sec 1: 11-16 Sec 2: 11-17	Project 4: design, building, analysis	Hw: -Concept building/reinforcement, -Write Introduction Section
NOVEMBER 21: Last day to drop a class with a W (for Eng'g Students only). DEAN'S permission required.		
#23 Sec 1: 11-21 Sec 2: 11-22	Project 4: design, building, analysis. Concept check-up.	HW: Post in the class wiki (http://engineeringexploration. wikispaces. com/) about Bioenvironmental Eng'g. Definition, job posting, questions or response. Every student must make 2 posts on the wiki-majors over the semester (not both in the same major). Some RU Career Infor/http://careerservices. rutgers. edu/CareerHandouts. shtml
NOVEMBER 23-27: THANKSGIVING HOLIDAY BREAK. No Classes		
#24 Sec 1: 11-28 Sec 2: 11-29	Project 4: design, building, analysis, Bioenvironmental presentation	HW: Write Methods Section HW: Submit via sakai concepts being used and supporting decisions in car design. HW: Post in the class wiki (http://engineeringexploration. wikispaces. com/) about Mechanical Eng'g. Definition, job posting, questions or response. Every student must make 2 posts on the wiki-majors over the

		semester (not both in the same major). Some RU Career Infor/http://careerservices. rutgers. edu/CareerHandouts. shtml
#25 Sec 1: 11-30 Sec 2: 12-1	Project 4: Testing and racing Concept Assessment review. Concepts due on Sakai	HW: Study for Concept Assessment. HW: finish presentations, review during next class
#26 Sec 1: 12-5 Sec 2: 12-6	Project 4: 1st draft of presentation due (In class critique) Concept Assessment (bring calculator)	HW: Work on project 4 Paper (Results section) & presentation HW: Post in the class wiki (http://engineeringexploration. wikispaces. com/) about Industrial Eng'g. Definition, job posting, questions or response. Every student must make 2 posts on the wiki-majors over the semester (not both in the same major). Some RU Career Infor/http://careerservices. rutgers. edu/CareerHandouts. shtml
#27 Sec 1: 12-7 Sec 2: 12-8	Project 4: Presentations (Dress to Impress) ME dept presentation	HW: Work on project 4 Paper & presentation HW: Class Survey on SAKAI
#28 Sec 1: 12-12 Sec 2: 12-13	Project 4: Presentations (Dress to Impress) IE dept presentation	Final paper due via SAKAI (this is your final exam)
DECEMBER 13 is the last day of classes for the Fall 2011 semester. Exams begin Dec 16th.		

Activity:	Points
Attendance-80 and HW (Wiki/FB)-20	100
Presentations (Civil, ECE, ME/IE) (group)	100
Quizzes (ECE, BME, ME)	100
Technical Paper (ECE)	100
Data Analyses (Civil/BME)	100
Concept Assessment Test	100
Final Paper (ME/IE)	100
Total	700

Grade	% total points
A	90
B+	85
B	80
C+	75
C	70
D	60
F	<60

Description of activities

Attendance and participation: Attendance and participation in each class meeting are crucial for your learning and for the classroom experience of your peers. Your attendance grade will be calculated as follows:

Absence points: Tardiness: 1 mark
Absence:3 mark

For 4, 5, and 6 marks, FIVE grade points each deducted from 100.
For marks 7 and up, TEN points each deducted from 100.

Ex1: 1 absence, 1 tardiness = 4 marks = 5 grade points deducted (absence grade of 95).
Ex2: 1 absence, 2 tardiness = 5 marks = 10 grade points deducted (absence grade of 90).
Ex3: 1 absence, 4 tardiness = 7 marks = 25 grade points deducted (absence grade of 75).
Ex4: 2 absence, 2 tardiness = 8 marks = 35 grade points deducted (absence grade of 65).

Presentations: All presentations will be done in groups- orally and via power point. Each person is expected to present a portion of the presentation. Your peers will evaluate the presentations and assign a grade. See the presentation rubric below for more details on formatting.

