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MEASUREMENT OF STUDENT ATTITUDES IN FIRST YEAR
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MEASUREMENT OF STUDENT ATTITUDES IN FIRST YEAR ENGINEERING – A MIXED METHODS APPROACH

By

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ABSTRACT

MEASUREMENT OF STUDENT ATTITUDES IN FIRST YEAR ENGINEERING – A MIXED METHODS APPROACH

BY

Qaiser Hameed Malik

This research study focused on freshman attitudes towards engineering in a newly implemented cornerstone sequence that emphasized holistic design experiences. The students' initial attitudes and changes in these attitudes were examined with the explanatory mixed methods approach that allows a sequential examination of the target population with two methods, using two sets of data, to investigate the treatment effects.

In the quantitative phase, the study compared changes in freshman attitude towards engineering, between the new 'design sequence' group (composed of freshmen in the cornerstone sequence) and the prior 'traditional sequence' group (composed of all other freshmen), over the course of one semester. The data were collected in fall 2008 at two time intervals and changes in the two groups' attitudes were examined with repeated measures analysis of covariance models. The analyses reported here include data from 389 students out of the total population of 722 freshmen. The analyses revealed that engineering freshmen joined the program with positive or strongly positive attitudes towards engineering. Those strong attitudes were durable and resistant to change. Students in the design sequence group had higher ACT scores, enjoyed math and science the most, and did not believe engineering to be an exact science. However, no appreciable time-group interaction was observed.

To validate the quantitative results, an interview protocol was developed to investigate initial freshman attitudes and changes, if any, that took place as a result of the new cornerstone sequence. One-on-one interviews with a sample of ten students out of the population of 272 freshmen revealed that freshmen in the cornerstone sequence entered the program full of enthusiasm and idealism, and with strongly positive attitudes towards engineering. The strong motivational factors included parental/teacher influences, childhood motivations, and high school extra-curricular experiences. The participants appreciated the team work and problem solving aspects of engineering; however, they reported negative experiences in the cornerstone sequence. Interestingly, their overall perception about engineering was not affected by any of the negative experiences. The qualitative phase substantiated the belief that strong attitudes are harder to change; they are durable, they have impact, and they are not significantly affected by a short treatment.

The results of this mixed methods study indicate that changing student attitudes may not be an easy task. One must develop a better understanding of student attitudes in order to improve understanding of the fine-grained details of curriculum and its implementation to be able to develop more effective cornerstone design courses. Clearly, tight and focused quantitative studies complemented with a qualitative component provide a much broader and deeper insight into the learning that takes place in freshman courses. This research also documents the use of a longitudinal study to track the design sequence group and observe their performance in their junior and senior years. This would provide a better understanding of the long term effects of the new sequence.

Dedicated to the memory of my daughter, Farina.

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TABLE OF CONTENTS

CHAPTER 4

CHAPTER 5

APPENDIX A

APPENDIX B

APPENDIX C

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

This chapter provides the background to the research study. It discusses the challenges being faced by the evolving field of engineering education and how this field is responding to these challenges. In this context, initial freshman attitudes and their changes during the freshman year, have been found to be highly correlated with retention rate. This chapter describes the cornerstone sequence, a new initiative launched by the College of Engineering at Michigan State University to meet the current challenges. It sets the stage by explaining the context of the study and defining the research questions. Conducting such a study has far-reaching implications towards molding the future trends in freshman engineering curriculum design.

1.1 Current Trends and Challenges

Engineering education has been experiencing new challenges during the past two decades [1]. Concerns that there might be something fundamentally wrong with science, technology, engineering, and mathematics (STEM) education surfaced in the mid-1980s. Studies based on the large national samples of freshmen at 2- and 4-year institutions, drew attention to a downtrend in the recruitment and retention of freshmen in STEM majors [2, 3]. The greatest losses to STEM majors (34-40%) were found among high school graduates who abandoned their intentions of entering STEM majors at or before college enrolment [4]. During college, 53% of the freshmen who started their academic program in engineering did not graduate with an engineering degree, and at least 50% of this attrition took place during the freshman year [5]. Clearly, the freshman year is critical for student success and retention in engineering programs [6]. Retention of freshmen has been identified as a nation-wide concern that will affect the strength of the future engineering workforce and, hence, the role of the United States as a dominant world player in engineering and technology [1]. This becomes a major challenge as we address the current global fiscal downturn and the technological advances needed to stimulate the national and world economies. Considerable effort has been directed to examining the high attrition rates at engineering institutions in order to develop effective interventions [7].

Research suggests that both cognitive and affective issues contribute to attrition among engineering students. While cognitive issues in engineering education involve student knowledge and skills, affective issues relate to their attitudes towards engineering and confidence in their abilities to succeed [8]. The literature shows a strong evidence that among all factors studied, attitudes have the highest correlation with retention [9]. The initial attitudes, and changes that take place in these attitudes during the freshman year, affect student motivation, performance, and retention in engineering programs [10]. For instance, a multi-institutional, longitudinal study of engineering attitudes and how they change during the first year by Besterfield-Sacre, *et al.,* found that the students who were most likely to choose engineering majors and completed degree requirements were those who held positive perceptions of engineering, and had a measurable interest in science and technology [11]. The same study found that students who avoided engineering majors, or dropped out from engineering, were those who generally had a negative impression of engineering, lacked confidence in their abilities to complete the engineering program, and had little or no motivation for studying science and mathematics. Interestingly, the authors also found that students who left engineering in good academic standing had significantly different attitudes about engineering and themselves than those who stayed in engineering and those who left engineering in poor academic standing. Students who left engineering in good standing started their program liking engineering less and had a lower appreciation of the engineering profession than the other students. This category of students also liked math and science less and had lower confidence in their ability to succeed in engineering [9].

Also, in another longitudinal study conducted by Seymour and Hewitt [12] on seven major 4-year institutions that produce most of the national supply of baccalaureate scientists, mathematicians, and engineers found that students who left engineering were not academically different than those who stayed in engineering, and that retention was better correlated with their attitudes than with academic factors. They also found that switchers (those who changed to non-engineering majors) and non-switchers had similar educational experiences, but the non-switchers made more effective use of the resources and strategies that enabled them to tolerate and overcome their difficulties [12].

These studies substantiate the argument that students' initial attitudes towards engineering are key to understanding attrition in engineering programs. Accurately measuring students' attitudes and changes in these attitudes over the course of the freshman year allows us to develop effective means to evaluate the engineering programs, to reduce attrition, and improve academic success [13, 14]. Attitude strength may be an important element in this context. Social psychologists have identified several aspects of attitude strength, ranging from the depth of knowledge that one possesses about an issue to the extremity of personal attitude about the issue [15]. Despite so much variability in the conceptualization of this construct, researchers do agree that strong attitudes are "resistant to change, persistent over time, and predictive of behavior" [16].

1.2 Institutional Efforts

The literature review indicates that several engineering institutions in the U.S. and abroad have conducted attitude related studies to better understand their students, to develop effective interventions, and to examine to what degree these interventions are meeting their desired goals and objectives [10, 11, 17, 18]. To affect a positive change in the students' initial attitudes, one common and the most talked about intervention that several institutions have adopted over the past fifteen years is the introduction of design and computation oriented courses – also called cornerstone or freshman sequence – in the freshman year. An early introduction of engineering as a design and computation oriented discipline is hypothesized to significantly enhance student interest and motivation towards engineering [19].

Sheppard and Jenison provide a framework for exposing freshmen to key design qualities and give specific examples of how engineering programs around the U.S. revised their freshman curricula to include engineering design [20, 21]. A number of NSF coalitions have developed valuable information on teaching freshman design courses to improve the undergraduate engineering curriculum [22]. Research shows that these courses significantly contribute to the progress in academic achievement, create a stimulating environment for advanced cognitive development, and offer diverse experiential backgrounds and perspectives [23].

Based on the success of these interventions, many institutions (*e.g.* Purdue) have developed regression models to predict attrition and student success even before the students begin their programs [24]. They claim that these models allow academic advisors to better inform students, especially those at high risk of attrition, of the opportunities that engineering offers to develop tailor made programs to suit varied student interests, and to set more realistic retention goals for the institutions [25]. Some of the institutions have also reported benefits of these changes in terms of significant improvements in retention rates [26]. Other efforts in this direction include: 1) a common freshman year with integrated curricula, which has indicated a positive impact on student retention and learning [27]; 2) integration of residential living-learning communities for making large campus environments smaller and more personal to connect freshmen more closely with one another and with faculty that has shown significant academic and environmental gains [28]; and 3) raising of separate freshman engineering entities (department/school/center) for better control and coordination of the freshman year. Table 1.1 presents the initiatives taken by some of the CIC (Committee on Institutional Cooperation) member universities, also named as Big Ten institutions, to improve retention.

CIC Institution	**Cornerstone Courses**	**Common Freshman Year**	**Residential Programs†**	**Predictive Modeling**	**Engr. Edu. Dept / School**
Purdue U.	1-3 courses	Yes	3	Yes	School
Michigan State U.	2 courses	Yes	8	No	Center*
U. of Minnesota	2 courses	Yes	22	No	No
U. of Michigan	2 courses	Yes	No	No	No
Northwestern U.	5 courses	Yes (2 year)	No	No	No
Ohio State U.	2-3 courses	Yes	No	No	No
U. of Iowa	2 courses, 1 seminar	No	No	No	No
U. of Wisconsin	2 courses§	No	Females only	No	No
Penn. State U.	1 seminar	No	3	No	No
U. of Illinois	No	No	No	No	No

* Center for Engineering Education Research (CEER) † All residential programs

Table 1.1: A presentation of freshman engineering initiatives taken by some of the CIC institutions to improve retention.

1.3 Freshman Engineering Experiences at Michigan State University

1.3.1 A Historical Perspective: The College of Engineering (CoE) at Michigan State University (MSU) offers nine undergraduate degree programs with a yearly intake of about 600-700 freshmen from all 50 U.S. states and dozens of other countries around the world [29]. Until 1978, when the enrollment was 'open', a student only had to declare engineering as his/her 'major' to get admitted to the CoE. Enrollments were high between 1978 and 1997; therefore the College limited admissions to junior year based on student GPA and class size. In order to save on student time to degree and to improve the student yearly intake, the Admit When Ready (AWR) initiative was launched in 2004. A student in the AWR initiative could be admitted any time, between one and four semesters, as soon as he/she fulfilled the requirement of five core courses and a minimum GPA. As a result, the students were able to take 200 level courses one semester sooner and were more focused in selecting their major. Between 2000 and 2005 engineering enrollments dropped substantially (about 30%; see Figure 1.1). This decline exceeded the national average largely due to the reduction in the manufacturing industry in Michigan.

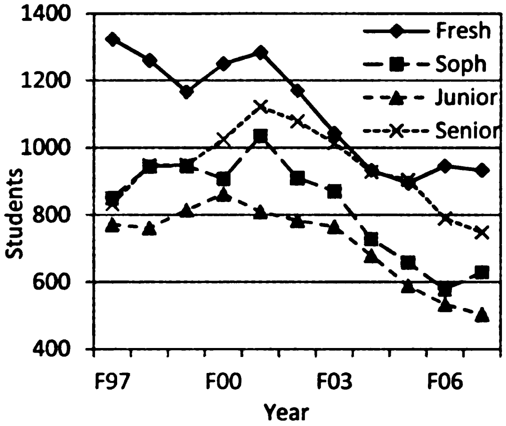

Figure 1.1: Engineering students' retention trends at MSU from 1997 to 2007.

A need was felt to increase the number of undergraduate engineers by recruitment, engagement, retention, or a combination of all. In an effort to overcome the sharp downtrend, the CoE took three major initiatives in a phased program:

1. Spring 2006: instituted the office of the recruitment and K-12 outreach.
2. Fall 2008: launched the cornerstone sequence and integrated the first year into a common freshman year. The five core courses requirement was accordingly changed to include the new sequence.
3. Fall 2009:
    a. Established the Center for Engineering Education Research (CEER) [30].
    b. Launched, "Engaging Early Engineering Students to Expand Numbers of Degree Recipients (EEES)", a $2.5 million NSF funded project aimed at increasing student retention in the CoE from the current 65 % to 75 % over a five-year period [31].

c. Upgraded and expanded its existing "Residential Option for Science and Engineering Students (ROSES)" program to a true living-learning experience.

d. Launched or continued discipline specific introductory design courses at department level.

The new residential option has since been integrated with the cornerstone sequence and named as "Residential Experience for Spartan Engineering". It formally started in fall 2009 with an initial participation of approximately 350 students. Wilson Hall, one of the many residential halls on campus, has been configured to provide several academic opportunities and services under one roof, in addition to holding classes and laboratories for the two cornerstone design courses. The academic services include student advisory services, free tutoring in math and science, peer leaders[1], and themed presentations by the College faculty [32]. It is intended to develop a community to bring another dimension to the common first-year curriculum to further enhance student knowledge of the engineering profession, cultivate their problem solving skills, connect students with campus and community resources, and enhance their communication skills.

The current admission policy of the College allows a student to remain no-preference until 56 credits have been completed, *i.e.,* until the beginning of the junior year. Under this policy there are three categories of engineering freshmen at CoE:

1. Engineering-preference: a particular engineering field declared as major.

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[1] A peer leader is an upper level student who assists freshmen with learning more about engineering majors, the curriculum, college research, engineering career fairs, engineering student organizations.

2. Engineering-no-preference: engineering declared as major without preference of a field.
3. University-no-preference: no field declared as major.

It is too early to comment on the outcomes of the new initiatives because it takes several years of data to determine the trend. It is worthwhile, however, to take a closer look at the fall 2008 initiative that forms the basis for this research study.

1.3.2 The New Cornerstone Sequence: The new sequence was designed to provide freshman engineering students with a broad introduction to engineering design, the engineering profession and its expectations, engineering problem-solving and teamwork skills. It was an attempt to introduce engineering as a profession early in the career of the students to put them on a path of inquiry. It was comprised of two new freshman courses: EGR 100 (Introduction to Engineering Design) and EGR 102 (Introduction to Engineering Modeling). EGR 100 was an addition to the existing five core courses requirement for admission to the engineering program (Math 132, Math 133, Physics 183, Chemistry 141, CSE231), and was also a prerequisite to EGR 102. EGR 102 was a replacement to the earlier computing course requirement (CSE 231) for all engineering disciplines except computer engineering and computer science; computer engineering and computer science majors continue to take CSE 231.

The College piloted the cornerstone design courses in fall 2007 for a test/trials period of one year (*i.e.* two semesters: fall 2007 and spring 2008). During this trial period the design courses were offered as optional courses to a limited number of freshmen. The cornerstone sequence was integrated into the freshman curriculum in fall 2008. Beginning fall 2008, the students were enrolled in the cornerstone sequence courses on a first-come first-served basis provided they fulfilled the other academic requirements. Fall 2008 was unique in two respects: the cornerstone sequence was running in full swing for the first time; and two distinct groups of freshmen were available. Those enrolled in the cornerstone sequence course(s) formed the design sequence (DS) group and those unable to enroll in the cornerstone course(s), either due to non-fulfillment of the math placement requirement or non availability of the classroom space formed the traditional sequence (TS) group.

1.3.3 EGR 100 - Introduction to Engineering Design: The objective of this course was to motivate and engage freshmen in the engineering profession. The course was focused on structured problem solving and the engineering design process, learning to work in teams and manage projects, ethics, the breadth of the engineering profession, the interconnection of its disciplines, and its diverse contributions to society. It also introduced computing tools and basic laboratory equipment used in support of engineering design. It included three short team design projects and provided an early grounding in the importance of gaining co-curricular professional experience throughout one's undergraduate years.

1.3.4 EGR 102 - Introduction to Engineering Modeling: The course focused on the use of computational tools to solve technical and engineering problems. It exposed the students to problem decomposition and identification of a solution approach using tools such as advanced spreadsheet features and MATLAB, data representation, curve fitting and analysis, mathematical modeling of engineering systems, and application of principles through team-based engineering projects. Collaborative group work was the major operating mode for students in this course, with strong dimensions of both individual and group accountability underscored for all students. The course was oriented towards 'Problem-Based Learning' (PBL) and 'Just In Time' (JIT) introduction of facets of computational tools to apply to selected engineering problems.

The broad goals of the new initiative were: 1) attracting top students to engineering programs and retaining them; 2) better preparing students to adapt to a quickly and constantly changing global engineering workforce by appreciating the importance of teamwork, project management, innovation, hands-on experience, ethics, career preparation and professionalism; 3) seeing engineering as a broad field with many opportunities; 4) positioning engineering as a favored choice for prospective students and parents; 5) providing an opportunity for an early connection with the CoE and its faculty; and most importantly, *6) effecting an appreciable and positive change in the freshmen attitude towards engineering*. The cornerstone sequence was aimed at achieving these objectives by raising the sense of community and interaction centered on design projects to reap the benefit of long, strong and integrated technical education, and social and professional development [33].

1.4 Context for the Study

This research study focused on the sixth goal discussed above. It sought to examine the effects of the cornerstone sequence on freshman attitudes towards engineering, and to establish whether the new sequence produced a significant improvement over the older traditional sequence (comprising students who did not experience the new sequence) with respect to student attitudes towards engineering. Whether or not this has been successful is an empirical question and one that this research study sought to answer. A study of this nature could be best designed if two cohorts were available for a direct comparison. In this respect, fall 2008 was a unique semester in that students in both the streams, the traditional sequence (TS) and the design sequence (DS) were available to form a comparison group and a treatment group, respectively. This opportunity set the stage for the study – to examine the key research question.

1.4.1 Primary Question: *Is the cornerstone sequence an improvement over the traditional sequence in terms of its effects on freshman perceptions and attitudes towards engineering?*

As a corollary to the above, it was worthwhile to investigate the student expectations and their reactions as they experienced the new sequence to better understand the outcomes of the primary research question. A secondary research question was accordingly formulated to reassure and reconfirm the findings of the primary phase.

1.4.2 Secondary Question: *What are the freshman expectations of, and experiences in, the new cornerstone sequence and how do these expectations and experiences contribute (or not contribute) towards shaping their initial perceptions and attitudes towards engineering?*

CHAPTER 2

DESIGN OF THE STUDY

2.1 The Mixed Methods Design

This study employed Explanatory Mixed Methods Design that is characterized by an initial and extensive quantitative phase followed by a qualitative phase. In this approach, critical results of the quantitative phase are reviewed with one or more qualitative methods to build, understand, and validate the earlier quantitative finding [34-36]. This dissertation is accordingly divided into three phases: Quantitative , Qualitative , and Interpretation. The quantitative phase is based on the quantitative data and an analysis that sought to answer the primary research question. To build on the results of the quantitative phase, the qualitative phase was launched sequentially to answer the secondary research question. The qualitative phase played a supporting role and the two phases were mixed in the final interpretation and discussion phase of the study as shown in Figure 2.1 [34].

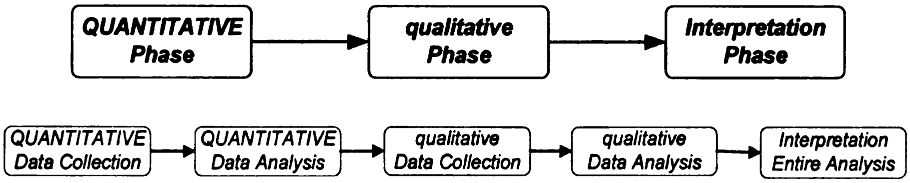

Figure 2.1: Explanatory mixed methods design.

2.2 The Quantitative Phase

To answer the main research question, a repeated measures approach was selected that includes both ‘between subject factors’ (BSFs) and ‘within subject factors’ (WSFs).

In this context, three well known hypotheses are of particular interest: the hypothesis of no-change-over-time, or the flatness hypothesis; the hypothesis of no-time-by-group-interaction, or the parallelism hypothesis; and the hypothesis of no-overall-group-differences, or the level hypothesis [37]. These three hypotheses are described below.

2.2.1 Flatness Hypothesis: Freshman attitudes do not change over time when disregarding group membership.

$$H_{0,a}:\ \mu_{pre} = \mu_{post} \tag{1}$$

Where, $\mu_{pre} \equiv$ average population mean of the two groups at pre-test, and

$\mu_{post} \equiv$ average population mean of the two groups at post-test.

2.2.2 Parallelism Hypothesis: Freshman attitudes *within* each group show similar patterns of change over time. In other words, there is no time-by-group interaction or *no treatment effect.*

$$H_{0,b}:\ \mu_{pre,TS} - \mu_{post,TS} = \mu_{pre,DS} - \mu_{post,DS}$$

$$\text{or,}\qquad H_{0,b}:\ \Delta\,\mu_{TS} = \Delta\,\mu_{DS} \tag{2}$$

Where, $\Delta\,\mu_{TS} \equiv$ pre- to post- difference in the TS population mean, and

$\Delta\,\mu_{DS} \equiv$ pre- to post- difference in the DS population mean.

2.2.3 Level Hypothesis: Freshman attitudes *between* groups are the same, disregarding time.

$$H_{0,c}:\ \mu_{TS} = \mu_{DS} \tag{3}$$

Where, $\mu_{TS} \equiv$ average TS population mean over time, and

$\mu_{DS} \equiv$ average DS population mean over time.

In geometrical terms the parallelism hypothesis states that if we graphically connect the means of the dependent variable *group* across *time*, then all resulting *group* specific profiles will be parallel. With regard to the main research question, the parallelism hypothesis is substantively the most interesting one. It asks whether there is a differential change over *time* (*i.e.,* treatment, intervention, etc.) on the response variable for the TS and DS groups, and for this reason it is addressed first. If there is no evidence that the groups' trajectories have different slopes over time, then the level and flatness hypotheses become more relevant. Hence, the no-interaction hypothesis (parallelism) was investigated first and only if it was not found to be significant were the flatness and the level hypotheses tested. The data from the two groups was collected with an existing survey instrument at two time intervals (pre-, post-) over the course of one semester. A General Linear Model (GLM) Repeated Measures Analysis of Covariance (ANCOVA) was selected for testing the three hypotheses because it provides estimates of effects for WSFs and BSFs [37]. For this profile analysis the statistical package SPSS© version 16.0 was used to process the data, represent the models, and analyze the results.

2.3 The Qualitative Phase

The secondary research question was investigated with a qualitative approach. The aim was to better understand the kind of learning that took place in the new cornerstone sequence and if it affected the participants' initial perceptions and attitudes towards engineering. Since, this was an exploratory question, there was no a priori hypothesis for this part of the study. Rigorous qualitative research involves its own set of data collection and analysis methods to ensure the trustworthiness and authenticity of the findings [38]. One-on-one interviews with a representative sample (from the DS group) were considered the most suitable qualitative approach for the secondary research question.

The overall objective was to understand initial freshman attitudes as they enrolled in engineering programs and whether those attitudes were affected by the new cornerstone sequence. Improved understanding of attitudinal changes could help in the formative evaluation of the new sequence. More importantly, it could help develop better evaluation methods for engineering programs by incorporating and integrating students' attitudes as an addition to the existing feedback system. Setting up a wider scope in the quantitative phase, using the three research hypotheses, was therefore a deliberate effort to not only observe the time effects on the attitudes of two student groups, but also study the changes in those attitudes due to important demographic factors (*e.g.,* gender and past academic performance) that could lead to a better understanding of engineering freshman. This study is a contribution towards applying mixed methods in the study of engineering education. The data collected in the empirical method could be built up further for developing predictive models that could help students make informed decisions assuring future success.

