TOWARDS THE DEVELOPMENT, APPLICATION, AND EVALUATION OF THE STUDENT SUCCESS – ORIENTED SYSTEM DESIGN METHODOLOGY

Tracee Walker Gilbert

Dissertation submitted to the Faculty of the
Virginia Polytechnic Institute and State University
in partial fulfillment of the requirements for the degree of

Doctorate of Philosophy
In
Industrial and Systems Engineering

Janis Terpenny, Chair
Brian Kleiner
Glenda Scales
Tonya Smith-Jackson
Bevlee Watford

December 3, 2010
Blacksburg, VA

Keywords: Student Success, Participatory Design, Performance Improvement, System Design

ABSTRACT

For over 70 years, researchers have been attempting to unravel the complexities associated with enhancing student success in higher education (Berger & Lyon, 2005). This research has resulted in a better understanding of why some students decide to leave while others persist on to graduation. Despite a sizable body of knowledge that has identified the various factors associated with student success in higher education, little work has been devoted to translating the various theoretical findings into specific strategies that will guide institutions in improving student success outcomes (Tinto, 2005; Tinto & Pusser, 2006).

This study, therefore, represents a unique attempt to bridge the gap between research and practice. Specifically, it integrates relevant findings on student success with a growing body of knowledge on system design and performance improvement in order to address the following pressing need: How can institutional leaders in higher education translate theoretical concepts into actionable solutions that will facilitate student success? In order to provide a concrete course of action for institutional leaders to design practices that meaningfully impact student success, this dissertation describes the development, application, and evaluation of a Student Success-Oriented System Design (S^2OSD) methodology.

The proposed methodology shifts the focus from trying to understand why students leave or stay, which is a well-researched topic in the literature, to examining how to satisfy student needs in ways that will improve student success outcomes. By doing so, this study focuses on assessing, understanding, and satisfying student needs within the context of student success theoretical perspectives. Moreover, this research proposes a methodology that institutions can use to tailor their practices to fit the unique needs of their students (Berger & Lyon, 2005). In summary, this research study was devised to achieve the following goals:

- Develop a research process that combines empirical and design methods in order to create, apply, and evaluate a system design methodology;
- Develop a guiding framework that provides practitioners with a set of mutually reinforcing principles, which is supported by a methodology designed to meet student needs;
- Develop a participatory design method and supporting tools to execute each phase of the research;
- Develop a performance-based evaluation framework to evaluate the usability of the S^2OSD methodology; and
- Develop a validated questionnaire to assess engineering student success needs.

DEDICATION

I dedicate this dissertation to my mother - Elaine Jones Mitchell.

Ever since I can remember, you have always represented the epitome of a mother - the consummate example of love, kindness, and splendid character. You have always given me the encouragement and support that has shaped me into the woman, wife and mother who I was destined to be. You have been by my side during all of my life's highs and lows to comfort, guide, and strengthen me. What I have become is because of you. You have been my greatest cheerleader at every step in the Ph.D. process and throughout my entire life. I could not have done this without you, and I am forever grateful for your unconditional love!

With love from your daughter,
Tracee Elaine

ACKNOWLEDGEMENTS

I stand on the shoulders of so many who have paved the way for me to succeed, and I want to express my deepest gratitude. First, I give honor to God for his grace and mercy. It was through this Ph.D. process that I developed a very close and personal relationship with Him, and I am so grateful to God for giving me the strength, determination, and the ability to complete my Ph.D. in Industrial and Systems Engineering.

To my advisor, Dr. Janis Terpenny, I thank you for your guidance and unwavering support. I am so grateful for your continual encouragement and belief in my capabilities—especially when I wavered in my own belief. This doctorate would not have been possible without you. I also appreciate that you provided me the opportunity to work as a graduate student with the National Science Foundation's Center for e-Design.

To my committee members—each of you has contributed significantly to this endeavor. I thank you for your support, guidance, and interest throughout my research process. To Dr. Brian Kleiner, I thank you for providing a systems perspective that challenged me to think critically. To Dr. Glenda Scales, I thank you for always taking the extra time to work with me, encourage me, and provide insightful and constructive critiques of my work. To Dr. Tonya Smith-Jackson, I thank you for helping me to shape and carry out the research methods. To Dr. Bevlee Watford, I thank you for helping me to gain the domain knowledge in engineering education. To my entire committee, I am forever grateful. Even when times got tough and I couldn't see the light at the end of the tunnel, I always leaned on your support.

I also owe a great deal of gratitude to my colleagues. During my eight years at Lockheed Martin, I had a number of incredible mentors, managers, and experiences that helped to shape me into the systems engineer that I am today. I thank Peter McEvoy, Norm Anderson, Don McCarron, Sonya Stewart, Bill Benton, Jerry Heilbronner, Blane Morse, Trish Forsythe, and Kent Matlick for supporting me and ensuring that I was successful throughout various points in my career. I am also very thankful to Dr. Kola Sunmonu and Dr. Carole Keane for my experience at the Department of Research and Evaluation. Thank you for giving me the opportunity to work with you, and for teaching me research skills that were so instrumental in helping me to complete this research. I also extend my gratitude to my research study participants at the pilot and main research sites, as well as to the student success practitioners who participated in the expert panel review.

I am so blessed to be surrounded by such a tight knit, loving and supportive family. To my great-grandparents, John and Elizabeth Ferguson, I wish you were here to see what I have accomplished. Nonetheless, I am thankful that I was able to experience your love and example well into my adult life. To my Granny, Wilnette Jones—I thank you for being the superwoman that my mother and I continue to aspire to be. During my Ph.D. process, I always felt your prayers during the hours of every meeting, exam, milestone, and obstacle that I faced. I so appreciate all of the newspaper clippings related to my research, and the numerous cards, phone calls and letters of encouragement that you sent my way throughout this entire process. And to my grandfather, Jerome Walker Jones, you have been alive and well in my spirit throughout my Ph.D. process. I often leaned on your shoulders to keep pressing forward. When I tried to imagine every aspect of your Ph.D. process so many years ago, I was humbled and continuously reminded that it was in my blood to finish.

To my husband and very best friend, William Gilbert, I could not have asked for a more loving, kind, selfless, and supportive spouse. You have been engaged in every detail of my research process as my coach, editor, counselor, and motivator. Words cannot express how much I love you and appreciate your support, patience, and help throughout this long journey. To my children, Gabrielle Elaine and Brianna Michelle Gilbert, I am so honored to be your mother. "You are my heart," and I love you more than life itself. You changed me as a human being by teaching me how to be more empathetic, compassionate, and to focus on what is really important in life. I am thankful for my Gilbert family – getting married and having children during my Ph.D. process was such a blessing. Because of you, I experienced another dimension of love and happiness that balanced the demands of my Ph.D. process.

To my parents, Larry and Elaine (Michelle) Mitchell, I thank you for the sacrifices that you made for me. You taught me to be all that I can be and to reach for my dreams. You have loved and supported me beyond measure, and I would not be the person that I am today without you. I thank you for continuing to teach me what it means be a phenomenal parent, and how to have a successful marriage. I am so honored to have you as parents, as well as friends.

A special thanks to my aunts, Sheryl Jones and Joyce Pruitt, who had to endure every aspect of my Ph.D. process. Thank you, Aunt Joyce, for always being there for me – always offering to lend a hand to help in any way that I needed. Thank you, Aunt Sheryl, for your daily phone calls, pep talks, and last-minute editing that you provided me throughout my process.

Lastly, I am deeply thankful for my sister, aunts, uncles, brothers, nieces, nephew, cousins, in-laws, and sister-friends for your prayers, love, and support. Also, thank you to my angel, Dr. Sharnnia Artis, who continued to motivate, guide and support me throughout my dissertation process. Thank you for reading all of my work, helping me to formulate ideas, and co-authoring with me. To my editors – Laurie Good and Cousin Kanika Vann– you are incredible writers, and I so appreciate all the work that you did in editing my documents.

This research marks the end of a long and arduous journey that has transformed me into the systems engineer, life-long learner, and person that I am today. I am deeply humbled and forever grateful to each and every one of you for standing by me! Many thanks to all of you!

AFFIRMATION

I know somewhere there is a MASTER PLAN
Outlined therein is everything that we do.
I know somewhere there is a MASTER HAND
That holds in balance sure a world or two.
I know somewhere there is a MASTER PLAN
What mortal world dare its content change
Be still, it is yet that MASTER HAND
Who, in due time, shall promptly print all plain.

- *Dr. Jerome Walker Jones, Sr.*

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1 INTRODUCTION

1.1 Engineering Student Success

Producing successful engineers has become increasingly important to the United States so that it can effectively respond to the existing and future needs of a technology-driven global society (Chubin et al., 2008). This goal, of course, requires our nation's colleges of engineering to train and graduate students in a variety of disciplines to meet those needs. As such, student success continues to be a pressing concern for higher education administrators, researchers, and policymakers.

In this context, the term "student success" is most often defined by graduation rates, which surprisingly have not significantly changed in the United States in the last 20 years (Carey, 2004). In fact, according to Tinto and Pusser (2006), graduation rates for students enrolled in four-year colleges and universities have remained steady at slightly over 50% for all students (National Center for Educational Statistics, 2005).

For engineering students, graduation rates are even lower. It is estimated that less than half of the freshmen who initially major in an engineering discipline go on to earn their bachelor's degree within five years. Moreover, underrepresented minorities (URM) (i.e., African Americans, Hispanics, and Native Americans) drop out at even higher rates than their majority peers (National Science Board, 2007). The disproportionate drop-out rate for minority engineering students is exacerbated by the fact that underrepresented minorities and women represent just a fraction of total enrollments in U.S. colleges of engineering. Specifically, the proportion of women who received undergraduate engineering degrees in 2006 was a mere 18%—despite the fact that they account for approximately 51% of the U.S. population (National Science Foundation, 2009). Furthermore, African Americans, Hispanics, and Native Americans collectively constituted 28% of the U.S. population in that same year, but they represented only 12% of the bachelor's degrees awarded in engineering (National Science Foundation, 2009).

The increasing difficulty of retaining engineering students has largely contributed to the decline in graduation rates (Felder et al., 1998). As a result, institutional practices to improve this trend are essential for enhancing student success in our nation's colleges of engineering (Berger & Lyon, 2005).

1.2 Context of the Problem

Although student success research has collectively provided an accounting of the various factors that influence student success in higher education (Kuh et al., 2006; Tinto & Pusser, 2006), there is a disconnect between theory and practice (Tinto & Pusser, 2006). As asserted by Tinto (2005),

> Despite all the research that has been conducted to date, little work has been devoted to the development of a model of student persistence that would provide guidelines to institutions for creating policies, practices, and programs to enhance student success. The absence of such a model is not the result of a lack of research but rather of the failure of past research to translate its many findings into forms that would guide institutional action (pg. ix).

Similarly, Heverly (1999) claimed that even though valuable information has resulted from the substantial body of research conducted over the years, a major limitation has been the difficulty in identifying specific focused changes in college processes that have led to improvements in student success outcomes. Tinto and Pusser (2006) have also asserted that too much research has focused on theoretically appealing concepts that do not translate easily into definable courses of action. In response to this disconnect between theory and practice, Chubin et al. (2005) has called for a practice-based agenda “with an eye toward action, namely, knowledge that is actionable in the sense of suggesting what to do, if not how” (pg.84).

Current macro-oriented theories have attempted to explain student attrition and persistence for all types of students at all types of campuses (Astin, 1984; Bean, 1980, 1983; Bean & Eaton, 2000; Kuh, 2001, 2009; Tinto, 1993). These theories have provided most of the empirical and conceptual knowledge that has shaped institutional practices designed to retain and help students succeed (Berger & Lyon, 2005; Kuh et al., 2006; Tinto & Pusser, 2006). As such, they serve as the foundation for the current study. This research, however, expands on the current body of student success research in two fundamental ways.

First, the research literature’s theoretical perspectives have provided an understanding of why students decide to leave or remain in college; however, few studies have focused on understanding student needs in the context of student success theoretical perspectives. Thus, motivated by a significant body of research on performance improvement and system design, this research re-conceptualizes students as the primary customers of higher education (Dahlgaard et al., 1995). In doing so, this study focuses on assessing, understanding, and satisfying student needs within the context of influential student success theoretical perspectives.

Second, this research recognizes that the current paradigm of a one-size-fits-all approach is no longer sufficient. This view reinforces Tinto’s (2003) assertion that there is no specific “cure-all” program that every institution can adopt to help students succeed, and no single program that has been shown to be effective for all students at all institutions. Instead, colleges and universities must tailor their practices to fit the unique needs of their students within their distinct campus environment (Berger & Lyon, 2005). Consequently, this study has addressed these issues by connecting actionable practices with well-tested theoretical premises that facilitate engineering student success.

1.3 Research Purpose

This research represents a unique attempt to integrate the literature on the student success theoretical perspectives with the current body of knowledge on customer-oriented systems approaches in order to respond to a real need: translating theoretical concepts into actionable solutions that facilitate student success. Therefore, the purpose of this study was to develop a methodology—the Student Success-Oriented System Design (S^2OSD, pronounced "*SAWS-D*")—that enables higher education administrators to design practices that facilitate student success.

1.3.1 Student Success-Oriented System Design Methodology

The S^2OSD methodology is intended to bridge the gap between theory and practice. Critical to this approach is the development of a system design methodology that focuses on the conceptual design stage of the systems engineering lifecycle. Conceptual design represents a process that begins with the identification of a need and progresses through a series of phases to generate optimum solutions to satisfy the identified need (French, 1998; Pugh, 1991). This process results in an action plan that links working steps to design phases that can be adapted in a flexible manner to solve complex problems (Pahl et al., 2007).

Although recent research has been conducted to improve the design process, many approaches are either too abstract or too narrowly focused. Thus, it makes it difficult to apply them to a nontechnical area (i.e., student success), which has been largely unexplored in the system design literature. Compounding the problem is the fact that there is a plethora of methods, processes, and tools that facilitate only portions of the conceptual design process (e.g., Quality Function Deployment, SWOT Analysis, Pugh Decision Matrix). Given that these approaches were developed in technical domains, little structure and guidance is available to institutional decision makers who wish to employ the conceptual design process as a whole in higher education settings. These significant gaps highlight the need to integrate improved methods and tools into a unified framework that can guide institutional leaders in designing effective practices that facilitate student success, while at the same time meeting the unique needs of their students.

At the core of the proposed S^2OSD methodology is a design philosophy that is based on five fundamental design principles that have been adapted from the customer-oriented systems approaches reviewed in Chapter 2: (1) Student Orientation Principle, (2) Analysis-Synthesis-Evaluation Principle, (3) Participation Principle, (4) Vital to Student Success Principle, and the (5) Holistic Principle. The incorporation of these critical elements also supports Avison and Fitzgerald (2003), who emphasized the importance of the philosophy behind the methodology, or in other words, the set of beliefs and assumptions that shape the definition of the methodology. These five principles are detailed below.

(1) Student Orientation Principle: Satisfying the needs of students is the driving force behind the design of institutional practices in higher education. The goal of satisfying customers is a fundamental tenet of the customer orientation, and is expressed by an organization's attempt to design and deliver products and services that fulfill customer needs (Dean & Bowen, 1994). From a system design perspective, the needs of a customer provide the basis from which successful systems are realized. Thus, the rationale for this tenet is the notion that a customer-oriented approach will lead to organizational success (AppiahAdu & Singh, 1998). This approach was applied to the primary customers of higher education institutions—namely, students.

(2) Analysis-Synthesis-Evaluation Principle: The traditional system design process consists of three iterative stages: analysis, synthesis, and evaluation (Cross, 2000; Jones, 1992; Verma et al., 1999). Jones described these stages as breaking a problem into pieces, putting the pieces together in a new way, and testing the proposed design to discover the consequences of the new arrangement. The analysis-synthesis-evaluation cycle provides the basic structure for the design process, which is intended to ensure that the problem is understood, that important elements are not overlooked (Cross), and that the broadest possible set of feasible (often innovative) solutions can be considered without being limited to fixed or conventional solutions (Dieter & Schmidt, 2009; Pahl et al., 2007). As a result, the design skills of abstraction, persistent questioning, identifying critical performance areas, and factorization are used to facilitate the design process.

(3) Participation Principle: Since participatory design is the primary method for identifying customer needs (Bayus, 2009), it is employed in this study. Following this line of research, this study emphasizes the fact that students should be considered experts with regard to the various factors that impact their success. As such, any design efforts intended to identify and address their needs should not become the sole responsibility of the administrators (Holzblatt & Jones, 1993). Therefore, the Student Success-Oriented Participatory Design (S^2OPD) method was used to facilitate the participation of both students and key decision makers to ensure that student needs were identified and improvement practices were developed to meet their needs.

(4) Holistic Framework: Following Aristotle's dictum that 'the whole is greater than its parts,' the holistic approach builds on important principles of systems engineering (Sage & Rouge, 2009). This holistic principle can be illustrated using a bicycle analogy, in which the parts (e.g., wheel, handle bars, etc.) of a bicycle serve particular functions. However, it is not

until it is assembled in a particular way that the bicycle has vehicular potential, which represents an emergent property of the whole that none of the individual parts possess (Checkland, 1993). As applied to this study, this principle provided a holistic framework that encompassed all of the phases of the conceptual design process that would be used to facilitate the translation of student needs into a plan of action for meeting student needs.

(5) Vital to Student Success Principle: This principle ensures that the design process focuses on specific aspects that are critical to student success. Juran (2002) coined the phrase "the vital few and the trivial many" (also called the "80/20 Principle") to describe the phenomenon that for any population that contributes to a common effect, a relatively vital few of the contributors account for the majority of the effect. Stated more simply, 20% of something is typically responsible for 80% of the results. This principle is deeply rooted in quality management literature (Berry et al., 1990; Crosby, 1979; Deming, 1986). It not only focuses the attention on the vital few (e.g., student needs, design requirements, improvement practices) throughout the design process, but also targets specific aspects that are critical to student success. For example, although housing services are needed by students, housing is not 'vital' to helping students succeed in the context of the student success theoretical perspectives.

Based on these five design principles, the S^2OSD methodology was developed to provide the methods, processes, and tools that institutional decision makers can use to accomplish the following goals: 1) target and identify student needs that promote student success, 2) assess and identify the unique needs of their students, 3) translate needs into improvement practices, and 4) develop a concrete course of action that addresses student needs within the context of a specific institutional environment.

1.4 Research Objectives

To achieve the purpose of this dissertation, three research objectives have been identified:

> <u>Research Objective 1</u>*: To integrate student success theoretical perspectives with system design and performance improvement methods, tools, and processes in order to* ***develop*** *the S^2OSD methodology.*
>
> <u>Research Objective 2</u>*: To* ***apply*** *the S^2OSD methodology in an institutional setting in order to aid practitioners in translating student needs into a plan of action.*
>
> <u>Research Objective 3</u>*: To* ***evaluate*** *the usability of the S^2OSD methodology by collecting continuous feedback from users (i.e., students and institutional decision makers) in order to refine and improve the methodology.*

1.5 Research Questions & Hypotheses

To achieve the research objectives, the following research questions and hypotheses are presented:

Research Objective 1: Develop the Methodology

Research Question (RQ)1: *What methods, processes, and tools should be developed to support institutional decision makers in designing practices that meaningfully facilitate student success?*

Broad Hypothesis (H)1: *From a review of the system design, performance improvement, and student success bodies of knowledge, the phases of the S^2OSD methodology, its associated methods and tools, and key outputs of each phase can be defined.*

Research Objective 2: Apply the Methodology

Research Question (RQ)2: *What information does the S^2OSD methodology provide institutional decision makers?*

Broad Hypothesis (H)2: *The S^2OSD methodology provides information to guide decision makers through the process of diagnosing the baseline, identifying needs, designing improvements, and developing a plan of action.*

2.1 Diagnose the Baseline

*RQ 2.1**:** How can decision makers assess their current state and define how to satisfy engineering student success needs in the future?*

H2.1: Phase I of the S^2OSD methodology can be used to assess and understand how to satisfy engineering student success needs.

2.2 Identify Needs

RQ2.2: What are the needs of engineering students that facilitate student success?

H2.2: Phase II of the S^2OSD methodology can be used to identify and prioritize engineering student success needs.

2.3 Design Improvements

RQ2.3: How can improvement practices be designed to meet engineering student success needs?

H2.3: Phase III of the S^2OSD methodology can be used to design improvement practices to meet the student success needs of engineering students.

2.4 Develop Plan of Action

RQ2.4: How can the information generated from the previous phases be translated into a plan of action that facilitates student success?

H2.4: Phase IV can use the information generated from the previous phases of the S^2OSD methodology to develop a plan of action.

Research Objective 3: Evaluate the Methodology

Research Question 3: *What methods can be used to evaluate the S^2OSD methodology in order to refine and improve it?*

Broad Hypothesis 3: *Formative and summative evaluation methods can be used to evaluate the S^2OSD methodology in order to refine and improve it.*

1.6 Research Approach

This study incorporated a three stage approach to address its purpose and objectives. In the first stage, preliminary research was conducted to develop a participatory design method to execute the S^2OSD methodology, as well as to create and validate the Engineering Student Needs Questionnaire (ESNQ). In the second stage, the following four phases of the S^2OSD methodology was further developed and applied to a top university's minority engineering program (MEP) and women in engineering (WIE) program in the second stage as follows:

Phase I – Diagnose the Baseline: The first phase of the S^2OSD methodology began with an effort to define and diagnose the baseline of the institutional unit (e.g., program, department) under study. In this stage, a performance measurement framework was developed to identify key performance areas that aligned student success needs with key aspects of the program that are vital to helping students succeed. Using the S^2OPD method, this framework was used to help institutional leaders assess the programs current state and define how to satisfy engineering student success needs in the future.

Phase II – Identify Needs: While the first phase was focused on student needs from the institutional leaders' perspectives, Phase II focused on understanding student needs from the students' perspectives. First, the conceptual research model (developed during the preliminary research) was tested in order to provide a statistically verified research model of student success needs. Then, the student needs identification (SNID) method was presented to capture vital student success needs directly from the students.

The SNID method consists of the following five step process: 1) administer the ESNQ, which was developed based on the research model; 2) analyze the data using statistical analyses; 3) create an action grid to organize the needs that were not being met into a hierarchy; 4) create an index to prioritize the critical unmet needs; and 5) review the results to identify those vital student success needs that could be considered for design improvements in Phase III.

Phase III – Design Improvements: In this phase, students translated the most 'vital' student success needs generated from Phase II into candidate options for improvement practices. Several tools (i.e., Brainstorming, Quality Function Deployment, SWOT, and the function-means method) were adapted to generate a set of feasible improvement practices to address student needs.