Peer Evaluations:For all projects, each student will be evaluated by their peers within the project group. Comments made by your peers will remain confidential to the instructor. Each student will receive a total average grade from the evaluations.

Technical Papers:Technical papers for the ECE and MAE projects will be graded on an individual basis. See the technical paper rubric below for more details. Reports are submitted online via sakai. Any comments/corrections will be in red. When you resubmit, keep the instructors comments in the paper, and add your new text in blue. If you wish to remove text, use the strikethrough feature and change it to blue color.

Concept Assessment: This assessment will be on scientific and mathematical concepts used in the projects. All students must learn these concepts. Some peer instruction may be necessary. The Concept assessment will be graded individually.

Wiki and Facebook Group:These two online tools will be used to collaborate ideas with fellow classmates and make networking connections with past and present Engineering Exploration student and staff. There are graded assignments using these tools throughout the semester.
Wiki: http://engineeringexploration. wikispaces. com/
Facebook Group: http://www. facebook. com/groups/203515939674147/

ASEE Definition of Engineering: “The profession in which knowledge of the mathematical and natural sciences, gained by study, experience, and practice, is applied with judgment to develop ways to use economically, the materials and forces of nature for the benefit of mankind. ”

Skills for the Engineer of 2020:

- Strong analytical skills, Practical ingenuity & creativity,
- Good communication skills
- Business, management skills
- High ethical standards, professionalism
- Dynamic, agile, flexible & resilient
- Lifelong learners
- Able to put problems in their socio-technical and operational context
- Adaptive leaders

Problem Solving Strategy – Develop this strategy throughout the semester
1.
2.
3.
4.
5.
6.

Presentation Rubric	
Adequate	▪ Goal (s) clearly stated. ▪ Math/Science concepts and methodologies used correctly and detailed properly. ▪ How goal was achieved is clearly stated. ▪ How do you know goal was achieved (assessment). ▪ Design Constraints and Limitations. ▪ Topics and information learned (reflection). ▪ None of the presenters read verbatim. ▪ Transition between presents was smooth. ▪ Slides formatted properly: bullet points, efficient use of words, spelling/grammar correct.
Needs Improve-ment	▪ Goals are present but not completely clear. ▪ Math/Science concepts and methodologies used are incomplete and/or unclear. ▪ Incomplete assessment. ▪ Little or no reflection. ▪ Little to no constraints or limitations addressed. ▪ Some of the presenters read verbatim from slides/notecards ▪ Transition between presenters needs some work. ▪ Slides may be wordy, poorly formatted, and/or unpleasing.

Inade-quate	▪ Goal unclearly stated or not present. ▪ Math/Science concepts and methodologies used are incorrect or not addressed. ▪ No reflection. ▪ No constraints or limitations addressed. ▪ Transition between presenters was not smooth ▪ Presenters read verbatim from slides/notecards ▪ Slides present but do not match presentation parameters.
Missing	▪ No presentation.

Technical Writing Rubric – Overall Assessment	
Adequate	▪ Goal (s) clearly stated. ▪ How goal was achieved is clearly stated. ▪ How do you know goal was achieved (assessment). ▪ Limitations. ▪ Topics and information learned (reflection). ▪ Math/Science concepts are correct and detailed properly. ▪ Text formatted properly: sections present and contain appropriate information. Bulleted/numbered where needed, efficient and accurate use of words, spelling, and grammar.
Needs Improvement	▪ Goals are unclear/incomplete. ▪ Incomplete assessment. ▪ No reflection. ▪ Concepts incomplete/unclear. ▪ Text poorly formatted. Some grammar/spelling mistakes
Inadequate	▪ There is some writing, but does not match report parameters. ▪ Math/Science concepts not addressed.
Missing	▪ No report.