2.4 Organization

The remaining part of this document is organized in three phases: Quantitative, Qualitative, and Interpretation/Discussion. Chapter 3 is devoted to the Quantitative phase of the study; it includes the methodology, collection and analysis of the quantitative data collected over the course of one semester (fall 2008). Chapter 4 discusses the qualitative phase; the methodology, development of interview protocol, collection and analysis of the data collected in the subsequent semester (spring 2009). Chapter 5 discusses the overall results and formulates conclusions based on the findings of the two phases in accordance with the mixed methods design approach.

CHAPTER 3

THE QUANTITATIVE PHASE

This chapter seeks to answer the primary research question with the quantitative approach. It has two key objectives: to describe the methodology of the quantitative approach and to analyze the collected data. To meet these objectives this chapter unfolds into five sequential processes: 1) development of a general statistical model to address the primary research question; 2) instrumentation including the process of instrument selection, transformation, confirmation with a pilot study, and implementation; 3) data collection and collation; 4) selection of variables for the model and implementation of the statistical model; and finally 5) data analysis and discussion. The chapter is divided into two parts: Methods and Results/Analysis.

Part I - Methods

3.1 The General Model

The General Linear Model (GLM) provides a flexible framework for the profile analysis of data in this phase of the study. Repeated measure ANCOVA was used for testing the three hypotheses for the main study. This model allows for comparison of the two groups on measurements made at the beginning and towards the end of the semester while controlling for one or more continuous and/or categorical covariates (for example, ACT scores and gender). The model facilitates testing hypotheses about the effects of the BSFs, for example group and gender (level hypothesis), and the WSF, *i.e.,* time (flatness hypothesis). More importantly, one can investigate interactions between factors as well as the effects of individual factors, including covariates, to answer the main research question (parallelism hypothesis). Estimated marginal means (EMMs) are the predicted mean values for the cells in the model after controlling for other variables. They allow us to interpret the main effects of categorical predictors such as group and gender, while profile plots (interaction plots) of EMMs illustrate the nature of interaction effects [37].

The general linear model can be represented in vector notation as

$$Y = X\beta + \varepsilon$$

$$Y = [1 \quad x_1 \quad x_2 \ldots x_k] \begin{bmatrix} \beta_0 \\ \beta_1 \\ \vdots \\ \beta_k \end{bmatrix} + \varepsilon$$

$$Y = \beta_0 + x_1\beta_1 + x_2\beta_2 + \cdots + x_k\beta_k + \varepsilon. \tag{4}$$

Where, $Y \equiv$ dependent variables vector,

$\beta \equiv$ unknown coefficients vector,

$X \equiv$ design matrix comprising independent variables including covariates,

$\varepsilon \equiv$ errors vector, and

$k \equiv$ number of independent variables.

In case of interactions among the independent variables, equation 4 will have appropriate interaction terms. For example, for all possible two way interactions among x_1, x_2, and x_3, equation 4 will have the form

$$Y = \beta_0 + x_1\beta_1 + x_2\beta_2 + x_3\beta_3 + (x_1 * x_2)\beta_4 + (x_2 * x_3)\beta_5 + (x_1 * x_3)\beta_6 + \varepsilon.$$

For a set of *n* outcomes, the model (main effects only) takes the form

$$\begin{bmatrix} y_1 \\ y_2 \\ \vdots \\ y_n \end{bmatrix} = \begin{bmatrix} 1 & x_{11} & \cdots & x_{1k} \\ 1 & x_{21} & \cdots & x_{2k} \\ \vdots & \vdots & \ddots & \vdots \\ 1 & x_{n1} & \cdots & x_{nk} \end{bmatrix} \begin{bmatrix} \beta_{01} & \beta_{02} & \cdots & \beta_{0n} \\ \beta_{11} & \beta_{12} & \cdots & \beta_{1n} \\ \vdots & \vdots & \ddots & \vdots \\ \beta_{k1} & \beta_{k2} & \cdots & \beta_{kn} \end{bmatrix} + \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \vdots \\ \varepsilon_n \end{bmatrix}. \tag{5}$$

Again, for interaction among the independent variables, the model will have the interaction vectors added to the design and unknown coefficients matrices. For repeated measures, the model is augmented with the number of levels or WSFs. For a pre-, post-design (two levels), the general model can be represented as

$$\begin{bmatrix} Pre_i \\ Post_i \end{bmatrix} = \begin{bmatrix} X & 0 \\ 0 & X \end{bmatrix} \begin{bmatrix} \beta_i \\ \gamma_i \end{bmatrix} + \begin{bmatrix} \varepsilon_i \\ \acute{\varepsilon}_i \end{bmatrix}. \tag{6}$$

Where, $Pre_i \equiv$ pre- dependent variables vector,

$Post_i \equiv$ post- dependent variables vector,

$\beta_i \equiv$ unknown coefficients matrix for pre-,

$\gamma_i \equiv$ unknown coefficients matrix for post-,

$X \equiv$ design matrix for independent variables (same for pre- and post-),

$\varepsilon_i \equiv$ errors vector for pre-, and

$\acute{\varepsilon}_i \equiv$ errors vector for post-.

Equation 6 was used to develop pre-, post- models for the study to examine the three null hypotheses (*i.e.,* equations 1, 2, and 3). The pre- and post- models in generic form are represented as equations 7 and 8, respectively. These models inherently incorporate the time interactions (*i.e.* pre- and post- or WSFs). Inter-independent variables interactions (BSFs) can be appropriately added to these models, if needed.

$$Pre_i = \beta_{0i} + x_1\beta_{1i} + x_2\beta_{2i} + \cdots + x_k\beta_{ki} + \varepsilon_i \text{, and} \tag{7}$$

$$Post_i = \gamma_{0i} + x_1\gamma_{1i} + x_2\gamma_{2i} + \cdots + x_k\gamma_{ki} + \acute{\varepsilon}_i. \tag{8}$$

3.2 Instrumentation

The first step in such a research study is the identification and/or development of valid and reliable measures to be used to evaluate student learning, attitudes, and experiences within an engineering program, and whether the new freshman engineering experiences were actually succeeding in meeting their declared goals. Given that both cohorts were available, the study involved comparing attitudes as outcomes of the DS group to that of the TS group. For this purpose a reliable and valid attitude measuring scale is required [39]. This section describes the selection and modification of a suitable attitude scale and its performance in a pilot study conducted in spring 2008 (prior to the main study).

3.2.1 Instrument Selection: The relevant literature identified several types of assessment instruments commonly used by engineering educators: closed form questionnaires, open-ended surveys, one-on-one interviews, focus groups, essay questions, ethnographic studies, portfolios, student journals, and verbal protocols. The closed form questionnaire was selected for the study because: 1) it provides a reliable assessment of student attitudes; 2) it is commonly used to measure impressions of engineering, enjoyment of working in groups, and self-assessed competencies; 3) it is easier to administer; 4) it can be given to a large number of subjects at a minimal cost; 5) the responses to the questionnaire can be given with a check list, Likert scale, or semantic differentials; and 6) repeated use of the instrument can measure changes in attitudes over time or the effect of a particular intervention [39-44].

Developing and validating good survey instruments are tedious and time consuming tasks. Experts in this field strongly recommend using available instruments to save time in instrument construction and validation [39, 45]. An extensive literature search was undertaken to identify a valid and reliable survey instrument that could measure attitudes among student cohorts and, particularly, how they were impacted by the cornerstone cornerstone sequence. The search revealed a general scarcity of standardized instruments in engineering education. Some need-based instruments have been developed by a few engineering institutions. Astin for example, developed a closed form survey to measure the attitudes and perceptions of entering freshmen [46]. The instrument, however, does not have the follow-up component to determine if the differences among the cohorts persist over the course of a semester. Four commonly used instruments were examined for this study.

1. Pittsburgh Freshman Engineering Attitudes Survey (PFEAS), developed at the University of Pittsburgh [19].
2. Freshman Engineering Attitude Survey (FEAS) and Freshman Engineering Perception Test (FEPT), developed at Texas A&M University [47].
3. Entering Freshman Engineering Survey (EFES), developed at Arizona State University [48].
4. Cooperative Institutional Research Program (CIRP) Survey, developed at the UCLA Higher Education Research Institute (HERI) [49].

3.2.2 Pittsburgh Freshman Engineering Attitude Survey (PFEAS): PFEAS was selected as the base line instrument for this study because: 1) it was the most relevant since it was originally developed for a similar study; 2) the student attitude was measured by grouping the items under thirteen measures or factors, most of which were of interest to this study; 3) it had been extensively used by various institutions and cited in a number of refereed publications [50]; and 4) it had an established high degree of validity and reliability [11]. A recent work has pointed out some weaknesses of the original instrument [51] and a revised version has been developed [52]. Unfortunately, this revised version is under test and evaluation and was not yet available when the study was conducted.

The pre-version of the scale was comprised of fifty items. It was designed to *measure* four facets of student attitudes: 1) student definition of engineering; 2) student attitude about engineering; 3) student self-assessed confidence; and 4) student self-assessed skills including working in groups. The post-version was comprised of twenty additional items that captured student perceptions of their attainment of the eleven Engineering Criteria (EC) 2000 outcomes as defined by ABET (Accreditation Board for Engineering and Technology) [53]. Data mapping on EC 2000 outcomes have been used to demonstrate cross institutional gender and ethnicity differences that parallel those found for the attitudinal measures [11]. For this research study, the pre- version of the scale was selected, since data mapping for EC2000 outcomes was not the scope of the study. For the purpose of this study PFEAS would imply the pre- version of the scale. The original PFEAS scale is attached as Appendix A.

The scale was originally developed in 1993 by Besterfield-Sacre *et al.*, for a similar study at the University of Pittsburgh [19]. Since then, it has been adopted by several institutions to evaluate their freshman programs, study attrition and probation issues related to freshmen, and to measure EC 2000 outcome issues [10, 54, 55]. As part of the validation process, PFEAS underwent rigorous pilot testing and improvement by means of item analysis, verbal protocol elicitation, and factor analysis [50]. The scale was thoroughly tested for reliability and validity [11, 40]. Fifty items of the instrument statistically cluster into thirteen attitudinal measures or subscales, as listed in Table 3.1 [55]. These subscales define the domain of the instrument's main construct: freshman attitude towards engineering. The survey items are rated on either a five point Likert scale or an ordinal self-assessed confidence scale.

No.	PFEAS Items	Subscale Name	Definition of Subscale
1	1-3,4*,5,6*,7,8*,9*	Career	General impression of engineering
2	10,14,21,23	Jobs	Financial influences for studying engineering
3	11, 20	Society	How engineers contribute to society
4	12,17,18,22,25,27,28	Perception	Work engineers do and engineering profession
5	13,19*	Math	Enjoyment of math and science
6	15,26	Exact	Engineering perceived as exact science
7	16,24	Family	Family influence to studying engineering
8	29,30,31,32,35	Basic	Confidence in basic engineering knowledge and skills
9	33,34,35	Communication	Confidence in communication and computer skills
10	39*,46	Study	Adequate study habits.
11	37,43*,45*	Groups	Working in groups.
12	38,40,42,49,50	Ability	Problem solving abilities.
13	36,44,47,48	Compatibility	Engineering abilities.

*Reverse scored items.

Table 3.1: Defining the PFEAS subscales.

The subscales of the instrument have been determined by factor analysis of a large sum of data collected from several universities and colleges at a national level [19, 40]. These subscales have, over the years, standardized to one common set of values or loadings [11]. An independent item analyses of the data collected in this study confirmed that the original thirteen subscales of the instrument hold well. Principle component method was used with Varimax rotation to extract the factors in SPSS© 16.0. A comparison of the factor loadings of the instrument using the data for this study and the one provided by the authors is given in Appendix B[2][56]. A close match between the two results points towards good reliability. Also the internal consistency as measured by Cronbach's alpha (CA) has been reported as 0.8 or better for each of the subscales [18,

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[2] This study data initially extracted fourteen factors that reduced to thirteen, as the participants increased.

57], which is good given the acceptable limit of 0.7 [58, 59]. The author's factor loadings were, therefore, mapped on to the study data (with the permission of the author) to develop the mathematical expressions for pre- and post- subscales. The mapping would also enable realistic comparison of results with other similar studies that employ PFEAS. It may be noted that mapped scales vary between 1 and 5 (with finer step variations) and were treated as continuous outcome variables. Table 3.2 shows the mapped expressions for pre- and post- subscales.

Pre-	Post-	Subscale Name	Mathematical Expressions for Subscales
Pre1	Post	Career	(0.124*Q1+0.121*Q2+0.120*Inv_Q4+0.114*Q3+0.114*Q7+0.113*Inv_Q8+0.104*Q5+0.100*Inv_Q9+0.090*Inv_Q6)
Pre 2	Post 2	Jobs †	(0.301*Q23+0.289*Q14+0.206*Q21+0.204*Q10)
Pre 3	Post 3	Society	(0.519*Q20+0.481*Q11)
Pre4	Post 4	Perception	(0.166*Q12+0.164*Q22+0.163*Q25+0.143*Q28+0.135*Q17+0.128*Q18+0.101*Q27)
Pre 5	Post 5	Math	(0.525*Inv_Q19+0.475*Q13)
Pre 6	Post 6	Exact	(0.516*Q15+0.484*Q26)
Pre 7	Post 7	Family †	(0.586*Q24+0.414*Q16)
Pre 8	Post 8	Basic	(0.244*Q30+0.233*Q32+0.224*Q31+0.169*Q29+0.130*Q35)
Pre 9	Post 9	Communication	(0.161*Q35+0.422*Q33+0.416*Q34)
Pre 10	Post10	Study †	(0.501*Q46+0.499*Inv_Q39)
Pre 11	Post11	Groups	(0.385*Inv_Q43+0.363*Q37+0.252*Inv_Q45)
Pre 12	Post12	Ability	(0.247*Q50+0.244*Q49+0.177*Q38+0.169*Q42+0.163*Q40)
Pre 13	Post13	Compatibility	(0.303*Q47+0.294*Q48+0.202*Q36+0.201*Q44)

† Not relevant to the study.

Table 3.2: Mapping of the PFEAS subscales.

3.2.3 Tuning the Scale: A detailed examination of the instrument revealed that three subscales, namely jobs (financial influences for studying engineering), family (family influence to studying engineering), and study (confidence about study habits) were not relevant to this study because any likely differences between the DS and the TS groups on any of these three subscales would not reflect a treatment effect since the curriculum does not address these topics. To ensure scale reliability, the original instrument was used for data collection and only the relevant ten subscales were examined for data analysis.

For consistency, the original names and numbers of the subscales were retained as shown in Tables 3.1 and 3.2. Another important factor for instrument construction is it's time-to-complete by an average participant. Participants generally lose interest if the instruments take longer than 20-25 minutes. To reduce the participants' time, demographic items were removed from the instrument as accurate demographic information was available from the Associate Deans' office. The relevant subscales for this study and their associated items are given in Table 3.3.

3.2.4 Institutional Review Board (IRB): PFEAS was submitted to the University's IRB for approval prior to its employment, in accordance with federal regulations. The study was approved in the category of '*Expedited Review*' which allows the researchers to retain personal identifiers for tracking the subjects in longitudinal studies. It requires students' written consent for the release of personal identifiers and demographics. Necessary consent forms for the purpose, as required by the state and federal regulations were prepared and made part of the survey questionnaire accordingly.

Sub-scale	Item	Item statement
1. Career	1	I expect that engineering will be a rewarding career.
	2	I expect that studying engineering will be rewarding.
	3	The advantages of studying engineering outweigh the disadvantages.
	4*	I don't care for this career.
	5	The future benefits of studying engineering are worth the efforts.
	6*	I can think of several majors that would be more rewarding than engineering.
	7	I have no desire to change to other major (bio, Eng., chem., art, hist., etc.)
	8*	The rewards of getting an engineering degree are not worth the effort.
	9*	From what I know, engineering is boring.
3. Society	11	Engineers contribute more to making world better than other occupations.
	20	Engineering is more concerned with welfare of society than other professions.
4. Perception	12	Engineers are innovative.
	17	Engineering is an occupation that is respected by other people.
	18	I like the professionalism that goes with being an engineer.
	22	Engineers have contributed greatly to fixing problems in the world.
	25	Engineers are creative.
	27	I am studying engineering because I enjoy figuring out how things work.
5. Math	13	I enjoy the subjects of science and mathematics the most.
	19*	I enjoy taking liberal art courses more than math and science courses.
6. Exact	15	Engineering is an exact science.
	26	Engineering involves finding precise answers to problems.
7. Basic	29	How confident you are of your abilities in chemistry.
	30	How confident you are of your abilities in physics.
	31	How confident you are of your abilities in calculus.
	32	How confident you are of your abilities in engineering skills
	35	How confident you are of your abilities in computer skill
9 Communication	33	How confident you are of your abilities in writing.
	34	How confident you are of your abilities in speaking.
	35	How confident you are of your abilities in computer skill
11 Group	37	Studying in group is better than studying by myself.
	43*	I prefer studying/working alone.
	45*	In the past, I have not enjoyed working in assigned groups.
12 Ability	38	Creative thinking is one of my strengths.
	40	I have strong problem solving skills.
	42	I feel confident in my ability to succeed in engineering.
	49	I enjoy solving open-ended problems.
	50	I enjoy problems that can be solved in different ways.
13 Compatibility	36	I feel I know what an engineer does.
	44	I am good at designing things.
	47	I consider myself mechanically inclined.
	48	I consider myself technically inclined.

*Reverse scored items.

Table 3.3: Itemized detail of the ten selected PFEAS subscales.

3.2.5 Pilot Study: The CoE piloted the cornerstone sequence courses for two semesters, prior to launching the full sequence in fall 2008. EGR 100 was piloted first in fall 2007, while in spring 2008, EGR102 was introduced alongside EGR100 as optional courses to a limited number of freshmen. Spring 2008 was the first time the new cornerstone sequence coexisted with the older traditional sequence forming two cohorts of students. This provided an opportunity for a pilot study with these goals: 1) to understand the new cornerstone sequence objectives; 2) to establish the efficacy of PFEAS and better understand its subscales and performance parameters; 3) to gain expertise in the collection and collation of data with on-line and paper-pencil surveys using the Survey Monkey® platform, a commercial survey agency; 4) to gain expertise in the effective use of SPSS© 16.0, a data processing and analysis package; and 5) to examine the performance of various demographic predictors as covariates for the main study.

The data of the pilot study was collected once, towards the end of the semester. The DS group population was approached in person during their regular lab sessions and was urged to take the survey via a link. The TS group population was not available in any single class so they were sent the link via the university e-mail system. The sample was comprised of 256 students from a population of 638 freshmen. It formed 73% of the DS group and 36% of the TS group. The high turnout for the DS group (73%) was because the survey was conducted in-class, which obviously makes a marked difference. A host of demographics were available that included age, gender, ethnicity, high school, high school GPA, and ACT/SAT scores. The ethnic distribution was 76% Caucasian, 6% Asian/Pacific Islander, 7% African American, 3% Hispanic and 8% Not reported. The ten attitude subscales were examined for the presence of significant differences in the two groups. The frequency distributions, histograms, kurtosis, and skewness results coupled with the Central Limit Theorem ($n > 30$) confirmed normality of the outcomes and supported the use of the parametric approach for the data analysis. The internal consistency for most of the subscales was above the acceptable limits ($CA > 0.7$) except math, exact, basic, and communication (CA: 0.5~0.7). The subscales with fewer items obviously suffer from internal consistency [51], however, the overall scale was known to hold well on internal consistency and content validity [9, 11, 18].

The statistical modeling or hypotheses testing was not within the scope of the pilot study. However, with the available data, it was important to understand the inter-relationship of the two groups with the demographic data. For the pilot study, gender and ACT-composite score were selected as predictors. Independent samples t-test (group vs. ACT-composite: $p = 0.414$) and chi-square test (group vs. gender: Pearson chi-square = 0.367) confirmed that selected variables did not have significant relationship with the two groups; a useful finding for the main study. The pilot study helped in developing better understanding of the two cohorts of students. Moreover, it provided a platform to test the survey instrument and a hands-on experience on data collection and data processing with SPSS$^{©}$. More importantly, it helped in selecting good demographic covariates for the main study. Also, the instrument in its original form was found to hold well in consistency and grouping of the subscales.

3.3 Data Collection

As mentioned earlier, data collection for the main study was conducted in fall 2008 when both groups, the TS group and the DS group, were running simultaneously – an ideal situation to examine the key research question and its related three hypotheses. The data was collected twice: at the beginning (pre-test) and towards the end of the fall semester (post-test). The aim was to capture the WSFs (time changes) for flatness and parallelism hypotheses, in addition to the BSFs for level hypothesis. Two factors that could affect the sample size were the time the survey was administered, and the mode of its administration.

3.3.1 Timing of the Survey: Ideally, for a pre- and post- study, the data should be collected at the beginning and towards the end of a treatment to capture its full effect. For this study the pre- and post- surveys were conducted during the 3rd and 14th week of the 16 week semester, respectively. This was necessary due to student availability and commitment issues. Since this was their first semester, student availability was low in the first two weeks. Also, towards the end, they were overly busy preparing for the design day presentations and final exams scheduled in the 15th and 16th weeks, respectively. This strategy did yield a moderate to good sample size but raised a question about the partial treatment effect (more on this in the Discussion section).

3.3.2 Mode of Survey Administration: The two groups, by definition, were different in many ways. Those enrolled in EGR 100 and/or EGR102 formed the DS group. These freshmen could be approached physically as they shared at least one classroom activity. Those not enrolled in the cornerstone sequence formed the TS group. These students had no common class to share and therefore could not be approached in person as a group.

The data collection methods and incentive offers for the two groups had to be made different in accordance with their peculiar circumstances. It is important to note that the two groups were not formed by a random selection of subjects as dictated for ideal statistical analysis. TS group was comprised of those students who were not admitted to the DS courses for any reason that ranged from ineligibility due to math deficiency to non-availability of classroom space for DS courses. This limitation was kept in view while drawing conclusions. A brief description of mode of survey administration for the two groups is presented below.

3.3.2.1 DS Group: To ensure maximum participation, the survey for the DS group was conducted in-class during laboratory sessions using laboratory computers. Students were sent a link to the survey from SurveyMonkey® and were encouraged to take the survey. An incentive of entry into a drawing for a free iPod was offered for completing the survey. Extra credit equal to one homework assignment was also arranged through the class instructors for taking the survey. There were 450 students registered in EGR 100 and 45 in EGR 102. EGR100 was further distributed in thirteen laboratory sections while EGR 102 had two sections. Conduct of the survey was a time-intensive process. Each of these fifteen sections of the DS group were personally visited at the beginning of the class session for a brief introduction to the study to encourage the students, to obtain their written consent before the survey, and to conduct the survey on the lab computers. It took approximately one week to complete each survey. The post-participation rate for the DS group was 82% and 84% for EGR 100 and EGR 102, respectively.

3.3.2.2 TS Group: Freshmen in the TS group were composed of 227 students spread all over the campus and were not physically approachable as an assembled group.

Therefore, an on-line survey was the best option. The TS group students were sent the survey link via the university's secure web mail and urged to respond. They were also offered the incentive of being entered into the drawing to win an iPod. Several e-mails were sent as reminders to persuade these students to take the survey. Despite the reminders and the incentive, the post-participation rate for the TS group was only 20%.

The sample size was further reduced because only subjects with both, pre- and post-responses could be considered for the study and subjects under the age of 18 years could not take the survey as per the federal regulations. The effective sample size was further affected due to "missing values" in the control variables added to the model (more on this later). Table 3.4 shows a summary of the data collected for the two groups.