Phase IV – Develop Plan of Action*:* Once the candidate options were generated in Phase III by the students, then this phase guided institutional leaders through the process of developing a plan of action based on the performance areas defined in Phase I. First, a decision matrix was used to ultimately facilitate the institutional decision makers' evaluation and selection of the most feasible improvement practices to meet the needs of students. A preferred course of action was then documented using the Student Success Action Planning Matrix.

Following the development and application of the S^2OSD methodology, the third and final stage of this research consisted of developing an evaluation framework to assess the usability of the S^2OSD methodology. First, formative evaluations were conducted with the users (i.e., institutional decisions makers and students) throughout the phases to identify strengths and weaknesses in order to refine and improve the S^2OSD methodology. Additionally, a summative evaluation was conducted at the conclusion of this research to evaluate the overall usability of the refined methodology.

1.7 Premises and Limitations

The research approach described herein is based on the premise that the S^2OSD methodology aids decision makers in designing effective institutional practices that facilitate student success. This study is applied to undergraduate engineering students in the MEP and WIE program within a single institution. The justification for designing a single institution study is based on the premise that the S^2OSD methodology can provide campus decision makers with a methodology to tailor practices to meet the unique needs of their students. Therefore, the problems and solutions that emerge from applying the four phases of the methodology are unique to its application. However, the methodology is generalizable in that it can be applied across institutions, departments, programs, etc. Furthermore, the application of the S^2OSD methodology is applied to demonstrate its usability. As a result, selected examples are presented to illustrate the usability of the methodology. However, future studies can be developed to explore more expansive applications of the S^2OSD methodology.

1.8 Research Relevance

Introducing systems engineering concepts in order to solve problems within the realm of higher education has the potential to expand the existing knowledge in both milieus, as well as enhance institutional practice. First, this research presents a unique opportunity to develop a system design methodology based on student success theoretical perspectives. The design philosophy of the S^2OSD methodology represents a paradigm shift in conventional thinking away from the current body of student success theoretical research, which is largely based on an understanding of why students decide to leave and/or stay in college (Tinto & Pusser, 2006). Instead, this research proposes that understanding and satisfying student needs can provide the foundation for student success. Secondly, this research proposes to align the unique needs of students within the context of a specific institutional environment. Instead of designing a standard set of best practices that can be adapted across institutions, this research proposes a methodology that can be used by institutions to tailor their practices to meet the unique needs of their students. Thirdly, this research adapted both systems design and performance improvement approaches to develop an integrated framework of methods, processes, and tools to assess and translate needs into solutions that guided institutional action. Specific contributions of this research include:

- A research process that combines empirical and design methods to develop, apply, and evaluate a system design methodology;
- A guiding framework that provides practitioners with a set of mutually reinforcing principles, which is supported by a methodology designed to meet student needs;
- A participatory design method and supporting tools to execute each phase of the methodology;
- A performance-based evaluation framework to evaluate the usability of the S^2OSD methodology; and
- A validated ESNQ to assess engineering student success needs.

Adapting creative thinking methods, design processes, and tools from the engineering discipline has the potential to result in new concepts for improving student success outcomes. According to Dieter and Schmidt (2009), innovation results from recognizing promising concepts that arise in other disciplines beyond engineering and applying them in inventive ways. Developing and applying the proposed S^2OSD methodology seeks to provide new solutions to a long-standing and pervasive problem in higher education.

CHAPTER 2 LITERATURE REVIEW

The S^2OSD methodology integrated the processes, methods and tools from a variety of sources to provide a holistic framework that institutional leaders can use to translate student needs into a plan of action that facilitates success. This chapter reviews two distinct bodies of research—*customer orientation* and *student success orientation*—in order to identify critical concepts and principles that were adapted to create the S^2OSD methodology.

Section 2.1: Customer Orientation: The first body of research was reviewed for the purpose of identifying processes, methods, and tools that were adapted for the development of the S^2OSD methodology. The customer orientation literature examines the systems engineering fundamentals related to performance improvement and system design. These bodies of knowledge have been applied in organizations to improve the performance of customer-oriented systems, products, and services.

Section 2.2: Student Success Orientation: The second source of relevant literature in higher education research was reviewed to provide the domain knowledge needed for developing the S^2OSD methodology. This body of literature is concerned with identifying those factors that influence student success from a theoretical perspective. It also pertains to how various theories have influenced practices for URM and female engineering students. Lastly, the performance improvement body of knowledge was revisited in the context of higher education.

2.1 Customer Orientation

Researchers in the field of marketing, management, and engineering have emphasized the importance of a customer orientation. From a marketing perspective, organizations adopt a customer orientation to obtain and use information from customers, develop strategies to meet customer needs, and implement those strategies by being responsive to customer needs (Ruekert, 1992). Similarly, a quality management approach adopts a customer orientation (i.e., customer focus) that requires the entire organization to be focused on providing products and services that fulfill customer needs (Dean & Bowen, 1994). Lastly, systems engineering provides an interdisciplinary process to transform customer needs into system solutions (Bahill & Gissing, 1998; Blanchard, 2008) that optimally satisfies those need. Central to each of these approaches is the underlying assumption that customer needs form the basis from which success is realized.

Translating the customer (also referred to as the user or consumer) needs into actionable solutions provides the foundation for the customer orientation literature review. Therefore, the purpose of this section is to review the methods, processes, tools, and customer-oriented system design methodologies that were adapted to develop the S^2OSD methodology.

2.1.1 System Design Perspective

The system design perspective uses systems engineering fundamentals, in which satisfying customer needs form the basis from which successful systems are realized. According to the International Council on Systems Engineering (INCOSE), systems engineering is "an engineering discipline whose responsibility is to create and execute an interdisciplinary process to ensure that customer and stakeholder needs are satisfied" (Blanchard, 2008, pg.15).

Although systems engineering can be defined in a number of ways, Blanchard and Fabrycky (2006, 2008) associated four fundamental principles with systems engineering: 1) *Top-down approach*, which views the system as being a set of interrelated components that make up a whole; 2) *Identification of system requirements*, which requires front end analysis to identify requirements, translate them into design goals and criteria, and ensure the effectiveness of decision making in the design process; 3) *Interdisciplinary*, which requires a team approach throughout the system design and development process to ensure that design objectives are met in an efficient and effective manner; and 4) *Lifecycle perspective*, which considers all phases of the systems engineering development lifecycle.

The lifecycle shown in Figure 2-1 (adapted from Blanchard & Fabrycky (2006, 2008) and Dieter & Schmidt (2009)) begins with the identification of a particular need and extends through system design (i.e., conceptual, preliminary, and detailed design), production, system utilization, and retirement (Blanchard & Fabrycky, 2006). Even though every component of the lifecycle is important, this study focused on system design. Within the context of systems engineering, system design is defined as a systematic activity that begins with the identification of a customer/user need and ends with the delivery of a product or service that satisfies that need (Blanchard, 2008).

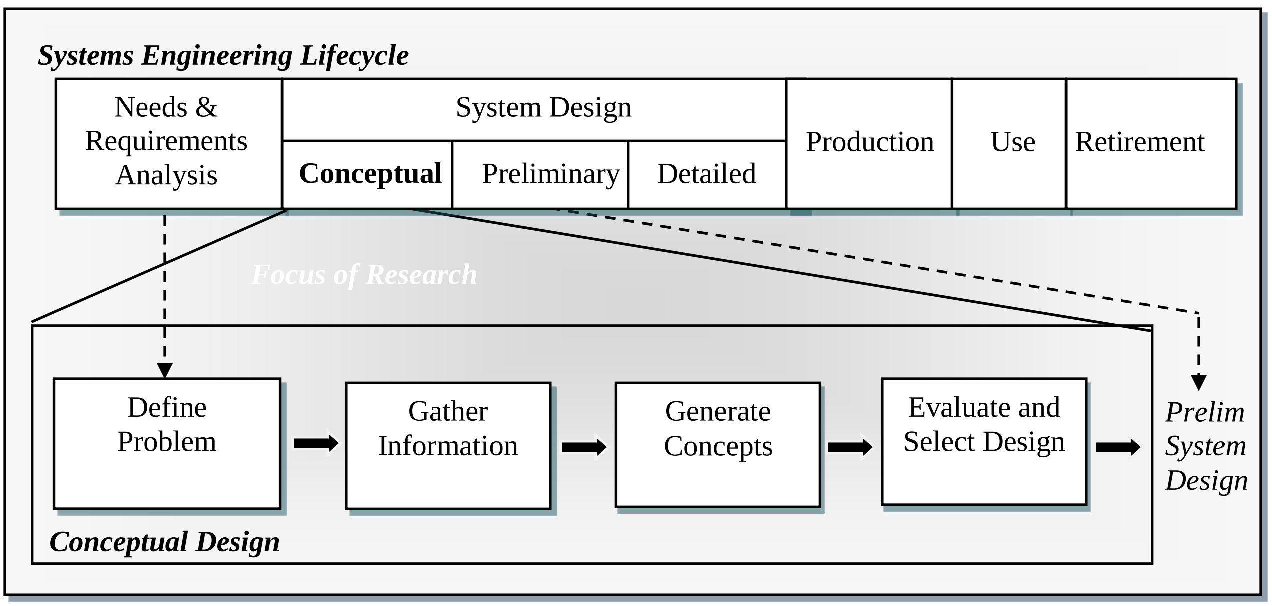


Figure 2-1: Systems Engineering Lifecycle - Conceptual System Design

Conceptual design is an essential part of the system design process during which new solutions are created for problems that have not been previously solved, or new solutions are developed for problems that have previously been solved in a different way (Dieter & Schmidt, 2009). Conceptual design is both a creative and problem solving process that is often carried out by a design team (i.e., the design engineer(s) and key stakeholders). Their goal is to develop new solutions that optimally satisfy a given need (Pahl et al., 2007).

As asserted by Pahl et al. (2007), a structured design process is essential for identifying optimum solutions to fulfill customer needs. A number of researchers (Alexander, 1964; Jones, 1992; Cross, 2000) have described the traditional design process, which consists of three stages: analysis, synthesis, and evaluation. Analysis is concerned with defining and understanding the problem. Synthesis involves finding solutions that address the problem. Evaluation involves assessing the design generated during the synthesis stage against specifications identified in the analysis phase to ensure that the design meets the requirements. Jones (1992) described these stages as breaking the problem into pieces, putting the pieces together in a new way, and then testing to discover the consequences of putting the new arrangement into practice.

There are a number of models that depict the various stages of the design process (Cross, 2000; French, 1998; Pahl et al., 2007; Roozenburg & Eekels, 1995; Ullman, 2003; Ulrich & Eppinger, 2008). However, the model developed by Dieter & Schmidt's (2009) was found to be particularly constructive because it approaches conceptual design as a problem to be solved in four phases. This solution-oriented approach is particularly useful for the proposed research because it seeks to provide solutions to a problem in higher education settings.

The conceptual design process collectively embodies pragmatic principles that underlie the practices associated with systems engineering. These pragmatic principles were developed in 1993 by the systems engineering practices working group associated with INCOSE. This process is also applicable to a wide range of problems and represents an abstract view of the analysis-synthesis-evaluation process. The conceptual design process and related SE principles are summarized in Table 2-1.

Table 2-1: Conceptual Design Phases

Phase	SE Pragmatic Principle
I. Define the Problem	• Know the Problem, the Customer, and the Consumer • Establish and Manage Requirements
II. Gathering Information	• Use Effectiveness Criteria Based on Needs to Make System Decisions
III. Concept Generation	• Identify and Assess Alternatives to Converge on a Solution
IV. Concept Evaluation & Selection	• Verify and Validate Requirements and Solution Performance
Overall	• Maintain the Integrity of the System • Use an Articulated and Documented Process • Manage Against a Plan

2.1.1.1 Conceptual Design Phase I: Define the Problem

Defining the problem or the need is an essential first step in the system design process. This step is focused on identifying customer needs, which is the basis from which all requirements and designs are derived (Grady, 2007), and in some cases forms the basis from which solutions are tested (Dieter & Schmidt, 2009). As a result, an analysis process is undertaken as the first step so that the design engineer can work with the customer to discover, collect, and capture the needs of the customer, and then translate those needs into requirements.

A requirement represents a customer's need, which is typically denoted by a statement that can then be used to derive solutions that address those needs. As defined by INCOSE, a requirement is a statement that identifies a system, product or process characteristic or constraint, which is unambiguous, can be verified, and is deemed necessary for stakeholder acceptability. Identifying requirements involves an interactive and iterative process supported by a number of methods and tools to elicit abstract customer needs (often in the words of the customer), and to translate them into requirements that meet the true needs (i.e., both articulated and unarticulated) of the customer.

The *Define Problem* phase, therefore, is concerned with the requirements engineering or functional decomposition method, which is the iterative process of breaking down or decomposing customer needs into functional requirements. These requirements can then be translated into design requirements that are used as the basis to formulate solutions in the *Generate Concepts* phase. Functional requirements essentially describe a specific or discrete action that is required to fulfill a need, while design requirements are the engineering characteristics or parameters of the design that communicate how the customer needs will be satisfied.

The ability to describe customer needs as functional customer requirements enables the design team to consider the broadest possible set of feasible conceptual designs without being limited to fixed or conventional solutions (Blanchard, 2008; Dieter & Schmidt, 2009; Pahl et al., 2007). By specifying the "what" before the "how" is considered (i.e., what is needed to be accomplished versus how it should be done) allows for the logical breakdown (i.e., factorization) of a product or service through a systematic abstraction of requirements (Blanchard & Fabrycky, 2006; Dieter, 2009; Pahl et al., 2007). For example, a customer may express the need for a garage. The design engineer works with the customer to understand the real need, which is then translated into a solution-neutral functional requirement such as: "to protect my car from the weather." The design requirements (e.g., to occupy a minimum space) are then determined to identify the characteristics or attributes of the functional requirements that must be fulfilled. Using the example of the garage, the process of rephrasing the need into a functional requirement and then translating it into a design requirement opens up the solution space to include the possibility of a car cover, a car port, a one-car garage, and so forth.

This simple example illustrates the importance of abstraction, which reduces complexity and emphasizes the essential characteristics of the problem. By doing so, this approach provides the opportunity to discover a broad range of solutions containing the identified characteristics. At the same time, this method supports both creativity and systematic thinking. It makes it possible to define the problem in such a way that conventional ideas are avoided and more generic (often innovative solutions) are discovered (Pahl et al., 2007).

2.1.1.2 Conceptual Design Phase II: Gathering Information

Gathering information is the second phase in the conceptual design process. In some cases, the problem under investigation may be in an area in which the design engineer has no previous background; therefore, this phase is concerned with gathering information to support the development of customer needs/requirements, design requirements, and conceptual solutions. As such, this phase requires the knowledge of a wide spectrum of information sources (e.g., the web, trade literature, reports, published literature, and network of professionals) and methods that should be utilized.

Ideally, design engineers gather information from customers in a team setting to increase the probability that resulting systems, products, or services can be built to satisfy customer needs (Hickey & Davis, 2003). Although gathering information is depicted as the second phase in the conceptual design process, gathering information actually is conducted throughout the systems engineering lifecycle (Hickey et al., 2003).

2.1.1.3 Conceptual Design Phase III: Concept Generation

The third phase in the conceptual design process is concept generation. This is the phase where methods, design skills, and engineering fundamentals are brought together to generate creative solution concepts that satisfy customer needs. Using the concept generation process, several solutions are determined through team-based creativity and problem-solving methods combined with efficient information gathering (Dieter & Schmidt, 2009).

From the functional customer requirements and the corresponding design requirements (or engineering characteristics) identified during Phase I, preliminary solutions are developed to satisfy the requirements. Pahl et al. (2007) emphasized that this stage should lead to several feasible solution variants or alternatives. As such, this phase relies heavily on creativity, which Cross (2000) described as the reordering or recombination of existing elements.

2.1.1.4 Conceptual Design Phase IV: Concept Evaluation and Selection

The final phase in the conceptual design process is the concept evaluation and selection phase, which is concerned with evaluating and selecting the best possible solution to meet the needs of the customer. During this step, design concepts are evaluated by decision makers so that alternatives can be compared before making the decision as to which concept is best suited to satisfy the need. Through the iterative process of evaluating alternatives, the design concepts are modified, and a single preferred solution evolves either through qualitative or quantitative methods.

2.1.2 Performance Improvement Perspective

The performance improvement perspective is consistent with the system design perspective in that systems are designed to fulfill a purpose. In other words, a system that achieves its purpose has performed as planned. However, the term "performance" has a variety of meanings and interpretations (Folan et al., 2007). This research adopted Lebas and Euske's (2002) action-oriented view that performance is the sum of the activities, which will lead decision makers to taking appropriate actions in the present that will lead to the generation of improved results.

Thus, the performance improvement perspective reflects the management systems approaches that were integrated into the S^2OSD methodology to improve the performance of higher education systems. Specifically, the principles and practices of Total Quality Management (TQM) were first introduced. Although it was popularized in the 1990s, Harnesk and Abrahamsson (2007) argue that TQM has been adapted over time. In fact, the authors purported that TQM represents an overarching umbrella term for several approaches such as Six Sigma, 5S, Total Productive Maintenance, and the Balance Scorecard.

Next, the review focuses on three elements of TQM that also possess distinct bodies of knowledge: strategic planning, performance measurement system design, and customer satisfaction. Strategic planning is presented to describe how organizations examine their future and how they go about determining a course of action to achieve that future. Performance measurement is presented to describe the system design processes and frameworks that guide decision makers through quantifying the efficiency and effectiveness of actions. Finally, the measurement of customer satisfaction is reviewed to describe how organizations determine how to satisfy the needs of the customers.

2.1.2.1 Total Quality Management

TQM provides a systems approach to management, a philosophy, and a set of guiding principles and practices that equip organizations with a template for success through meeting the needs of their customers (Dean & Bowen, 1994; Spencer, 1994). Miller (1996) defined total quality management as "an ongoing process whereby top management takes whatever steps necessary to enable everyone in the organization in the course of performing all duties to establish and achieve standards which meet or exceed the needs and expectations of their customers" (pg. 157).

The genesis of TQM began almost two decades ago with the teachings of quality gurus such as W. Edwards Deming, Joseph Juran, and Philip Crosby (Hackman & Wagemen, 1995). Since that time, TQM has become a management philosophy that has found its way into most sectors of contemporary business practices (Sousa & Voss, 2002). TQM has also diffused into other organizational structures, such as healthcare, government, non-profit organizations, educational institutions (Hackman & Wageman, 1995), and service organizations. Additionally, a number of quality awards, including the Deming Prize in Japan, the Malcolm Baldrige Quality Award in the U.S. and the European Quality Award, have all adopted core TQM ideas to promote quality and to serve as frameworks against which organizations assess or measure themselves (Bohoris, 1995).

Despite the variety of definitions, models, and frameworks associated with TQM, quality management has typically been characterized according to its guiding principles, practices, and techniques (Dean & Bowen, 1994). Evans and Lindsay (2008) maintained that much of what has been written about quality in the context of management frameworks is based on three principles: customer focus (described hereafter as "orientation"), continuous improvement, and teamwork.

Customer Orientation: This principle is based on the notion that customer satisfaction is a vital requirement for long term organizational success, requiring the entire organization to be focused on meeting customer needs (Dean & Bowen, 1994). Thus, the goal of satisfying the needs of the customer is a fundamental tenet of the quality management perspective. Organizations carry out this principle by designing and delivering products and services that fulfill customer needs.

Continuous Improvement: The second principle is continuous improvement, which requires the ongoing examination of processes with the ultimate goal of improved methods. Underlying this principle is the assertion that organizations are systems of interrelated processes that can be enhanced to meet the needs of the customer (Dean & Bowen, 1994). The Plan-Do-Study-Act (PDSA) cycle, first introduced by Shewhart (1939) and later popularized by Deming (1986), broadly defined the four-step continuous improvement process.

- **P**lan – gather data to identify and define the problem that needs improvement, and develop a plan of action to identify the means to achieve those improvements (Temponi, 2005).
- **D**o – Execute the plan.
- **Study** – Collect data and evaluate the results.
- **A**ct – Understand the results and take action to improve the process.

According to Evans and Lindsay (2008), incorporating these processes links all of the necessary activities together to achieve desired results. The PDSA cycle is based on the essential elements of the scientific method: *hypothesis* (a theoretical explanation of observations), *experiment* (a test of the hypothesis) and *evaluation* (a systematic and rigorous assessment of the design, implementation, or outcomes of a program). Shewhart (1939) described these three steps in terms of a quality control process. In other words, the analysis and design processes are carried out to complete the planning stage for the *specification* of what is wanted, the plans are implemented during *production* to satisfy the specification, and the implementation is evaluated during *inspection* to determine if the results produced ultimately satisfy the specification.

Teamwork: Teamwork is the third principle. The participation of the entire organization towards meeting customer needs is critical to organizational success. These principles are interlinked. An organization's customer orientation shapes its business strategies; continuous improvement is needed for achieving customer satisfaction; and teamwork is essential for carrying the processes that span hierarchical, functional, and organizational boundaries. Therefore, the quality management perspective provides a set of mutually reinforcing principles that are supported by a set of practices and techniques centered on meeting the needs of the customer (Dean & Bowen, 1994).

Although TQM was popularized in the 1990s as noted, many different varieties and interpretations are present today. A review of the literature for Strategic Planning, Performance Measurement System Design, and Customer Satisfaction are reviewed – each of which have distinct bodies of knowledge that overlap aspects of TQM. These elements are particularly important because they were integrated into the development of the S^2OSD methodology.

2.1.2.2 Strategic Planning

While TQM consists of planning/designing, implementing, using, and improving the performance of organizations, the S^2OSD methodology is focused on the planning aspect of the continuous improvement cycle. Planning is an important aspect of the performance improvement perspective because it provides "a disciplined effort to produce fundamental decisions and actions that shape and guide what an organization (or other entity) is, what it does, and why it does it" (Bryson, 2004, pg.6). Whereas planning is an integral component of performance improvement, "strategic" planning is within itself a vast and important body of knowledge that is currently being applied to "virtually all large corporations around the world" (Steiner, 1979, pg.vii).

As argued by Mintzberg (1994), the emphasis of strategic planning is on strategy, which is realized through the consistency of decision making and actions. Steiner (1979) described strategic planning as a process, a philosophy, and a structure. The futurity of current decisions means that organizational leaders should be able to systematically analyze the chain of cause and effect consequences over time of actual or intended decisions that are to be made. Alternative courses of action should also be explored to essentially design a desired future and identify ways to bring it about. As a process, strategic planning begins with the identifying of organizational aims, defining strategies and policies to achieve them, and developing detailed plans to ensure needed strategies are implemented to achieve desired results. As a philosophy, strategic planning is a thought process that requires individuals to make decisions based on some desired view of the future, which involves a determination to plan systematically and consciously. As a structure, strategic planning provides a structural framework to link strategic plans to programs, budgets and operating plans.