Technical Writing Grading Rubric					
Section (pp)	Areas to be covered	Adequate	Needs improvement	Inadequate	Missing
Abstract (¼-½pg)	A condensed version of the main technical paper that highlights the major points covered (including the results), and reviews the writing's contents in abbreviated form. In the abstract, the reader should understand at a high level everything that is contained in the main body of the paper.	10	7. 5	5	0
Introduction (½ to 1 pg)	A detailed description of the problem at hand.	7. 5	6	3. 75	0
Concepts (1 to 3 pgs)	Write your paper as if a high school student (stranger to Eng'gExpl) was reading it and you did not know their level of expertise in the subject at hand (ex. physics/electricity). Describe well the math and science concepts used.	15	11	7. 5	0
Design andConstraints (½ to 2 pgs)	Detail of your plan or design to solve this problem. If there are any constraining factors as designated in the project write-up, include them in this section.	15	11	7. 5	0
Methodology (½ to 2 pgs)	Detail of how you will carry out your plan.	15	11	7. 5	0
Results and Limitations (½ to 2 pgs)	Describe the results and any limiting factors encountered while carrying out the project.	10	7. 5	5	0
Conclusions (½ to 1 pg)	Summary of the outcome of the project	10	7. 5	5	0

Grammar and Mechanics					
Tense	Technical papers are written in the passive tense, meaning you **cannot** use the 1st, 2nd, or 3rd person (no I, we, the group, our, one, etc.) Acceptable: "the solar panel was tested"vs. Unacceptable: "the group tested the solar panel"	10	7. 5	5	0
Font, format, and, cohesive-ness	12 font, double spaced. Figures, Diagrams, Charts labeled clearly and referred to in the text. Your paper should read fluidly. Each of the sections listed above should be addressed and should be connected in your text. When you transition from one section to another, you should have some text leading into the next section. Always reread your paper;	7. 5	6	3. 75	0

	check for grammar, spelling, and cohesiveness.				
	TOTAL	100	75	50	0

Appendix 4a: Retention data

Engineering Exploration (all races)					
Cohort	Retention	Gender	Cohort Size	# Enrolled in SOE	Percent Enrolled SOE
Fall 2009 EE Students	1-YEAR	Men	12	10	83. 33%
		Women	12	12	100. 00%
		Total	24	22	91. 67%
	2-YEAR	Men	12	9	75. 00%
		Women	12	12	100. 00%
		Total	24	21	87. 50%
	3-YEAR	Men	12	8	66. 67%
		Women	12	10	83. 33%
		Total	24	18	75. 00%
Fall 2010 EE Students	1-YEAR	Men	26	23	88. 46%
		Women	22	18	81. 82%
		Total	48	41	85. 42%
	2-YEAR	Men	26	22	84. 62%
		Women	22	18	81. 82%
		Total	48	40	83. 33%
	3-YEAR	Men	26	23	88. 46%
		Women	22	18	81. 82%
		Total	48	41	85. 42%
Spring 2011 EE Students	1-YEAR	Men	13	13	100. 00%
		Women	4	4	100. 00%
		Total	17	17	100. 00%
	2-YEAR	Men	13	12	92. 31%
		Women	4	3	75. 00%
		Total	17	15	88. 24%
	3-YEAR	Men	13		
		Women	4		
		Total	17		
Fall 2011 EE Students	1-YEAR	Men	28	22	78. 57%
		Women	20	17	85. 00%
		Total	48	39	81. 25%
	2-YEAR	Men	28		
		Women	20		
		Total	48		
	3-YEAR	Men	28		
		Women	20		
		Total	48		