Freshman	**TS Group**		**DS Group**					
			EGR 100		**EGR 102**		**Total**	
	Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**
Population (N)	227	227	450	450	45	45	495	495
Sample (n)	71	46	381	368*	43	38	42	406
Participation rate	31	20	85	82	95	84	86	82

*9 incomplete surveys dropped.

Table 3.4: Pre- and post- data collection during 3rd and 14th week of fall 2008, respectively.

3.3.3 The Sample: An overview of the sample gives a general description of the freshman population at MSU. There is a large difference between the two sample sizes: 406 in the post-DS group (EGR 100 and EGR 102 combined); and, 46 in the post-TS group (Table 3.4). It is known that large differences in sample sizes could affect the robustness of the model [60]. The data from EGR 102 was dropped from the main study because: 1) it reduced the absolute difference in sample sizes without affecting the TS group; 2) it simplified the DS group dynamics, now belonging to one course, *i.e.* EGR 100; and most importantly, 3) it was a computational course offered to a select group of majors as a replacement to the existing CSE 231 course. EGR 100 was the new addition to the curriculum. It was the design component of the new sequence and was mandatory for all majors. The post-sample sizes for the DS and TS groups (after dropping the data of EGR 102) were 368 and 46, respectively. The post-sample included 83% males and 17% females. The ethnic distribution was 80% Caucasian, 5% Asian/Pacific Islander (PI), 8% African-American (AA), 3% Other and 4% Not Reported (NR) as given in Table 3.5.

Group	**Gender**			**Ethnicity**					
	M	**F**	**Total**	**Caucasian**	**Asian/PI**	**AA**	**Other**	**NR**	**Total**
DS	307	61	368	322	19	11	9	7	368
TS	35	11	46	10	3	22	3	8	46
Total	342	72	414	332	22	33	12	15	414
Percentage	83	17		80	5	8	3	4	

Table 3.5: Gender and ethnicity distribution of the sample.

3.4 Selection of Variables

Prior to developing the specific models for the study, the data was examined for selection of relevant variables for these models. To select the best possible combination of predictors, covariates, and outcomes, all available demographics were considered. The rationale for selecting (or excluding) these variables is discussed below.

3.4.1 Dependent or Response Variables (DVs): Thirteen PFEAS subscales formed the domain of the main construct, that is, freshman attitudes towards engineering. These subscales were the outcomes or DVs for the statistical model. PFEAS subscales are the proven outcomes of factor analysis of a large sum of data from multiple longitudinal studies. The subscales were developed by simple addition of the factored PFEAS items, duly normalized, with the original factor loadings. Normalization was done for ease of reference and standardization. Two sets of thirteen DVs were defined: Pre1-Pre13 for pre-test scores and, Post1-Post13 for post-test scores, as given in Table 3.2. The ten selected DVs for this study were examined for treatment effects while controlling for the confounding effects of carefully selected predictors or independent variables.

3.4.2 Independent or Explanatory Variables (IVs): It is essential for a statistical model to have a good set of IVs (also called predictors, covariates, and explanatory variables) that could explain maximum variations in the response variable(s); the higher the predictability, the better the IV. Equally important, if not more, is the choice of IVs that is contingent upon the research question which dictates the relationship to be tested. IVs must be able to represent this relationship. In other words, the IVs should have high correlations with the outcome(s) and should be independent of each other or at least have low correlations with each other. It was therefore necessary to search for a parsimonious set of IVs that could explain maximum amount of variance in the outcome(s) thus minimizing the error term (equation 4). A set of seventeen IVs available for this study is briefly discussed below.

3.4.2.1 Group: A dichotomous variable that distinguished between the two cohorts of freshmen: the DS (treatment) group comprising freshmen in the new cornerstone sequence (EGR 100 only), and the TS (control) group formed by freshmen not registered for the cornerstone sequence, in the so called older traditional sequence. It may be pertinent to re-emphasize that fall 2008 was a unique semester from the stand point of this study since both cohorts were available for direct comparison. The TS group size would considerably decline in the subsequent semesters as the College increased its capacity to enroll more students for the mandatory courses. "Group" was the most important predictor since it reflected the effect of primary interest in the research question. Other IVs were added to the model to control for their effects while examining the group-vs.-DVs relationship over time.

3.4.2.2 Other IVs: To select the best fit for a statistical model, the sixteen other IVs were grouped into three categories: background, past performance, and present performance as shown in Table 3.6.

Variable	Type	Potential Range	Remarks
Background			
- Group*	Dichotomous	0, 1	Most relevant
- Age	Interval	18-21	Low variability
- Gender*	Dichotomous	0, 1	Most interesting
- Ethnicity	Nominal	1-5	Low cell count
- Citizenship	Nominal	1-3	Low cell count, low variability, less relevant
- Resident State	Nominal	1~50	Less relevant, low variability
- Resident County	Nominal	1~80	Less relevant
- H.S.† attended	Nominal	1~500	Less relevant
Past Performance			
- ACT composite*	Interval	11-36	Relevant covariate
- ACT math	Interval	11-36	High correlation
- SAT math	Interval	200-800	High correlation
- SAT verbal	Interval	200-800	High correlation
- H.S.† GPA	Interval	1.00-5.00	Non standard
- Math competency	Ordinal	1-3	High correlation, low cell count
Present Performance			
- FS07 GPA	Interval	1.00-4.00	High correlation
- SS08 GPA	Interval	1.00-4.00	High correlation
- SS08 CGPA	Interval	1.00-4.00	High correlation

* Selected. † High school

Table 3.6: Defining the three categories of other IVs.

1. **Background:** As the name suggests, this category of variables was associated with the participants' identity. It included age, gender, ethnicity, citizenship, resident state, resident county, and high school attended.
2. **Past Performance:** Past performance defined the subject's academic performance before joining the university as a freshman. It included ACT composite, ACT math, SAT math, SAT verbal, high school GPA and math

competency. Math competency was an ordinal variable; it defined the subject's math proficiency *vis-à-vis* a math course pre-requisite for the cornerstone sequence (Math 116 or equivalent). Table 3.7 shows the distribution of this variable.

3. **Present Performance:** This category described the subject's current academic performance as a freshman. It included fall 2007 GPA, spring 2008 GPA and spring 2008 CGPA.

3.4.3 Selection Criteria: Each of the sixteen other IVs was examined for relevance and usability *vis-à-vis* the research question. Variables not useful and/or not useable were dropped based upon the following selection criteria.

3.4.3.1 Correlation: Highly correlated IVs reduce power, pose collinearity issues and therefore must be avoided. IVs in the past performance and present performance categories represented the students' academic capability/performance and were obviously highly correlated. Only one variable from these two categories could be selected that best explained (correlated with) most of the response variables and at the same time represented the freshman's true academic capability. Present performance category represented students' GPAs for one or two semesters and was, therefore, not a true reflection of their academic performance.

Past performance was comprised of three types of scores, high school GPA, math competency, and ACT/SAT score. High school GPA could have been an ideal candidate but it suffered from non standard format. High Schools in the U.S. do not have a standard grading system; some grade on a 4.00 scale and others on a 5.00 scale. It is difficult to compare the two scores with reasonable accuracy. Math competency represented only one aspect of the student performance. The variable also suffered from low cell count (n < 10, see Table 3.7).

Level	**Definition**	**Math qualification (course name)**	**DS**	**TS**	**Total**
1	Under-qualified	MTH-1825/103	6	29	35
2	Qualified	MTH-116/124/132/152H	255	10	265
3	Over-qualified	MTH-133/153H/234/254H/235	95	5	100
Total			356	44	400*

*14 missing values.

Table 3.7: Distribution of math competency between DS and TS groups showing low cell count (n < 10).

ACT or SAT score is considered a measure of the student academic performance by most of the engineering institutions. The two scores are highly correlated (r = 0.854). Most of the applicants in the Midwestern region take the ACT whereas students in the other U.S. regions and most of the foreign students take the SAT exam [61]. ACT scores were available more often, so SAT scores were converted to equivalent ACT scores wherever the latter were not available or missing [62]. The ACT score is comprised of two components: ACT composite and ACT math. The two are known to be highly correlated. The ACT composite was selected because it is broad based and is commonly used for admission screening by the engineering institutions. The ACT composite is a continuous variable with a normal distribution (Figure 3.1). An independent-samples t-test for ACT composite score showed DS group means were significantly higher than TS group means (Table 3.8). ACT composite was found to be mildly positively correlated with most of the ten outcomes (.015 < r < .276). It should work as an important covariate and be watched for collinearity issues.

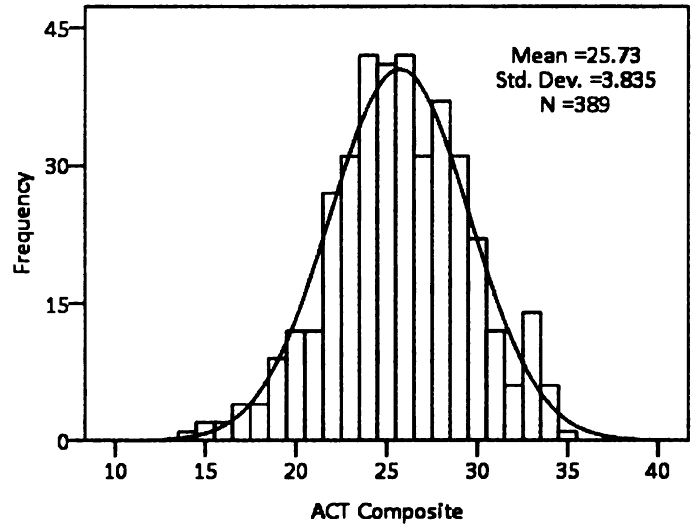

Figure 3.1: The ACT composite score distribution in the sample.

	Group Statistics			**t-Test for Equality of Means**					
ACT composite	**Group**	**N**	**Mean**	**t**	**df**	**Sig. (2-tail)**	**Mean Diff.**	**99.9% Confd.**	
	TS group	38	20.71					Lower	Upper
	DS group	351	26.27	-9.395	387	.000	-5.560	-6.724	-4.397

Table 3.8: Independent samples t-test for ACT composite score in the two groups.

3.4.3.2 Variability: Low variability is of little utility to the model. Three variables in the background category: age, citizenship, and resident state had low variability as shown in Table 3.9; therefore, these variables were dropped.

Resident State (%)		**Citizenship (%)**		**Age (years)**	
Michigan	86.5	US Citizen	94.5	Mean	18.75
Non Michigan	13.5	Non Citizen	3.3	Minimum	18.02
		Permanent Resident	2.2	Maximum	21.35

Table 3.9: IVs with low variability.

3.4.3.3 Cell Count: It is important to select variables that are reliable and pertinent predictors of the outcomes. Low cell count (n < 10) affects the reliability of the variable(s) and render them unfit for realistic analysis. Ethnicity and math competency suffered from low cell count (see Tables 3.5 and 3.7). Math competency also had high correlation with ACT composite (Pearson correlation r = 0.560) and had missing data (14 missing values as seen in Table 3.7), which would have further reduced the effective sample size. These two variables (ethnicity and math competency) were therefore dropped. Gender has always been of interest in such like studies. It had acceptable cell count (Table 3.5) and was found to be uniformly distributed in the two groups (χ^2 (1) = 1.399, df = 1, p = 0.226).

3.4.3.4 Relevance: The background category variables including citizenship, resident state, resident county, high school attended had little relevance to the research question and were, therefore, dropped from the model. These variables could be useful for future studies involving such demographics.

3.5 The Specific Model

In the light of the above discussion, the variables selected for the model were:

DVs: ten PFEAS sub scales.

IVs: *group, gender, ACT-composite* (hereafter simply called *ACT*). The selected IVs along with *time* shall be italicized from here onwards to distinguish the covariates for the model.

The model with the selected variables becomes

$$Pre_i = \beta_0 + x_{group}\beta_1 + x_{gender}\beta_2 + x_{ACT}\,\beta_3 + \varepsilon \qquad (9)$$

$$Post_i = \gamma_0 + x_{group}\gamma_1 + x_{gender}\gamma_2 + x_{ACT}\,\gamma_3 + \acute{\varepsilon}. \qquad (10)$$

Where, $Pre_i \equiv$ Pre-DVs,

$Post_i \equiv$ Post-DVs,

$\beta \equiv$ Unknown pre- coefficients,

$\gamma \equiv$ Unknown post- coefficients,

$x \equiv$ IVs; *gender, group, ACT*,

$\acute{\varepsilon} \equiv$ Post- error, and

$\varepsilon \equiv$ Pre- error.

Before analyzing the data with the above model it was prudent to check it for parametric test assumptions to ensure the validity of results. Any deviation from the assumptions must be documented and further investigated before drawing conclusions. The next section is, therefore, devoted to the parametric test assumptions.

3.6 Test Assumptions

Parametric ANCOVA is a powerful tool for analyzing data, especially if the underlying assumptions of linearity, normality, and homoscedasticity are not violated [60, 63]. Moreover, outliers and influential data points sometimes distort the results and may have to be resolved [64]. To ensure that repeated measures ANCOVA accurately summarizes the relationship between the predictors and the outcomes, SPSS© diagnostic tools were used to check the validity of each assumption [64]. A summary is presented below.

3.6.1 Linearity: Linearity is fundamental to multivariate statistics because solutions are based on the general linear model (GLM) [37]. Linearity of the relationship between variables was examined with two kinds of scatter plots: 1) scatter plots of raw residuals vs. predicted values superimposed with lowess smoothing lines; and, 2) scatter plots of covariate *ACT* vs. outcomes. No evidence of gross nonlinearity was found between the pre- and post- measures and the predictors.

3.6.2 Normality: If there is normality, the residuals are normally and independently distributed [37]. To test normality, histograms and Quantile-Quantile (Q-Q) plots of studentized residuals were examined. All the ten models generally met the normality assumption except for a few outliers in the data. The Central Limit Theorem also supported the normality assumption because the sample size was larger than the typical figure of 30 [65].

3.6.3 Homoscedasticity: The pattern of data spread was examined with scatter plots of studentized residuals vs. predicted values. The data were found to be homogeneous except for six out of twenty measures (ten pre- and ten post-) where evidence of heteroscedasticity was found. Box's tests of equality of covariance matrices supported this pattern (Table 3.10) [66].

3.6.4 Influential Data: Highly influential data points can change the fit of the model. On examination of bubble plots of studentized residuals, four data points were found highly influential in most of the outcomes (seventeen out of twenty measures including the pre- and post-data) [66]. The data points were highly influential due to the large Cook's distance paired with large residuals and large leverage values. For example, the bubble plot of sub-scale Pre5 math (Table 3.2) is shown in Figure 3.2 with three influential data points, that is, 310, 410, and 412 duly highlighted.

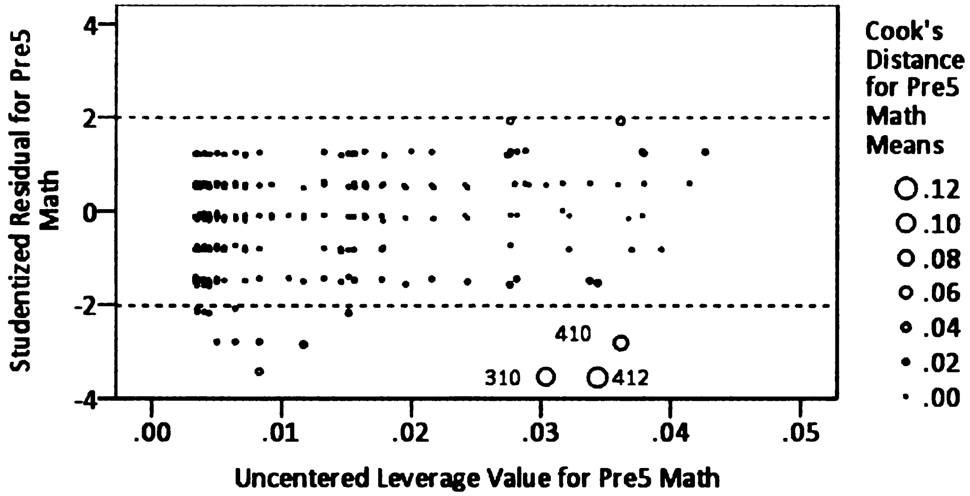

Figure 3.2: Bubble plot for Pre5 math showing three influential data points.

3.7 Data Transformation

Removal of influential data points – two out of four belonged to the TS group – was neither justified nor recommended for a relatively small TS group. Although parametric ANCOVA is generally robust to violations of assumptions, the data was rank-transformed because rank transformation removes the effects of influential data, reduces the importance of normality or homoscedasticity assumptions, and promotes robustness and power in the analysis of covariance [60, 63, 67]. Rank transforming the outcome variable effectively converts the ANCOVA into a non-parametric procedure that no longer assumes normality or homoscedasticity (though it has little effect on the linearity assumption). Bubble plots of the rank-transformed data showed no influential observations. For example, Figure 3.3 shows the bubble plot of rank-transformed sub-scale Rank Pre5 math. Box's tests also confirmed equality of covariance matrices for all the ten rank-transformed outcomes (Table 3.10).

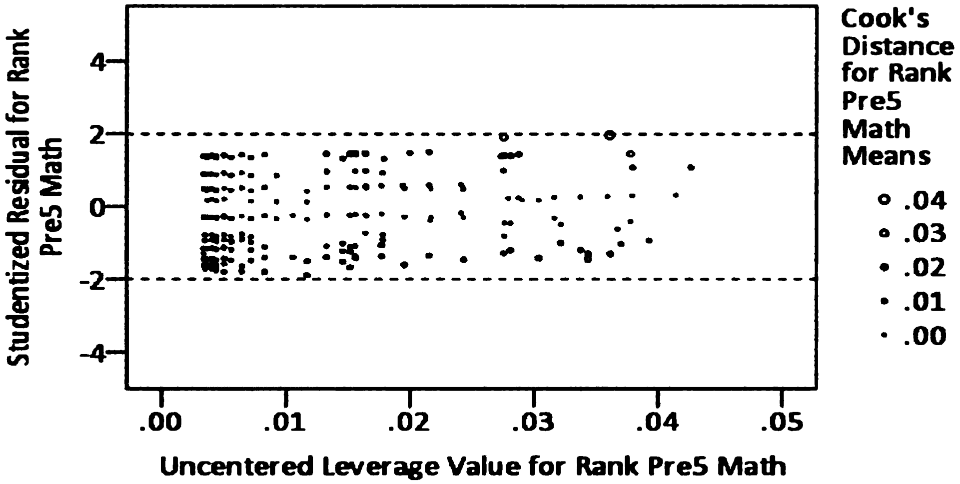

Figure 3.3: Bubble plot for Rank Pre5 math showing no effects of influential data.

Outcome	Raw Data				Rank-transformed Data			
	Box M	F	dfl/df	Sig.	Box M	F	dfl/df2	Sig.
Career	10.09	1.076	9/7265	0.377	1.162	0.124	9/7265	0.999
Society	3.831	0.408	9/7265	0.932	5.161	0.55	9/7265	0.839
Perception	13.43	1.431	9/7265	0.169	8.465	0.902	9/7265	0.523
Math	20.71	2.207	9/7265	0.019	1.384	0.147	9/7265	0.998
Exact	5.642	0.601	9/7265	0.797	3.83	0.408	9/7265	0.932
Basic	32.32	3.443	9/7265	<0.001	7.847	0.836	9/7265	0.583
Communication	5.764	0.614	9/7265	0.786	3.14	0.334	9/7265	0.964
Groups	19.42	2.069	9/7265	0.029	10.87	1.159	9/7265	0.317
Ability	40.11	4.274	9/7265	<0.001	14.81	1.578	9/7265	0.115
Compatibility	20.79	2.215	9/7265	0.018	14.77	1.574	9/7265	0.117

Table 3.10: Box's test for homoscedasticity for raw and rank-transformed data. The transformation corrected homoscedasticity problems apparent in the raw data for the math, basic, groups, ability and compatibility subscales.

Part II – Analysis/Discussion

Based on equations 9 and 10, ten models were developed in SPSS$^{©}$, one for each of the selected PFEAS subscales. These models represent attitude subscales as a function of the two *groups* of freshmen while controlling for the confounding effects of their *gender* and *ACT* score. This part presents the test results of ten models. Each model is examined independently, followed by an analysis of the accumulated effect of the ten models that form the domain of the main construct, *i.e.* freshman attitude towards engineering. Two sets of data were used with each model – raw data and rank-transformed data – to observe the test violations, if any, and to confirm the reliability of test results.

The analyses reported here are based on raw (untransformed) data, except the outcomes that showed marginal differences and were examined with rank-transformed data as well. Table 3.11 shows a summary of the ANCOVA results of ten models with raw and rank-transformed data. Each model was examined in the light of the three hypotheses by observing WSFs, and BSFs. The Estimated Marginal Means (EMMs) for the two groups were examined with respect to their profile plots. Table 3.12 provides a summary of the EMMs for *time*group* and *gender*. The performances of other predictors (*gender* and *ACT*) were also examined to understand the complete model. Tables 3.11 and 3.12 are exhaustive and shall be frequently referred to for the analysis and discussion of the ten models presented below.

Source			Raw Data					Rank-transformed Data				
Outcome	**Hypotheses**		**SS**	**df**	**F**	**Sig.**	**η2**	**SS**	**df**	**F**	**Sig.**	**η2**
Pre1- *Post1* *Career*	WSF	Time	0.25	1	1.60	0.20	0.00	22365	1	3.64	0.057	0.009
		time*group	_0.07_	_1_	_0.46_	_0.49_	_0.00_	_9184_	_1_	_1.49_	_0.222_	_0.004_
		time*gender	0.32	1	2.10	0.14	0.00	12506	1	2.03	0.154	0.005
		time*ACT	0.02	1	0.18	0.66	<.00	21115	1	3.44	0.064	0.009
		error (time)	60.0	3				236280	38			
	BSF	Intercept	318.	1	707.	<.00	0.64	830684				
		Group	0.55	1	1.22	0.26	0.00	30431	1	1.41	0.236	0.004
		Gender	0.30	1	0.68	0.40	0.00	3774	1	0.17	0.676	<.00
		ACT	2.51	1	5.59	0.01	0.01	172963	1	8.01	0.005	0.020
		Error	173.	3				830684	38			
Pre3- *Post3* *Society*	WSF	Time	0.06	1	0.23	0.63	0.00	5701	1	0.70	0.4	0.002
		time*group	_0.04_	_1_	_0.17_	_0.67_	_<.00_	_186_	_1_	_0.02_	_0.879_	_0.001_
		time*gender	0.10	1	0.37	0.53	0.00	11036	1	1.37	0.242	0.004
		time*ACT	0.00	1	0.01	0.91	<.00	1170	1	0.14	0.703	<.00
		error (time)	107.	3				309734	38			
	BSF	Intercept	319.	1	444.	<.00	0.53	796215	1	425.	<.00	0.525
		Group	1.90	1	2.65	0.10	0.00	48084	1	2.56	0.110	0.007
		Gender	1.06	1	1.49	0.22	0.00	26032	1	1.39	0.239	0.004
		ACT	15.8	1	22.0	<.00	0.05	327624	1	17.4	<.00	0.043
		Error	276.	3				720995	38			
Pre4- *Post4* *Perce-* *ption*	WSF	Time	0.11	1	1.57	0.21	0.00	19692	1	3.03	0.082	0.008
		time*group	_0.29_	_1_	_3.96_	_0.04_	_0.01_	_19811_	_1_	_3.05_	_0.081_	_0.008_
		time*gender	0.02	1	0.26	0.60	0.00	19.73	1	0.00	0.956	<.00
		time*ACT	0.08	1	1.09	0.29	0.00	3897	1	0.60	0.439	0.002
		error (time)	29.0	3				249751	38			
	BSF	Intercept	328.	1	123	<.00	0.76	742303	1	341.	<.00	0.470
		group	0.21	1	0.81	0.36	0.00	11432	1	0.52	0.469	0.001
		gender	<.00	1	<.00	0.98	<.00	4229	1	0.19	0.659	0.001
		ACT	2.04	1	7.68	0.00	0.02	120823	1	5.56	0.019	0.014
		error	102.	3				836454	38			
Pre5- *Post5* *Math*	WSF	time	0.49	1	2.29	0.13	0.00	5688	1	1.20	0.273	0.003
		time*group	_0.16_	_1_	_0.75_	_0.38_	_0.00_	_521.18_	_1_	_0.11_	_0.740_	_<.00_
		time*gender	0.05	1	0.24	0.62	0.00	1111.6	1	0.23	0.627	0.001
		time*ACT	0.18	1	0.87	0.35	0.00	8592	1	1.82	0.178	0.005
		error (time)	83.3	3				181384	38			
	BSF	Intercept	217.	1	217.	<.00	0.36	537166	1	239.	<.00	0.383
		group	12.2	1	12.2	0.00	0.03	258674	1	11.5	0.001	0.029
		gender	0.03	1	0.03	0.84	<.00	8911	1	0.39	0.529	0.001
		ACT	0.00	1	0.00	0.93	<.00	22066	1	0.98	0.322	0.003
		error	385	3				863666	38			
Pre6- *Post6* *Exact*	WSF	time	0.47	1	1.69	0.19	0.00	4819	1	0.76	0.382	0.002
		time*group	_0.58_	_1_	_2.08_	_0.14_	_0.00_	_11592_	_1_	_1.84_	_0.176_	_0.005_
		time*gender	0.75	1	2.68	0.10	0.00	11616	1	1.84	0.175	0.005
		time*ACT	0.95	1	3.42	0.06	0.00	2899	1	0.46	0.498	0.001
		error (time)	107.	3				242615	38			
	BSF	Intercept	268.	1	308.	<.00	0.44	905051	1	456.	<.00	0.542
		group	4.80	1	5.51	0.01	0.01	99915	1	5.03	0.025	0.013
		gender	4.48	1	5.14	0.02	0.01	87800	1	4.42	0.036	0.011
		ACT	12.7	1	14.6	<.00	0.03	265448	1	13.3	<.00	0.034
		error	335.	3				763419	38			

Table 3.11: Repeated measures ANCOVA test results for each of the ten PFEAS subscales based on analyzing both raw and rank-transformed data.