The literature abounds with the benefits of strategic planning, most notably its ability to set direction and a course of action that is designed to meet performance objectives. Greenley (1986) extracted from the literature a list of the following strategic planning process advantages: 1) Helps identify future opportunities; 2) Provides an objective view of management problems; 3) Creates a framework for the review of planned execution and control activities; 4) Minimizes the effects of adverse conditions and changes; 5) Enables decisions to be more effectively aligned with objectives; 6) Facilitates the allocation of time and resources to identified opportunities; 7) Provides coordination of the execution and tactics of plans; 8) Provides a holistic effort; 9) Minimizes time and resources dedicated to correcting ad hoc decisions; 10) Creates a framework for internal communication between personnel; and 11) Facilitates the identification of priorities.

Additionally, a number of studies have reported a positive association between strategic planning to organizational performance (Greenley, 1994). The performance implications of the formal strategic planning process have been subjected to empirical investigations since the 1950s (Armstrong, 1982), and continues to be an extensive debate today (Rudd et al., 2008). Despite the positive claims, research findings on the relationship between formal strategic planning and organizational performance have yielded inconsistent findings (Greenley, 1994; Andersen, 2000; Delmar & Shane, 2003; Falshaw et al, 2006). In spite of the evidence and continuing criticism, the formal planning approach outlined in this section continues to be advocated (French, 2009) in the performance improvement literature. As a result, the planning aspect of the performance improvement cycle, which is also the focus of the conceptual system design process, is the focus of the S^2OSD methodology.

2.1.2.3 Performance Measurement System Design

Performance measurement research has been the focus of practitioners and academics across a diverse set of disciplines. While measurement is a critical element of TQM, researchers in areas such as operations research, industrial engineering, information systems, management, manufacturing, marketing, and accounting are contributing to the thriving body of knowledge in performance measurement. As a consequence of the multidisciplinary nature of the research, several definitions have been proposed with little consensus regarding the main elements and characteristics of performance measurement (Folan & Browne, 2005; Franco-Santos et al., 2007).

Neely et al. (1995) provided the most cited definitions for a 1) a *performance measurement*, which is the process of quantifying the efficiency and effectiveness of action; 2) an individual *performance measure*, which is a metric used to quantify the efficiency and/or effectiveness of an action; and 3) a *performance measurement system*, which represents a set of metrics (i.e., dimensions) used to quantify both the efficiency and effectiveness of actions.

Although these precise definitions are very useful, they do not convey the totality of what is being defined in the literature or in practice as performance measurement (Bourne et al. 2003). In contrast, Franco-Santos et al. (2007) identified key characteristics of performance measurement systems from a review of 17 definitions associated with some 300 studies in the literature. Their analysis of these definitions revealed some commonalities with respect to features, role(s), and processes, which is summarized in Table 2-2.

Table 2-2: Characteristics of Performance Measurement Systems

Features	Roles	Processes
(1) *Performance Measures* - metrics or indicators	(1) *Measure Performance* - monitors progress, measures, and evaluates performance	(1) *Selection and Design of Measures* - identifies stakeholders needs, planning, strategic objectives, measures design and selection, and target setting
(2) *Supporting Infrastructure* - method to acquire, collect, analyze, interpret, report, and disseminate performance information	(2) *Strategy Management* - planning, strategy formulation, strategy implementation/execution, and strategy alignment	(2) *Collection and Manipulation* - provides data capture and analysis
(3) *Goals* – specific objectives that organizations plan to achieve	(3) *Communication* - internal and external communication, benchmarking and compliance with regulations	(3) *Information Management* - provides information provision, interpretation, decision making
	(4) *Influence Behavior*- rewarding behavior, managing relationships and control	(4) *Performance Evaluation and Rewards* - evaluate performance and link it to rewards
	(5) *Learning and Improvement* - providing feedback, organizational learning	(5) *System Review* – procedures to review and modify the performance measurement system

Table 2-2 identifies three features to describe properties or elements, five roles to describe the functions that are performed, and five processes to describe the series of actions that comprise the performance measurement system. Additionally, a wide range of criteria have been developed that describe attributes of effective performance measures and measurement system design. In particular, characteristics of what to measure, processes for how to measure, and frameworks that consider the set of performance measures and an associated structure are presented. Historically, the foundation for performance measurement system design emerged through a series of recommendations that assisted in the process of developing robust performance measures. Many of the system design recommendations were proposed in the late 80s and early 90s (Fortuin, 1988; Franco-Santos & Bourne, 2005; Globerson, 1985; Lea & Parker, 1991; Lynch & Cross, 1991; Maskell,1989), and have been extended upon in more recent literature (Folan & Browne, 2005; Franco-Santos & Bourne, 2005; Hudson et al., 2001; Neely et al., 1997; Pun &White, 2005).

Neely et al. (1997), in particular, provided a comprehensive review of the system design recommendations that identified 22 attributes of effective performance measures, which Hudson et al. (2001) later developed into the typology shown in Table 2-3. The typology consists of dimensions of performance, characteristics of performance measures and the performance measurement development process requirements.

Table 2-3: Characteristics of Effective Performance Measurement System Design

Performance Dimensions	Characteristics of Performance Measures	PM Development Process Requirements
Quality	Explicit purpose	Need evaluation/existing PM audit
Flexibility	Relevant and easy to maintain	Key user involvement
Time	Simple to understand and use	Strategic objective identification
Finance	Provide fast accurate feedback	PM development
Customer Satisfaction	Link operations to strategic goals	Periodic maintenance structure
Human Resources	Stimulate continuous improvement	Top management support
	Measure performance areas critical to success	Full employee support
		Clear and explicit objectives
		Set timescales

Many frameworks have been proposed that support the key characteristics of effective performance measurement systems described in Table 2-3. The purpose of the frameworks is to assist organizations with defining a set of performance dimensions that reflects their goals and evaluates their performance appropriately (Kennerly & Neely 2003). According to Folan and Browne (2005), performance measurement frameworks can be classified based on two aspects: procedural and structural frameworks. A procedural framework provides the process for designing measures based on strategy, and the structural framework provides the typology for managing through measures. Table 2-4 summarizes a considerable amount of key structural and procedural frameworks (Folan & Browne, 2005; Kennerly & Neely, 2002; Tangen, 2004).

Table 2-4: Performance Measurement System Frameworks

Structural Framework	**Reference**	**Dimensions**	**Process Framework**
Performance Measurement Matrix	Keegan & Eiler (1989)	Cost, Non-cost, Internal Environment, External Environment	Keegan & Eiler (1989)
Results and Determinants Matrix	Fitzgerald et al. (1991)	Results (Competitiveness, Financial Performance), Determinants (Quality, Flexibility, Resource Utilization, Innovation)	-
SMART (Performance) Pyramid	Lynch and Cross (1991)	Vision, Market, Financial, Customer Satisfaction, Flexibility, Productivity, Quality, Delivery, Cycle Time, Waste	Cross and Lynch (1995)
Balanced Scorecard	Kaplan & Norton (1992)	Financial, Customer, Innovation and Learning, Internal Business, Processes	Kaplan & Norton (1996)
Brown's Framework	Brown (1996)	Inputs, Processes, Outputs, Outcomes	-
Comparative Business Scorecard	Kanji (1998)	Stakeholder Value, Delighting the Stakeholders, Process Excellence, Organization Learning	-
Integrated Performance Measurement Framework	Medori & Steeple (2000)	Quality, Flexibility, Cost, Time, Delivery And Future Growth	Medori and Steeple (2000)
Performance Prism	Neely et al. (2002)	Stakeholder Satisfaction, Strategies, Processes, Capabilities, Stakeholder Contribution	-
Sink and Tuttle Model	Sink and Tuttle (1989)	Effectiveness, Efficiency, Quality, Productivity, Quality of Work Life, Innovation, Profitability/ Budgetability	Sink and Tuttle (1989)
Time based performance measurement framework	Azonne (1991)	Time, Internal Configuration, External Configuration	Azonne (1991)
-			Andersen & Fagerhaug (2002)
-			Wisner and Fawcett (1991)
-			Neely et al. (2000)

The performance measurement system frameworks in Table 2-4 consist of a wide range of diverse dimensions. Furthermore, the process frameworks vary from simple processes to detailed steps to implement each framework. For example, both Keegan & Eiler (1989) and Azzone et al. (1991) provided a simple three step performance measurement system design process. On the other hand Wisner & Fawcett (1991) and Neely et al., (2000) proposed a more detailed process (9 and 10 steps respectively). Similarly, Kaplan and Norton (1993) provided detailed 8 step process to design measures for the balanced scorecard that is based on a series of interviews and workshops with senior managers and executives.

The diversity of dimensions and processes suggests that there is not a one size fits all approach to measuring performance within businesses. Furthermore, not all of the dimensions in Table 2-4 are applicable to higher education. As a result, the S^2OSD methodology will incorporate the characteristics of effective performance measurement system design and adapt relevant dimensions and processes to measure performance in higher education.

2.1.2.4 Customer Satisfaction

Anderson et al. (1994) defined customer satisfaction as "the degree to which an organization's customers continually perceive that their needs are being met by the organization's products and services. As a result, customer satisfaction comes from meeting customer needs. This is exemplified by a customer-driven focus" (Tennant, 2002, pg. 480), which is also known as customer orientation.

Oliver (1997) asserted that customers attempt to satisfy their needs based on two reasons. On the one hand, a customer may be concerned with eliminating a deficit. For example, an individual who purchases a car seeks to remedy the lack of viable transportation. Oliver referred to this concept as "restoration" because the customer seeks to restore the deficit to a satisfactory state. On the other hand, a customer may seek ways to add value to their life—such as through the addition of a car sunroof—which is referred to as an "enhancement." Whether a customer is seeking an enhancement or the removal of a deficit, a need simply represents "what" is needed by customers, whereas design parameters, engineering characteristics, and design requirements deal with "how" a need is satisfied by a specific product or service (Bayus, 2009).

Organizations use customer satisfaction as a measure of the success of their products and/or services (Anderson et al., 1994). According to Churchill and Surprenant (1982), the centrality of the marketing concept is that profits are generated through the satisfaction of customer needs. As such, there is widespread acceptance of the relationship between customer satisfaction and organizational performance (Anderson et al. (1994). Specifically, research has demonstrated that customer satisfaction translates to better economic returns for an organization (Anderson et al., 1994, 2004; Fornell et al., 2006).

Many organizations conduct customer satisfaction questionnaires as a way to understand if they are satisfying customer needs, as well as to identify areas that need improvement. Kano et al. (1984) developed a model of customer satisfaction that captures the quality attributes of a product or service based on how well the attribute satisfies customer needs. The model illustrates that not all needs are equal, and that all needs do not have the same impact on customer satisfaction. In fact, the degree of customer satisfaction varies depending on the fulfillment of customer needs. Figure 2-2 depicts the three types of customer needs that have been identified in Kano's model. The horizontal axis indicates the extent to which a customer's need has been fulfilled, while the vertical axis represents a satisfaction continuum.

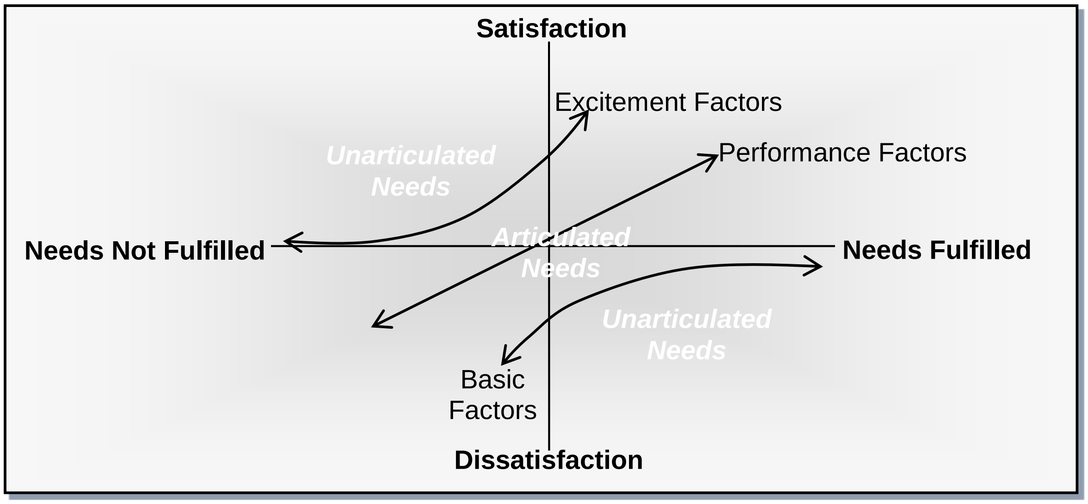


Figure 2-2: Kano's Model of Customer Satisfaction

The three primary types of customer needs illustrated in Figure 2-2 are basic, performance, and excitement factors. The *basic factors* represent features that are expected by customers as prerequisites that must be fulfilled. These requirements are so germane to the product or service that they are often taken for granted. However, when their fulfillment does not lead to higher levels of satisfaction, the customer is likely to be extremely dissatisfied. The *performance factors* represent a linear relationship between customer satisfaction and the level of fulfillment. These needs are often explicitly stated by the customer, and result in satisfaction when fulfilled and dissatisfaction when not fulfilled. The *excitement factors* are elements of products or services that exceed customers' expectations and thus enhance customer satisfaction levels. Although these excitement factors result in greater proportional satisfaction, the absence of these needs does not create dissatisfaction because they often are not expected or clearly required by customers.

Kano's model demonstrates that needs can be either known and articulated by the customer, or unknown (i.e., unarticulated). This helps to explain why customers often experience difficulty in articulating their needs (Fuller & Matzler, 2007). Therefore, the design process must incorporate methods to bring forth both articulated and unarticulated needs. Moreover, this model illustrates the importance of determining the most vital needs of the customer—namely, those needs that are likely to have the greatest impact on customer satisfaction.

In traditional customer satisfaction questionnaires, organizations typically select those attributes with the lowest satisfaction rating to focus improvement efforts. The weakness with this approach is that attributes with lower satisfaction levels could be of little concern to customers. Since customers typically evaluate quality performance on the basis of a few vital attributes, merely collecting information regarding satisfaction levels is not necessarily the most appropriate method for determining areas of improvement. Therefore, an approach that incorporates both satisfaction and importance is more useful in identifying needs where improvements would have the greatest impact (Yang et al., 2003, 2009).

2.1.3 System Design and Performance Improvement Methods & Tools

A number of performance improvement and system design methods and tools were adapted to develop the S^2OSD methodology, as described in Chapter 3. A cursory review of these methods and tools are summarized in this section, and further detailed in Chapter 3.

2.1.3.1 Importance Satisfaction Analysis (ISA)

Importance-Satisfaction Analysis (ISA) offers practitioners a method for measuring customer satisfaction and focusing on priorities requiring the greatest attention. To overcome the shortcomings of traditional customer satisfaction questionnaires, satisfaction and importance are merged into a single questionnaire (Graf et al., 1992). Originally introduced by Martilla and James (1977) as an importance performance analysis tool, ISA provides a diagnostic tool to illustrate the importance that a customer attaches to their satisfaction with how a specific need is being met (Yang et al. 2003, 2009).

2.1.3.2 SWOT Analysis

SWOT (Strengths, Weaknesses, Opportunities, Threats) Analysis was developed as a strategic planning tool to examine an organization's internal strengths and weaknesses and the external environment's opportunities and threats. While SWOT analysis can be used for a number of decision making processes, this method was initially developed in the 1960s to help Fortune 500 companies understand why corporate planning failed (Humphrey, 2004).

By providing a template for assessment, SWOT analysis allows organizations to determine the current state as well as identify the desired state. As such, SWOT analysis results in the identification of an organizational strategy, which builds on the organizations strengths while avoiding the weaknesses, thereby enabling the organization to leverage future opportunities while mitigating any threats.

2.1.3.3 Quality Function Deployment (QFD) Method

Quality Function Deployment (QFD) is a method that integrates conceptual system design and performance improvement perspectives in order to carry out the first phase of the conceptual system design process. Developed in Japan during the late 1960s, the objective of the QFD method is to design quality products that satisfy customer needs (Akao, 2004).

QFD is a team-based approach that uses a set of matrices as a tool to translate customer needs into engineering characteristics, after which appropriate quality functions that contribute most to satisfying customers are deployed throughout the development process (Akao, 2004). The first matrix, referred to as the House of Quality (which is at the core of the QFD concept) provides the means to coordinate the communication and planning processes of the diverse groups who are responsible for developing or refining a new product or service.

2.1.3.4 Function Means-Tree

The function means-tree is another tool that is used in system design to identify the functional elements in a system. The functional decomposition process is based on the Hubka's law, which posits that there are causal relationships between the functions and the means of systems. The functions describe the purpose and are expressed as verb-noun pairs. A function is realized by a means. Based on this law, the system can be modeled as a function-means tree, which consists of a hierarchical arrangement of function levels and means levels connected by lines. These lines correspond to the causal relationships between the function and the means (Hansen, 1995).

2.1.3.5 Pugh Decision Matrix (PDM)

The Pugh Decision Matrix (PDM) is a concept evaluation method that offers an approach for decision makers to select the most promising design concepts (Dieter & Schmidt, 2009). The PDM compares the generated design concepts in a matrix format against a number of performance criteria. This is a useful tool for scoring each concept based on its ability to meet customer needs/requirements (Pugh, 1991). Ullman (2003) asserted that PDM is a useful tool to test the understanding of requirements, quickly identify the strongest concepts, and facilitate the generation of new concepts. This requires the development of the performance criteria, selection of the most promising design concepts for evaluation, and the generation of scores to provide the basis for evaluation.

2.1.3.6 Strategic-X Matrix

Several studies have highlighted a range of strategic tools that have been used in a variety of contexts (see Ghamdi, 2005; Gun & Williams, 2007; for a detailed review). The Strategic-X matrix offers a tool to align the organization's objectives, initiatives, plans, performance measures and resources into a single matrix representation. The Strategic X-Matrix represents five key areas: 1) Key Objectives describe both tactical and strategic objectives; 2) Main Initiatives describe "how" to obtain the key objectives; 3) Key Tactics provide a further "how" on the execution of the initiatives; 4) Key Metrics track the performance of plans that are aligned with key objectives; and 5) Resource Accountability identifies who owns the implementation of each line item (Marhevko, 2007).

This matrix provides a management systems tool that can be used to develop action plans. This matrix also facilitates senior leaderships ability to make data driven decisions, in which they have the means to quantitatively assess the implementation stage (i.e., the "Do" phase in the PDSA continuous improvement cycle discussed in the Performance Improvement Perspective). Finally, the matrix can be used to concisely represent the strategic areas during status review meetings to periodically review the progress of the strategy.

2.1.3.7 Information Gathering Methods and Tools

Although gathering information is depicted as the second phase in the conceptual design process, gathering information is actually conducted throughout the systems engineering lifecycle (Hickey et al., 2003). Several methods and tools have been adapted to gather information throughout each phase of conceptual design. Table 2-5 provides a high level review of these approaches (see Davis et al., 2006, Hickey et al., (2003), and Dieter & Schmidt, (2009) for a more comprehensive review).

Table 2-5: Information Gathering Methods & Tools

Method & Tools	Description	Source
Interviews with experts	This method is described as a guided conversation (Blee & Taylor, 2002) intended to uncover the meaning behind an interviewee's experiences (Kvale, 1996).	Davis et al., 2006; Goguen & Linde 1993 Hickey et al., 2003;
Questionnaires	A research tool for collecting information from respondents through a series of questions.	Goguen & Linde 1993; Dahlgaard et al., 2005
Focus Groups	This method interviews a homogeneous group of people guided by a focused discussion to collect information.	Duggan, 2003; Hickey et al., 2003; Goguen & Linde 1993
Affinity Method	A brainstorming method that facilitates the generation of ideas in a team setting. It also provides a diagramming tool that organizes those ideas into natural groupings to understand the problem and help identify innovative solutions.	Duggan, 2003; Dahlgaard et al., 2005;
Participatory and Application Development methods	Collaborative requirements workshop approach that brings key stakeholders together over the course of several days. Approach emphasizes teamwork, communication, and expedites the development process.	Beynon-Davies et al., 1999; Davidson, 1999; Duggan, 2003; Carmel et al., 1993

2.1.4 System Design Methodology

To this point, the relevant literature related to systems engineering fundamentals in the conceptual design phase of the lifecycle has been reviewed. A variety of methods and tools used to carry out each phase has also been reviewed. While each method provides the tools to carry out a specific phase in the design process, it is important to have a unified framework or structured methodology to foster and guide the overall design process.

A methodology provides a collection of integrated processes, methods, and tools that can be used to carry out the design process in a structured manner (Avison & Fitzgerald, 2003; Winstanley, 1991). Common to most design activities are the following activities: (1) Know or understand customer needs; (2) Define the problem that must be solved to satisfy customer needs; (3) Conceptualize the solution through synthesis; (4) Perform analysis to optimize the proposed solution; and (5) Evaluate the resulting design solution to check if it meets the original customer needs (Suh, 2001).

Avison and Fitzgerald (2003) also noted the importance of the philosophy behind the methodology. In other words, they stressed the importance of the beliefs and assumptions that underpin a specific methodology. Furthermore, a design methodology is prescriptive because it provides a concrete course of action for achieving specific goals and solving design problems (Pahl et al., 2007). Several customer-oriented system design methodologies exist that are centered on the needs of the customer. Three methods are briefly reviewed: axiomatic design, participatory design, and user-centered design.

2.1.4.1 Axiomatic Design

Axiomatic design establishes a scientific basis for design and provides the designer with a theoretical foundation based on processes and tools to improve design activities. Axiomatic design essentially facilitates the analysis, synthesis, evaluation, and improvement of design using a mathematical framework and a general set of rules (i.e., axioms) to guide the designer through the decision making process (Suh, 2001).

The design process is carried out across several domains. The output of each domain evolves from abstract concepts to detailed information in a top-down hierarchical manner. The design team goes through an iterative process by "zigzagging" through domains in order to decompose the design problem (El-Haik, 2005). Figure 2-3 also illustrates a core concept of axiomatic design—namely, that it requires a mapping process between the customer, functional, physical, and process domains.