Appendix 4b: Retention data 2

Engineering Exploration - AfrAmer, Hisp, AmerInd					
Cohort	Retention	Gender	Cohort Size	# Enrolled in SOE	Percent Enrolled SOE
Fall 2009 EE Students	1-YEAR	Men	8	6	75. 00%
		Women	1	1	100. 00%
		Total	9	7	77. 78%
	2-YEAR	Men	8	5	62. 50%
		Women	1	1	100. 00%
		Total	9	6	66. 67%
	3-YEAR	Men	8	5	62. 50%
		Women	1	0	0. 00%
		Total	9	5	55. 56%
Fall 2010 EE Students	1-YEAR	Men	9	6	66. 67%
		Women	9	5	55. 56%
		Total	18	11	61. 11%
	2-YEAR	Men	9	5	55. 56%
		Women	9	5	55. 56%
		Total	18	10	55. 56%
	3-YEAR	Men	9	5	55. 56%
		Women	9	5	55. 56%
		Total	18	10	55. 56%
Spring 2011 EE Students	1-YEAR	Men	1	1	100. 00%
		Women	1	1	100. 00%
		Total	2	2	100. 00%
	2-YEAR	Men	1	1	100. 00%
		Women	1	1	100. 00%
		Total	2	2	100. 00%
	3-YEAR	Men	1		
		Women	1		
		Total	2		
Fall 2011 EE Students	1-YEAR	Men	9	7	77. 78%
		Women	8	7	87. 50%
		Total	17	14	82. 35%
	2-YEAR	Men	9		
		Women	8		
		Total	17		
	3-YEAR	Men	9		
		Women	8		
		Total	17		

Appendix 5: Interview Protocol

Interview Protocol
Today we are here to talk about your engineering experience at Rutgers. Your experience is important to the shape and future of the engineering experience. Your candid and honest answers will help make engineering at Rutgers a better place.

1. What is your name and RU ID?

2. Before you came to college, what led you to pursue a major in engineering?

3. Do your parents want you to be an engineer? If yes, what major would you have selected without their direction?

4. How did you define engineering before you came do college?

5. How do you define engineering since you came do college?

6. Do you think that engineering will be a rewarding career? Why/Why not?

7. Do you feel that engineers contribute more to making the world a better place than people in most other occupations? Why? Explain your answer.

8. How would you describe your first year experience in terms of the academic instruction?

9. How would you describe your first year experience in terms of the study environment?

10. How would you describe your first year experience in terms of the social environment?

11. How satisfied are you with your engineering major? Do you plan to stay in your major? Do you plan to stay in the School of Engineering? If no to any of these, why?

12. Have you overcome any setbacks in your life before college in order to conquer a challenge?

13. Have you overcome any setbacks during college in order to conquer a challenge?

14. What changes would you make in the first year engineering curriculum (if you were an administrator, dean, or professor)?

15. How do you feel your 1st year experience has been in comparison to your 2nd yr?

16. What were the most valuable courses in your first year? Why?

17. What course did you take in your first year: Intro to Orientation Lectures-440:100 or Engineering Exploration-440:125?

18. How useful do you feel Intro to Orientation Lectures-440:100 or Engineering Exploration-440:125 has been in choosing your engineering major? Why?

19. How useful has Orientation Lectures-440:100 or Engineering Exploration-440:125 been to your academic experience.

20. Have you learned any academic skills, concepts, or tools in 440:125/440:100 that you use in your other engineering courses?

21. How useful do you feel Intro to Orientation Lectures-440:100 or Engineering Exploration-440:125 has been to your non-academic college experience in engineering? Why?

22. Do you prefer studying alone, working with one other, or in a group? Explain. Give an example of your study routine.

23. (for 440:125 students) Have you made any friendships or relationships (friends, study partners, faculty, staff) from 440:125 that you probably would not have made otherwise? If so, please state how the friendship/relationship was developed during 440:125 and to what extent the relationship exists now.

24. What majors are most of your friends that you ‘hang out’ with pursuing?

25. (for 440:125 students) Have students that didn’t take Engineering Exploration asked you about Engineering Exploration. If so, what do they say?

26. (for 440:100 students) Have you heard of Engineering Exploration-440:125? If so, what did you hear about it? Did you wish you had taken that course instead of Intro to Orientation Lectures-440:100?

27. Do you do any extracurricular activities, belong to any student organizations? If so, do you hold any positions in these? What led you to join these?