Source			Raw Data					Rank-transformed Data				
Outcome	Hypotheses		SS	df	F	Sig.	η2	SS	df	F	Sig.	η2
Pre8-Post8 Basic	WSF	time	0.10	1	1.05	0.30	0.00	813	1	0.16	0.687	<.001
		*time*group*	*0.63*	*1*	*6.22*	*0.01*	*0.01*	*18143*	*1*	*3.61*	*0.058*	*0.009*
		time*gender	0.04	1	0.44	0.50	0.00	483.94	1	0.09	0.756	<.001
		time*ACT	0.16	1	1.62	0.20	0.00	7529.9	1	1.50	0.221	0.004
		error (time)	38.9	3				193200	38			
	BSF	Intercept	132.	1	285	0	0.42	280019	1	134.	<.00	0.258
		group	1.12	1	2.40	0.12	0.00	40685	1	1.95	0.163	0.005
		gender	7.34	1	15.7	<.00	0.03	334881	1	16.0	<.00	0.040
		ACT	8.55	1	18.3	<.00	0.04	398137	1	19.0	<.00	0.047
		error	179.	3				803382	38			
Pre9-Post9 Commu-nication	WSF	time	0.15	1	0.99	0.31	0.00	1165	1	0.30	0.581	0.001
		*time*group*	*0.04*	*1*	*0.28*	*0.59*	*0.00*	*67*	*1*	*0.01*	*0.895*	*<.00*
		time*gender	0.16	1	1.10	0.29	0.00	2132	1	0.30	0.581	0.001
		time*ACT	0.01	1	0.08	0.76	<.00	32.277	1	0.00	0.927	<.001
		error (time)	58.7	3				147269	38			
	BSF	Intercept	208	1	209.	<.00	0.35	630393	1	255.	<.00	0.399
		group	0.54	1	0.55	0.45	0.00	21523	1	0.87	0.351	0.002
		gender	0.58	1	0.58	0.44	0.00	14458	1	0.58	0.445	0.002
		ACT	0.00	1	0.00	0.96	<.00	25928	1	1.04	0.306	0.003
		error	382.	3				951211	38			
Pre11-Post11 Groups	WSF	time	<0.0	1	<.00	0.99	<.00	6579	1	1.15	0.284	0.003
		*time*group*	*0.37*	*1*	*1.66*	*0.19*	*0.00*	*8944*	*1*	*1.56*	*0.212*	*0.004*
		time*gender	0.06	1	0.28	0.59	0.00	453.7	1	0.07	0.778	<.001
		time*ACT	0.08	1	0.35	0.54	0.00	1460	1	0.25	0.614	0.001
		error (time)	86.6	3				220278	38			
	BSF	Intercept	291.	1	318.	<.00	0.45	859360	1	398	<.00	0.508
		group	2.06	1	2.25	0.13	0.00	48962	1	2.26	0.133	0.006
		gender	0.82	1	0.90	0.34	0.00	21179	1	0.98	0.323	0.003
		ACT	19.9	1	21.7	<.00	0.05	548878	1	25.4	<.00	0.062
		error	352.	3				831269	38			
Pre12-Post12 Ability	WSF	time	0.23	1	2.49	0.11	0.00	797	1	0.15	0.690	<.001
		*time*group*	*0.04*	*1*	*0.46*	*0.49*	*0.00*	*3552*	*1*	*0.71*	*0.400*	*0.002*
		time*gender	0.02	1	0.21	0.64	0.00	3381	1	0.67	0.412	0.002
		time*ACT	0.08	1	0.88	0.34	0.00	302	1	0.06	0.806	<.001
		error (time)	35.8	3				192658	38			
	BSF	Intercept	214.	1	459.	<.00	0.54	530725	1	230.	<.00	0.375
		group	0.23	1	0.51	0.47	0.00	348	1	0.01	0.902	<.001
		gender	1.78	1	3.82	0.05	0.01	128247	1	5.57	0.019	0.014
		ACT	0.35	1	0.76	0.38	0.00	8859	1	0.38	0.535	0.001
		error	179.	3				885029	38			
Pre13-Post13 Compat-ibility	WSF	time	0.07	1	0.53	0.46	0.00	3776	1	0.68	0.408	0.002
		*time*group*	*0.41*	*1*	*3.11*	*0.07*	*0.00*	*12911*	*1*	*2.34*	*0.127*	*0.006*
		time*gender	0.06	1	0.49	0.48	0.00	4673	1	0.84	0.357	0.002
		time*ACT	0.32	1	2.44	0.11	0.00	2693	1	0.48	0.485	0.001
		error (time)	50.9	3				212003	38			
	BSF	Intercept	216.	1	387.	<.00	0.50	525491	1	240.	<.00	0.384
		group	0.82	1	1.47	0.22	0.00	35587	1	1.62	0.203	0.004
		gender	10.1	1	18.2	<.00	0.04	360574	1	16.4	<.00	0.041
		ACT	0.40	1	0.72	0.39	0.00	21772	1	0.99	0.319	0.003
		error	214.	3				842348	38			

Table 3.11: Continued.

Outcome	**Group*Time Effect**				**Gender Effect**	
	DS		**TS**			
	Pre-test	**Post-test**	**Pre-test**	**Post-test**	**Males**	**Females**
Career	4.11	3.99	4.25	4.05	4.07	4.13
Society	3.49	3.62	3.28	3.47	3.51	3.42
Perception	4.27	4.22	4.14	4.23	4.21	4.21
Math	4.09	3.91	3.57	3.49	3.77	3.77
Exact	3.19	2.91	3.38	3.31	3.30	3.10
Basic	3.80	3.75	3.55	3.71	3.83	3.57
Comm.	3.50	3.73	3.57	3.86	3.63	3.70
Groups	3.35	3.12	3.08	3.01	3.18	3.10
Ability	3.93	3.87	3.90	3.78	3.93	3.81
Compatibility	3.58	3.66	3.37	3.63	3.71	3.41

Table 3.12: Mean scores for ten PFEAS subscales from the ANCOVA analyses, broken down to illustrate the *group*time* and *gender* effects.

3.8 Career (Pre1-Post1)

This subscale measured the subject's general impression of engineering as a profession, career, and a field of study. The subscale is comprised of nine items of the scale as listed in Table 3.3 (Items 1-9). Four items of this subscale (item 4, 6, 8, and 9) were reverse coded to retain positive sense of the Likert scale. This was the biggest and the most reliable of the PFEAS subscales.

3.8.1 Tests of WSFs: These tests check for significant changes in the outcome (career) with respect to time (pre- and post-). They include tests for the flatness and the parallelism hypotheses for *time,* and *time*group* interaction. These tests failed to reject both hypotheses ($H_{0,a}: p = 0.206,$ and $H_{0,b}: p = 0.497$). In other words, the subscale did not significantly change at the two *time* intervals irrespective of the *group* membership; and it did not show significant *time*group* interaction. The two *groups* were not significantly different on their general impression of engineering over the span of one semester; they had parallel trajectories over *time*, meaning no treatment effect on this subscale. Apart from these two hypotheses, other predictors in the model, that is, *gender* and *ACT*, did not show significant interaction with *time*. The model, as such, explained very little of the variations as indicated by the values of Partial Eta Squared (η^2 $\leq 0.5\%$).

3.8.2 Tests of BSFs: These tests looked for significant changes in the outcome due to IVs disregarding the *time* factor (averaging over *time*) and included tests for the level hypothesis. The tests failed to reject the level hypothesis ($H_{0,c} : p = 0.269$); the *group* did not influence the subscale. In other words, the two groups had similar impressions about engineering while disregarding or averaging the *time* factor. In addition, the tests showed that *gender* did not influence whereas *ACT* significantly influenced the outcome (β_{pre}=-0.018, $\beta_{post} = -0.015, p$=0.019). Students with higher *ACT* scores had lower impressions about engineering when controlling for *gender* and *group* affiliations and disregarding the *time* effects.

3.8.3 EMMs: The profile plots for *time*group* interaction indicate that while the interaction was insignificant, the overall EMMs for both groups remained above 3.99 on a scale of 1-5 as shown in Figure 3.4 and given in Table 3.12. This indicates that the initial impression of engineering in both the groups was strongly positive and it did not change significantly over the course of one semester.

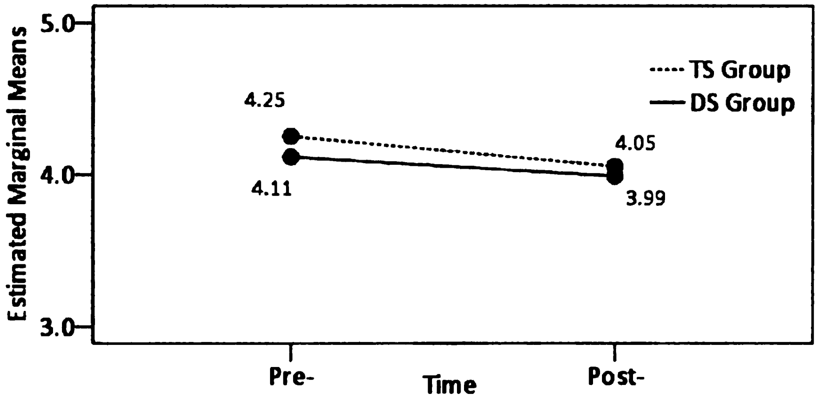

Figure 3.4: Profile plot of the *time**group* interaction on the career subscale. The longitudinal trajectories from pre-test to post-test for the two groups were nearly identical, which was why the interaction effect was not significant.

3.9 Society (Pre3-Post3)

This subscale measured the freshman perception of how engineers contribute towards the welfare of society compared to other professionals. The subscale was comprised of two items as listed in Table 3.3 (items 11, 20) and was among the smallest of the PFEAS subscales.

3.9.1 Tests of WSFs: The tests failed to reject the flatness and the parallelism hypotheses ($H_{0,a}: p = 0.631,$ and $H_{0,b}: p = 0.676$). The rejection of the two hypotheses means the *time* and *time*group* interactions were not significant for this subscale. The two *groups*' perception of how engineers contribute to the society did not change over the course of one semester, meaning no treatment effect for this subscale could be observed. The model also did not show interaction of other predictors as no *time*gender* and *time*ACT* interactions were observed. As such, the model explained very little of the variations in the subscale ($\eta^2 < 0.1\%$).

3.9.2 Tests of BSFs: The tests failed to reject the level hypothesis ($H_{0,c}: p = 0.104$); the *group* did not influence the subscale. The two groups had a similar perception of how engineers contribute to the society while disregarding the *time* factor. In addition, the tests showed that *gender* did not influence whereas *ACT* significantly influenced the outcome (β_{pre}=-0.042, β_{post}=-0.041, $p < 0.001$). Students with higher *ACT* scores had a lower perception of how engineers contribute towards the welfare of the society when controlling for *gender* and *group* affiliations and disregarding the *time* effects.

3.9.3 EMMs: The profile plots for *time*group* interaction indicate that though the interaction was insignificant, the overall EMMs for both groups remained above 3.28 on the raw scale of 1-5 as shown in Figure 3.5 and Table 3.12. This indicates that freshman perception of how engineers contribute towards the welfare of the society in both the groups was mildly high in the beginning and it did not change significantly over the course of one semester.

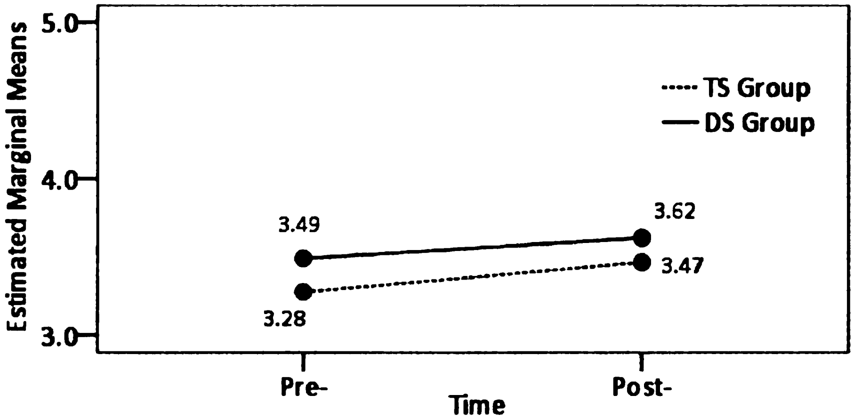

Figure 3.5: Profile plot of the *time*group* interaction on the society subscale. The longitudinal trajectories from pre-test to post-test for the two groups were nearly identical, which was why the interaction effect was not significant.

3.10 Perception (Pre4-Post4)

This subscale measured the freshman perception of the work engineers do in terms of innovation, creation, problem solving, use of technology, and the professionalism and respect that go with it. It was comprised of seven items as listed in

Table 3.3 (Items 12, 17, 18 22, 25, 27, 28) and was among the most reliable of the PFEAS subscales.

3.10.1 Tests of WSFs: The parallelism hypothesis was rejected with the raw data, however, the corresponding test on the rank data failed to reject the parallelism hypothesis($H_{0,b}: p = 0.047$ for raw data, $H_{0,b}: p = 0.081$ for rank data). The difference between the two tests was due to the presence of a few outliers in the raw data, and therefore the rank-transformed results were more credible. The two *groups* effectively had parallel trajectories in how their perceptions of engineering work and the engineering profession changed over the span of one semester. In other words, there was no treatment effect on this subscale. The tests also failed to reject the flatness hypothesis for both data sets ($H_{0,a}: p = 0.21$ for raw data, $H_{0,a}: p = 0.082$ for rank data) implying there was no *time* effect – the trajectories were not only parallel, they were also flat. Additionally, *gender* and *ACT* did not significantly interact with *time* in both the data sets. The partial eta squared measures show that these WSF effects explained very little of the variance in this subscale ($\eta^2 \leq 1\%$ for raw data and $\eta^2 \leq 0.1\%$ for rank data).

3.10.2 Tests of BSFs: These tests failed to reject the level hypothesis in both data sets ($H_{0,c}: p = 0.369$ for raw data, $H_{0,c}: p = 0.469$ for rank data); *group* had no influence on the subscale when disregarding *time* effects. In addition, *gender* did not influence it ($p = 0.982$), whereas *ACT* significantly influenced the subscale in both data sets (β_{pre}=-0.012, β_{post} = -0.018, p=0.006 for raw data and β_{pre}=-0.099, β_{post} = -0.142, p = 0.019 for rank data). In other words, students with higher *ACT* scores had lower perception about this outcome when controlling for *gender* and *group* affiliations and disregarding the *time* effects.

3.10.3 EMMs: The profile plots for *time*group* interaction for raw and rank data are shown in Figures 3.6 and 3.7, respectively. There is only a trivial difference between the slopes for the two trajectories in both the figures. The failure of the rank data to confirm the presence of an interaction that is detected in the raw data suggests that it is only significant in the raw data due to the excessive influence of a few outliers. However, the overall EMMs for both groups remained above 4.14 on the raw scale of 1-5 and above 177 on a rank scale of 1-389. This indicates that the freshmen in both the groups joined the semester with strongly positive impression of engineering and this impression did not change significantly over the course of one semester.

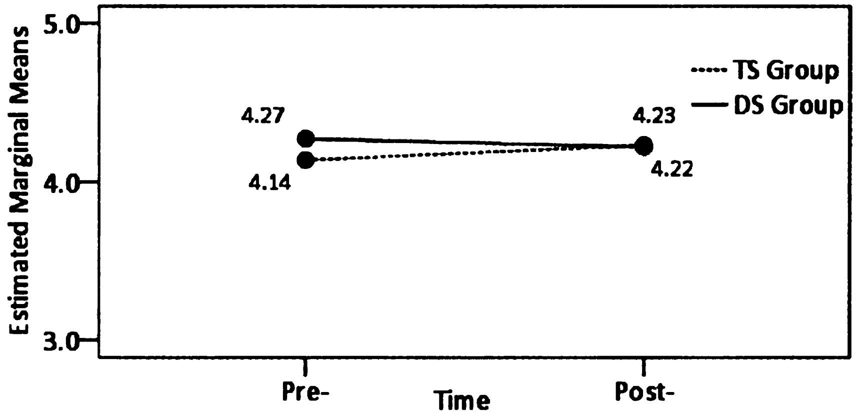

Figure 3.6: Profile plot of the *time*group* interaction on the perception subscale. The longitudinal trajectories from pre-test to post-test for the two groups differ significantly, but by a trivial amount that was due to the presence of few outliers.

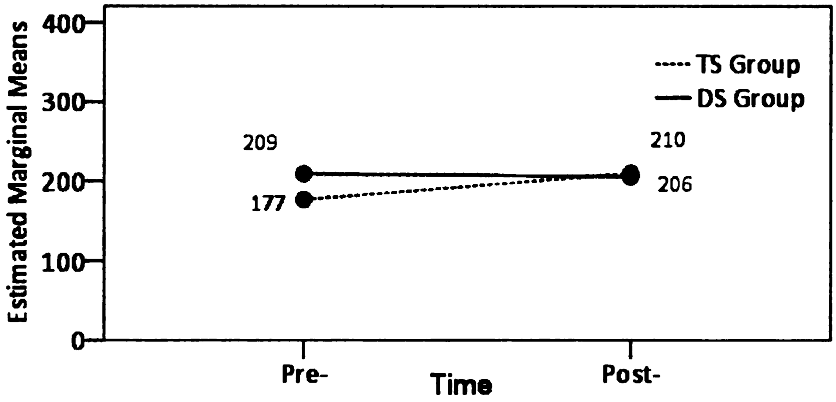

Figure 3.7: Profile plot of the *time*group* interaction for rank data on the perception subscale. The longitudinal trajectories from pre-test to post-test for the two groups were nearly identical, which was why the interaction effect was not significant.

3.11 Math (Pre5-Post5)

This subscale measured how much a freshman enjoyed the subjects of math and science compared to liberal arts courses. It was comprised of two items (items 13, 19) as listed in Table 3.3. The scale was balanced with one positive and one negative (reverse scored) item.

3.11.1 Tests of WSFs: The tests failed to reject the flatness and parallelism hypotheses ($H_{0,a}: p = 0.131,$ and $H_{0,b}: p = 0.386$). The two *groups* were not different in their enjoyment for math and science subjects over the span of one semester, hence, no treatment effect was seen on this subscale. Additionally, the other two explanatory variables, *gender* and *ACT*, did not show significant interaction over *time*. The partial eta squared measures show that these WSF effects explained very little of the variance in this subscale ($\eta^2 \leq 0.6\%$).

3.11.2 Tests of BSFs: The tests rejected the level hypothesis($H_{0,c}: p = 0.031$); meaning that *group* significantly influenced the subscale. Other predictors in the model namely *gender* and *ACT*, did not significantly influence the outcome.

3.11.3 EMMs: Estimated marginal means for the *time*group* interactions, as shown in Figure 3.8, indicate that the interaction was not significant. The DS group means, however, were significantly higher than the TS group means. The DS group enjoyed math and science more than the TS group compared to liberal art courses disregarding the *time* effects, or averaging over *time* as indicated in Figure 3.9. Interestingly, the overall marginal means remained above 3.49 on a scale of 1-5 as shown in Table 3.12. Irrespective of the group distinction, freshmen enjoyed math and science subjects more than liberal arts courses.

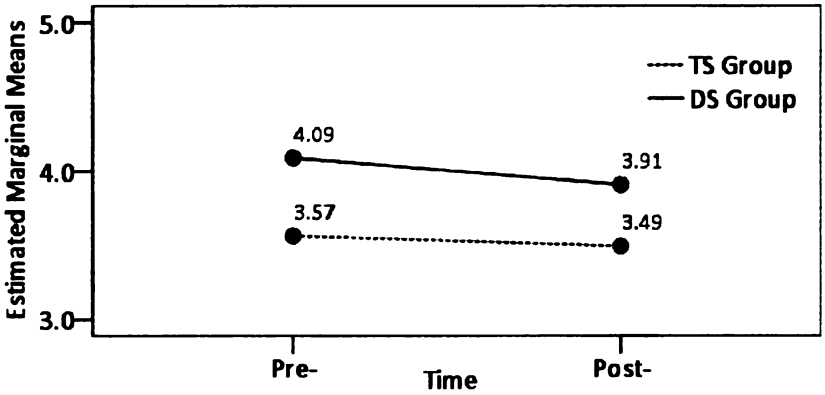

Figure 3.8: Profile plot of the *time*group* interaction on the math subscale. The longitudinal trajectories from pre-test to post-test for the two groups were nearly identical, which was why the interaction effect was not significant.