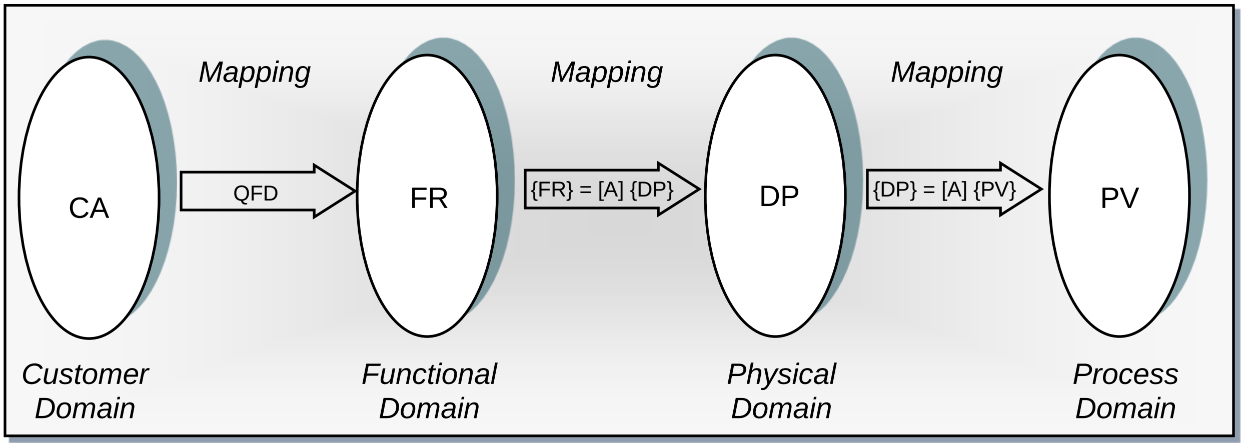


Figure 2-3: Axiomatic Design Mapping Process

The mapping process begins in the "customer needs" domain on the left, which specifies "what we want to achieve," and progresses to the domain on the right that represents the solution of "how to achieve it" (Suh, 2001). The customer domain represents the customer attributes (CA) desired in a product. In the functional domain, CAs are specified in terms of functional requirements (FRs) and constraints (C). While FRs provide the set of independent requirements that characterize the functional needs of the products, the constraints are the bounds on acceptable solutions. The physical domain specifies the design parameters (DP). DPs are the key variables that characterize the design and satisfy the FRs. Lastly, the process domain– specifies the process variables (PV) that are needed to generate the product in terms of DPs. Process variables are the essential variables that characterize the key processes needed to realize the DPs. This mapping is very similar to the process described in Phase I where customer needs are translated into customer requirements, design requirements, and ultimately design solutions. The process domain, however, is unique to Suh's approach.

The design process shown in Figure 2-3 can be represented mathematically by describing the mapping between FRs and DPs as vector in Equation 1:

$$\{FR\} = [A]\{DP\} \quad (1)$$

where [A] is the design matrix, which characterizes the system design and describes the relationship between the FRs and DRs given by:

$$[A] = \begin{bmatrix} A_{11} & A_{21} & A_{31} \\ A_{12} & A_{22} & A_{32} \\ A_{13} & A_{23} & A_{33} \end{bmatrix} \quad (2)$$

An element in the design matrix is given by Equation 3. If A_{ij} is constant, then the design is said to be linear; otherwise, it is a non-linear design:

$$A_{ij} = \partial FR_i / \partial DP_j \quad (3)$$

In order to achieve an optimal design, the mapping process must be carried out while satisfying two fundamental axioms (and additional theorems and corollaries that are also derived from these axioms - see Suh, 1990).

- *Axiom 1: The Independence Axiom. Maintain the independence of the functional requirements.*
- *Axiom 2: The Information Axiom. Minimize the information content of the design*

The independence axiom establishes a relationship between the DPs and FRs such that a specific DP can be satisfied by its corresponding FR without affecting the other FRs. The shape and the dimension of the design matrix [A] is used to characterize the design, and is based on one of the following categories: uncoupled (ideal), decoupled (good), coupled (undesirable). In order to satisfy the independence axiom, the design matrix [A] must be diagonal or triangular. For the diagonal design matrix, each FR can be satisfied independently by a DP. This is the ideal case, which is referred to as an uncoupled design. For the decoupled design, at least one DP affects two or more FRs. To satisfy the independence axiom, the DPs must be adjusted in a fixed sequence to match the corresponding functional requirements one by one such that the design matrix is upper or lower triangular. The independence axiom is not achieved in a coupled design. In this case, the off elements of the design matrix cannot be rearranged to a triangular state (El-Haik, 2005; Suh, 1998, 2001). The design matrices in Figure 2-4 summarize the relationship between the FRs and DPs for an uncoupled, decoupled, and coupled design. An X in a cell indicates that the column's DP affects the row's FR, and a 0 represents the opposite.

Uncoupled Design (Ideal)

	DP1	**DP2**	**DP3**
FR1	X	0	0
FR2	0	X	0
FR3	0	0	X

Decoupled Design (Acceptable)

	DP1	**DP2**	**DP3**
FR1	X	0	0
FR2	X	X	0
FR3	X	0	X

Coupled Design (Undesirable)

	DP1	**DP2**	**DP3**
FR1	X	X	X
FR2	X	X	0
FR3	X	0	X

Figure 2-4: Uncoupled, Decoupled, and Coupled Design Matrices

The second axiom (information axiom) is defined in terms of the probability of successfully satisfying FRs or DPs. Generally, in the case of FRs, the information content is defined as:

$$I = \sum_{i=1}^{n} \left[\log_2 \frac{1}{\mathrm{pi}}\right] \quad (4)$$

where p_i is the probability of DP_i satisfying FR_i. Since there are *n* FRs, the total information content is the sum of the probabilities. In order to satisfy the Information Axiom, the smallest *I* is the best design because it requires the least amount of information needed to satisfy the functional requirements of the design (Suh, 1998; 2001).

Axiomatic design is one of the most widely recognized design methodologies in academia. Even though its mathematical base introduces rigor into the design process, and its mapping process provides a systematic approach to functional decomposition, axiomatic design features several limitations. First, most designs are coupled in practice. Therefore, it is often not practical to maintain the independence of the functional requirements by decoupling existing coupled designs to create improvements. Furthermore, these axioms are difficult to understand and apply in practice, especially for institutional leaders who are typically not required to have a background in engineering design. Lastly, the axiomatic design methodology is descriptive; as such, it does not seek to prescribe steps in order to achieve design solutions (Dieter & Schmidt, 2009).

2.1.4.2 Participatory Design

The axiomatic design methodology provides the structure to gather and map the necessary requirements for system design. Nonetheless, this approach lacks a specific methodology to ultimately prescribe how customers/users are involved in the design process. Participatory Design (PD) is both a system design methodology and philosophy that advocates the direct involvement of the people that are intended to use the system. It assumes that the users themselves are in the best position to help determine system improvements. This approach differs from traditional design approaches in that it assumes that users possess the most knowledge about what they do and what they need, while the design engineers act as technical consultants (Schuler & Namioka, 1993).

Originating in Scandinavia, this methodology grew out of the workplace democracy movement to make system design more participatory and democratic (Muller et al., 1993). PD empowers workers to be actively engaged in the analysis and design of the systems they will eventually use to carry out their work functions. Two themes govern the implementation of the PD principles: mutual reciprocal learning and learning by doing. In mutual reciprocal learning, the designer and user learn from each other about work practices through joint experiences. This is particularly useful in assisting the designer in becoming familiar with the user's work setting and activities. With respect to learning by doing, the PD methodology engages users in creative design through a variety of hands-on practices.

A number of methods and tools can be used to support the PD methodology. For example, Muller et al (1997) identified 61 PD methods, including problem identification, work analysis, requirements analysis, high-level design, detail design, evaluation, field-customization, and redesign. Even though a number of methods exist, Baecker et al. (1995) conceptualized five defining characteristics of the PD methodology, including 1) *building relationships* between the customer and design team; 2) *conducting contextual inquiry* through workplace interviews to develop a better understanding of the context of the work problems; 3) *brainstorming sessions* to generate ideas for improvement; 4) the use of *storyboarding* to develop ideas into illustrated scripts of a "day in the life" of customers; and 5) the use of *iterative process* in which the design is carried out in an iterative fashion.

In contrast to the axiomatic design methodology, the PD methodology is typically implemented with "low-tech" tools (e.g. Blackboards, index cards, and Post-It notes), making it easier for the customer to understand and use (Carmel et al., 1993). As Brown (1997) indicated, these methods and tools are seen more as a resource for designers to use as needed, rather than essential for producing a coherent framework. However, they do provide the benefit of prescribing who participates, how they participate, and at what point (i.e., when) in the systems development lifecycle the method should be employed (Allen et al., 1993).

2.1.4.3 User-Centered Design

User-centered design (UCD) is a design methodology that also focuses on the needs of the user throughout the design process. The seminal work of Norman and Draper (1986) proposed that UCD should be driven by the needs of the user. Consequently, UCD not only represents a design methodology, but also a philosophy that places the user at the center of the process. At one end of the UCD spectrum, user involvement may be relatively minimal. At the other end, however, involvement can be intensive with users actively participating (i.e. participatory design) throughout the design process (Abras et al., 2004). Although PD prescribes how customers/users should be involved in the design process, it lacks a unifying framework that addresses each phase of the conceptual design process.

Karat (1997) argued that the goal of UCD is the development of usable systems. Although this goal is achieved through involvement of the users in system design, the methodology is fairly open as to how this is accomplished. The ISO 13407 (1999) standard, "Human-centered design processes for interactive systems," provides guidance for accomplishing user-centered design. The ISO 13407 (Figure 2-5) advocates four design principles: 1) the active involvement of users and a clear understanding of user requirements, 2) a functional allocation of requirements, 3) the iteration of design solutions, and 4) a multidisciplinary design approach. ISO 13407 also features an iterative design process.

This process is consistent with the analysis-synthesis-evaluation cycle inherent in conceptual design, which begins with the identification of a need. The next step in the process is to understand and specify the context of use. This entails understanding the characteristics of the user, the tasks and the environment in which the system operates, and the relevant aspects that are important for the system design. The next step in user-centered design seeks to identify user and organizational requirements with respect to efficiency, effectiveness, and satisfaction. Once that has been accomplished, design solutions are developed based on existing knowledge and user input, which is typically an iterative process until design objectives are met. Finally, the design is evaluated to determine if user requirements have been achieved.

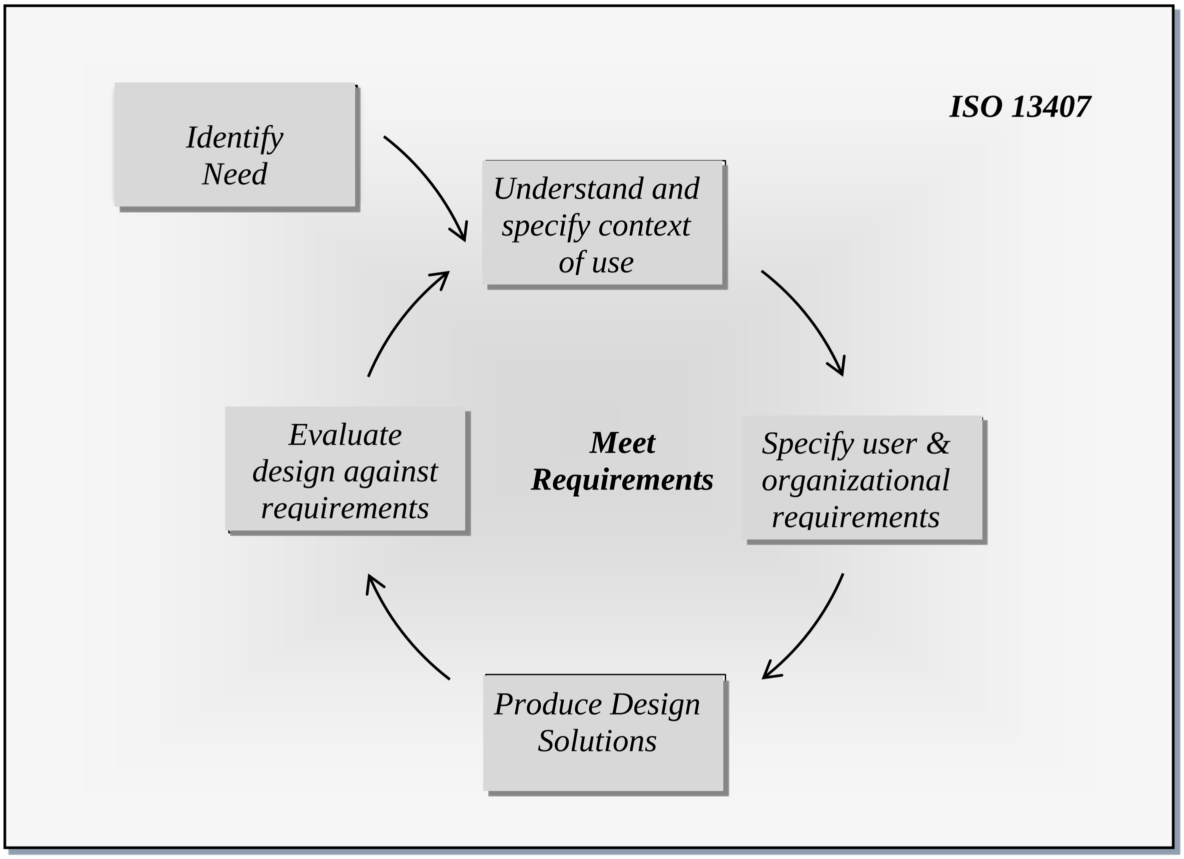


Figure 2-5: ISO 13407 Process

2.1.5 Customer Orientation Summary

A customer orientation literature review was conducted to identify critical concepts and principles that were integrated into the S^2OSD methodology. Particular emphasis was paid to the customer-oriented systems approaches (i.e., the system design and performance improvement perspectives) related to identifying, evaluating, and addressing the needs of customers. Although these concepts focused on customers (also referred to as users, consumers), the fundamental premises offer promising insights for understanding and designing a plan of action to meet the needs of engineering students.

The fundamental tenet of the quality management perspective is a customer orientation that emphasizes customer satisfaction. Additionally, quality management also advocates the continuous examination of processes in search for improved methods, as well as a team-based approach to improvement. As noted, a system design perspective provides the processes, methods, and tools needed to develop a methodology based on systems engineering fundamentals. While quality management is useful in shaping a management philosophy that focuses on the continuous improvement of all functions within an organization (Flynn et al., 1994; Kaynak, 2003), the system design perspective focuses on conceptual design, which was integral to the development of the S^2OSD methodology. Underpinning each of these perspectives is the notion that meeting customer needs is the path to success.

Each of the methodologies, methods, and tools discussed in this chapter was adapted to develop the S^2OSD methodology in Chapter 3. Additionally, the literature review helped to conceptualize the S^2OSD methodology and its associated principles at the conclusion of the literature review. However, in order to fully develop the usability of S^2OSD methodology in higher education, the domain knowledge is needed. Therefore, the next section addresses student success research and practice in higher education.

2.2 Student Success Orientation

Improving student success in higher education has been the subject of empirical inquiry for more than 70 years (Braxton et al., 2004). According to Kuh et al., (2006), student success is defined as “academic achievement, engagement in educationally purposeful activities, satisfaction, acquisition of desired knowledge, skills and competencies, persistence, attainment of educational objectives, and post-college performance” (pg. 7). This definition differs from the more common term, “student retention,” which implies that students are successful only when they persist to graduation (i.e., earn a degree). Thus, the extensive literature on student success reflects the fact that students can experience success at several stages in the college experience process.

Perna and Thomas (2006) suggested that student success can be defined in terms of four key transitions or stages in the college experience process: becoming ready for college, enrolling in college, college achievement (or the college experience), and post-college attainment. This definition of student success emphasizes certain conditions or outcomes—namely, that all students should receive adequate high school preparation; they should be accepted to college; they should persist to program/degree completion; and they should go on to pursue careers/and or further their education.

Although there are several indicators of success during the college experience, many researchers consider degree attainment to be the definitive measure of student success (Kuh et al., 2006). However, a number of terms and quantifiable indicators have been commonly used in the literature. Braxton (2006), for example, proposed the following nine "markers of student success" as viable measures: educational achievement, academic attainment, acquisition of general education, development of academic competence, development of cognitive skills and intellectual dispositions, occupational attainment, preparation for adulthood and citizenship, personal accomplishments, and personal development. These diverse markers of success across the various stages of the college experience signify the vastness of the student success body of knowledge. Therefore, the purpose of this section is to provide a high level review of both research and practice, identify and understand those factors that influence student success from a theoretical perspective, and understand how they have been applied in practice. It should be emphasized, however; the focus of this research is on the post-enrollment college experience.

2.2.1 Student Success Theoretical Perspectives

The most frequently cited theories define student success in college in terms of persistence, educational attainment, and obtaining a degree (Kuh et al., 2006). As a result, the following terms are frequently found in the literature pertaining to student success: student departure, attrition, retention, and persistence. Although several theories have been developed, an overview of the most comprehensive and influential theoretical models are presented in order to provide an understanding of the factors associated with student success.

The seminal work of Tinto's (1975, 1987, 1993) student integration model has become the most widely accepted model for student success. In fact, it has achieved near paradigmatic status in higher education student success research (Berger & Milem, 1999; Braxton et al., 1997; Guiffrida, 2006; Kuh et al., 2006; Pascarella & Terenzini, 2005). In an attempt to challenge the shortcomings of Tinto's model, several other theoretical perspectives have been presented in the literature to address its limitations from various perspectives. Therefore, Tinto's sociological perspective is discussed in detail, and a brief summary of the organizational, psychological, financial, minority, involvement/engagement perspectives is provided to identify student success factors that have been tested in the research literature.

2.2.1.1 Sociological Perspective

Tinto's integration model of student departure (Figure 2-6) has had been widely cited in the literature on student success, and has served as the conceptual framework for several subsequent studies (Berger & Milem, 1999; Braxton et al., 1997; Guiffrida, 2006; Kuh et al., 2006; Pascarella & Terenzini 2005). Seidman (2005), in fact, asserted that Tinto's theory is the most studied, tested, modified, and critiqued theory in the literature.

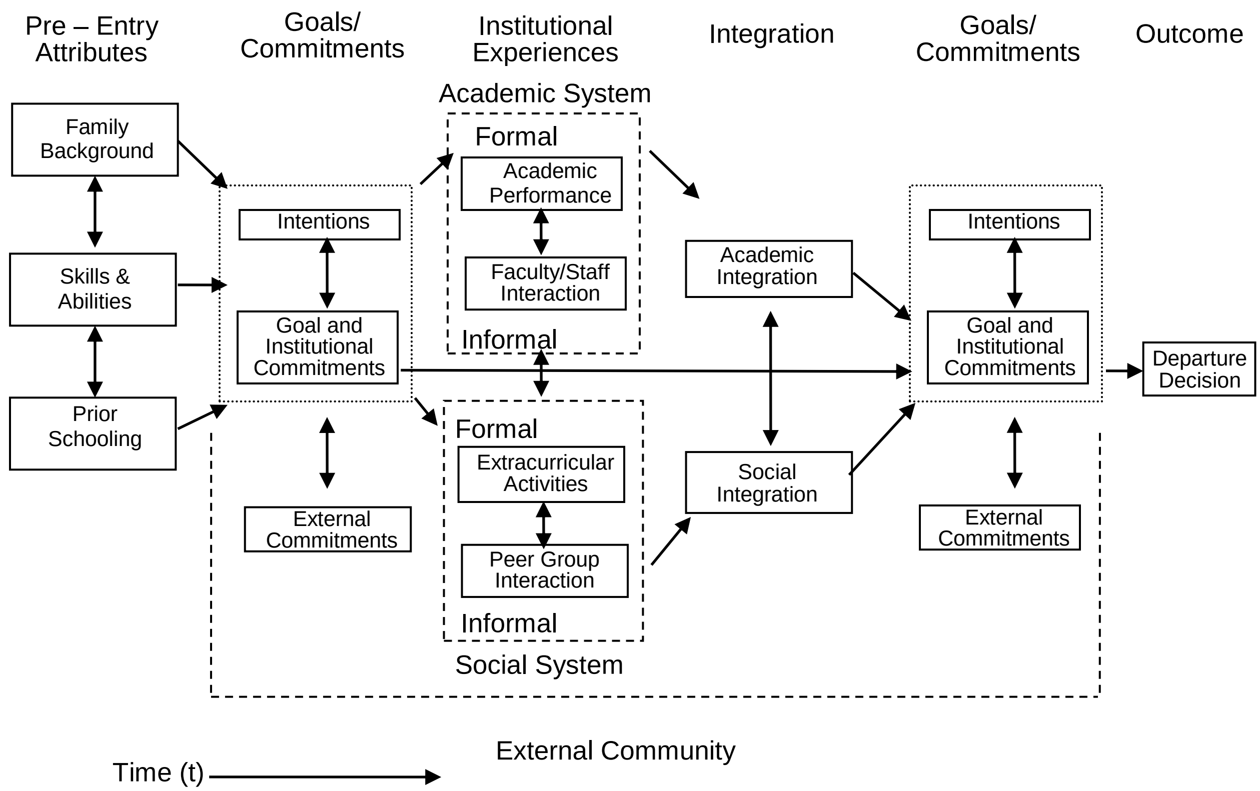


Figure 2-6: A Sociological Perspective: Tinto's (1993) Student Integration Model

Building upon the earlier work of Spady (1970), Tinto's (1975) model was initially based on the sociological concept of suicide. Spady (1970) first applied Durkheim's theory of suicide to dropping out, which asserted that individuals are more likely to commit suicide when they are insufficiently integrated socially and intellectually. When this notion is applied to student retention, it highlights the importance of the student integrating into the social and academic systems of the institution. Tinto (1987, 1993) later incorporated Van Gennep's (1960) studies of the rites of passage in tribal societies that focused on the movement of individuals from membership in one group (e.g., youth) to that of another (e.g., adulthood). Van Gennep argued that the process for succeeding groups was marked by three distinct phases—separation, transition, and incorporation. Tinto related these phases to student departure, in that students entering college must separate from their prior communities, transition from high school to college, and fit into college life. This expanded view incorporates a time dimension in the form of longitudinal stages of the integration process, which specifically addresses the early stages of separation, transition, and the challenges that students face in the academic and social realm of college life (Swail et al., 2003). Drawing from these theories, Tinto (1975, 1987, 1993) developed an "interactive model of student departure," shown in Figure 2-6.

Student departure can be viewed as a longitudinal process of interactions between the individual and the academic and social systems of the institution. As shown in Figure 2-6, Tinto (1975, 1987, 1993) theorized that students enter college with a wide range of pre-entry attributes such as family background, personal attributes, varying types of skills, and precollege educational experiences. Each is argued to have a direct impact on student departure decisions because of its impact on the level of academic achievement in college. Furthermore, these attributes are posited to have an indirect affect through their influence on the goals and commitments (both to college completion and the institution), as well as future educational activities. These factors, coupled with the pre-entry attributes, establish the initial conditions for subsequent interactions between the student and the other members of the institution.

The model also suggests that subsequent experiences within the academic and social systems of the institution are related to further persistence in college. Tinto (1975, 1987, 1993) asserted that the student's commitment to the institution, as well as the commitment towards college completion, is central to whether an individual persists to graduation or drops out of college. As a result, the level of social and academic interactions during college can either strengthen or weaken the student's goals and commitments regarding their decision to stay or withdraw from the institution (Tinto 1975, 1987, 1993).

2.2.1.2 Organizational Perspective

The organizational perspective is concerned with the impact that an institution (i.e., organization) has on the socialization and satisfaction of students (in the case of an academic institution). Bean (1980) argued that students leave their institutions for reasons similar to those that cause employees to leave their work organizations. Bean further argued that previous studies, including Tinto's (1975) sociological perspective, have neglected to address some of the major determinants of student attrition, which is why he adapted the Price (1977) model of turnover in work organizations.

Bean's (1980, 1983) Student Attrition Model was developed from the attitude behavior theory. Whether in industry or academia, an individual's decision to leave is based on a feedback loop from beliefs to behavior, such that beliefs lead to attitudes, which lead to intentions, which lead to behavior (Bean & Eaton 2000). In the case of academia, student beliefs are shaped by their experiences with their college or university. For example, do students feel connected to the school? Do they believe they are receiving a quality education? Moreover, students' experiences also influence their attitudes and the degree to which they are satisfied with the institution, which, in turn, impacts their intentions and subsequently their desire to either persist or drop out.

2.2.1.3 Psychological Perspective

Tinto's (1975, 1987, 1993) model has been modified to investigate how psychological processes can be understood in the student departure process. Bean and Eaton (2000) characterized a student's decision to drop out of college as a behavioral decision that is psychologically motivated, in which collective issues of sociology playing a secondary role in that decision.

Bean & Eaton (2000) integrated the organizational perspective with three psychological theories to formulate their model on student departure. Similar to Tinto's model, Bean and Eaton asserted that students enter with precollege characteristics that shape how they experience the college environment. Interactions with the institutional environment then result in psychological processes (i.e., positive self-efficacy, approach and avoidance behavior, locus of control) that affect motivation. Psychological characteristics that impact a student's decision to leave or stay can be found both at the level of the individual student as well as at the level of the college environment. These processes then lead to similar variables from the sociological and organizational perspective: academic and social integration, institutional fit and loyalty, intent to persist, and persistence (Braxton & Hirschy, 2005).

2.2.1.4 Financial Perspective

Predictably, finances do play a significant role in persistence decisions. Although several studies examined the role of finances in persistence decisions, the earlier sociological and psychological approaches did not include finances as an independent variable. The exceptions were Bean (1982) and Tinto (1987, 1993), who recognized the importance of finances in persistence decisions.

Later researchers agreed that a student's ability to afford college plays an important role in persistence versus departure decisions. Throughout the college process, students weigh the anticipated educational and occupational return of earning a degree against the cost of receiving a college education (Pascarella & Terenzini, 2005). With the rising cost of tuition and fees, students depend on financial aid as a method for gaining access to higher education, and ultimately for earning their degrees. Since family income has not kept up with rising costs, college is becoming less affordable. Studies that concentrate on the financial perspective have typically focused on the following three topics: 1) financial aid receipt—receiving financial aid in the form of grants, scholarships, work study, and loans; 2) unmet needs—the financial needs that remain after financial aid and family support have been exhausted; and 3) Ability to pay—a measure of a student's ability to pay for college (Pascarella & Terenzini).

St. John et al. (1996) integrated the financial perspective with the psychological (Spady 1970, 1971; Tinto 1987, 1993) and sociological perspectives (Bean 1980) to develop a theory of the financial nexus between college choice and persistence (St. John et al., 2000). Once the student enters college, institutional characteristics, collegiate experience, and academic performance help to change or reinforce whether their academic and social experiences are worth the academic, social, and financial cost (St. John et al., 2000). If students' post-entry experiences are aligned with their pre-college expectations of the benefits and costs, then they are more likely to persist on to graduation.

2.2.1.5 Minority Perspective

The minority perspective suggests that underrepresented students experience unique challenges that diminish the quality of their college experience (Kuh et al., 2006). Padilla et al. (1997) developed a taxonomy of the barriers that successful minority students must overcome. They include discontinuity barriers, lack of nurturing barriers, lack of presence barriers, and resource barriers. Discontinuity barriers are those that hinder a student's transition from high school to college, such as leaving one's hometown, learning to live with a roommate, and so forth. Lack of nurturing barriers (e.g., lack of family support, lower expectations by faculty and staff, lack of minority role models) can be exacerbated by the absence of supportive resources on campus to facilitate the adjustment of minority students. Lack of presence barriers can be exemplified by the lack minorities in the curriculum, the lack of support programs, cultural isolation, racial isolation, lack of minority mentors, and an institutional culture that does not celebrate diversity in overt ways. The final barrier that successful minority students must overcome is the resource barrier, which corresponds to a lack of money and/or financial aid support.

To address the barriers that impede the retention of minority students, Nora and Cabrera (1996) built upon the work of both Tinto's (1975, 1987) Student Integration Model and Bean's (1980, 1985) Student Departure Model to develop their Student Adjustment Model. This model was developed to examine the role of prejudice and discrimination on the adjustment and persistence of minority students in college. Building on Nora and Cabrera's (1996) model and furthered by the work of Nora and associates (Cabrera & Nora, 1994, Cabrera et al., 1992; Nora & Cabrera, 1996), Nora (2003) developed the Student/Institution Engagement Model. This model emphasizes the unique interactions between the student and the institution, which creates a connection or engagement that leads to persistence.

2.2.1.6 Involvement/Engagement Perspective

While the previous theories have focused on both pre-college and post-entry factors, the involvement/engagement perspective pertains exclusively to post enrollment factors – namely, the behaviors that students engage in while in college (Braxton & Hirschy, 2005). Astin (1984) developed the theory of student involvement based on five basic tenets: 1) involvement requires a student to devote both psychological and physical energy to the college experience; 2) involvement is a continuous concept in which different students devote varying levels of energy to different activities; 3) involvement has both qualitative and quantitative features; 4) learning is directly proportional to the quality and quantity of involvement; and 5) the effectiveness of policy and practice is related to an institution's capacity to induce student involvement.

Kuh (2009) presented a student engagement construct for institutional assessment, accountability, and improvement efforts. Similar to Astin's (1984) Theory of Involvement, student engagement represents the amount of time and effort students put into their studies and other educationally purposeful activities (e.g., study habits, peer involvement, interaction with faculty, time on task). However, it also considers how the institution deploys its resources (e.g., first year experience, academic support, campus environment, peer support, teaching and learning) to induce students to participate in activities that lead to the experiences and desired student success outcomes (Kuh, 2006). Even though the involvement/engagement perspective does not meet generally accepted definitions of a theory (Pascarella & Terenzeni, 1991), it is included herein because of its applicability to both research and practice.

2.2.1.7 Summary of Theoretical Perspectives

This literature review examined six of the most influential student success theoretical perspectives. The underlying assumptions of each of these perspectives have been detailed in this section, and are also summarized in Table 2-6.

In reviewing the array of literature, consistent patterns have emerged from across the various theoretical perspectives. First, each of these theoretical perspectives (with the exception of the involvement/engagement perspective) focused on retention and persistence. Even though these perspectives have provided a review of the factors that impact student success, few studies have focused on understanding students' needs in the context of the student success theoretical perspectives. This research shifts the focus from trying to understand why students leave/stay to examining how to satisfy student needs.

Table 2-6: Relevant Student Success Theoretical Perspectives

Perspective	Theory	Source	Purpose
The Sociological Perspective	Student Integration Model	Tinto, 1993	Describes the influence of the academic and social structure on students' departure decisions.
The Organizational Perspective	Student Attrition Model	Bean, 1980, 1983	Concentrates on the impact that the institution (i.e., organization) has on the socialization and satisfaction of students.
The Psychological Perspective	Student Attrition Model	Bean & Eaton, 2000	Focuses on the role of psychological characteristics that distinguish between those students that persist and those that depart.
The Financial Perspective	Financial Nexus Model	St. John, 2005	Highlights the role that finances play in persistence decisions
The Minority Perspective	Student/ Institution Engagement Model	Nora, 2003	Emphasizes the unique challenges that diminish the quality of minority students' college experience
The Involvement /Engagement Perspective	Theory of Involvement (Astin) Student Engagement (Kuh)	Astin, 1984 Kuh, 2009	Focuses on the behaviors that students engage in while in college

Secondly, these theoretical perspectives emphasize that student characteristics/ behaviors and institutional conditions impact student success. Student behaviors include involvement in extracurricular activities, interaction with faculty and peers, motivation, and commitment. Institutional conditions include the resources and educational practices that facilitate positive student behavior (Kuh, 2006). Since institutions vary considerably in their size, culture, and student demographics, a methodology is needed that would allow institutions to tailor their practices to fit the unique needs of students within their campus environment (Berger & Lyon, 2005).

Lastly, factors identified in the literature that impact student success consist of both pre-entry (outside of the scope of this research) and post-entry variables. The multitude of variables from each of these perspectives are summarized in Table 2-7 to provide an understanding of the factors that are critical to student success. These variables are categorized into a typology based on the student success theoretical research literature as follows: academic, psychological, social, financial, and environmental. This categorization guided the problem definition for the S^2OSD methodology in Chapter 3, thus enabling the identification of specific student needs that are relevant and vital to student success. For example, even though institutions offer a number of services to facilitate the college experience (e.g., such as food and recreation services), they do not fit into the context of student success theoretical perspectives.

2.2.2 Engineering Student Success Practices

Academic institutions have implemented a wide range of practices to help students succeed. According to Beal and Noel (1980), the following activities are essential for student success: 1) *Academic stimulation and assistance*: support for and challenging academics; 2) *Personal future building:* the identification of student goals and future direction; and 3) *Involvement experiences:* student participation and interaction with programs and services on the campus. Over 20 years later, Tinto (2003) listed a wide range of intervention programs that institutions have employed to help students succeed.

> These range from pre-admission and orientation programs, early learning assessment and mandated academic assistance, mandatory first-year advising and counseling, intrusive monitoring and assessment of first-year student academic progress, freshman courses that provide new students with the knowledge and skills needed for satisfactory college performance, faculty and peer mentor programs, staff development programs that enable

Table 2-7: Typology of Student Success Factors

Factors	Sociological	Organizational	Psychological	Financial	Minority	Involvement	Engagement
Pre-Entry	Family Background	Performance	Past Behavior	Student Background	Pre College Ability	N/A	N/A
	Skills and Abilities	Socioeconomic Status	Personality	College Choice Fixed Costs	Psychsocial Factors		
	Departure Decision	State Resident	Self Efficacy and Attribution	College Choice	Financial Assistance/Need		
		Distance Home	Normative Beliefs	Controllable Costs	Encouragement/Family Support		
		Hometown Size	Coping Strategies		Environmental Pull Factors		
			Motivation to Attend				
			Skills & Abilities				
Academic	Academic Performance	University GPA	Academic Integration	Grades	Involvement in Learning Communities	Time/Energy Studying	Level of Academic Challenge
	Academic Integration		Academic Performance		Academic Performance	Time on Campus	Active and Collaborative Learning
			Academic Interactions		Academic and Intellectual Development	Student Organizations	Enriching Educational Experiences
Financial	N/A	N/A	N/A	Financial Costs	N/A		
Social	Extracurricular Activities	Integration	Social Interactions	N/A	Social Experiences	Faculty Interaction	Student-Faculty Interaction
	Peer Group Interactions	Advisor	Social Integration		Faculty Interactions	Student Interaction	
	Faculty/Staff Interactions	Staff/Faculty Relationship			Validating Experiences		
	Social Integration	Campus Organizations			Mentoring Experiences		
Psychological	Institutional Fit	Goal Commitment	Self Efficacy	Aspirations	Noncognitive Gains	N/A	N/A
	Institutional Commitment	Major (certainty)	Coping (Approach/Avoidance)		Educational Aspirations		
			Attributions		Educational Goal		
			Intentions		Institutional Commitment		
			Goal Commitments				
			Institutional Commitments				
			External Commitments				
Environmental	N/A	Routinization	Bureaucratic Interactions	College Experience	Campus Climate	N/A	Supportive Campus Environment
		Development	External Interactions				
		Practical Value					
		Institutional Quality					
		Communication					
		Development					
		Centralization					
		Campus Job					
		Major (area)					
		Housing					
		Opportunity					
Outcomes	Departure Decision	Institutional Satisfaction	Intent to Persist	Probability of Persistence	Re-enrollment	N/A	N/A
		Institutional Commitment	Persistence Behavior				
		Dropout					

- Typology of Student Success Factors

> faculty to acquire the skills they need to become more effective teachers, to the development of learning communities that enable new students to share their learning experiences. (pg. 9)

While a vast majority a student success studies focus on the experiences of general education students, engineering education is considered uniquely different from other majors (Daempfle, 2003/2004; Veenstra et al., 2009). To begin with, the engineering curriculum requires problem solving and analytical skills that are shaped by a fast paced and demanding load of courses, heavily grounded in science and math (Adelman, 1998; Veenstra et al., 2009). Furthermore, the engineering college culture is typically described as a white male-dominated, competitive environment that features rigid discipline, intense academic pressure, and weeding-out practices that begin early in the introductory courses (Florman, 1996; Seymour & Hewitt, 1997, Streett, 1993; Vogt et al., 2007).

As asserted by Seymour and Hewitt (1997), the engineering college environment has a disproportionate impact on the well-being, adjustment, and self-concept of women and URMs, who are faced with a culture and structures that pose difficulties and present obstacles that stand in the way of their success. Furthermore, women and minorities often experience bias (i.e., gender, racial discrimination) that undermine their experience, in which they feel isolated, alienated, and lack a sense of not belonging (Hackett et al., 1992; Seymour, 1995). The lack of women and minority role models, the lack of a critical mass of like-minded peers in their classes, and the lack of supportive networks often create a chilly climate that is embedded in the culture of engineering (Daempfle, 2003/2004; Felder et al., 1995; Friedrich et al., 2007). As a result, understanding the various practices that have been created to improve the success of minority and women engineering students requires special attention.

2.2.2.1 Minority Engineering Program

Minority Engineering Programs (MEPs) were introduced in the early 1970s in an effort to recruit underrepresented students, build academic skills, foster a supportive environment, and ultimately increase the number of minority engineering students that persist to completing their degrees (Landis, 1988; Morrison & Williams, 1993). With more than thirty years of experience in improving the odds for minority engineering students, MEPs have been replicated at many institutions across the country (Gandara & Maxwell-Jolly, 1999). In fact, according to Landis (2005), approximately 100 out of the 300 accredited undergraduate engineering colleges created formal MEPs during the 30-year period from 1973-1993. Although the number of MEPs has appeared to decline to approximately 85 by 2003 (with not all programs implementing a comprehensive approach), additional programs have emerged that are built on the precepts of MEPs (Chubin, 2005).

The MEP model was developed in 1973 and first published by the Retention Task Force of the Committee on Minorities in Engineering (Landis 1985). The MEP model builds upon Astin's (1984) Student Involvement Theory, which equates student involvement to the quantity and quality of the physical and psychological energy that students invest in the college experience. Among other goals, the MEP model is designed to facilitate high levels of student involvement by creating a supportive academic community, delivering academic support, and facilitating the personal and professional growth of the minority engineering students (Landis, 1988).

Since research has demonstrated a high attrition rate for first-year students, the MEP model adopts the principle of front loading educational resources to serve the critical needs of first-year students. Front loading has become an almost axiomatic principle of effective retention interventions because it ensures that the support reaches students at a time where they are most vulnerable to attrition (Pope et al., 2005; Seidman, 2005; Tinto, 1993).

Additionally, the concept of student subcultures is at the heart of the MEP model. Student subcultures refer to creating environments where a sufficient number of people from similar backgrounds provide communities of support for one another (Landry, 2002/2003). The notion of subcultures is consistent with Tinto's (1993) Student Integration Theory, which asserts that students who establish membership with a compatible group are more likely to persist. Although the existence of a minority student subculture on a college campus does not guarantee minority student success, the absence of such a subculture has been shown to negatively impact minority student success (Tinto, 1993).

Morrison and Williams (1993) built upon the work of Landis (1985) to develop a theoretical model for MEPs. The model includes 1) *pre-enrollment activities* (recruitment, admissions, summer bridge programs and transitional services), 2) *matriculation services* (community building, academic support, student personal/professional development), and a set of characteristics that define the 3) *institutional environment* in which programs operate (institutional commitment, fiscal resources, staffing, office space, faculty involvement and reporting lines).

The California Postsecondary Education Commission (1985) evaluated the effectiveness of 12 MEPs. The Commission found that students participating in these programs were being retained at higher rates than all engineering students at each of the 12 institutions, and at a rate of 3 times higher than minority engineering students who did not participate in the program. More recently, additional authors have found that the MEP model increases the retention rate for minority engineering students).

A number of other minority engineering intervention programs have adopted a holistic approach for improving the retention and success of minority engineering students. Although the literature does not explicitly state that these programs are extensions of the MEP model, the basic tenets of the MEP paradigm are featured in their program design (Chubin, 2005). This notion, for example, was illustrated by Gándara and Maxwell-Jolly (1999), who identified specific practices that have been successful in promoting the high achievement of underrepresented STEM (science, technology, engineering and math) students, and to assess the extent to which the programs are achieving their goals. Five program components (each of which is consistent with the student success factors from the theoretical models described in Table 2-7) were identified as best practices of successful programs:

1. *Mentoring:* Includes faculty/staff advising, upperclassmen peer mentors, program participants serving as mentors to younger students, and industry mentors.
2. *Financial support:* Includes support provided to cover or offset the cost of tuition and expenses.
3. *Academic support:* Includes support to increase the number of minority students through enhancing academic achievement.
4. *Psychological support:* Includes personal counseling, building a cohort of peers, providing housing as a unit, and involving family or participation in cultural events.
5. *Professional opportunities*: Includes opportunities for students to experience the professional world that they are preparing to enter.

2.2.2.2 Women in Engineering Program

Similar to the MEPs, efforts to facilitate the success of women in engineering (WIE) take the form of programs and sets of activities that respond to those obstacles that adversely affect women during their engineering program (Clewell et al. 1991, 2002; Daniels, 1988). According to Fox et al. (2009), there are three central claims that underlie WIE programs. First, WIE programs have a positive effect on WIE student success outcomes. Second, WIE programs embody institutional leaders' assumptions of the problems their students face and the solutions that can be implemented to overcome problems with the participation and the performance of WIE students. Third, conceptions of the problem illustrate the extent to which institutional action is carried out on an individual versus structural approach.

In the individual approach, the status of WIE students is attributed to the student's individual characteristics such as attitudes, behaviors, aptitudes, skills, performance, and experience. Conversely, the structural approach (also referred to as the organizational or environmental approach) attributes the success of failure of WIE students to features of the institutional setting that are beyond individual student characteristics. Fox et al.'s (2009) cross-institutional study of 10 undergraduate WIE programs found that institutions that view problems and solutions of WIE as rooted in the structural as opposed to the individual approach are associated with more positive outcomes.

Successful WIE programs have been also characterized according to a number of attributes. Successful programs tend to define problems more comprehensively and emphasize the structural aspects of the underrepresentation of women. In other words, the problems reported are generally not limited to the number of women recruited and enrolled, but involve a broader range of environmental issues including faculty and classroom bias, grading systems that functioned to weed-out students, and a ‘‘pipeline of support’’ for continued graduate study that tends to be less helpful to women than their male counterparts. Additionally, successful programs habitually offer a variety of solutions to address problems—mostly commonly in the form of bridge programs to ease the transition from high school to college, living-learning residence halls, and formal mentoring programs. They also incorporate new initiatives such as facilitating workshops with faculty to get their buy-in, and hands-on experiences (e.g., undergraduate research) with faculty.

Program leadership was identified as a defining characteristic that distinguished successful programs from unsuccessful programs. The personal characteristics of successful directors include being able to collaboratively work with students, resourcefulness, and a network-orientation that actively promotes the program. Successful programs also typically exhibit an academic connection, visibility, and increased linkages to the administration. Finally, successful programs are characterized by a well-developed plan of how they will look in the future. Moreover, successful programs seek more visibility and expand the range of activities offered—particularly those that included partnerships and faculty involvement. Also deemed important are research proposals that provide funding to equip students with effective tools to navigate the institutional environment more successfully.

2.2.3 Performance Improvement in Higher Education

Both MEP and WIE programs offer approaches to help underrepresented minorities and women succeed. Higher education institutions also apply performance improvement approaches to a wide range of academic problems and opportunities because of the success that organizations in private industry have experienced (Koch & Fisher, 1998). The application of the performance improvement approaches from Section 2.1.2 was revisited in the following discussion of performance improvement applications for higher education.

2.2.3.1 TQM in Higher Education

Quality management in higher education has been referred to as total quality education, which is defined “as an educational culture characterized by increased customer satisfaction through continuous improvement in which all employees and students actively participate” (Dahlgaard et al., 1995). Just as the definition of total quality education is similar to the definition of TQM, the principles associated with TQM have also been applied to total quality education. Beaver (1994) claimed that TQM in higher education is essential to ensuring that institutions (as a whole) succeed and that the customers of higher education (i.e., students) are being well served. A review of the principles and practices are presented below.

Customer Orientation: The customer orientation principle is the most important concept of TQM as it applies to higher education. The fundamental tenet of TQM is satisfying the needs of its customers; therefore, implementing TQM in higher education requires a customer orientation. A continuing debate among both researchers and practitioners is whether students should be viewed as “customers.” When a customer is defined as anyone who is provided a product or service (West-Burnham, 1992), then, indeed, higher education institutions do serve customers. This basic analogy isn’t so simple, however, since there is little consensus as to who are the true customers of higher education. Institutions of higher education have a responsibility to a number of constituencies, including students, their parents, the administration, faculty members, prospective employers, and college/university employees (Eagle & Brennan, 2007; Sahney et al., 2004).