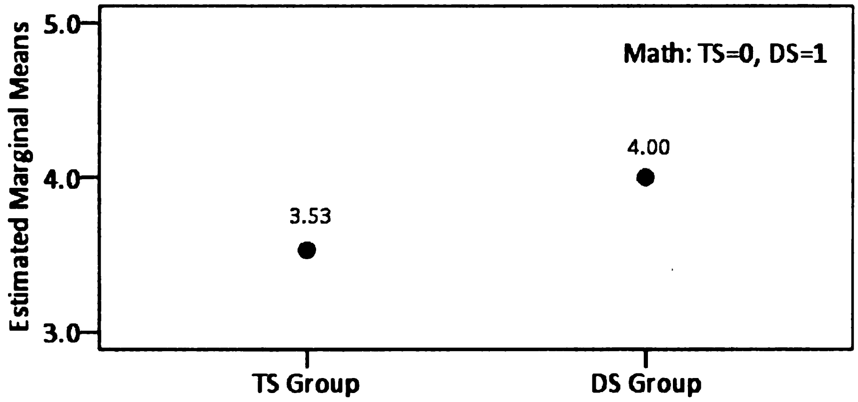

Figure 3.9: Profile points for *group* marginal means on the math subscale. The DS group enjoyed math more than the TS group compared to liberal art courses.

3.12 Exact (Pre6-Post6)

This subscale measured the freshman perception of engineering as an "exact" science. This is defined as how much they liked finding precise answers to problems vs. open ended problems, or multiple solutions to a given problem. This subscale, like the previous one, was asked in two different ways; hence it had two items (items 15, 26) as given in Table 3.3. Though a small scale, it signified an important constituent of the construct because engineering strongly encourages finding multiple or alternative solutions to a given problem.

3.12.1 Tests of WSFs: The model showed no interaction over *time* for any of the predictors. It failed to reject the flatness and parallelism hypotheses ($H_{0,a}: p = 0.194$, and $H_{0,b}: p = 0.149$). The two *groups* were not different in their perception of engineering as an exact science, meaning no treatment effect on this subscale. The partial eta squared measures show that these WSF effects explained very little of the variance in this subscale ($\eta^2 \leq 0.9\%$).

3.12.2 Tests of BSFs: The model showed significant contributions by all the predictors. It rejected the level hypothesis meaning that *group* significantly influenced the subscale ($H_{0,c} : p = 0.019$). *Gender* showed significant contributions (β_{pre}=-0.118, β_{post} = -0.281, p = 0.024 for females). Also *ACT* showed significant effect on the outcome (β_{pre}=-0.027, β_{post} = -0.047, p = 0.037). The partial eta squared values indicated the model was able to explain some variance in the subscale ($\eta^2 \leq 2.4\%$).

3.12.3 EMMs: Estimated marginal means for *time*group* interactions show that although the interaction was insignificant the overall *group* means remained above 3.5 on a scale of 1-5 as shown in Figure 3.10. More importantly, the TS group means remained significantly higher than the DS group means as also shown in Figure 3.11 and Table 3.12. It implies that the TS group perceived engineering as an exact science more than the DS group. Also, males had significantly higher perception of engineering as an exact science than females as shown in Table 3.12.

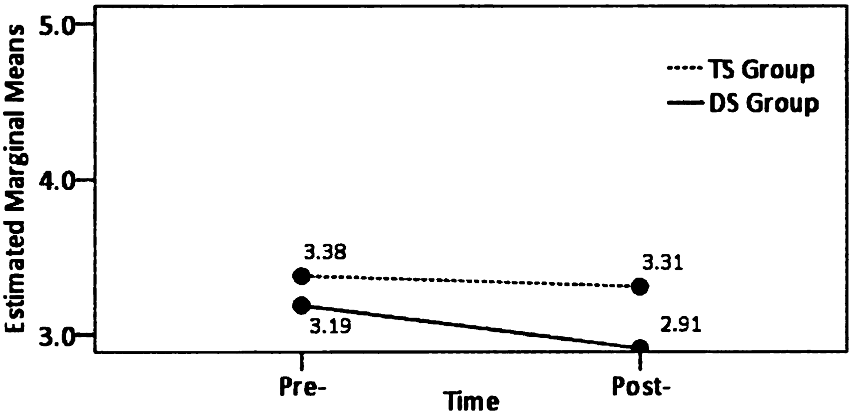

Figure 3.10: Profile plot of the *time*group* interaction on the exact subscale. The longitudinal trajectories from pre-test to post-test for the two groups were nearly identical, which was why the interaction effect was not significant.

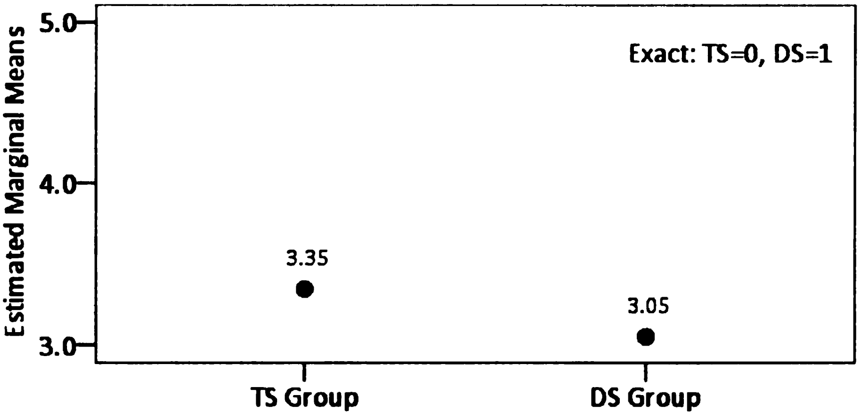

Figure 3.11: Profile points for *group* marginal means on the exact subscale. The TS group perceived engineering as an exact science more than the DS group.

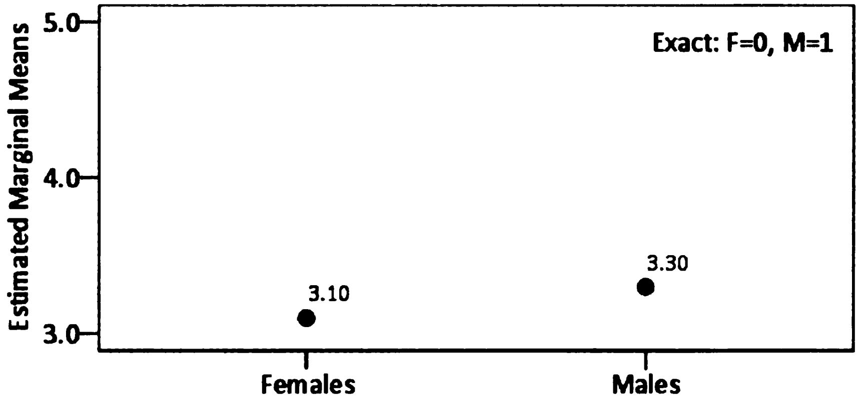

Figure 3.12: Profile points for *gender* marginal means on the exact subscale. Females perceived engineering as an exact science less than males.

3.13 Basic (Pre8-Post8)

This subscale measured the students' confidence level on basic engineering subjects (chemistry, physics and math), engineering skills and computer skills. The scale is comprised of five items, one for each of its ingredients (items 29-32, 35), as listed in Table 3.3.

3.13.1 Tests of WSFs: The parallelism hypothesis was rejected with the raw data, however, the corresponding test on the rank data failed to reject the parallelism hypothesis ($H_{0,b}: p = 0.013$ for raw data, $H_{0,b}: p = 0.058$ for rank data). The difference between the two tests was due to the presence of a few outliers in the raw data, and therefore the rank-transformed results were more credible. The two *groups* effectively had parallel trajectories in how their confidence in basic engineering knowledge and skills changed over the span of one semester. In other words, there was no treatment effect on this subscale. The tests also failed to reject the flatness hypothesis for both data sets ($H_{0,a}: p = 0.304$ for raw data, $H_{0,a}: p = 0.687$ for rank data) implying there was no *time* effect – the trajectories were not only parallel, they were also flat. Additionally, *gender* and *ACT* did not significantly interact with *time* in both the data sets. The partial eta squared measures show that these WSF effects explained very little of the variance in this subscale ($\eta^2 \leq 1.6\%$ for raw data and $\eta^2 \leq 0.1\%$ for rank data).

3.13.2 Tests of BSFs: These tests failed to reject the level hypothesis in both data sets ($H_{0,c}: p = 0.122$ for raw data, $H_{0,c}: p = 0.163\ for\ rank\ data$); *group* had no influence on the subscale when disregarding *time* effects. However, *gender* and *ACT* significantly influenced the subscale in both the data sets (*gender*: $p < 0.001$; *ACT:* β_{pre}=0.026, $\beta_{post} = 0.035$, p<0.001 for raw data, and β_{pre}=0.188, $\beta_{post} = 0.248$, p<0.001 for rank data). In other words, students with higher *ACT* scores had higher confidence in their engineering knowledge and skills when controlling for *gender* and *group* affiliations and disregarding the *time* effects.

3.13.3 EMMs: Estimated marginal means for *time*group* interaction indicates that though the interaction is not significant. The overall means remain above 3.55 on a scale of 1-5 for raw data and above 150 on a rank scale of 1-389 thus indicating that freshman generally had higher confidence levels in basic engineering knowledge and skills in both the groups (see Figures 3.13, 3.14 for raw and rank data profile plots, respectively, and

Table 3.12). Moreover, males were found to have a significantly higher confidence level in the basic engineering knowledge and skills than females when controlling for *group* and *ACT* and disregarding *time* effects, as shown in Figures 3.15 and 3.16 for raw and rank data, respectively, and Table 3.12.

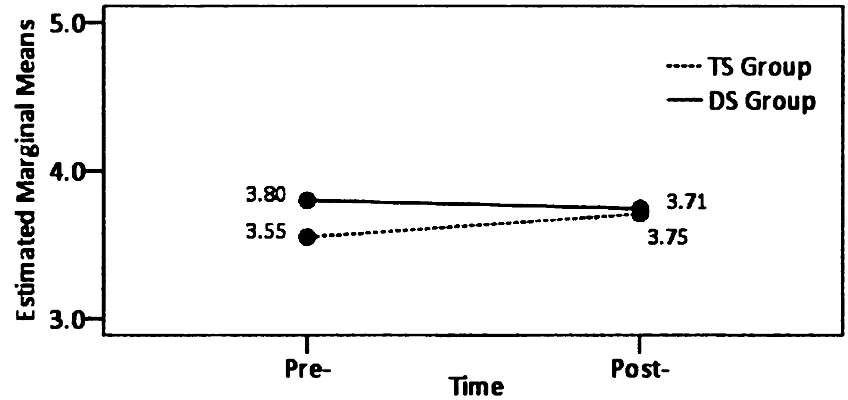

Figure 3.13: Profile plot of the *time*group* interaction on the basic subscale. The longitudinal trajectories from pre-test to post-test for the two groups differ significantly, but by a trivial amount that was due to the presence of few outliers.

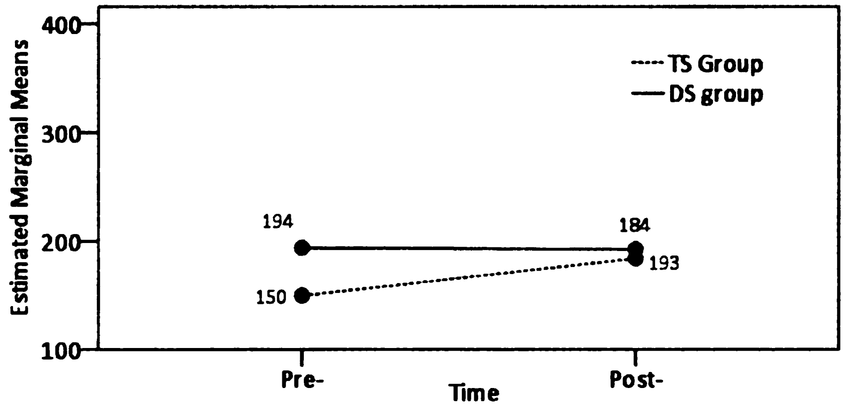

Figure 3.14: Profile plot of the *time*group* interaction for rank data on the basic subscale. The longitudinal trajectories from pre-test to post-test for the two groups were nearly identical, which was why the interaction effect was not significant.

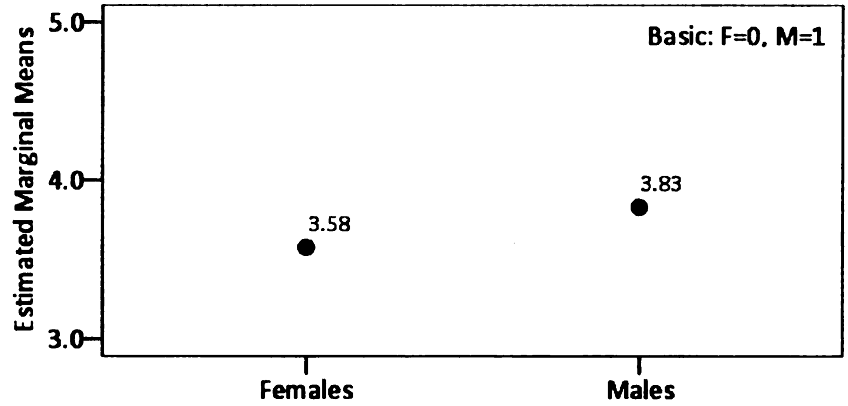

Figure 3.15: Profile points for *gender* marginal means on the basic subscale. Males had higher confidence level in basic engineering knowledge and skills than females.

Figure 3.16: Profile points for *gender* marginal means for rank data on the basic subscale. Males had higher confidence level in basic engineering knowledge and skills than females.

3.14 Communication (Pre9-Post9)

This subscale measures the student confidence level in their communication skills for three categories: writing, speaking and computer usage. The scale is comprised of three items, one for each of the categories as listed in Table 3.3.

3.14.1 Tests of WSFs: The model showed no significant interaction of any of the predictors over *time*. It failed to reject the flatness and parallelism hypotheses ($H_{0,a} : p = 0.318$, and $H_{0,b} : p = 0.593$). The two *groups* were not different in their confidence levels on communication skills, hence, no treatment effect was noticed on this subscale. Additionally, *gender* and *ACT* did not significantly interact with *time*. The partial eta squared measures show that these WSF effects explained very little of the variance in this subscale ($\eta^2 \leq 0.3\%$).

3.14.2 Tests of BSFs: These tests failed to reject the level hypothesis ($H_{0,c} : p = 0.459$); *group* had no influence on the subscale when disregarding *time* effects. In addition, *gender* and *ACT* did not influence the subscale. The model explained very little of the variance in the outcome ($\eta^2 \leq 0.2\%$).

3.14.3 EMMs: Estimated marginal means for *time*group* interaction indicates that though the interaction was not significant, the overall means remained above 3.5 on a scale of 1-5 as shown in Figure 3.17. This indicates that initial confidence in communication skills was positive and it remained positive over the semester for both groups.

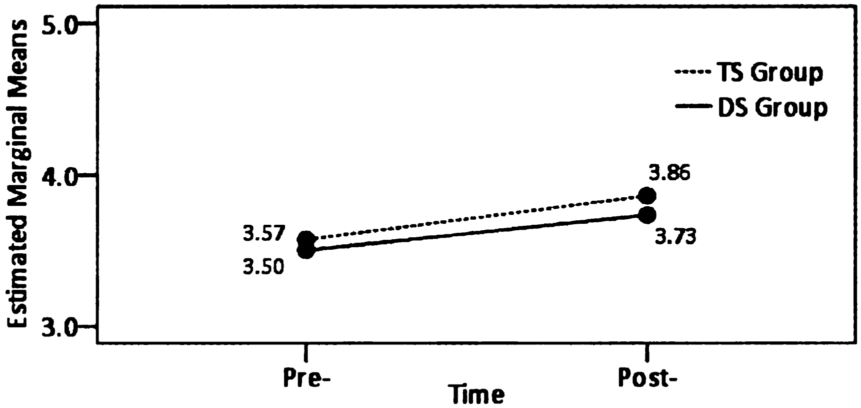

Figure 3.17: Profile plot of the *time*group* interaction on the communication subscale. The longitudinal trajectories from pre-test to post-test for the two groups were nearly identical, which was why the interaction effect was not significant.

3.15 Group (Pre11-Post11)

This subscale measured the student enjoyment of working in a group. It was one of the important subscales of engineering attitudes because a majority of engineering work involves group activity. The scale was comprised of three items (items 37, 43, 45) as listed in Table 3.3. Two of the items were reverse coded to retain a positive sense of the Likert scale.

3.15.1 Tests of WSFs: The tests failed to reject the flatness and parallelism hypotheses ($H_{0,a}: p = 0.992,$ and $H_{0,b}: p = 0.198$). The two *groups* were not different in their perception about group work over the span of one semester. Hence, no treatment effect was observed on this subscale. Additionally, *gender* and *ACT*, did not show significant interaction over *time*. The partial eta squared measures show that these WSF effects explained very little of the variance in this subscale ($\eta^2 \leq 0.4\%$).

3.15.2 Tests of BSFs: The model was unable to reject the level hypothesis ($H_{0,c}: p =$ 0.134); meaning that *group* did not significantly influence the subscale. *Gender* did not influence whereas *ACT* significantly influenced the subscale (β_{pre}=-0.043, $\beta_{post} = -0.049$, p<0.001). In other words, students with higher *ACT* scores had lower preference of working in groups when controlling for *gender* and *group* affiliations and disregarding the *time* effects. This was due to the *ACT*, that the model was able to explain some variance in the outcome as shown by the value of partial eta squared ($\eta^2 \leq 5.3\%$).

3.15.3 EMMs: Estimated marginal means for *time*group* interaction indicates that though the interaction was not significant, the overall means remained above 3.10 on a scale of 1-5 thus indicating that freshmen had neutral impression about the group activity (see Figure 3.18 and Table 3.12).

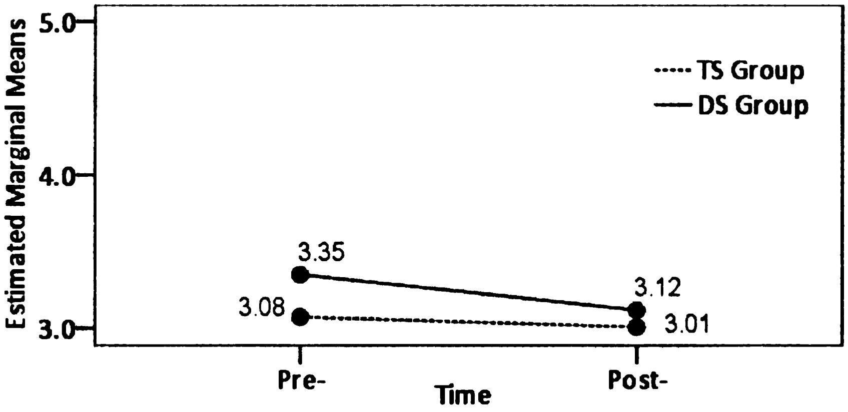

Figure 3.18: Profile plot of the *time*group* interaction on the group subscale. The longitudinal trajectories from pre-test to post-test for the two groups were nearly identical, which was why the interaction effect was not significant.

3.16 Ability (Pre12-Post12)

This subscale measured the students' problem solving abilities through creative thinking, confidence in success, and enjoyment of solving open ended problems. The scale was comprised of five items (Items 38, 40, 42, 49, 50) and was one of the important subscales of the main construct (Table 3.3).

3.16.1 Tests of WSFs: The model showed no significant interaction of any of the predictors over *time*. It failed to reject the flatness and parallelism hypotheses ($H_{0,a}: p = 0.115$, and $H_{0,b}: p = 0.497$). The two *groups* were not different in their perception of problem solving abilities. Hence, no treatment effect was observed on this subscale. The model as such explained very little of the variations in the outcome.

3.16.2 Tests of BSFs: The model was unable to reject the level hypothesis ($H_{0,c}: p = 0.475$) meaning that *group* did not significantly influence the subscale. In addition, *gender* significantly influenced (p = 0.05) and *ACT* did not influence the subscale. The model did not explain much of the variance in the subscale ($\eta^2 \leq 1\%$).

3.16.3 EMMs: Estimated marginal means for *time*group* interaction indicates that though the interaction was not significant, the overall means remained above 3.8 on a scale of 1-5 thus indicating that freshmen had a positive impression of their problem solving abilities (see Figure 3.19 and Table 3.12). Moreover, males had significantly higher perception of problem solving abilities than females as shown in Figure 3.20 and Table 3.12.

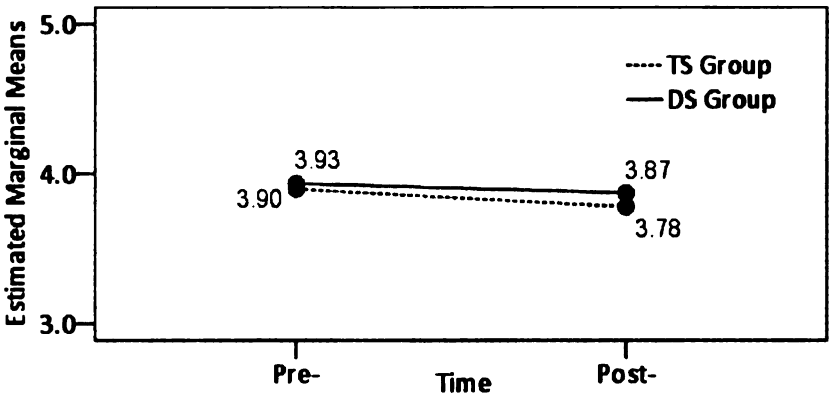

Figure 3.19: Profile plot of the *time*group* interaction on the ability subscale. The longitudinal trajectories from pre-test to post-test for the two groups were nearly identical, which was why the interaction effect was not significant.

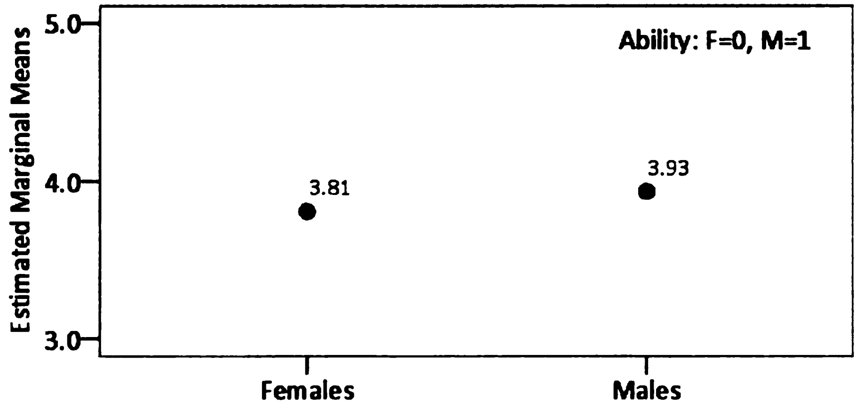

Figure 3.20: Profile points for *gender* marginal means on the ability subscale. Males had higher confidence of problem solving abilities than females.

3.17 Compatibility (Pre13-Post13)

This subscale measured the students' engineering abilities through confidence in engineering knowledge, design capabilities and inclination towards mechanical and technical abilities. The subscale was comprised of four items (Items 36, 44, 47, 48) as listed in Table 3.3. This was also considered an important subscale of the main construct.

3.17.1 Tests of WSFs: The model showed no significant interaction of any of the predictors over *time*. It failed to reject the flatness and parallelism hypotheses ($H_{0,a}: p = 0.465$, and $H_{0,b}: p = 0.078$). The two *groups* were not different in their perception of engineering abilities hence, no treatment effect was observed on this subscale. The model as such explained very little of the variance in the outcome ($\eta^2 \leq 0.8\%$).

3.17.2 Tests of BSFs: The model was unable to reject the level hypothesis meaning thereby that *group* did not significantly influence the subscale. *ACT* also did not influence the model but *gender* significantly affected the outcome ($p < 0.001$).The model explained some variance due to *gender* as noted by the values of eta squared ($\eta^2 \leq 4.5\%$).