A number of scholars, however, have argued that the primary customer of higher education institutions is the student (Downey et al. 1994; Sallis, 1993; Ho & Wearn, 1995). Other critics, however, refute this assertion (Sirvanci, 2004) maintaining that students are being educated because they have not formed the requisite skills to judge or know what they need (Spanbauer, 1995). On the other hand, Aliff (1998) argued that institutions can benefit from identifying the student as the customer because it places an emphasis on students and their needs. Sahney et al. (2004) asserted that the metaphor of "student as customer" is highly dependent on which aspect of the educational process is being considered. Since this research is motivated by student success theoretical perspectives, it has adopted the view that students are the primary beneficiaries of the college experience; therefore, a student orientation that seeks to understand and satisfy student needs served as the focus of this dissertation.

Continuous Improvement: TQM is a continuous process of improvement that is people-focused and emphasizes learning, adaptation, and self-assessment as keys to success. In higher education institutions, continuous improvement requires the exploration of the needs of the institution's customer base, as well as ongoing evaluation of the effectiveness of related practices and programs to ensure that needs are being met. While continuous improvement initiatives in higher education are not well documented, those that have been described are principally applied to institutional administrative systems and maintenance processes, and much less to academic programs and systems (Temponi, 2005).

Teamwork: People at all levels of the higher education system are essential to the success of colleges and universities, since they produce and maintain the intellectual capital from which a high quality education is achieved (Johnson & Golomski, 1999). Therefore, the success of a

TQM approach in higher education requires the participation of everyone rather than being the sole responsibility of the administration.

A number of colleges and universities have reported successful applications of TQM in higher education (Daniels, 2002; Everett, 2002). In fact, Lozier and Teeter (1996) reported that in the 1990s there were approximately 300 higher education institutions that were applying quality management principles to their processes. Koch (2003), however, reported that two-thirds of academic institutions using TQM in early 1990s had largely abandoned those approaches by 1996. Researchers and practitioners who are skeptical of TQM argue that higher education institutions are uniquely different from business organizations (Bolton 1995; Koch & Fisher, 1998). According to Houston (2007), the university must balance the needs of its students, employees, employers, the local community, as well as the research and development needs of society as a whole. Moreover, universities possess values of academic freedom, collegiality, and professionalism, and engage in complex processes of teaching, research and community service. As a result, the TQM models originally developed for business do not translate easily to educational institutions.

Another criticism is that most implementations of TQM principles have been focused on the administrative and non-academic processes (e.g., admissions) of higher education institutions (Aly & Akpovi, 2001; Koch, 2003; Montano & Utter, 1999; Sirvanci, 2004). Such improvements are valuable to institutions, but they fail to address the most challenging issues. For these reasons, QFD, which provides a systematic method to translate customer needs/requirements into design requirements, has been used to improve academic processes in engineering education (Koksal & Egitman, 1998) teaching and advising (Jaraiedi & Ritz, 1994), curriculum design (Hwarng & Teo, 2001; Owlia & Aspinwall, 1998), and faculty support (Ermer, 1995).

Although TQM has been considered a fad by some researchers and practitioners (Birnbaum, 2000; Henson, 1993), others have advocated TQM as a viable approach for improving quality in higher education (Owlia & Aspinwall, 1997; Sirvanci, 2004; Sakthivel & Raju, 2006; Venkatraman, 2007). The criticism "does not by itself negate the paradigm; it merely suggests to its adherents that the puzzle has not yet been solved and that further work is necessary" (Birnbaum, 2000, pg. 13). In fact, a number of models exist today that have been developed based on the principles of TQM, including the Malcolm Baldrige National Quality Award (MBNQA) for Higher Education, which was adapted from the Baldrige Award criteria for business. These models seek to represent the interrelationships between quality dimensions that form the basis for improvement efforts (Kanji et al., 1999). While these dimensions and associated criteria have been commended for being very clear about what should be managed, the criteria have been criticized for being light on how and why.

Two studies (Owlia & Aspinwall, 1998; Sakthivel & Raju, 2006) have documented questionnaires that define quality dimensions as they relate specifically to engineering education. Even though the quality dimensions vary from one review to the next, there are common themes. With respect to student success theoretical perspectives, these instruments consider academic factors and to some extent environmental factors, but they fail to consider a wide range of psychological, social, and financial factors that have been linked to student success. Additionally, these instruments review the implementation of quality principles as well as services (i.e., campus facilities) that are outside the scope of this research. These facts, therefore, highlighted the need to develop an instrument that assesses the needs of engineering students in the context of student success theoretical perspectives. Table 2-8 illustrates the dimensions of quality that have been defined by these authors.

With respect to student success theoretical perspectives, these instruments consider academic factors and to some extent environmental factors, but they fail to consider a wide range of psychological, social, and financial factors that have been linked to student success. Additionally, these instruments review the implementation of quality principles as well as services (i.e., campus facilities) that are outside the scope of this research. These facts, therefore, highlighted the need to develop an instrument that assesses the needs of engineering students in the context of student success theoretical perspectives.

Table 2-8: Quality Dimensions in Engineering Education

Academic Factors		**Environmental Factors**	**TQM Principles**	**N/A**
Academic Resources	Course Delivery	Congenial Learning Environment	Commitment of Top Management and Leadership	Campus Facilities
Academic Staff Competence	Communication		Customer Focus	
Academic Staff Attitude			Continuous Assessment and Improvement	
Engineering Degree Content			Customer Value	
			Customer Satisfaction	
Owlia & Aspinwall (1998)	Sakthivel & Raju, (2006)			

2.2.3.2 Strategic Planning/Performance Measurement in Higher Education

Evaluating performance and incorporating those evaluations into the strategic planning process has been useful to institutions in their quest for performance improvements. Although planning and measurement are key aspects of TQM applications in higher education, little research is available on strategic performance measurement systems for colleges and universities. Moreover, very few studies have been devoted to developing and applying these approaches in higher education. From a review of the literature, Table 2-9 summarizes studies that have been conducted in higher education.

Table 2-9: Strategic Performance Measurement Systems in Higher Education

Measurement System	**Description**	**Sources**
Balanced Scorecard	Applies the Balanced Scorecard in Education	Chen et al., 2006; Cullen et al., 2006; Karathanos & Karathanos, 2005; Kettunen, 2006; Papenhausen & Einstein, 2006; Lawrence & Sharma, 2002; Umashankar & Dutta, 2007
Malcolm Baldrige National Quality Award	Provides a comprehensive framework to assess performance across the institution based on criteria for performance excellence.	http://www.nist.gov
Six Sigma	Presents frameworks and/or applications of the Six Sigma methodology in *higher education*	Bandyopadhyay et. al. 2007; Ho et al. 2006; Jenicke et al., 2008; Montgomery et al. 2005
	Presented Frameworks and/or applications of the Six Sigma methodology in *engineering education*	Hargove & Burge, 2002; Burtner, 2004
Strategy Formulation Framework	Integrated SWOT analysis, balanced scorecard, QFD methodology and MBNQA education criteria to develop a strategy formulation framework.	Lee et al. (2000)

2.2.3.3 Student Satisfaction

One important but sometimes overlooked outcome in determining the quality of the undergraduate experience is student satisfaction (Kuh et al., 2006). Research has shown that students who are satisfied with their college experience are more likely to persist in comparison to dissatisfied students (Sanders & Burton, 1996). Similar to the relationship between customer satisfaction and organizational performance, student satisfaction relates to the bottom line (i.e., student success) for higher education institutions. Research has found that satisfaction is positively related to both persistence (Pascaralla & Terenzini, 1991; Tinto, 1987; Titus, 2004) and academic achievement (Bean & Bradley, 1986; Bean & Vesper, 1994; Lindsay & Kolb, 1992; Pike, 1993, 1997).

Student satisfaction is defined as “a pleasurable emotional state resulting from a person’s enactment of the role of being a student” (Bean & Bradley, 1986, p. 398). Similarly, Astin (1993) asserted that a student’s degree of satisfaction with the college experience is much less dependent on their background characteristics, and more dependent on various influences from the college environment. Alternative definitions of student satisfaction are more closely aligned with Astin, and have defined satisfaction as the student’s evaluation of their college experience (Danielson, 1998; Oliver & DeSarbo, 1989).

While student satisfaction has been used to measure student success, it is also a useful measure of institutional success (Levitz et al., 1999). Since students are the primary beneficiaries of the college experience, their satisfaction level with those experiences correlates with institutional success (Gielow & Lee, 1988). In fact, institutions use the results from student satisfaction questionnaires to identify areas where the institution is performing well, to target areas for improvement, and to identify future needs such as new programs (Billups, 2008).

A number of methods exist for assessing the student college experience. Very few studies, however, have investigated how to measure student satisfaction from a student success orientation. In the mid-1990s, Julliert (1995) reported that only three student satisfaction scales were documented in the literature: the Monitor of Student Satisfaction (MOSS) (Cooper & Bradshaw, 1984), the Perceived Quality of Academic Life (PQAL) (Okun, et al., 1986), and the College Student Satisfaction Questionnaire (CSSQ) (Betz et al., 1970).

More recently, three additional scales have appeared in the literature: Noel-Levitz (2009), Billups (2008), and Wang and Grimes (2000/2001)—each of which feature questionnaires of varying length and complexity. Table 2-10 outlines the student success factors that have been identified in the student satisfaction questionnaires.

Table 2-10: Student Satisfaction Questionnaire

Measure	**Noel-Levitz (2009)**	**Billups (2008)**	**Wang & Grimes (2000/2001)**
Student Population	Undergraduate Students	Undergraduate Students	
Instrument	Noel-Levitz Student Satisfaction Inventory		
Academic Factors	Academic Advising Effectiveness Instructional Effectiveness	Educational Experience Development of Skills & Knowledge Faculty Contact	Student Faculty Interaction
Financial Factors	Financial Aid Effectiveness		
Social Factors	Campus Life	Personal and Social Growth	Student-Student Interaction, Participation in Campus Activities
Psychological Factors	Campus Support Services Concern For The Individual Student Centeredness	Sense of Community	
Environmental Factors	Campus Climate Campus Safety and Security		
Non-Student Success Factors	Recruitment Effectiveness Registration Effectiveness Service Excellence		
Outcomes		Overall Commitment to and Satisfaction with College	Student Satisfaction

The array of variables under scrutiny is consistent with the theoretical perspectives summarized in Table 2-7. However, a number of statements (e.g., *The quality of instruction I receive in most of my classes is excellent; The instruction in my major field is excellent*.) are not structured in ways that provide institutional leaders with an understanding of what is required to address student needs. Another dilemma with each of these studies is that none have investigated engineering students' satisfaction with the college experience from a student success-orientation.

Thus, the S^2OSD's ESNQ developed for this research was intended to address these limitations. Furthermore, this research used a systems engineering approach for developing questionnaire statements as functional needs. Specifically, the ESNQ statements describe a specific or discrete action (written such that an active verb is followed by a noun), in order to provide the basis for designing actionable solutions.

2.2.4 Student Success Orientation Summary

The persistence, retention, or attrition of college students represents an ill-structured problem for researchers and practitioners who seek to enhance student success in college. As such, college student departure requires the consideration of multiple theoretical perspectives in order to develop solutions to address the problem (Braxton, 2003). The student success orientation section of this literature review provided the domain knowledge needed to develop the S^2OSD methodology.

First, this section provided a review of the most influential theoretical perspectives that helped to identify and understand those factors that can be considered relevant to student success (i.e., persistence, retention, and academic achievement). Even though these perspectives have thoroughly investigated the student success factors that impact why students decide to leave or stay in college, these studies have not focused on understanding students' needs in the context of the student success theoretical perspectives. Based on the literature review, key factors that contribute to student success have been identified and categorized as follows: academic, social, psychological, environmental, and financial needs. These student success factors formed the basis from which student needs could be examined in the context of this research.

Secondly, this section reviewed the student success practices that relate specifically to URM and female engineering students. These programs are driven by general education theoretical perspectives, but also seek to address student needs by helping these underrepresented groups overcome unique barriers to success in order to improve their participation and performance in engineering. However, in an era of increasing accountability, the effectiveness of these interventions is constantly called into question. "Currently, many programs are designed based either on other programs that are operating successfully at other institutions or on methods that should be effective based on the current literature." (Dean, 1998, pg. 4). Many studies have highlighted the importance of understanding student needs as a way to enhance student success (Braxton, 2003; Kuh, 2006; Lotkowski et al., 2004; Pope et al., 2005; Tinto, 2003). Moreover, scholars have asserted that institutions must abandon the one-size-fits-all approach that every institution can adopt to help students succeed, and that no single program can possibly be effective for all students at all institutions (Davidson et al., 2009; Tinto, 2003; Pope et al. 2005). Few studies, however, have focused on designing practices that meaningfully impact student success based on the needs of a diverse student body.

Lastly, the performance improvement sections from the customer-oriented literature review were revisited in the context of higher education. Even though quality management continues to be a topic of debate, many principles of quality management are relevant to higher education institutions. Furthermore, strategic performance measurement and student satisfaction were reviewed in terms of their relevance to the development of the S^2OSD methodology. Based on the factors and gaps that were identified, the literature review provided the following information:

- A greater understanding of how the student success theoretical perspectives have influenced practices for URMs and female engineering students.
- A greater understanding of how student success-oriented satisfaction questionnaires have been designed.
- A greater understanding of which aspects of the university experience are vital to student success.

This domain knowledge was integrated with the customer orientation body of knowledge to develop the S^2OSD methodology for this study.

2.3 Towards a Conceptualization of the S^2OSD Methodology

This chapter reviewed the *customer orientation* and *student success orientation* body of knowledge in order to identify critical concepts and principles that could be adapted toward the development of the S^2OSD methodology. In particular, the student success orientation review of the literature provided the domain knowledge needed to develop the S^2OSD methodology.

A review of relevant theoretical perspectives—combined with an examination of student success practices—helped to focus the research problem on the following typology of student success factors: academic, social, psychological, environmental, and financial factors. Additionally, the customer orientation literature review provided methods, processes and tools that could be adapted for the S^2OSD methodology. As shown in Table 2-11, five S^2OSD principles were developed from relevant quality management principles and systems engineering principles as a foundation for the development of the S^{2}OSD methodology.

Table 2-11: Summary of S^{2}OSD Design Principles

S^{2}OSD Methodology Principles	Quality Management Principles	Systems Engineering Principles
(1) Student Orientation: Satisfying the needs of students is the driving force behind the design of institutional practices.	***Customer Focus***: Emphasizes an organization's orientation towards satisfying the needs of its customers	-
(2) Analysis-Synthesis-Evaluation: Structures the improvement process based on core phases of conceptual design to ensure that student needs are identified and solutions are developed to improve institutional practices that meet their needs	***Continuous Improvement***: Emphasizes an ongoing effort to improve products, services or processes with regard to efficiency, effectiveness and quality	***Lifecycle perspective:*** Considers all phases of the systems engineering development lifecycle
(3) Participatory: Requires a team approach that empowers the institutional leaders and students to be actively involved in the design of improvement efforts	***Teamwork:*** Requires cooperative work conducted by a team to facilitate communication, problem solving, and active engagement in the quality improvement process	***Interdisciplinary***: Requires a team approach throughout the system design and development process to ensure that design objectives are met in an efficient and effective manner
(4) Holistic Framework**:** Provides a unifying structured framework to guide institutional leaders throughout the translation of student needs into a plan of action	-	***Top-down approach:*** Views systems in a holistic manner while also recognizing that the system is made up its component parts
(5) Vital to Student Success: Focuses the design process on those aspects that are critical to student success.	-	***Identification of system requirements:*** Requires a front end analysis to Assess Needs/requirements, translate them into design goals and criteria, and ensure the effectiveness of decision making in the design process

Table 2-12 summarizes the S^{2}OSD phases (roman numerals), the S^{2}OSD principles (numbers in the columns), and the relevant literature approaches that helped to shape the S^{2}OSD methodology (first column). While each approach contributed to at least one principle and one phase (either partially or in its entirety), these approaches lack a holistic framework. For example, gathering information methods and tools can be used throughout each of the S^{2}OSD phases; however, they only provide guidance related to the third principle (i.e., participation). It can be argued, therefore, that a combination of these approaches will ensure coverage of the entire process.

Table 2-12: Contribution to S^{2}OSD Principles and Phases

	S^{2}OSD Phases				S^{2}OSD Principles				
	I	II	III	IV	1	2	3	4	5
ISA Method		●							○
SWOT Analysis	●					○	○		
QFD Matrix Tool		●			○	○	○		○
Function-Means tree		●				○	○		
Strategic - X				●	○	○	○	○	○
Pugh Decision Matrix Tool			●		○		○		
Information Gathering Methods and Tools	●	●	●	●			○		
Axiomatic Design Methodology		●				○	○	○	
Participatory Design Methodology	●	●	●	●	○		○		
User-Centered Design Methodology	●	●	●	●	○	○	○	○	

Thus, a structured framework was needed to guide institutional leaders from one phase to the next in translating student needs into a plan of action. Furthermore, none of the approaches were considered to be adequate for guiding institutional leaders in terms of identifying aspects of the university experience that were vital to student success. Therefore, the various approaches listed in Table 2-12 were adapted (described in Chapter 3) to further develop the following four phases of the S^2OSD methodology:

(I) Diagnose the Baseline

(II) Identify Needs

(III) Design Improvements

(IV) Develop Plan of Action

CHAPTER 3 RESEARCH METHODOLOGY OVERVIEW

Based on the literature review from Chapter 2, this chapter presents the research design that was used to develop, apply, and evaluate the S^2OSD methodology. In accordance with the research purpose and objectives, this research endeavor consisted of a mixed method approach, which incorporated both qualitative and quantitative methods that were carried out in the three stages (Figure 3-1). The first stage describes the methods for conducting the preliminary research. This stage served as the basis for carrying out the study's second stage, which involved the further development and application of the S^2OSD methodology. The third and final stage provided the research methods for evaluating the S^2OSD methodology.

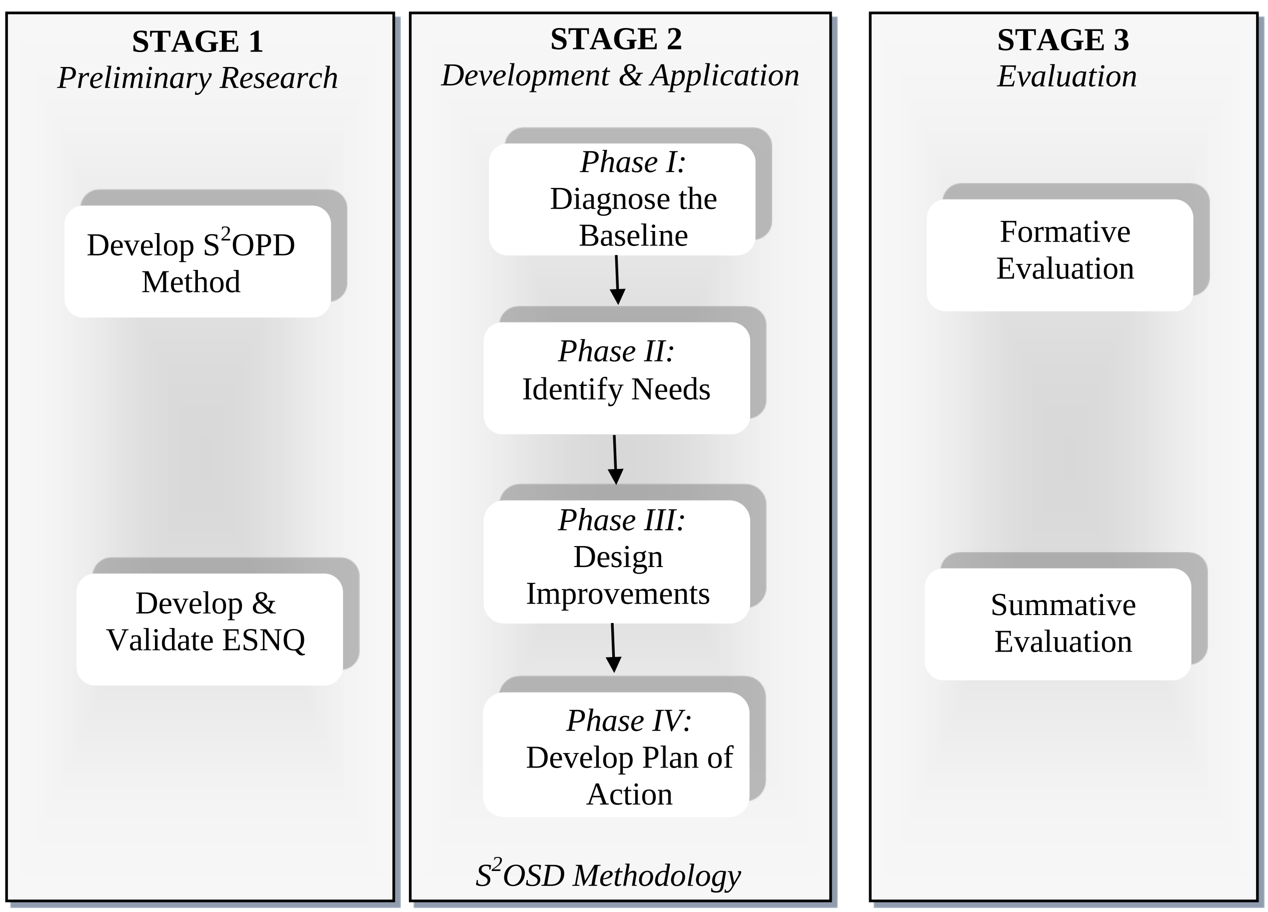


Figure 3-1: Research Methodology

3.1 Stage I: Preliminary Research

Stage I consisted of preliminary research to develop the S^2OPD method and the ESNQ. The S^2OPD method is defined as a participatory system design method that facilitates a team-based meeting approach to diagnose the baseline, identify and document student needs, improvement practices, and a plan of action that would foster student success. The S^2OPD method was developed in order to provide the scope and guidance for formulating the stages of this research by generating tools for decision making.

The S^2OPD method was also used to develop the ESNQ, which is at the heart of the S^2OSD methodology. The ESNQ was developed to define and document the specific needs of engineering students, and was used as a basis for quantitatively providing information for decision making. Therefore, preliminary research also consisted of the development and validation of the ESNQ so that the final instrument could be used to carry out Phase II of the S^2OSD methodology.

3.1.1 Develop the S^2OPD Method

The S^2OPD method is a participatory system design method that was developed to carry out this research. Central to this method is a participatory and customer-centered design philosophy that incorporated the primary beneficiaries (i.e., the students) of the college experience into defining student needs and developing student success practices to meet their needs.