3.17.3 EMMs: Estimated marginal means for *time*group* interaction indicates that though the interaction was not significant, the overall means remained above 3.37 on a scale of 1-5 thus indicating that freshmen had a mildly positive impression about their engineering abilities in both the *groups* (see Figure 3.21 and Table 3.12). Moreover, the EMMs indicate that males had significantly higher engineering abilities than females as shown in Figure 3.22 and Table 3.12.

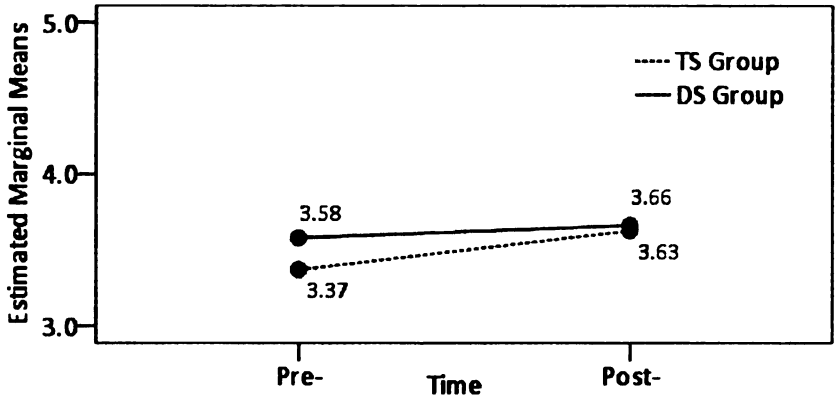

Figure 3.21: Profile plot of the *time*group* interaction on the compatibility subscale. The longitudinal trajectories from pre-test to post-test for the two groups were nearly identical, which was why the interaction effect was not significant.

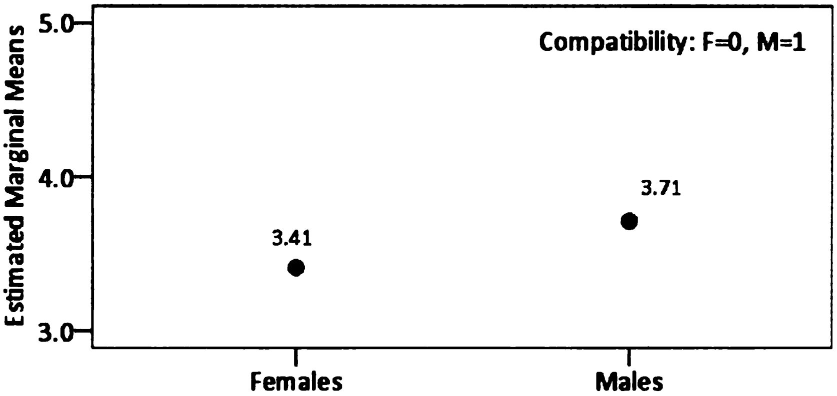

Figure 3.22: Profile points for *gender* marginal means on the compatibility subscale. Males had higher engineering abilities than females.

3.18 Summary of Analysis

A summary of the analyses on the ten repeated measures ANCOVA models is presented below [68-70].

- The parallelism hypothesis was not rejected in any of the ten outcomes; the *time * group* interactions were not statistically significant for any of the subscales. The significance noted in the raw data for two of the subscales – perception and basic – was due to four highly influential data points and therefore disregarded in favor of the rank-transformed results. There was no treatment effect on the DS group in terms of changes in freshman attitudes towards engineering compared to the TS group.

- The flatness hypothesis was not rejected in any of the ten outcomes; the student attitudes were not affected over *time* (pre-, post-) when disregarding the *group* membership. The partial eta squared measures show that the WSF effects explained very little of the variance in all the models ($\eta^2 \leq 2\%$).
- The EMMs for all the ten outcomes showed positive initial attitudes and these attitudes did not change during the course of one semester. The attitudes were measured on a raw scale of 1-5 (with scores of 1-2 meaning negative perceptions, 3 meaning neutral perceptions, and scores of 4-5 meaning positive perceptions). Career and perception, the most reliable PFEAS subscales, were strongly positive (M > 4.0). Freshmen had joined the program with strong perceptions about engineering in relation to innovation, creation, problem solving, and professionalism and respect for the career. Math, basic, communication, ability, and compatibility were positive (3.5 < M > 4.0), and society, exact, and group were mildly positive (3.0 < M > 3.5). The mildly positive subscales were either those that required the knowledge participants were not exposed to, *e.g.* working in groups, finding multiple solutions to a problem, or the subscales were low in reliability because of only two items. Notwithstanding the reason, none of the scales were negative. Most scales were positive in the beginning of the course and did not change during the semester.
- The level hypothesis was rejected in two subscales: math and exact. The DS group had higher EMM for math and lower EMM for exact compared to the TS

group. This means that DS group enjoyed math and science subjects more and was less likely to believe that engineering was an exact science. The significantly more positive attitudes in the DS group could be due to their stronger background in math and science (the DS group must meet a higher math requirement imposed by the CoE), higher *ACT* scores, and better understanding that engineering was not an exact science.

In addition to the three hypotheses, the models were examined for two covariates, *gender* and *ACT*, for their response in relation to other similar studies. Some interesting findings are outlined below.

- Definite gender differences were found in four of the subscales. Females rated lower than males in all the four attitude measures: basic; ability; compatibility; and exact. In other words females had lower confidence levels in basic engineering knowledge and skills, problem solving abilities, and engineering abilities. These findings are consistent with the literature in the area [11]. Interestingly, females perceived engineering as being an exact science less than their male counterparts. This means males liked finding precise answers to problems more than females. In other words, females showed a better inclination towards finding solutions to open ended problems and are, perhaps, more akin to engineering.
- The covariate, *ACT* significantly affected six of the subscales in both data sets: career, society, perception, exact, basic, and group. *ACT* was also related to the explanatory variable *group* – the DS group had higher *ACT* scores than the TS

group – which was why it was important to adjust for this covariate in the models. The literature also supports the strength of this predictor [9, 71].

3.19 Discussion

This part of the study was aimed at finding an answer to the primary research question whether the new cornerstone sequence was more effective than the older traditional sequence at positively influencing freshman attitudes about engineering over the course of one semester. A comparison of freshmen in the new DS group to freshmen in the previous TS group was done by collecting attitude data twice over the course of a semester. The data was examined for changes in the two groups' attitudes with repeated measures ANCOVA models. It was found that freshmen join the program with positive (EMMs > 3.00) and strongly positive (EMMs > 4.00) attitudes toward engineering that could be resistant to change. Students in the DS had higher *ACT* scores, enjoyed math and science more, and did not believe engineering to be an exact science. Some interesting results were found in how *gender* and *ACT* performed as covariates in the model. The DS group, however, had a similar longitudinal trajectory to the TS group, so there was no evidence of differential influence on student attitudes. In other words there was no treatment effect in the DS group.

The lack of treatment effect could be because of one or all of the factors given below that could have affected the models' ability (power) to detect differences.

- The DS was a set of newly designed courses that would certainly require a break-in period and constant feedback to reach a level of maturity before this could fully meet the course objectives. It may not be realistic to expect a new course to meet all of its goals and objectives at the outset.

- The short time between pre- and post- surveys – eleven weeks of experience – may simply not be enough to affect an appreciable change in the two groups' attitudes.
- The study only looked at one of the two DS courses that were designed for sequential treatment over the freshman year. The compound effect of taking the two courses in the intended sequence could be significantly larger than that of taking only the first part alone.
- The different data collection methods and their associated incentives for the TS and DS groups could have contributed to large differences in participation rates due to selection bias. There may have been a selection bias for higher achieving or more motivated students to complete the online surveys, which may have skewed the data for TS group.
- PFEAS subscales are being revised to further improve the internal reliability and structural validity of the scale [51]. The revised scale, whenever available, could improve the models' ability to detect intervention effects.
- The structure of the two groups was not based on the random selection. The TS group was comprised of students who could not be admitted to the DS courses for a number of reasons, and therefore could be skewed. There could be some strongly motivated students in the TS group who could not get admitted due to the shortage of classroom space or lack of pre requisites for the DS courses.

Based on the above, it was prudent to test the results of this phase with some other method that could validate the quantitative results, especially the lack of treatment effect. Qualitative methods are one way to probe deeper into the quantitative results, to better understand the construct, and bring out the subtle changes that are not possible with a quantitative approach [72]. A one-on-one interview with a representative sample, a qualitative approach, was adopted with further collection of data and its analysis [38]. The next chapter is devoted to the qualitative approach.

CHAPTER 4

THE QUALITATIVE PHASE

The most important findings of the quantitative phase of this study were that the tests of within subject factors (WSFs) had not been significant in any of the ten PFEAS sub-scales that collectively defined the main construct of the primary research question, namely, freshman attitudes towards engineering. These tests failed to reject the flatness and parallelism hypotheses for all the ten models. This implied that neither the new cornerstone sequence nor the older traditional sequence significantly affected the freshman attitudes over the course of a semester. It was hypothesized in the quantitative phase that perhaps a time frame of one semester of engineering experience (eleven weeks, to be precise - time between pre- and post- surveys) may not be enough to affect an appreciable change in freshman attitudes towards engineering. To probe deeper into the results of the quantitative phase, especially the lack of the treatment effect, qualitative methods are more suitable because they allow for the generation of rich, contextual description of data, also called a "thick" description [36].

As many researchers have pointed out, rigorous qualitative research involves its own set of data collection and analysis methods to ensure trustworthiness of the findings [73]. Qualitative methodology could generate rich and detailed descriptions of the student expectations and experiences for a deeper understanding of their attitudes [74]. It was therefore worthwhile to examine the student experiences and their expectations of the new sequence using qualitative methods to seek a possible relationship and to validate the earlier results. For this part of the study, the secondary research question was formulated (in Chapter 1): *What were the freshman expectations of and experiences in* *the new cornerstone sequence and how did they contribute (or not contribute) towards shaping their initial perceptions and attitudes about engineering?*

This chapter presents an investigation of the secondary research question by probing a sample of the new cornerstone sequence population with a qualitative approach. It has two key objectives: to describe the methodology of the approach (instrument development, data collection, reduction and display, conclusions and verification) and analysis of the data. The chapter is accordingly divided into two parts: Methods and Data Analysis/Discussion.

Part I - Methods

4.1 The Context

When the quantitative results are inadequate to provide explanation of outcomes, the problem may be better understood by using qualitative data to enrich and explain the quantitative results. In the quantitative phase we were unable to reject the parallelism hypothesis implying no-treatment-effect on the DS group insofar as freshman attitude towards engineering was concerned. A need was felt for further interpretation of the quantitative results, perhaps with more detailed views of select participants. For such situations mixed methods design is considered the preferred approach [75].

The qualitative approach for this study involved one-on-one interviews with a sample of freshman volunteers from the DS group. This part of the study was conducted in spring 2009, after the completion of the quantitative phase in fall 2008. A majority of the freshmen who took EGR100 in fall 2008, and hence would have participated in the quantitative phase, registered for EGR102 in spring 2009 (computer engineering and computer science majors take CSE 231 instead of EGR102). It was, therefore, a good opportunity to sample the same cohort of students from the DS group using one-on-one interviews for a deeper understanding of their attitudes. The participants were asked a number of open-ended questions regarding their experiences in the cornerstone sequence and whether these experiences affected their perceptions about engineering. It is pertinent to mention that this part of the study did not require data from the TS group because the secondary research question did not address it. The qualitative study is equivalent to testing of the flatness hypothesis in a quantitative study.

When considering the responses of the student participants, two factors are important. First, the student participants (freshmen) were young adults between 18-20 years of age, they were interviewed in a relaxed atmosphere, and they were assured that their views would be kept confidential and would not affect their grades. Second, an understanding of the cornerstone courses provides the context of the study, especially because many students commented on the peripheral details of these courses. It may, therefore, be worthwhile to revisit the cornerstone sequence before delving into the qualitative data.

4.2 Cornerstone Sequence - A Revisit

4.2.1 EGR 100: EGR 100 introduced the discipline of engineering to freshmen in their very first semester at MSU. These students had presumably joined the engineering program with varied and mixed initial perceptions. As it provides the first impression to new engineering students, it is argued that EGR 100 could play an important role in shaping their initial perceptions about engineering. The purpose of EGR 100 was to engage the freshmen with the engineering profession. At the end of this two credit course the students were expected to be able to: 1) implement an organized methodology in solving new and unfamiliar engineering design problems and effectively communicate the solutions to others; 2) function effectively on cross-functional design teams; and 3) understand the unique aspects of the engineering profession, its significance to society, its ethical framework, and career opportunities. The course was delivered in lecture-cum-recitation format (one 50-minute lecture followed by one 110-minute lab session per week). Lectures were delivered in a large lecture hall by the course instructor and subject specialists from different engineering disciplines. There were weekly clicker quizzes and lab assignments. No textbook was specified for the course.

The lab sessions were conducted by graduate teaching assistants (TAs). The laboratories were comprised of three team-based design projects conducted in groups of 4-5 students. The aim of these projects was to introduce the methodology for solving simple engineering problems in an integrated team setting without commitment to a specific engineering discipline. Several projects were experimented during the two pilot offerings of EGR 100 in fall 2007 and spring 2008. The projects for fall 2008 were selected on the basis of their relevance to the course objectives, positive student feedback from the pilot runs, and faculty discussions and recommendations. These projects were: 1) design, construct and test an edible car that meets project requirements, that is, to travel down a given track while minimizing the elapsed time; 2) determine the most cost-effective, eco-friendly means for a team to travel to a meeting site while minimizing total trip cost, carbon emissions, and elapsed time; and 3) design and prototype a product or process to remove a frequent inconvenience in your daily life.

4.2.2 EGR 102: EGR 102 was focused on the use of computational tools to solve engineering problems. The competencies the students were expected to demonstrate at the completion of this two credit course were: 1) strategy to solve engineering problems; 2) write programs to model systems using the MATLAB environment; and 3) portray two and three dimensional data in a meaningful manner, draw logical conclusions, and make appropriate recommendations using the MATLAB. The course was delivered in lecture-cum-recitation format (one 50-minute lecture followed by two 80-minute lab sessions per week). Unlike EGR 100, its weekly laboratories consisted of mostly MATLAB oriented individual assignments. It had one group project towards the end of the semester. The project involved a team of four students tasked with developing a MATLAB model for a water system to determine the necessity of a secondary water supply. EGR 102 was a fast paced course with weekly lecture and lab assignments as well as class quizzes. It required a strong mathematical base to fully understand the course content. No textbook was prescribed for this course.

4.3 Development of Interview Protocol

Qualitative research is characterized by two aspects: instrumentation, and context of the research question. Instrumentation involves development of qualitative instrument (surveys, interviews, focus group protocols etc.), and collection and examination of textual data. One-on-one interviews were the most suitable method for collecting qualitative data for this study because: 1) interviews can give the most detailed feedback; 2) interviews are flexible because they allow researchers to gauge initial reactions and probe for more in-depth responses; and 3) in a private encounter people tend to be more willing to speak their minds than they are in group settings.

The first step in the qualitative phase of the study was developing an instrument or the interview protocol. As mentioned earlier, Engineering Education is relatively new; it is rapidly developing to become an independent discipline of engineering [36, 76]. There is, understandably, a scarcity of reliable instruments especially in the realm of qualitative research because engineers do not often use qualitative methods [36]. There were no existing protocols for this kind of study in the literature. To economize on the efforts and time required for a valid and reliable instrument, the interview protocol was written in collaboration with the EEES research group[3] working on student expectations and experiences in the freshman year.

The interview protocol was developed in two parts in a semi-structured format to allow for flexibility in the order and precise content depending on the participants' responses [38, 39]. Part I, comprising seven items, addressed the general freshman experiences and expectations. This part was developed by the EEES research group; it focused on issues such as academic and social integration, motivation to pursue degree, classroom experiences and faculty integrations. Part I broadly covered the PFEAS subscales, and could be mapped on to the quantitative part of this study. The data from Part I was categorized into three subcategories: engineering perceptions, engineering abilities, and basic skills. This part prepared the participants to focus on their initial

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[3] The EEES (Engaging Early Engineering Students to Expand Numbers of Degree Recipients) research group was engaged in a pilot study to collect preliminary data in Spring 2009. This group works under the Center for Engineering Education Research (CEEE) that was established at MSU in August 2009.

perceptions and relate them to their experiences in the first two semesters of the engineering program.

Part II of the protocol was written by this researcher. It was specific to the cornerstone sequence and addressed the secondary research question. It focused on freshman experiences and expectations in the cornerstone sequence and how those experiences and expectations changed or did not change students' initial perceptions and attitudes towards engineering. This part of the protocol was comprised of six items that inquired into student experiences in EGR100 and EGR102 with regard to content learning and conduct of the courses, and their effects on participants' initial perceptions and attitudes towards engineering. For example, it asked the participants to: 1) describe their experiences in the DS courses; 2) compare their learning in the DS courses with learning in other courses; 3) how their thinking about themselves changed as a result of the DS courses; and 4) how their perception about engineering changed since they joined the DS courses. Two subcategories emerged from this part: DS experiences and DS effects on perceptions. Probing questions were used to prompt participants to explore their experiences in the DS courses and to keep them focused on how those experiences affected their initial perceptions about engineering.

To ensure good validity and reliability, the protocol was reviewed, pilot tested, and finally used on one common sample for data collection. It was reviewed by four experts from two colleges, the College of Education and the College of Engineering, for content, selection of probes, sequence of questions, and wording of questions that may resonate better with undergraduate freshmen. It was then tested on three engineering graduate students to confirm that the item statements were clear, concise, and conveyed what they were meant to convey without confusion or ambiguity. The protocol was pilot tested on a sophomore in the College of Engineering who had recently experienced the first-year transition into engineering. This student provided feedback on both form and content and suggested additional probes based on his experience. The instrument and its associated consent form were approved by the university's IRB before they were used for this study in spring 2009. The interview protocol is attached as Appendix C [77].

4.4 The Sample

A total of 533 freshmen were registered for spring 2009. All of these freshmen, except 14 transfer cases and 8 first semester students, registered for one or both of the DS courses. In other words, the TS group was almost nonexistent in the population. This was not a disadvantage because this part of the study required data from the DS group only – the secondary research question addressed the experiences and expectations of the DS group. The population for this part of the study was comprised of 272 freshmen – those who had experienced EGR 100 in fall 2008 and were enrolled for EGR 102 in spring 2009. It is important to note that a portion of the population that opted for computer engineering or computer science majors did not take EGR 102 and was therefore not a part of the population for the qualitative phase. The population was approached through a recruitment e-mail to participate in one-on-one interviews and earn $25 as compensation. A good-to-moderate response was expected (20~25%). The intent was to form a stratified sample of approximately 10-15 students from various demographic backgrounds and levels of academic achievement. Unfortunately, fewer students responded than expected. Ten students volunteered as a result of six e-mail attempts to 113 students. All ten respondents were interviewed towards the end of the semester to ensure they had sufficient exposure to EGR102. Table 4.1 presents the breakdown of the sample's characteristics, demographics, and their pseudonyms.

Student ID	**Ethnicity***	**Gender**	**ACT Score**	**Declared Engineering Major**	**EGR100 Term**	**EGR100 Grade**	**Current Semester**
Sara	African	Female	19.00	Electrical	FS08	3.0	SS09
Lora	Caucasian	Female	30.00	Bio-systems	FS08	3.0	SS09
Erin	Caucasian	Female	23.00	Civil	FS08	3.5	SS09
Jane	Caucasian	Female	23.00	Bio-systems	FS08	4.0	SS09
Pat	Caucasian	Male	25.00	Civil	FS08	3.5	SS09
Matt	African	Male	17.00	Electrical	FS08	3.5	SS09
Don	Caucasian	Male	25.00	Mechanical	FS08	4.0	SS09
Brad	Caucasian	Male	34.00	Mechanical	FS08	4.0	SS09
Mike	Caucasian	Male	28.00	Applied. Sciences	FS08	4.0	SS09
Jon	African†	Male	20.00	Electrical	FS08	4.0	SS09

*Ethnic designation based on self-identification. † Not African American.

Table 4.1: The sample characteristics showing pseudonyms, demographics and academic performmance.

The demographics of the sample were not fully representative of the College student population in terms of ethnicity and gender. The fall 2008 statistics for the College[4] was not truly reflected in the sample insofar as the ethnic minorities were concerned. This is not surprising given the sample size. The majority ethnic group, Caucasian, was adequately represented but minority groups such as Hispanics and Asians were not represented at all. It may be noted that three participants self identified as minorities. The characteristics of the sample roughly matched the target population in terms of ACT scores and EGR 100 course grades. The participants' gender distribution was skewed (40% females) since females actually made up 20% of the target population.

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[4] Caucasians: 77.8%, African Americans: 5.8%, Asians: 5.4%, Hispanic: 1.8%, American Indians: 0.6%, not reported: 8.5%, Females: 16.9%, Males: 83.1%, ACT lowest 25th percentile: < 23, ACT middle 50th percentile: 23-27, ACT highest 25th percentile: > 27 – Office of the Associate Dean, Sep 9, 2008.

Over-sampling here helped to examine possible diversity of views among female students because success of women in engineering is an important issue [4, 78]. Table 4.2 presents a comparison of the characteristics of the participants in the sample with the targeted freshman population in terms of their EGR 100 course grades, ACT-composite score, and gender.

Group	**N/n**	**EGR 100 GPA Fall 08**		**ACT-Composite Scores***			***Gender* (Females)***
		≤ 3.0	**> 3.0**	**Lowest**	**Middle 50%**	**Highest 25%**	
Population	272	14%	85%	13%	53%	34%	*20%*
Sample	*10*	*20%*	*80%*	*30%*	*40%*	*30%*	*40%*

* see footnote 4 for CoE statistics for fall 2008.

Table 4.2: Characteristics of the sample vs. the population.

An interesting aspect of the sample was that all the ten participants belonged to Category-1, engineering-preference (see Chapter 1); they could remain in the program for two years to take this decision. It points towards their strong preference for the engineering major. The demographic peculiarities of the sample and their relationship with the target population were important and kept in view while drawing conclusions from the results.

4.5 Data Collection, Reduction, and Display

The interviews with the participants were conducted one-on-one by the researcher from the EEES research group, and observed by this researcher, during the 13th-15th weeks of the semester. The interviews took 60-75 minutes per participant. The purpose of the research was explained to the interviewees and their written consent was obtained before each interview in accordance with the IRB regulations. These interviews were audio recorded in addition to taking of field notes by the two researchers. At the conclusion of each interview session, the two researchers reviewed, elaborated, and consolidated the field notes to ensure the data were complete. The interviews were transcribed by a professional transcriptionist. The transcriptions were substantiated with the consolidated field notes of the interviewer and the observer.

The raw data was simplified, reduced, and transformed by coding statements into categories for various themes [72]. The raw transcribed file of the ten participants was large. It had redundancies, repetitions and errors/omissions due to voice/dialect recognition issues. The redundancies, repetitions, errors/omissions were carefully examined in the context of the subject and removed/corrected with the mutual consent of the two researchers. Each transcript was studied in depth to identify the relevant quotes and to group them into the selected themes in case of Part I, and emergent themes in case of Part II. Following the coding process, the ideas were grouped into themes, subcategories and groups and finally converted into a matrix of key themes. The data was then revisited to note the presence or absence of these themes in each of the interviews and coded for each theme as '+' (positive response), '–' (negative response), '0' (neutral response), and 'blank' (absence of a response) [38, 72]. In this manner the data was reduced to the display in Table 4.3 and converted into a primary data file for further analysis. The qualitative display was intended to present the data in an organized, compressed format that could permit illustration of certain patterns and help in forming logical and key conclusions [38]. The data reduction and display was independently developed by the two researchers, and was later compared, verified and validated for inter-coder reliability check before drawing conclusions [79].

Student ID	Interview Protocol Part I			Interview Protocol Part II							
	Engineering Perceptions	Engineering Abilities	Basic Skills	DS Experiences							DS Effects on Perceptions
				EGR100				EGR102			
				A	B	C	D	B	C	D	
Sara	+	+ †	†	-	-		-	0	-	-†	0 †
Lora	+	+	-	-			-	+			+
Erin	0	+	-	+	+			+	-		0
Jane	+	0	+	0	0			+	0	0	0
Pat	+	+	0	-	-	-	-	+	-	+	0
Matt	+	+		+	0	+	-	-	-	+	0
Don	+	+	0	0	-	-	-	-			0
Brad	+	+	+	-	-	-	-	+	0	+	0
Mike	+	+	+	0			-	+		+	+
Jon	+	+	+	+					-		0

* *A-Projects experiences, B-Class experiences, C-Time per credit, D-Conduct of course,*
† '+' *Positive response,* '-' *Negative response,* '0' *Neutral response,* 'blank' *No response*

Table 4.3: Qualitative data display showing presence or absence of themes for each participant.

Before analyzing the qualitative data, a brief explanation of various themes, subcategories and their relevance to the research question is given below.

4.5.1 Part I - General Engineering Perceptions: The data in this part broadly covered the PFEAS subscales and was grouped into three subcategories:

4.5.1.1 Engineering Perceptions: This category was broad in meaning; it encompassed several themes to include participants' perceptions about engineering as a discipline, major, career, job, and profession. It also included their perception of engineering as an art, engineering as a science, its impact on society, and parent/ teacher influences on the formation of such perceptions. With regard to the PFEAS sub-scales, the category included themes that broadly covered six of the thirteen sub-scales: sub-scale 1, 2, 3, 4, 6, and 7 as given in Table 3.1.

4.5.1.2 Engineering Abilities: This category included themes on the participants' confidence in problem solving abilities, technical inclination, designing abilities, ability to work in groups, and their study habits. In terms of PFEAS sub-scales, the themes broadly covered four of the thirteen sub-scales: sub-scale 10, 11, 12, and 13 as shown in Table 3.1.

4.5.1.3 Basic Skills: This category included themes on the participants' science skills including math, physics, chemistry, and computers, and communication skills including writing and speaking. In terms of PFEAS sub-scales, the themes broadly covered three of the thirteen sub-scales: sub-scale 5, 8, and 9 as shown in Table 3.1.

4.5.2 Part II - DS Related Perceptions: Part II of the protocol was specific to the cornerstone sequence. It was divided into two subcategories: DS experiences and DS effects on perceptions.

4.5.2.1 DS Experiences: Participants talked about their expectations of and experiences in the two courses in four themes: 1) Project experiences in three group project activities during lab sessions; 2) Class experiences in lectures and Powerpoint presentations; 3) Time per credit expended by the students; and 4) Conduct of the courses. The data for this subcategory was primarily collected with the first four items of Part II.

4.5.2.2 DS Effects on Perceptions: This subcategory was the most important with regard to the research question. It focused on one theme: did the participants' perception about engineering change because of their experiences in the new freshman sequence courses. The focus of the analysis for this theme was on the last two items of the instrument.

Part II - Analysis/Discussion

4.6 Data Analysis

The data was analyzed by examining the pattern of each theme with supporting quotes as evidence. The aim was to capture the participants' true feelings in all possible dimensions without prejudice to any one specific opinion. As mentioned earlier, Part I of the protocol was a reflection of the PFEAS subscales and was primarily developed by the EEES research group. The data in this part was mapped onto the results of the quantitative phase. Part II was specifically developed for this study and was treated at length to explore initial perceptions of freshmen and why the initial perceptions were not affected by the treatment. The subsections below provide a detailed description of the data analysis with relevant quotes. Some parts of the quotes are italicized by the author to add emphasis.

4.6.1 Part I - General Engineering Perceptions: A general view of the data showed the majority of participants responded positively to Part I of the Protocol. Themes in two of the subcategories, engineering perceptions and engineering abilities, were overwhelmingly positive whereas themes in the third subcategory, basic skills, had mixed responses. The data showed that the participants joined the freshman year with strongly positive perceptions about engineering and had confidence about their engineering abilities. However, they had mixed feelings about their basic skills, *i.e.* basic sciences, computer and communication skills. The three subcategories are briefly discussed below.

4.6.1.1 Engineering Perceptions: Positive engineering perceptions of the participants were deeply rooted and had been developed over time, often since childhood. Parents and high school teachers played an important role in developing these perceptions especially if they themselves were engineers. Talking of positive engineering perceptions, Don[5], like most of the other participants, viewed parents and high school teachers as a source of inspiration. For him, selection of mechanical engineering was a natural instinct since he grew up around automobiles as was apparent from this statement:

> Well my dad actually works for BMW of North America. He previously was a master mechanic in a shop, certified many times and won a lot of awards. He's an absolute genius when it comes to automobiles. So growing up it was an inspiration there. Also, one of my favorite teachers in high school was an engineer... She always said that I was capable of it because of my math skills so it was kind of an inspiration... I kind of grew up with an engineering background.

The participants defined three aspects of engineering that interested them, in addition to their general interest in math and physics: 1) engineering as a practical, hands-on profession; 2) problem solving nature of the job with multiple solutions; and 3) working on projects in a team setting. They appreciated engineering in different roles, *i.e.* as a discipline, as a job, as a profession, etc. and they liked all of these roles. Pat was highly motivated to be a mechanical engineer. He defined and described what he liked about engineering in these words:

> I always liked the problem-solving and working in teams. In engineering, there is a lot of different ways to get to that one solution and it makes you think about all those different possibilities. So you kind of see yourself as a kind of problem-solving, hands-on type. I loved to see how things worked, whether it was a refrigerator or how a house was put together, anything. So I always wanted to be a mechanical engineer.

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[5] All names in this document are fictitious and used only for illustrative purposes.

Most of the participants enjoyed math and physics. They understood the requirement of the basic science subjects for engineering and took engineering as a natural consequence. Brad, for example described engineering in these words:

> Since I was junior high, maybe even earlier, I've known I was going to do engineering of some type... I haven't really had to make a decision on what field to study, to pursue, because math always came easy, physics always came easy, and those are what I enjoyed. I wanted to get into design of some kind with a math and physics background. And that's basically describing engineering.

The participants were also aware that engineering was not math and science alone. Mike, for example, talked about his perception of engineers in these words: "Engineers can do more than just math." Lora, a Bio-systems major, did not like math and physics, yet she was persistent to continue with her choice because she knew she could still be successful in her choice of engineering if she could survive the initial challenges of math and physics. She said:

> I am not a math major and I am not really interested in physics but I got to take them. And it kind of turned me off engineering a little bit... So I was actually considering switching out of engineering at the beginning of the semester.

When asked what kept her in, she said:

> I was looking at the classes, I was like , if I can just get through these, you know, two more classes of calculus, one more class of physics and then I can start taking the stuff I' m actually interested in. So I gave it a second chance.

The participants considered engineering as a rewarding career that could earn them a good job with decent salary despite the economic crunch these days. Mike, for example, said:

> I'm willing to work hard, and I think engineering will make me work hard... So, I just want to get basically a solid degree that will be able to give me a job and make money.

Interestingly, Don termed engineering as "artistic" because he believed every engineer is unique and innovative. His elaboration of this notion shows a strong commitment and desire to become an engineer:

> It's more rewarding just because it's something that I would actually appreciate doing, working on a design team, getting to actually express your own opinions and kind of being artistic at the same time that you're getting paid to do work and crunch numbers... The idea of being in a group project and having your own opinion to solve a problem in a way that nobody else saw that it could be solved,... to have that intricacy. And everybody has that capability, every engineer at least, and to have a whole bunch of those people together it's just an awesome, awesome experience.

Positive engineering perceptions were deeply rooted and had developed over time since childhood. Parents and teachers played an important role in the development of these perceptions. Participants defined what it meant to be an engineer with practical hands-on nature; they appreciated working in teams and problem solving with multiple solutions. They mostly liked math and science subjects, those few who did not like them understood their requirement for engineering and took them as challenges. Some termed engineering as artistic and rewarding and commented that they "really enjoy design and engineering".

4.6.1.2 Engineering Abilities: The participants commented on their confidence and understanding of their engineering abilities specifically problem solving, designing, leadership, and working in groups. Sara, for example, elaborated on different engineering skills and expressed her confidence of these skills in these words:

> Team working skills, problem solving skills, are able to work under little supervision, and be able to communicate when you need help. You got to analyze things and review things and do compare and contrast; you don't really get the opportunity to do that as much as in engineering... I like learning new stuff; I like not always knowing the answer... Coming up with a new way to get the answer.

Lora added to Sara's description of engineering abilities, though she did not express her explicit fondness for these abilities. She believed creativity and knowledge, in addition to good communication and team work, were important for engineers.

> Definitely you got to be creative about thinking of solutions to your problems. You got to know about pretty much all aspects of engineering... In a group working on the same project, you got to be able to know what other people are talking about. You have to be able to work well with others, like good communication.

Two aspects of engineering abilities were new to the participants because they were not fully exposed to these activities in their high school years: working in groups, and finding multiple solutions to a given problem. Irrespective of whether they liked these activities or not, most students appreciated their importance in engineering. Pat said while comparing engineering with other degrees:

> I always liked the problem-solving and working in teams... Other degrees it's like, 'learn this, learn this, here's the equation." In engineering, it's like there is a lot of different ways to get to that one solution and it makes you think about all those different possibilities.

Jon on the other hand was not happy with the team work aspect though he appreciated its importance. He expressed his views in these words:

> It is all part of the experience. Not just getting the project done but figuring out the way to adapt to what is going on to the group of people working on the project. Some people are satisfied; some

> people find ways to come to an agreement, some people just don't work out. And we were the one team with the people that somewhat didn't work out... That part was the hardest part of the projects.

4.6.1.3 Basic Skills: Participants cited the match between basic skills and the demands of engineering as a motivating force for selecting the engineering major. Mike, for example, based his decision on his math and writing skills:

> I've been strong in math and my writing was okay. And I discovered the applied engineering sciences major, which kind of implemented both and decided that's what I was going to do.

Some participants did not like basic science subjects. They, however, considered them as initial challenges and expressed their confidence to overcome those in due course to achieve proficiency in the basic skills. Lora, as noted earlier, was not happy with her performance in math and physics but was persistent in continuing with the major and meeting these challenges:

> I had to repeat my calculus class because I did not do so great the first semester... math is not my favorite subject and neither is physics, and not really sure why I have to take so many classes of it. I know it's like the general college requirement, so I'm pretty sure that mechanical engineering needs to know that stuff. But that's definitely been a challenge ... But I know I have to take them.

Part I of the protocol inquired about participants' initial perceptions and expectations as they joined the program, and their experiences and challenges during the freshman year. The three subcategories and their related themes from this part were considered an extension of the PFEAS subscales. Participants' responses were aligned with the quantitative results in so far as the flatness hypothesis was concerned. The DS group had joined the program with strongly positive initial perceptions about engineering. They could define engineering in many roles and expressed confidence in their engineering abilities and basic skills. They appreciated their new experiences of team work and problem solving with multiple solutions. The majority understood that engineering was much more than math and physics. Those who liked these basic science subjects correlated them to their preference for engineering; those who did not like them still persisted to continue, considering them as challenges.

4.6.2 Part II - DS Related Perceptions: This part of the protocol was specific to the cornerstone sequence and directly addressed the secondary research question. It focused on freshman experiences and expectations in the cornerstone sequence and how those experiences affected their initial perceptions and attitudes about engineering. Two major subcategories emerged: DS experiences and DS effects on perceptions, each of which had themes.

4.6.2.1 DS Experiences: The two courses in the cornerstone sequence were distinctly different in their objectives. EGR 100 was an introductory level course aimed at engaging the students with the profession of engineering emphasizing the importance of organized methodology, team work, good communication, work ethics and multi-dimensional problem solving. The course involved extensive team work on small projects. EGR 102, on the other hand, was focused on the use of computational tools to solve engineering problems, mathematical modeling with specific solutions, and much more individual work. Understandably, student reactions were different for the two courses, as discussed below.

EGR 100: The participants' expectations were not very well aligned with the course objectives. They expected the course to be more of an advanced exposure to engineering design with real world engineering projects. Their responses could, therefore, be misleading if not seen in the context of the course objectives. The data emerged into four themes: project experiences, class experiences (other than projects), time per credit (appropriateness of time spent per credit hour), and course conduct. The participants' responses were mostly negative but some were positive in all of the four themes.

Project Experiences: The projects for this course were designed to get students to appreciate the importance of implementing an organized a methodology for solving a given design problem. The emphasis was on the process, not on the problem itself. Participants seemed to have somehow missed out on the projects' objectives. Seven out of ten participants were not happy with the projects; they considered them irrelevant, boring, and out of the context of engineering. Some did like projects but complained of logistic problems and less-learning-more-fun. Sara conveyed her disappointment in these words: "Not one project I did in EGR100 that I felt like helped me engineering wise, not one…" Pat furthered Sara's point of view. To him the projects had no relevance to engineering; they were there just to keep students busy:

> I wasn't a huge fan of a lot of the projects… They were boring. I thought they had nothing to do with engineering. They were just kind of mundane tasks. It almost seemed like busy work. That's what I definitely felt like and talking with other students in the class, they definitely felt like as well.

Matt, like few others, enjoyed the project experience and called them 'fun time', but desired more science and math content.

> I think EGR 100 was like the best experience for me... pretty much what I expected, come here and learn something and still have fun at the same time... fun thing is to just work in groups, figure out those things... I think if they would have threw [*sic*] a little more math - I mean calculus and chemistry... in Engineer100 and kind of prepared me for 102.

Erin, liked projects but had trouble in the implementation phase. She expressed her views:

> I enjoyed EGR100 better just because of the projects. The projects were kind of cool... it at time seemed like it was kind of a pain in the butt because we were freshmen. And it was hard to be able to go get stuff. But then once we figured that out that the bus went right to Meijer [grocery store], it was all right.

The students' expectations were different from the project objectives. They were more interested in the problem solving aspect than its process. As this was their first exposure to a design project, they expected to see in it everything they knew about engineering. The responses of Pat and Sara should, therefore, not be surprising. They found the projects overly simple with no direct relation to engineering, for example, the food car project, and were obviously disappointed. There was a mismatch between student expectations and the learning objectives; hence the participants called the activities "boring" and "pointless". However, they appreciated the benefits of team work and the intricacies of logistics involved in managing the work together.

Class Experiences: The class lectures were organized in an attempt to cause the student to appreciate the unique aspects of engineering profession, its significance to society, its ethical framework, and career opportunities in this field. In addition to the class instructor, lectures were delivered by the experts in different engineering disciplines from academia and industry. The participants had more negative than positive feelings about the class lectures. Four out of seven respondents (three did not respond) thought the lectures were not interesting and they attended only for clicker quizzes. Pat did not like the class lectures, he called them boring and pointless in these words:

> It was a class that you went to every week and you just did the quiz and then you just kind of sat there because it was pointless. I think a lot of other people felt the same way. You didn't gain anything from it… It wasn't interesting compared with some of my other classes. It didn't really intrigue me in any way… I've seriously considered not being an engineer before because of the classes. Because I've thought, "Man, these classes are so boring. This is what the whole Engineering School is going to be like".

Pat's statement was strong with some serious ramifications, and may require study of the type of instructional material and the instructor's teaching style – the two aspects out of the scope of this study. It, however, was apparent that lectures in large lecture halls were not generating enough interest. Don had similar sentiments about the lectures:

> You could've just stayed home, read the Power Point that he [instructor] posted on Angel and you would've gotten the exact same education. The only reason that you went to class for EGR100 was for the clicker quizzes.

Erin felt differently. To her the class was helpful in understanding the engineering profession and its different disciplines:

> I thought EGR100 was really helpful because I was able to meet with people and get an introduction to engineering. Hear from the professors from all different majors so… it would really help you decide what you wanted to do before you got three years into it and decided that wasn't what you wanted. It helps you be familiar with some policies and things that happened and how stuff worked.

Time per Credit: Unlike the class lectures which some students liked and others didn't, they unanimously agreed that the work load for the project portion was too high. Students were new to group work and faced difficulties in communication and decision making in a group activity. They suggested the credit hours be adjusted to reflect actual and realistic time requirements. Pat indicated his frustration about how much time he spent on the projects.

> There would be weeks where we spent twenty hours on a project for EGR 100… and this is a two-credit class. So that was definitely frustrating. It's a lot of work for a two-credit class.

Don supported Pat's views:

> I think we would've really appreciated it if it was either a reduced workload or if it was at least a 3-credit course. There was a lot of work… I didn't spend that much time studying for my 4-credit classes.

Brad summed up student frustration on time spent on projects in these words:

> They're two-credit courses, but the amount of time I was expected to put into them was way beyond what I feel a two-credit course

> should be. EGR100, I spent hours and hours and hours doing that Food Car project. I don't know how many trips to Meijer I made, and it ended up being a two-credit...

Talking about the timing of the projects, Mike thought it was too early to do group projects. He said:

> I was surprised at the physical aspects of it, where we had to make, within the first few weeks, a food car with a group of random kids. And it was a little weird because I didn't really know where anything was and they expected us to go out and buy food and stuff and I had really no idea how to even get places... *they just gave the project really soon..*

The participants touched on two issues with regard to the work load for this course: projects were time consuming and they were given too early in the course. They admitted though that the projects were simple and did not require much of engineering knowledge. It may be pertinent to point out that for many of the freshmen this was the first time they were exposed to an independent environment away from their homes. They did not have a personal transport (freshmen are not allowed to keep automobiles on campus), so their travel was restricted to foot, bicycle or public transport. They were passing through a life changing phase. They were grouped in teams of students whom they were meeting for the first time and they had to learn to adjust to each other's personality and yet produce a joint work within the time constraint. All of these issues take time to settle and this time varies from individual to individual. Some of the students took more time to adjust than others, especially in the group work, hence the complaint about projects given too soon.

Conduct of the Course: Fall 2008 was the first semester when the cornerstone sequence was in full swing. It was expected to encounter problems and difficulties in the beginning. All participants opined that the course lacked in preparation and execution, and that it had no prescribed syllabus and textbooks. They unanimously agreed that lectures and projects were easy, and required little or no preparation to earn a good grade. Sara expressed her concern about the course execution. She reflected:

> Well, I have that easier EGR100 course which is a total waste of time in my opinion… They had really pointless assignments. It didn't have a topic… I just don't feel like it was executed well.

Brad, like most others, knew EGR 100 was a new course and that new courses do not go as well as the established ones. He recounted that:

> It seemed like they were still trying to work some kinks out. And that just didn't really feel that good, being like the guinea pigs. I know it's a new course, so that's probably to be expected – a little bit of a sense of disorganization...

Brad went on to say that course was not difficult from the material standpoint:

> It didn't seem like there was any real testable material that we talked about… And they weren't too hard. I mean, I feel like someone off the street could walk in and take EGR100 exam and pass it on common sense alone…

Don supported Brad on the course difficulty level and claimed his 4.0 came with little effort:

> Most of EGR 100 was just kind of straightforward. It was pretty easy and I can't really say anything that was really difficult in lecture or lab really. It's all prior knowledge, it's as long as you understand human beings you will pass the class. To be completely honest, I didn't study once for the midterm exam or final exam, and I 4-pointed the class.

The course was considered easy in terms of its content by most of the participants. They did not find enough challenge in it; lectures were easy, projects were easy, and there was not much testable material to prepare to get a good grade. Students knew it was a new course and were somewhat aware of the problems with new courses.

Unfortunately, all but few of the participants were dissatisfied with EGR 100 in terms of their class experiences. Although this introductory level course was aimed at motivating and engaging students to the discipline of engineering, the majority of participants criticized the course in all the areas: projects, lectures, conduct, and workload. The main cause for general dissatisfaction was that their expectations did not match the course objectives. They joined the course with strongly positive perceptions about engineering. They expected to learn and implement engineering design techniques in some real world design projects. Their experiences fell short of their expectations. They found projects boring and lectures as pointless activities. They appreciated the new experience of working in teams but reported excessive time consumed in team activities due to communication, coordination and logistics issues. Although the majority participants expressed excitement about studying engineering, this first introductory course failed to build upon that enthusiasm.

EGR 102: This two credit course was primarily designed to learn problem solving with the MATLAB. The typical class session would begin with a lecture on a MATLAB aspect followed by a programming assignment and a quiz at the end. It was a well structured course with definite boundaries and mostly individual assignments except one project activity towards the end of the course. The course contents were not new; they had been taught in other courses for a long time and had well organized lecture plans with focused activity. The students' responses emerged into three themes: course experiences, course credits, and conduct of the course. Unlike EGR 100, participants mostly enjoyed the learning experience of this course mainly because their expectations were aligned with the course objectives. Some participants, however, reported a disproportionately high level of difficulty.

Course Experiences: Participants had mostly positive experiences in this course. Those who liked math liked EGR 102 because MATLAB is based on math concepts. Unlike EGR 100, this course had a more focused approach that participants appreciated. The participants' expectations seemed to align with the course objectives. Talking of positive learning experiences, Lora compared the two courses in these words: "I learned way more in EGR 102 than I did in 100." Erin followed Lora's sentiments about the positive learning experience. She said:

> I think I learned a lot in MATLAB. I learned a lot in Excel too. I probably learned more in EGR102. I mean stuff I didn't really want to learn but I did.

Brad talked about his achievements and the course outcomes. He was happy with the course learning though he had to spend more time on it than his other courses:

> I've enjoyed EGR102 a lot better because that's more of a specific goal of the class. You're learning MATLAB and learning programming methods... And it's been interesting. I've learned new techniques... and 102 has been a lot more enjoyable... I've put a lot of time into it, but it's felt a lot more worth it, because there's actually a finished product from the class. I know how to use these techniques, and I know how to run MATLAB now. And that's what I took from the class.

Mike liked the course because he thought it was more relevant and rewarding:

> And in 102, it's more systematic, and a little more relevant, it gives you an idea of more technical ability feel...I enjoyed 102, I think, because of the relevance. I felt like it was more rewarding. It was a little more work, though. But I think *I enjoyed 102 more than 100.*

Don was one, not too happy with the course experience because he did not enjoy math. He summed up his sentiments in the following way:

> It's basically just applied calculus. What was the class covering? I couldn't even tell you. It was basically, go to class, learn a new formula and take a quiz on it...

The positive learning experience was one common theme by the majority hence terms like "systematic", "relevant", "rewarding", were commonly used. They enjoyed the course despite the fact that they had to put in more effort for this course. EGR 102 was based on math concepts. Those who enjoyed math, or realized its relevance to engineering enjoyed the learning experience in the course. They termed it much more rewarding than EGR 100. However for those like Don who did not enjoy math, EGR 102 did not make much sense to them.

Course Credits: Most of the participants felt the course was much more demanding than a two credit course should be; they had to spend extra time to finish the assigned work. Matt, for example, called it a demanding class in these words:

> Engineering 102; *it was a handful.* It was a lot— way more work that time pretty much… I'd say for it to be a two credit class is pretty tough. It's more time consuming than any other class and it's more demanding.