Figure 3-2 illustrates how the S^2OPD method was embedded into the phases of the S^2OSD methodology. This method was used to develop the ESNQ in preliminary research; to diagnose the baseline in Phase I; to design improvement practices in Phase III, and to develop a concrete course of action in Phase IV. Phase II is the only phase for which the S^2OPD method was not used. Instead, the ESNQ that was developed as a result of preliminary research was used as the basis for identifying the needs of the students.

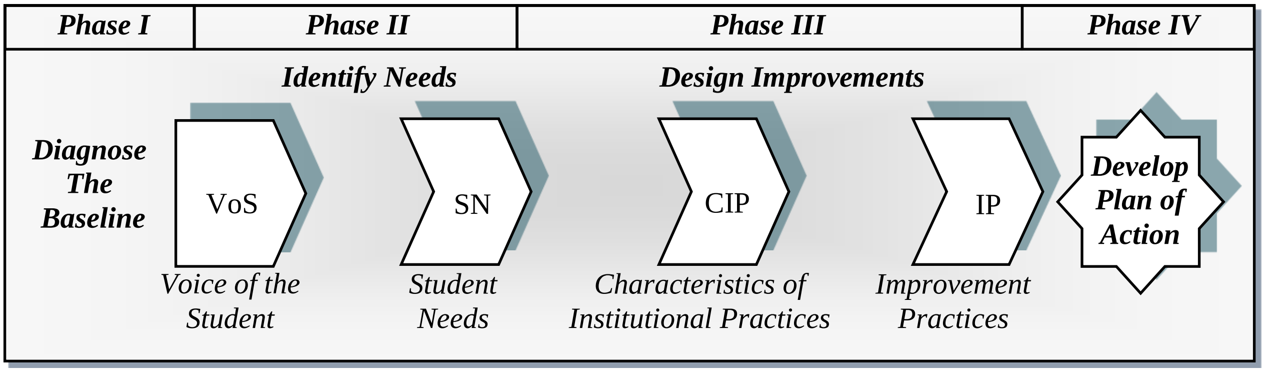


Figure 3-2: S^2OPD method embedded within the S^2OSD Methodology

Table 3-1 summarizes key aspects of the S^2OPD method, which were adapted from the information gathering and participatory design methods described in Chapter 2. Based on these methods, the following five-step structured meeting process was developed (Figure 3-3) for this research.

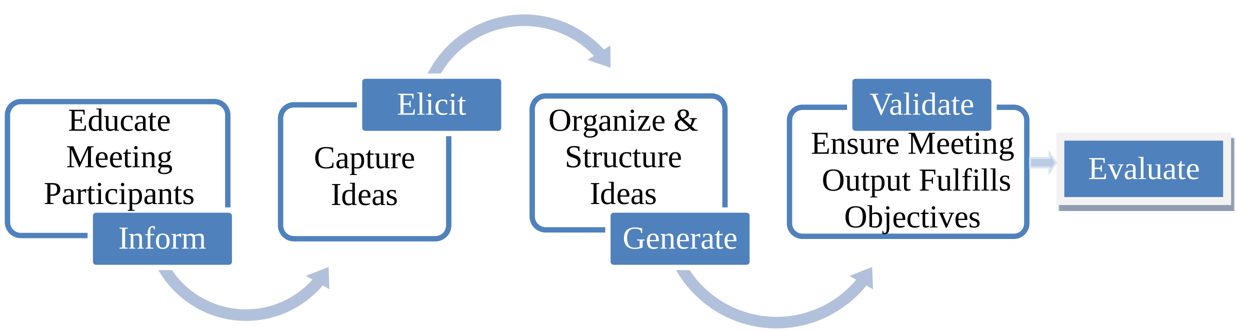


Figure 3-3: S^2OPD Meeting Process

As illustrated in Figure 3-3, the S^2OPD meeting process began with the *Inform* step, which educated participants about the goals and objectives, procedures, key outputs, and the participants' roles and responsibilities during the meeting. During the *Elicit* step, the researcher guided a group discussion to obtain information to help determine the perceptions and ideas of

Table 3-1: Key Concepts Adapted to Develop the S^2OPD Method

S^2OPD Method	Adapted From	Source	Benefits
Involves 4-6 participants	Focus Groups	Langford & McDonagh, 2003	Although traditional focus groups are larger (Krueger, 2008; Morgan, 1997), smaller groups are preferred for design research sessions (Langford & McDonagh, 2003).
Involves 3 -5 group sessions	Focus Groups	Morgan, 1997	More groups seldom provide meaningful new insights (Morgan, 1997).
2 hour sessions	Focus Groups	Krueger & Casey, 2008	Covers the needed information without exhausting the participants (Stewart et al., 2007).
Team approach is guided by a Facilitator (e.g., facilitates a group discussion following independent individual level work)	Focus Groups, Nominal Group Technique Participatory Design	Delbecq et al., 1975; Krueger, 2008; Schuler & Namioka, 1993;	Group perspective can lend additional insight that could not otherwise be gained from an individual level of analysis (Silverman & Silverman, 1994).
Focused discussion guided by predetermined questions in which the facilitator also asks probing and clarifying questions	Focus Groups	Krueger & Casey, 2008	Obtain in-depth rich information that is guided by student success theory.
Meeting participants work independently and silently to generate and record ideas. They then share their ideas in a round robin fashion.	Nominal Group Technique	Delbecq et al., 1975	Minimizes pervasive influences by other group members (Siebold & Krikorian, 1997).
Empowers students to be actively engaged in identifying and analyzing their needs and developing improvement strategies to address their needs.	Participatory Design	Muller et al., 1993	Unlike any of the preceding techniques, participatory design requires participants to identify significant patterns, and organize resulting data. Thus, the team will participate in the data analysis *during* the S^2OPD meeting process.
Determines (by learning, uncovering, extracting, surfacing, or discovering) the needs of students	Requirements Elicitation Tools/ Techniques	Goguen & Linde, 1993; Hickey & Davis, 2003	Requirements elicitation techniques ensure improvement strategies can be generated with a higher probability of satisfying student needs (Hickey & Davis, 2003).

the group. The *Generate* step then used system design and performance improvement tools to organize the initial brainstorming ideas resulting from the *Elicit* step into a structured format. Finally, participants ensured that the output addressed the meeting's goals and objectives during the *Validate* step.

At the conclusion of the meeting, the results were evaluated. Participants were asked to evaluate the usability of the framework by completing a short formative evaluation questionnaire during the *Evaluate* step. The questionnaire evaluated design goals, ease of learning, ease of participation, usability of tools, and usability overall (see Chapter 9: S^2OSD Evaluation Framework). As a result, any needed design changes were incorporated into subsequent meetings to improve the usability of those meetings.

The S^2OPD method provided a step-by-step process and associated tools for executing this research. First, the meeting process was structured to capture ideas, which were then organized such that actionable information could be generated in a structured format that could subsequently be used for decision making. The design skills of abstraction, persistent questioning, identifying critical performance areas, and factorization were infused into the meetings to facilitate the analysis-synthesis-evaluation principle (Pahl et al., 2007):

- *Abstraction:* Emphasizes the essential characteristics of a problem, thereby opening up the solution space to search for and find a broader range of solutions containing the identified solutions;
- *Persistent questioning*: Provides systematic procedures for developing persistent questions to stimulate thought and intuition;
- *Factorization*: Breaks down the system of practices into manageable, less complex, more easily definable factors; and

- *Critical performance area identification*: Identifies critical performance areas that impact success.

Second, this approach adapted customer-oriented systems approaches reviewed in Chapter 2 to improve the quality of information needed to make decisions and take action in order to facilitate student success. Third, a structured method was used to guide each phase of this research such that important issues were not overlooked. Finally, the structured method was self-documenting so that the tools employed created a record for the decision-making process, which could be used for future reference (Ulrich & Eppinger, 2008).

Additionally, the S^2OPD method incorporated qualitative data analysis activities into the structured meeting format. Typically, a researcher must take additional time after the meeting to make sense of the data collected during the meeting. According to Patton (2002), the challenge of qualitative analysis is transforming the massive amounts of data into essential findings. For example, a one-hour interview might yield 10 to 15 single spaced pages of transcribed text notes. Consequently, a two-hour S^2OPD meeting could yield an estimated 20 to 30 pages of notes. As a result, a manageable classification and coding scheme would subsequently need to be developed to transform the transcribed notes to identify and label the primary patterns of data. Finally, critical and creative thinking would then be needed to make judgments about the substantive significance in presenting the findings (Patton, 2002).

Each of these qualitative analysis steps were incorporated into the S^2OPD method, which used the team-based meeting approach to transform the massive amounts of data into findings that provide the essence of what the data reveal. As a result, the S^2OPD method eliminated the need to both transcribe the meeting data and develop a coding scheme for identifying and labeling primary patterns of data. Furthermore, the S^2OPD method resulted in specific tools developed for this research that documented the output, which helped to guide the decision-making process.

3.1.2 Develop and Validate ESNQ

Once the S^2OPD method was developed, the ESNQ was created as a means to assess and identify the needs of the students. Therefore, in order to provide a concrete course of action for institutional leaders to design practices that meaningfully facilitate student success, the ESNQ incorporated a fundamental premise that is germane to most, if not all, engineering design efforts—namely for institutional leaders to first have an understanding of the needs of their students.

As revealed in Chapter 2, current student success theoretical perspectives are not based on providing an understanding of student needs. Therefore, the ESNQ was developed and validated in Chapter 4 to provide an instrument that comprehensively assessed the needs of engineering students in the context of student success theoretical perspectives. While the S^2OPD method and customer-oriented methods and tools were embedded into the questionnaire development process, the questionnaire validation process followed recommended standard procedures that were consistent with the extant literature (Churchill, 1979; Clark & Watson, 1995; Devillis, 2003; Netemeyer et al., 2003; Nunnally, 1978).

3.2 Stage II: Development and Application

Stage II describes the development and application of the S^2OSD methodology, which was initially conceptualized in response to the literature review in Chapter 2. Chapters 4, 5, 6, and 7 further developed the four phases, their associated methods and tools, and the key outputs of each phase. As such, the nature of this study points towards an applied research method. The purpose of applied research is to contribute knowledge that brings an understanding to the nature of a problem in order to develop interventions that address the problem (Patton, 2002). Ackoff's (1962) classic text outlined the six phases of applied research. As shown in Table 3-2, the four phases of the S^2OSD methodology correspond to the first four phases of Ackoff's Applied Research Model; the implementation phase is beyond the scope of this research.

Table 3-2: S^2OSD Phases related to Applied Research

S^2OSD Phases		**Ackoff (1962) Applied Research Phases**
(I)	Diagnose the Baseline	Formulate the problem
(II)	Identify Needs	Construct the model
		Test the model
(III)	Design Improvements	Derive the solution from the model
(IV)	Develop Plan of Action	Implement the solution (Outside the scope)

In contrast to basic research that seeks to generalize across time and space, applied research is typically limited to a specific time, place, and condition (Patton, 2002). Hence, a single institution study was used for this research because the S^2OSD methodology is intended to provide campus decision makers with a methodology to tailor their practices to meet the unique needs of their students. Therefore, the problems and solutions that emerge from applying the methodology are unique to its application. However, the methodology is generalizable in that it can be applied across institutions, departments, programs etc.

3.2.1 Applied Research Site

The S^2OSD methodology was applied to a doctoral-granting institution's WIE and Minorities in (Science) and Engineering Programs. (Note: the MEP designation was used because the analysis focused exclusively on engineering students.) Although the S^2OSD methodology was applied to the program level of the institution, it can also be applied to a range of student populations at various institutional levels. Since this study focused on improving student success outcomes, URM and female engineering students (who tend to be less successful in obtaining an engineering degree in comparison to the general student population NSF, (2009)), were the principal cohort for this stage of the research.

In order to develop a purposeful sample, the research site was selected based on a criterion sampling strategy (Patton, 2002). Selection criteria were developed to ensure that the applied research site provided a rich environment to apply the S^2OSD methodology in a real-world institutional setting. A large university in the northeast was selected based on the criteria shown in Table 3-3. Additionally, the researcher's accessibility to the site was also considered to be an important factor. However, the principal rationale for selecting the applied research site was its reputation as a top university with a large student population offering a number of engineering majors.

Table 3-3: Selection Criteria for the Applied Research Site

#	Criteria	Applied Research Site
1	Four year university	2968 Engineering Undergraduate students 670 Freshmen engineering students
2	Doctoral-Granting Institutions (formerly referred to as a Research I university)	9 undergraduate majors in engineering
3	Predominantly white institution	19.9 % female 10.4 % underrepresented minorities 20.1% minorities

3.3 Stage III: Formative and Summative Evaluations

The third and final stage of this research consisted of developing and implementing the S^2OSD evaluation framework to systematically acquire feedback about its usability. While formative evaluations were conducted to provide continuous feedback during each phase of the S^2OSD methodology, a summative evaluation was conducted retrospectively to judge the overall value or worth of the design process.

Performance-based evaluation questionnaires were developed based on the following usability dimensions: design goals, ease of learning, ease of participation, usability of tools, and overall usability of the S^2OSD methodology. Users of the S^2OSD methodology completed the formative evaluation at the conclusion of each phase, and the program administrators completed the summative evaluation once Phase IV was completed. As a result, the formative evaluations are conducted after each S^2OPD meeting. However, the development of the evaluation framework and the results of both the formative and summative evaluation are described in Chapter 9.

3.4 Summary of Research Methodology

Chapter 3 provided a broad overview of the S^2OSD methodology that was applied and evaluated for the MEP and WIE programs at the selected research site. A summary of the three stages of this research are shown below:

1. *Preliminary Research:* Describes the S^2OPD method that was used to execute the phases of the S^2OSD methodology and the development of the ESNQ;
2. *Development and Application of the S^2OSD Methodology*: Describes the development and the application of the methods and tools that were used to carry out the four phases of the S^2OSD methodology at the applied research site;
3. *S^2OSD Evaluation*: Describes the summative and formative evaluation framework that was used to evaluate the S^2OSD methodology.

Table 3-4 summarizes the three stages of this study, which outlines the research activities, primary objectives, research questions, and the methods and tools used to carry out each stage.

Table 3-4: Summary of the Research Methodology

Stage	Activities	Research Questions	Objectives	S^2OSD Methods/ Tools
1	Develop S^2OPD Method *(Chapter 3)*	-	• To prescribe how key stakeholders are involved in the design process • To provide a structured group method that can be used throughout the S^2OSD phases • To create tools that can be used for decision making	S^2OPD Method
	Develop and Validate the ESNQ *(Chapter 4)*	-	• To develop the ESNQ • To conduct two rounds of expert reviews • To conduct a pilot study • To assess the reliability and validity of the instrument	S^2OPD Method Define Student Needs Analysis Method and Tool
2	Phase I: Diagnose the Baseline *(Chapter 5)*	*RQ2.1:* How can decision makers assess their current state and define how to satisfy engineering student success needs in the future?	• Identify current state of affairs • Identify desired state of affairs	Baseline Diagnosis Method and Tool S^2OPD Method
	Phase II: Identify Needs *(Chapter 6)*	*RQ2.2:* What are the needs of engineering students that facilitate student success?	• To provide decision makers with a fundamental understanding of needs that are critical to student success	ESNQ Index Action Grid
	Phase III: Design Improvements (*Chapter 7*)	*RQ2.3:* How can improvement practices be designed to meet engineering student success needs	• To have students design and recommend improvement strategies that address their needs	DI Method Improvement Practice Synthesis Tree and Matrix
	Phase IV: Develop Plan of Action *(Chapter 8)*	*RQ2.4:* How can the information generated from the previous phases be translated into a plan of action that promotes student success?	• To have decision makers create a concrete course of action based on the information generated from the previous phases	DPA Method Improvement Practices Decision Matrix Student Success Action Planning Matrix
3	Formative Evaluation *(Chapter 5, 6,7,8)*	*RQ3:* What methods can be used to evaluate the S^2OSD methodology in order to refine and improve it?	• To provide continuous feedback on how to improve the design during each phase of the S^2OSD methodology	Evaluation Questionnaire
	Summative Evaluation *(Chapter 9)*		• To assess the overall usability of the S^2OSD methodology	Evaluation Questionnaire

CHAPTER 4 ESNQ DEVELOPMENT AND VALIDATION

Chapter 4 describes the development and validation the ESNQ, which was designed to comprehensively assess the needs of engineering students in the context of the student success theoretical perspectives—in essence, to capture “the voice of the student (VoS).” While system design methods and performance improvement tools were embedded into the questionnaire development process, the questionnaire validation process followed recommended standard procedures that are consistent with the extant literature (Churchill, 1979; Clark & Watson, 1995; Devillis, 2003; Netemeyer et al., 2003; Nunnally, 1978). Figure 4-1 summarizes the ESNQ development and validation process detailed in this chapter.

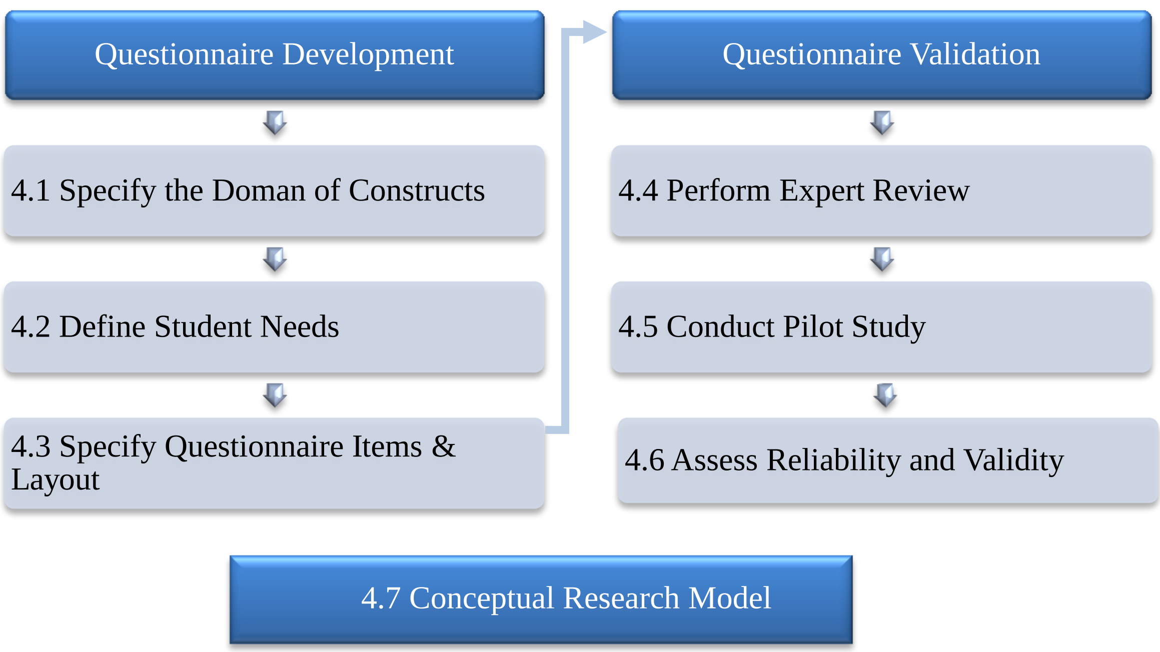


Figure 4-1: ESNQ Development and Validation Process

The ESNQ development process integrated relevant system design and performance improvement methods and tools described in Chapter 2 with Churchill’s (1979) questionnaire development process. Specifically, the questionnaire development process consisted of three stages: (1) *Specify the Domain of Constructs*, which defined what should be both included and excluded from the ESNQ based on student success theoretical perspectives; (2) *Define Student Needs*, which incorporated the S^2OPD method to define the needs of students as the basis for developing the ESNQ; and (3) *Develop Questionnaire Items & Layout*, which specified actionable need statements and dimensions of student success needs in order to assess both the importance and satisfaction with the institution in meeting student needs.

For the questionnaire validation process, construct validity was the ultimate goal. "Construct validity refers to how well a measure actually measures the construct it is intended to measure" (Netemeyer et al., 2003, pg. 11). Once an initial questionnaire had been developed as a result of the questionnaire development process, its construct validity was assessed along three lines, as suggested by Peter and Churchill (1986). First, construct validity was assessed during the development of the questionnaire based on the authors' assertion that measures undergoing extensive development and scrutiny are judged to be more valid than those that are proposed haphazardly. Second, the measures were evaluated to ensure that they examined the theoretical relationships and empirical estimates of reliability and validity. These collectively refer to whether the items within a given measure are sufficiently similar, yet sufficiently different from other measures (Malhotra & Grover, 1998). The third and final assessment of construct validity examined the theoretical relationships and empirical estimates of nomological validity. This refers to the hypothesis-testing stage in the research process, which provides empirical evidence of the relationships between the measures of conceptually related constructs (Peter & Churchill).

In order to adhere to these recommendations, the ESNQ underwent an expert peer review and a pilot test. This led to a conceptual research model, which was formally validated through reliability and validity statistical analyses. Based on the results, a pilot ESNQ emerged that underwent the third and final assessment of construct validity during the hypothesis testing stage in Chapter 6, after which the final research model was presented.

4.1 Specify the Domain of Constructs

The first step in the questionnaire development process was to delineate what should be included in the domain of the construct (Churchill, 1979). Determining what should be included—as well as what should be excluded—were critical steps because sources of invalidity can originate in the construct definition process (Netemeyer et al., 2003). The decision to incorporate this initial stage was based on a review of the literature and the importance of the student satisfaction construct. This construct refers to a student's satisfaction with an institution's ability to meet their needs based on aspects of the college experience that impact student success.

The multitude of variables from each of the student success theoretical perspectives reviewed in Chapter 2 led to the development of the typology of student success factors. This typology was used to specify the domain of constructs, which broadly categorized these variables as follows: academic, social, psychological, environmental, and financial factors. Pre-entry variables were considered to be outside of the scope of this study; only post-enrollment variables were included in the range of factors that an institution could directly impact. Moreover, by specifying the domain of the construct, it was clear that additional needs such transportation, housing, food, facilities, etc., were also beyond of the scope of this research.

4.2 Define Student Needs (DSN)

In order to design a concrete course of action that would enable institutional leaders to formulate practices for facilitating student success, institutional leaders must first have an understanding of the needs of their students. This is the goal of any engineering design problem:

to translate the voice of the customer (VoC) into a description of what needs to be improved (Ullman, 2003). Therefore, the second step in the questionnaire development process was to define the true needs of the students.