They however admitted to have learned the most in this course. As an example, Pat remarked:

> It's definitely a lot of work for a two-credit class. I would say it's definitely an interesting class. You do a lot more with the actual engineering... *I would have to say the MATLAB that I learned the most.*

It may be interesting to note that participants claimed both DS courses demanded more time than a normal two credit course, but, for different reasons. For EGR 100, students faced problems in logistics issues and working in groups; the course contents were easy. For EGR 102, it was a tough and demanding course, "a handful", that required extra time to complete the assigned work.

Conduct of the Course: Not all the participants talked about the conduct of EGR102. Those who did, had mixed feelings. Mike thought the course was better conducted than EGR100, in these words:

> … 100 was new… it just felt may be not completely professionally organized… And in 102, it seems like they kind of had it down more, where it's more systematic…

Don complained of excessive homework assignments and quizzes in class:

> The only reason that you went to class for EGR102 was for the homework due and the quizzes at the end of class.

Sara was the only participant who did not like the way this course was conducted. She reflected:

> But, that class is just a waste of time. It's not really like a structure…it jumps around it doesn't have like a certain straight forward outline course.

EGR 102 was considered better than EGR 100 in terms of the learning experience, maturity of curriculum, and alignment of student expectations with the course objectives. They had to spend extra time on the assignments but appreciated the enjoyment and learning they experienced during the course. The interviewed participants specifically enjoyed learning MATLAB as a useful tool for engineers. Those who did not enjoy math and MATLAB did not enjoy the course.

4.6.2.2 DS Effects on Perceptions: This segment of the study was the most directly related to the research question. None of the participants gave a negative response in this category (see Table 4.3). Eight out of ten said loud and clear that the cornerstone sequence courses did not affect their initial perceptions about engineering. Interestingly, the majority of the participants admitted to strong negative experiences in at least one of the two courses, yet when asked to reflect on the effects of the DS courses on their perceptions, the participants clearly denied that negative experiences affected their perceptions. When Pat was asked if the DS courses changed his initial opinion about engineering, he said:

> It didn't really change my perception at all. I would say I kind of expected this from [pause]. MATLAB has been useful, but other than that, neither of the courses, if I was undecided, have guided me, would have guided me in any way or have even, I'm not one hundred percent sure I want to be a Civil engineer. They haven't swayed me to want to be a Mechanical Engineer in any way.

To Don, it didn't matter either. He had clear objectives set forth no matter what happened in the initial courses. He said:

> Not really. I would say basically just kind of broadened my horizons. I'm just excited for engineering. It's kind of a thing where I just want to be an engineer now and it really doesn't matter. I'm just really excited and I think I'm doing what I should be doing and I'm really excited to have a career.

For two participants, Lora and Don, it did make a difference – a strengthening of their already positive perception of engineering. Lora said:

> I respect engineers a lot more now that I know the difficulty that goes into it. And how much work you have to put into it. That's definitely changed my viewpoint a lot; they're smart kids.

Sara's comments were unique; she reiterated that her perception of engineering remained unchanged, but pointed towards another aspect that could make a marked difference in student attitude, namely, instructor attitude. This aspect was, however, out of the scope of this study.

> No, that wouldn't change, you're not going to always have people in the real world that, are going to be nice all the time so, whatever, I would have to stick it out and deal with it... Teachers' attitudes are just bad sometimes and they shouldn't be. I feel the teachers sometimes make it seem like they're doing us a favor.

Brad had strong views about his self but was concerned about his roommate who he thought might switch to a different major because of the negative experiences in EGR 100. Brad reflected:

> Not really, because I've been able to move past, maybe not such a good experience in EGR100, because I know that engineers aren't going to sit around and learn about other engineers. That's not what it is. But that's kind of what it seemed like you did in EGR100. I'm trying to get my roommate to understand that, you know, like, "I know that you have hated these intro classes, but this isn't what you're going to do... So if you just get past these intro courses, I think you're going to really like the stuff you start to learn." And so I hope that he doesn't change his major based on these.

These comments are particularly concerning because negative experiences could be effecting the perceptions of students with not-so-positive (mild) initial perceptions about engineering.

Students like Pat, Don, and Brad had strong initial perceptions about engineering. These students had clear objectives set forth for their future goals. They did not care about negative experiences in DS courses because they could see the reward four years down the road. They had joined the program with a definitive aim of becoming an engineer. These students had identified several issues about the DS courses (specifically for EGR 100). The most important ones were: 1) student expectations were not aligned with the course objectives; 2) they appreciated team work but it consumed excessive time; 3) lectures in big halls were not rewarding; 4) EGR 100 lacked coherence and coordination, course contents lacked testable material, and a textbook was not assigned; 5) excessive quizzes and assignments to turn in for EGR 102 that took a lot more time. Despite these negative experiences in the cornerstone sequence, the participants' initial perception about engineering remained unchanged. They were firm in their commitment to continue with their engineering major and join the profession of their choice. In fact, for two of the participants the DS experience had a positive impact on them. It further strengthened their perception and concept of engineering.

4.7 Discussion

The qualitative phase of this study provided a unique opportunity to probe deeper into the kind of learning that took place in the newly introduced cornerstone sequence. A sample of ten freshmen from the DS group was interviewed one-on-one. The sample was comprised of students who had undergone EGR100 in the previous semester and were in the final stages of EGR102 in the current semester. In other words these students had experienced the full cornerstone sequence. All the participants belonged to Category 1, which could point towards a strong preference for the field.

Part I of the protocol showed the participants had joined the program with strongly positive initial perceptions about engineering. These perceptions had developed over a long period since childhood and were mostly influenced by parents and teachers, especially if they belonged to this profession. The preference for math and science subjects also contributed towards strong preference for the engineering field. The participants appreciated working in group activities, and on open-ended problems with multiple solutions. They radiated confidence in their abilities to succeed as engineers.

Part II of the protocol focused on the participants' experiences in the new cornerstone sequence. They generally had negative experiences in EGR100 because the course objectives fell short of their expectations. They considered it to be an easy course; it offered little academic challenge and did not add much to their already acquired knowledge. They appreciated the concepts of team work and problem solving in engineering. They expressed their understanding of engineering to be of a much wider scope than just math and science. Participants were disappointed with almost every aspect of EGR 100 including content and conduct. They did not like projects and lectures, and were dissatisfied with the way it was conducted mainly because their perceptions were not aligned with the course objectives. On the other hand they liked EGR102 more because their expectations more or less were aligned with the course objectives. They complained of excessive work load for both courses but for different reasons; EGR 100 had more administrative issues whereas EGR 102 was full of lengthy MATLAB assignments.

Despite negative experiences in the DS courses that might have dampened their enthusiasm, the participants expressed their firm commitment to becoming an engineer of their choice. When asked if their initial perception about engineering had changed in any way because of the negative experiences, all but two of the participants unanimously disagreed. Those, two who agreed, had more positive perceptions about engineering. Students in the DS group had joined the program with strongly positive attitudes towards engineering. The negative DS experiences did not significantly change these strong perceptions [77].

Before drawing conclusions and recommendations it may be pertinent to review the limitations of this qualitative framework. First and foremost, as with all qualitative research, the issue of generalizability needs to be considered with regard to the sample-size and representativeness of the target population before making informed decisions about the new sequence [34]. The sample did not include a portion of the population that took CSE 231 instead of EGR 102. Moreover, the sample could have been skewed because of the type of incentive offered, $25, perhaps by not attracting those who did not need the incentive as much. Researcher bias in a qualitative research also could sway the results of the analysis [80]. Maximum efforts were made to remove the researcher bias by engaging in rechecking of the coding by another researcher and repeating the coding several times before drawing conclusions.

CHAPTER 5

CONCLUSION

This study involved an explanatory mixed methods design that is characterized by an initial and extensive quantitative phase built upon by a subsequent qualitative phase. The quantitative phase was designed to answer whether the new cornerstone sequence was more effective than the older traditional sequence at positively influencing freshman attitudes about engineering over the course of one semester. Students in the new cornerstone sequence were compared to students in the previous traditional sequence by collecting attitude data twice over the course of one semester and examining changes in the two groups' attitudes with repeated measures ANCOVA models. It was found that freshmen join the program with positive and strongly positive attitudes towards engineering. Students in the cornerstone sequence had higher *ACT* scores, enjoyed math and science more, and did not believe engineering to be an exact science. Females had lower confidence levels in basic engineering knowledge and skills, problem solving abilities, and engineering abilities. The DS group, however, had a similar longitudinal trajectory to the TS group, so there was no evidence of differential influence on student attitudes. In other words there was a lack of treatment effect in the DS group [68, 69].

To probe deeper into the quantitative results, especially the lack of the treatment effect, the qualitative approach was adopted with further collection of data and its analysis. One-on-one interviews were conducted with a representative sample from the DS group. The analysis of textual data revealed that freshmen joined the engineering program with strongly positive initial perceptions about engineering. These perceptions were based on their childhood and high school experiences and were influenced by parents and teachers, more so if their parents and/or teachers had stressed STEM-based education. The preference for math and science subjects also contributed towards a strong preference for engineering. The two cornerstone sequence courses impacted the students' attitudes about engineering in several ways. The participants appreciated: 1) the significance and challenges associated with team work; 2) that engineering was not an exact science; 3) that engineering was not only math and science, team work, communication and ethics were equally important for success; 4) that the usual high school formula for credit load does not work with design courses because of intangible factors like group activity [77].

The above notwithstanding, most of the freshmen reported negative experiences in the DS courses, specifically in EGR 100. Some of the major impediments were: 1) their expectations were not aligned with the course objectives; 2) the course being a new course lacked coherence and coordination, giving a sense of disorganization; 3) excessive workload (projects in EGR 100, and class quizzes and home assignments in EGR 102); 4) a sudden shift in students' academic and living environments. These negative experiences were dampening their enthusiasm for engineering and need to be addressed. This criticism is consistent with previous research on why students leave the STEM majors [4]. A review of the course curriculum, especially the course projects, could help in matching up the student expectations with the course objectives. Interestingly, despite the impediments, the participants' initial attitude and perception towards engineering did not change significantly. When asked if their initial perception about engineering had changed negatively because of the negative experiences, the participants unanimously disagreed. Students in the DS group had joined the program with strongly positive attitudes about engineering. The negative DS experiences did not significantly change these strong perceptions.

The qualitative phase validated and supported the quantitative findings. Students in the DS group were found to have joined the program with strongly positive attitudes about engineering that were deeply rooted. These attitudes were not affected by the short (one semester) and predominantly negative treatment effects of DS courses as indicated by the participants' responses in the qualitative phase of the study. All of the participants were firm in their commitment to continue with their engineering major and join the profession of their choice. It substantiated the belief that strong attitudes are harder to change: they are durable, and they have impact [15, 16, 81]. They are not much affected by a short treatment, especially if it is not very well organized and focused.

The cornerstone sequence was new; it was passing through a transient phase. Many of its conduct and execution issues would be resolved as the course is fine tuned and reaches maturity. At this time it may not appear to be as effective a treatment as it was initially perceived. It would therefore be prudent to allow at least 2-3 iterations for the sequence to reach a steady state. This study could meanwhile continue to collect data to build upon the quality analysis.

It was pointed out in the beginning that the new cornerstone sequence required two semesters or one complete freshman year for implementation. To capture the opportunity window of one semester in which both the groups were available for a comparative study, the quantitative phase of this study was launched concurrently for one semester. In the quantitative phase, data for EGR 100 was used for statistical modeling, thus capturing only partial effects of the sequence. Similarly, for the qualitative phase, one-on-one interviews were conducted when the semester was still in progress thus capturing full effects of EGR 100 but losing some effects of EGR 102. Also, a portion of the freshman population that opted for computer engineering or computer science majors was lost because they did not take EGR 102. It is argued that compound effects of the two courses in the intended sequence could be significantly larger than these partial effects. It therefore suggests that the study be continued to capture the full effects of the sequence.

In the quantitative phase the time between pre- and post- surveys was only eleven weeks. Due to administrative reasons the surveys could not be conducted nearer the beginning and closer to the end of the semester. This could have resulted in the loss of vital experience given the fact that the initial few weeks of the semester are important, and also the fact that the learning curve is typically not linear. It was argued then that a short treatment of a partial semester of eleven weeks may not be enough to affect a significant change in student perceptions, more so when the perceptions are durable and deep rooted [69]. It has been found that treatment effect can capture the non-linear changes in the learning cycle if the samples are taken more frequently [82]. It is suggested that the study may be spread over two semesters to capture the full effects of the sequence by taking more frequent samples throughout the year with a gap of 4-6 weeks.

The study also identified several issues with the two samples due to selection bias in both the phases. Different data collection methods and their associated incentives could have skewed the samples towards higher achieving, more motivated, and/or lower socioeconomic groups. In qualitative research the issues of researcher bias and generalizability also need to be considered with regard to the sample size and its representation of the target population. A larger and more homogenous sample size is therefore desirable and could be achieved with concerted efforts in the subsequent data collections.

PFEAS subscales are being revised to further improve the internal reliability and structural validity of the scale [51]. The upgraded version of PFEAS may become available shortly, which could improve its power to detect intervention effects. It is also pertinent to build up our own data and develop our own norms to improve the reliability of the scale. A short, compact, and more powerful scale would be able to precisely measure and detect the differences with accuracy.

This mixed methods study also brought to light some other variables out of the scope and context of this study that could impinge upon the student attitudes and may be good covariates for the future studies. These include course content, instructor attitude, and teaching style. It may also be interesting to add other forms of qualitative data to further look into the construct for a broader view, for example, classroom observations, focus groups, student portfolios, and interviews with class instructors. Adding more variables may make the model more complex, but at the same time it would be more realistic and complete and may throw more light on the *time*group* interactions.

The results of this mixed methods study indicate that changing student attitudes may not be an easy task. We need to develop better understanding of the fine-grained details of the actual implementation of such cornerstone engineering courses. Such research is critical for the formative evaluation of these programs in order to improve curriculum development efforts. Clearly tight and focused quantitative studies complemented with a qualitative component provide a much broader and deeper insight into the learning that takes place in freshman courses. We must engage in a broader and larger research program that should include improved instrumentation with a larger and homogeneous sample size, with same collection methods, and with frequent samples at 4-6 weeks intervals (instead of pre- and post-) to capture the subtle, non linear and full effects of the cornerstone sequence. The accuracy of the model could be further enhanced by the addition of carefully selected covariates, for example, student GPA, ethnicity, high school. attended, and socioeconomic status. Other forms of qualitative methods including classroom observations, focus groups, interviews with the class instructors, consideration of instructor attitude and teaching styles would certainly provide further depth to our understanding of student attitudes.

The mixed methods approach is a useful tool for developing a better understanding of students' life experiences with freshman courses [36]. To measure the longitudinal effects of the new sequence, the fall 2008 cohort of students should be observed during their junior and senior years in a progressive manner and with a larger and diversified sample to represent the population in a true sense with little or no limitations and preferably with the revised version of the PFEAS, if possible. This would provide a clearer and better understanding of the freshman engineering experience so vital to improve the quality of our program and reduce attrition.

APPENDIX A

PITTSBURGH FRESHMAN ENGINEERING ATTITUDES SURVEY (PFEAS) [19]

This is a survey to elicit Freshman Engineers' opinions and feelings about engineering. Please do not spend more than 25 minutes to complete the questionnaire, so work as quickly as you can. Remember these are your own personal attitudes, not your friend's. Your first response is usually the most accurate for you.

For each statement about engineering, please fill in the number that corresponds to how strongly you disagree or agree with the statement.

1. I expect that engineering will be a rewarding career.
2. I expect that studying engineering will be rewarding.
3. The advantages of studying engineering outweigh the disadvantages.
4. I don't care for this career.
5. The future benefits of studying engineering are worth the efforts.
6. I can think of several other majors that would be more rewarding than engineering.
7. I have no desire to change to another major (biology, English, chemistry, art, history, etc.).
8. The rewards of getting an engineering degree are not worth the effort.
9. From what I know, engineering is boring.
10. Engineers are well paid.[6]

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[6] Items 10, 14, 16, 21, 23, 24, 39, and 46 in grey shade, were not used for this study.

11. Engineers contribute more to making the world a better place than people in most other occupations.
12. Engineers are innovative.
13. I enjoy the subjects of science and mathematics the most.
14. I will have no problem finding a job when I have obtained an engineering degree.
15. Engineering is an exact science.
16. My parents are making me study engineering.
17. Engineering is an occupation that is respected by other people.
18. I like the professionalism that goes with being an engineer.
19. I enjoy taking liberal art courses more than math and science courses.
20. Engineering is more concerned with improving the welfare of society than most other professions.
21. I am studying engineering because it will provide me with a lot of money; and I cannot do this in other professions.
22. Engineers have contributed greatly to fixing problems in the world.
23. An engineering degree will guarantee me a job when I graduate.
24. My parents want me to be an engineer.
25. Engineers are creative.
26. Engineering involves finding precise answers to problems.
27. I am studying engineering because I enjoy figuring out how things work.
28. Technology plays an important role in solving society's problems.

For the following subjects and skills, please fill in the number corresponding to the response that describes how confident you are of your abilities in the subject or skill.

29. Chemistry.

30. Physics.

31. Calculus.

32. Engineering.

33. Writing.

34. Speaking.

35. Computer Skills.

For the following statements about studying, working in groups and personal abilities, please fill in the number corresponding to the response that best describes how strongly you disagree or agree with the statement.

36. I feel I know what an engineer does.

37. Studying in group is better than studying by myself.

38. Creative thinking is one of my strengths.

39. I need to spend more time studying than I currently do.

40. I have strong problem solving skills.

41. Most of my friends I "hang out" with are studying engineering.

42. I feel confident in my ability to succeed in engineering.

43. I prefer studying/working alone.

44. I am good at designing things.

45. In the past, I have not enjoyed working in assigned groups.

46. I am confident about my current study habits or routine.

47. I consider myself mechanically inclined.

48. I consider myself technically inclined.

49. I enjoy solving open-ended problems.

50. I enjoy problems that can be solved in different ways.

APPENDIX B

PFEAS FACTOR LOADINGS

Statements 1-28

	Author supplied Measures [56] / *Study based Measures*©							**Normalized Weight**
No	**Perception**	**Career**	**Jobs**	**Society**	**Math**	**Exact**	**Family**	
12	0.68/*0.47*							0.166
22	0.67/*0.48*							0.164
25	0.67/*0.47*							0.163
28	0.58			*/0.46*				0.143
17	0.55/*0.74*							0.135
18	0.53/*0.64*							0.128
27	0.42	*/0.45*						0.101
1		0.66/*0.84*						0.124
2		0.64/*0.85*						0.121
4		-0.64/*-0.65*						0.120
3		0.61/*0.75*						0.114
7		0.61/*0.69*						0.114
8		-0.60/*-0.47*						0.113
5		0.55/*0.72*						0.104
9		-0.53/*-0.58*						0.100
6		-0.48/*-0.67*						0.090
23			0.74/*0.75*					0.301
14			0.71/*0.64*					0.289
21			0.51/*0.61*					0.206
10			0.50/*0.50*					0.204
20				0.83/*0.70*				0.519
11				0.77/*0.70*				0.481
19					-0.83/ *0.41(Comm.)*			0.525
13					0.753/ *0.65 (Basic)*			0.475
15						0.819/*0.81*		0.516
26						0.76*70.74*		0.484
24							0.87/*0.83*	0.586
16							0.62/*0.63*	0.414

© Study based measures are italicized.

Statements 29-35

	Author supplied Measures/_Study based Measures_©		**Normalized**
Number	**Basic**	**Communication**	**Weight**
30	0.74/*0.56*		0.244
32	0.71/		0.233
31	0.68/*0.65*		0.224
29	0.51/*0.65*		0.169
35*	**0.395/_0.67 (Compatibility)_**	**0.317**	**0.130/0.161**
33		0.83/*0.70*	0.422
34		0.82/*0.73*	0.416

*Statement 35 is shared by both components due to relative weak relationship to both measures.
© Study based measures are italicized.

Statements 36-50

	Author supplied Measures/_Study based Measures_©				**Normalized**
Number	**Ability**	**Compatibility**	**Groups**	**Study**	**Weights**
50	0.79/*0.7*				0.247
49	0.78/*0.67*				0.244
38	0.56/*0.47 (Comm.)*				0.177
42	0.54/*0.53 (Career)*				0.169
40	0.52/*0.46*				0.163
47		0.79/*0.72*			0.303
48		0.77/*0.81*			0.294
36		0.53/*0.53 (Ability)*			0.202
44		0.52/*0.59*			0.201
41		**0.37/_0.58_**			†
43			0.85/*-0.86*		0.385
37			-0.81/*0.79*		0.363
45			0.56/*-0.62*		0.252
46				0.84/*0.80*	0.501
39				-0.84/*-0.82*	0.499

© Study based measures are italicized. † Statement 41 too weak to be considered.

APPENDIX C

ONE-ON-ONE INTERVIEW PROTOCOL

First-Year Engineering Students' Learning, Attitudes, and Experiences

Institution: Michigan State University

Interviewee: (Title and Name)________________

Interviewer: ________________________________

Part I – Student Experiences in the Freshman Year

1. Tell me why you chose to pursue an engineering degree at MSU?
    a) What motivated you to pursue an engineering degree?
    b) What other options did you consider? Dual major what would you choose?
    c) In what ways were you influenced by others (*e.g.* family, friends, high school teachers)?
2. Now I want to ask you about your transition to MSU. How has your transition to MSU been?
    a) In terms of academic preparation and fit?
    b) In terms of developing friendships and peer groups? Within engineering?
    c) To what extent do you feel part of an academic community at MSU? Where is it based?
    d) To what extent do you feel part of a social community at MSU? Where is it based?

3. Now I want to spend some time discussing your expectations for your undergraduate experience here.
    a) What expectations did you have for your classroom experiences (*e.g.* instruction, projects, etc.)?
       To what extent have these expectations been met?
       Important to your experience?
    b) What expectations did you have for the workload or effort required of you?
       To what extent have these expectations been met?
       Important to your experience?
    c) What expectations did you have for interactions with faculty?
       To what extent have these expectations been met?
       Important to your experience?
    d) What expectations did you have for interactions with peers in the engineering college?
       To what extent have these expectations been met?
       Important to your experience?
    e) What did you expect the College of Engineering to be like in general?
       To what extent have these expectations been met?
       Important to your experience?
    f) Any additional expectations that I may not have asked about specifically?
4. What have been the most significant challenges or obstacles to your success here?
5. What types of support have been important to your success? Where did you find them?

    a) For advising?
    b) For help with classes?
    c) For personal support/friendship?
    d) For social opportunities?

6. What ways have you sought support but were not satisfied with the result?
7. Looking back on your first-year here, describe any changes you would make to the engineering program? In what ways, could the engineering experience at MSU be improved to facilitate your success?

Part II – Freshman Experiences in the Cornerstone sequence

Now we would like to ask you a few questions specifically about the EGR sequence.

1. Describe your experience in EGR 100/102?
2. What are some of the topics you have covered in EGR 100/102?
3. Which of those topics you think are most difficult, and why?
    a. Which of those topics did you enjoy the most, and why?
    b. From which of those topics did you learn the most, and why?
4. How do you compare your learning in EGR 100/102 with the learning in other courses?
    a. How is this different from what you were expecting before joining the course?
    b. Which learning approach do you prefer and why?
5. How has your thinking about yourself changed as a result of EGR100/102?
    a. About how you learn.
    b. About your future plans.

6. How has your perception about engineering changed since you joined EGR 100/102?
    a. About what you think makes a good engineer
    b. About what are the advantages/disadvantages of studying engineering
    c. About your likes/dislikes about engineering

Thank you for your time.

Would you like to comment on any part or aspect of this interview or add anything that I might have missed?

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