Griffin and Hauser (1993) asserted that a need is neither a solution (e.g., a summer bridge program) nor a physical measurement (e.g., number of tutoring services offered by the university). Following this assertion, a need can be defined as a detailed description of what is required of institutional practices that contribute to the success of engineering students. To capture student needs, the S^2OPD method was used to identify the needs as voiced by the students.

Customer-oriented systems approaches emphasize the importance of capturing the VoC; however, few sources explain how to actually go about understanding and obtaining the needs of the customer (Burchill & Brodie, 2005). Therefore, the purpose of this section is to present a method for capturing the "VoS" in the context of student success theoretical perspectives, and to transform that data into actionable information. The information resulting from this step served as the basis for developing the content of the ESNQ. As Astin (1993) pointed out, the richest source of data for students' college experience is the students themselves. Since students are the primary recipients of higher education, they serve as a vital resource for identifying their specific needs.

4.2.1 Participants

To facilitate the development of the ESNQ, the researcher referenced Beyer and Holtzblatt (1998), who asserted that the best results can be achieved by studying a sample of a diverse population, rather than by studying a homogeneous group. In order to identify any common underlying structure that encapsulates the needs of the engineering student population as a whole, a maximum variation (heterogeneity) sampling strategy was undertaken to study a diverse range of student subgroups. However, homogeneity within the groups (a goal of focus groups: see Krueger & Casey, 2008) was obtained by categorizing student subgroups according to one characteristic: minority/majority status.

Participants were recruited from the engineering college at the applied research site. Flyers were posted in the engineering buildings, and engineering list servs were used to recruit the following 21 study participants described in Table 4-1.

Table 4-1: DSN Meeting Participants

Subgroups	Description	# of Participants
Underrepresented Minorities	African American and Latino female engineering students	3
	African American and Latino engineering students	3
Female	Caucasian female engineering students	5
Male (Majority Population)	Caucasian male engineering students	5
Other Minorities	Asian female engineering students	1
	Asian male engineering students	3
TOTAL		21

4.2.2 DSN Method, Process, & Tools

Four DSN meetings were carried out using the S^2OPD method, during which participants were asked to share their experiences in a guided group discussion over a 2-hour period. The objective of this meeting was to identify student needs as the basis for developing the content for the ESNQ. Figure 4-2 summarizes the steps that were used in the DSN meetings.

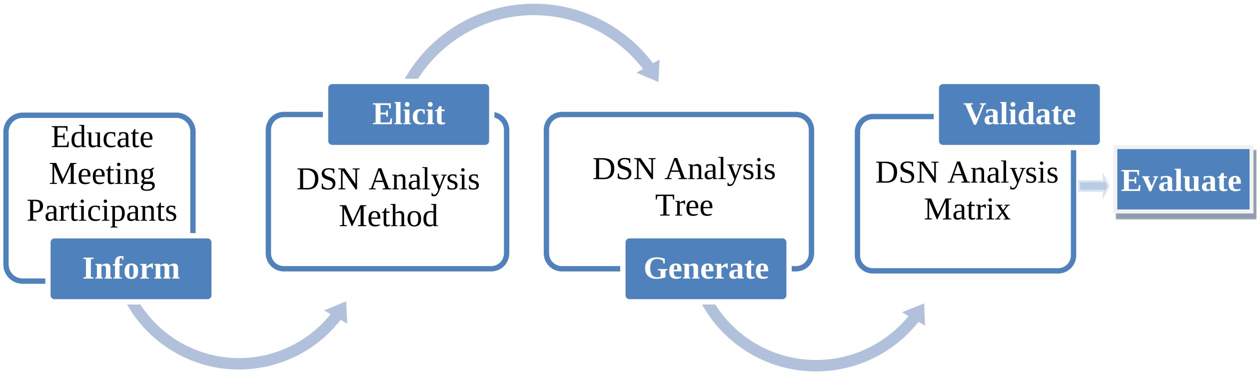


Figure 4-2: DSN meeting process

A pilot meeting was also conducted to test the procedures (see Gilbert et al., 2010). Furthermore, the meeting protocol, which appears in Appendix A, outlines the meeting procedures. Central to the DSN meeting approach was utilizing a functional decomposition process in which student needs were systematically elicited and decomposed into actionable need statements. This required an approach that emphasized what is general and essential without being influenced by fixed or conventional ideas (Pahl et al., 2007). Figure 4-3 illustrates this functional decomposition process, which is referred to as the Define Student Needs Analysis Method developed for this research. This method was embedded into the S^{2}OPD method, which ultimately produced a final set of student success needs.

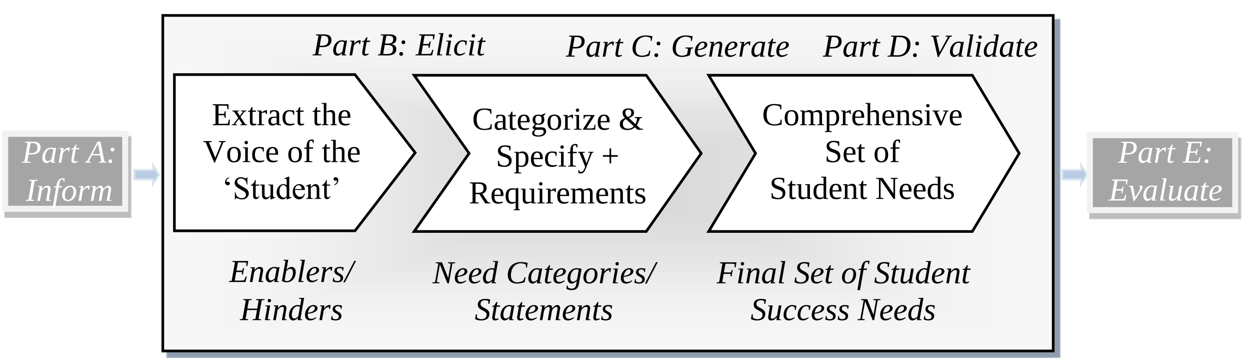


Figure 4-3: Define Student Needs Analysis Method

4.2.2.1 DSN - PART A: INFORM

The first step was to inform participants about the goals and objectives of the meeting (Table 4-2), which were established to translate the VoS into a comprehensive set of student success needs. The first two objectives were formulated to ensure that the DSN meeting was focused on identifying needs in the context of student success theoretical research. In fact, the typology of student success needs was used as the starting point for the meeting in order to achieve this objective. The second objective further limited the scope to include only those aspects of the college experience that the institution could directly impact. The third objective provided guidance on how to generate actionable need statements, which was used as the basis for developing the ESNQ.

Table 4-2: DSN Meeting: Goals and Objectives

Goals	Objectives
1) Identify enablers and hinderers of engineering student success.	1) Define critical factors in the context of student success
2) Translate enablers/hinderers into student need statements.	2) Include only aspects the engineering college experience that the institution can directly impact.
3) Provide a comprehensive set of student needs.	3) Generate actionable need statements.

In order to achieve these goals and objectives, a number of pre-determined discussion questions were developed by the researcher to guide the meeting, which facilitated the persistent questioning design skill. First, participants were asked to reflect on their own personal experiences and answer discussion questions in writing using color-coded Post-It notes. Then, in round-robin fashion, participants shared the information from their Post-It notes, which were also posted on the wall. This facilitated the factorization design skill that allowed the meeting process to be broken down into manageable pieces. Also, this allowed participants to reflect on their own experiences first, and then engage in a group discussion to generate additional ideas.

The following color-coding scheme was used in the remaining steps to track key aspects of this process:

- Blue – Enablers
- Pink – Hinderers
- Yellow – Student Success Need Statements
- Green – Student Success Need Categories
- White –Student Success Factors (i.e., based on the typology)

4.2.2.2 DSN - PART B: ELICIT

Since needs are not always known or easily articulated (Bayus, 2009), the DSN meeting integrated brainstorming and root cause analysis to elicit the perceptions of the participants based on the goals and objectives of the meeting. By doing so, this type of needs analysis was able to uncover ideas that are often overlooked or not even initially considered. Additionally, the typology of student success needs was used as the starting point, and the following discussion questions were used to further guide the process.

- *Discussion Question #1: What characteristics of your engineering experience have enabled and/or hindered your success? (Students wrote enablers on a blue and hinderers on a pink Post-it note.)*

The first discussion question required participants to identify enablers or causes that they believed led to student success, as well as hinderers or barriers that impeded their success. By doing so, participants were encouraged to put forward their ideas without any need to justify them. As a result, participants were able to create a list of enablers and hinderers for each student success factor of the typology.

- *Discussion Question #2: How would you group the enablers and hinders into major categories? (Students wrote the categories on a green Post-it note.)*

Once the enablers and hinderers were identified, the participants were asked to group the enablers and hinderers into major categories or dimensions of student success needs. Short phrases were developed to create heading names that grouped the enablers and hinderers.

4.2.2.3 DSN - PART C: GENERATE

During the generate step, actionable need statements were developed and the participants' responses were structured based on the affinity method. Since needs provide a detailed description of what is required of institutional practices to foster student success, participants were asked to describe the needs that must be fulfilled in order to enable their success. Whenever possible, need statements were written such that an action verb was followed by a noun. As an example, Figure 4-4 provides a sample of DSN Analysis Tree that was generated from one of the DSN meetings.

- *Discussion Question #3: What needs must be fulfilled in order to facilitate the success of engineering students? (Students wrote the need statements on a yellow Post-it note.)*

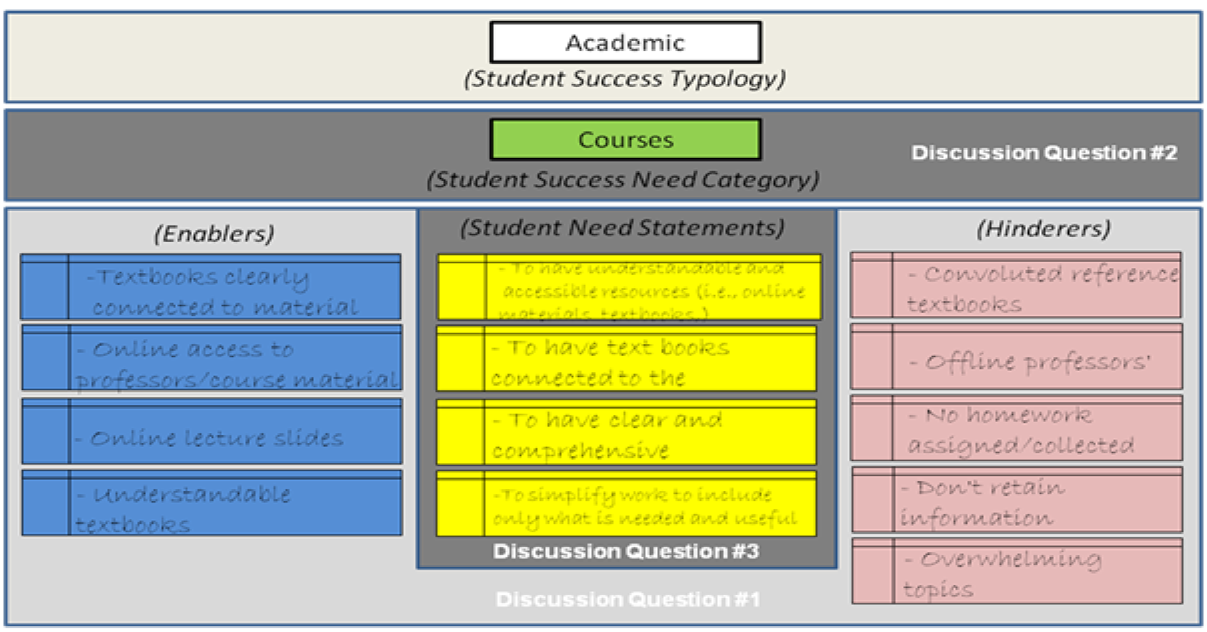


Figure 4-4: Sample Output – Needs Analysis Tree

Figure 4-4 illustrates how discussion questions were answered for the Academic student success factors, which were later used to develop and transform the enablers/hinderers into actionable need statements for a sample of the “Courses” student needs category. The final output of the Generate step is this DSN Analysis Tree, which depicts these key aspects of the Define Student Needs Analysis Method.

4.2.2.4 DSN - PART D: VALIDATE

During the Validate step, participants reviewed the goals and objectives to ensure that they were met. To do so, the DSN Analysis Matrix (Figure 4-5) was used to help the team verify whether all of the need statements were critical to student success with respect to each student success factor, and if additional categories or need statements were required to comprehensively address the needs of students. The following two questions guided this process.

- *Discussion Question #4: Are all of the need statements critical to student success?*
- *Discussion Question #5: Do you have additional input that is needed to make the Needs Analysis Tree complete?*

During this step, the team was divided into sub-teams of two to three people to complete the tool. Essentially, the tree was transcribed into the matrix. If additional input needed to be added, the participants would iterate through the meeting process to elicit, generate, and validate the output. Figure 4-5 illustrates how the tree from Figure 4-4 was transcribed into the matrix tool, and how it was then edited by the team to finalize the output of the meeting. The tool was used to help the team determine that one enabler and hinderer fit better in another category (i.e., professors). Additionally, the need statements were edited to more concisely convey student needs. Figure 4-5 reflects the final output of the DSN meeting, which was consolidated with the matrices from all four DSN meetings, and used to develop the ESNQ.

Student Success Factor	Academic			
Student Success Need Category	Courses			
Enablers	• Textbooks clearly connected to material • Understandable Textbooks • Online lecture slides • Understandable Textbooks	• ~~Online access to professors and course material~~	• Overwhelming topics	• No HW assigned/ collected
Hinderers	• Convoluted reference textbooks	• ~~Offline professors'~~		
Student Success Need Statements	1. To have understandable and accessible resources (i.e., textbooks, online materials) 2. To have text books ~~that relate~~ connected to the material		3. To have clear and comprehensive course work	4. To simplify work to include only what is needed and useful

Figure 4-5: Define Student Needs Analysis Tool

4.2.2.5 DSN - PART E: EVALUATE RESULTS

As shown in Figure 4-5, the data analysis was largely carried out during the DSN meetings. According to Patton (2002), the challenge of analyzing qualitative data involves reducing raw information into significant patterns to communicate what the data reveal. For this study, use of the DSN Analysis method in the meeting was intended to overcome this challenge. Nonetheless, further data analysis was still needed to consolidate and evaluate the output produced by each of the four DSN meetings. Therefore, content analysis was conducted, which "involves identifying, coding, categorizing, classifying, and labeling the primary patterns of data (Patton, 2002, pg. 463).

The output from each of the DSN meetings was consolidated by the researcher in order to thoroughly analyze the data to discover patterns, themes, and interrelationships. The final output consisted of the final dimensions (Table 4-3) of student success needs and associated need statements, which was used to develop the questionnaire items for the ESNQ. The following four steps were performed to consolidate the output of the four DSN meetings:

1. The output from the Define Student Needs Analysis Tool for each DSN meeting was transcribed into a table format in MS Excel so that patterns and common themes could be identified and organized.
2. The categories and need statements from each DSN meeting were then consolidated into a single MS Excel spreadsheet. The output was coded such that the categories were identified (e.g., A, B, C, etc.). As shown in Table 4-3, a roman numeral was also affixed to every identifier (e.g., IV_A) to indicate the DSN meeting number (Minority = I, White Male = II, Female =III, Asian =IV).
3. The associated need statements received the category number, followed by a number to uniquely identify each item. For example, IV_A_01 indicated the first category and the first need statement in that category from the fourth DSN meeting.
4. As shown in Figure 4-5, similar categories and their associated needs were grouped together and redundancies were eliminated in order to develop questionnaire items. Questionnaire items were labeled for each dimension (e.g., 01) followed by a number to uniquely identify each item (e.g., 2).

Table 4-3: DSN Consolidated Categories and Final Dimensions

FACTORS	DSN I CATEGORIES	DSN II CATEGORIES	DSN III CATEGORIES	DSN IV CATEGORIES	DSN FINAL DIMENSIONS
Academic	I_A Course Structure	II_A Courses	III_B Class Material/Class Time	IV_A Class Time	**Teaching and Learning**
	I_B Tutoring/ Study groups/ Help		III_C Preparation	IV_D Help Outside of Class/ Tutoring	**Skills**
	I_C Teaching/Learning	II_C Application		IV_ B Course Materials/ Assignments/Class	**Student - Faculty Interactions**
	I_D Faculty Advising	II_B Professors	III_A Professors	IV_E Professors/Faculty/ TAs/Professors/Professors	**Resources**
		II_D Collaboration		IV_F Textbooks	
	I_E Academic Resources		III_D Extra Engineering Department	IV_C Technology/ Resources	
Social	I_F Student Network	II_G Social	III_E Other Students/ Friends Family/Support	IV_G Community	**Student-Student Interactions**
			III_ F Extra-curricular activities	IV_H Classmates/Peers	
				IV_ I Family/Friends	
				IV_J Social support	
Psychological	I_G Workload	II_E Stress/ Workload/	III_L Motivation	IV_ L Interest	**Workload Management**
	I_H Rewards		III_M Support	IV_ M Stress	
Environmental	I_I Minority		III_K Stereotypes		**Community Environment**
Financial	I_J Financial	II_F Financial Resources	III_ G Work	IV_K Money	**Financial**
			III_ H Tuition		
			III_ I Money		
			III_J Scholarships		

4.2.2.6 DSN EVALUATE USABILITY

The DSN formative evaluations (see Appendix A – Part E) were conducted to determine if the methods, processes, and tools were able to facilitate a comprehensive identification of student success needs. A total of 4 DSN meetings were conducted with 21 students, who provided feedback to improve the usability of the DSN meeting during the preliminary research. The results of the evaluation questionnaire are presented for each DSN meeting and then summarized for all students collectively.

4.2.2.6.1 DSN Meeting #1 – URM Engineering Students

The DSN meeting was first held with 6 URM engineering students, who evaluated the design goals and the design process usability dimensions (see Chapter 9: S^2OSD Evaluation Framework). As shown in Figure 4-6, the ratings for the usability dimensions ranged from 4.44 (Overall Usability) to 4.83 (Ease of Participation). These results indicated that the design process and the outcome of the DSN were rated "Excellent" by URM engineering students, with the exception of the Overall Usability Dimension, which was rated "Good" by the URM engineering students.

Four of the students expressed that the functional decomposition process, which was guided by discussion questions using the Post-it notes, was effective. One student commented that "*It was visually helpful*," and another student noted that "*The organization of needs into different categories helped me organize my thoughts and issues.*" Four of the students also commented on the effectiveness of the group meeting. A student noted that "*The (group) setting was great because it was really comfortable and some of the ideas I forgot others would say*." Another student added that the researcher "*should stick with a small group because a bigger group would be too many comments and inputs.*"

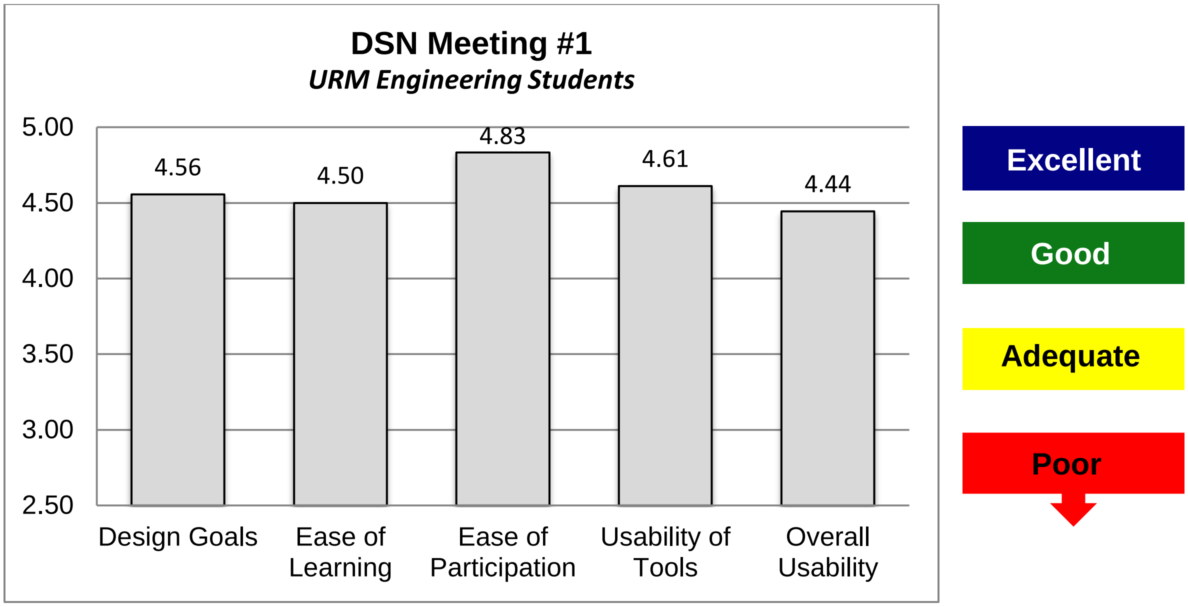


Figure 4-6: Usability Ratings for DSN Meeting #1 - URM Engineering Students

Five of the students initially encountered problems understanding the process. In fact, one student noted it was difficult "*understanding the scope at first but the examples were helpful*." Similarly, another student noted that "*I struggled with the organization of the color coding system at first but I caught on eventually.*" Another student reported specific problems with the questioning method, and mentioned that "*In the beginning the questions were a bit confusing but they got better as we went along.*" Based on the problems that were encountered, the students made a number of recommendations to improve the DSN meeting. These recommendations resulted in two design changes (Table 4-4) that were made to improve DSN meeting #2.

Table 4-4: Design Changes to Improve DSN Meeting #1 based on Recommendations

Attribute	Recommendations	Design Changes
Time	• Add more time to the meeting • Have the group work together to answer discussion questions	• More time was not added to the meeting. However, during the "*Generate*" and "*Validate*" steps, participants worked together in groups of 2 or 3 to answer the discussion questions. Students continued to work individually in the "*Elicit*" step so that they could share their own ideas without being biased by others' responses
Clarifying the Process	• Make the discussion questions clearer at the start • Include another example	• Initially an example of eating healthy food was used to show participants how to complete the process. Specific details were added to the example to clarify the process

4.2.2.6.2 DSN Meeting #2 – White Male Engineering Students

The recommendations from DSN Meeting #1 were incorporated into the second DSN meeting, which involved five White male engineering students. As shown in Figure 4-7, the ratings for the usability dimensions ranged from 4.33 (Design Goals, Usability of Tools, and Overall Usability) to 4.60 (Ease of Learning). While the mean responses for each dimension were well above the threshold where improvements needed to be made, the researcher incorporated the feedback from the students' responses into the open-ended questions.

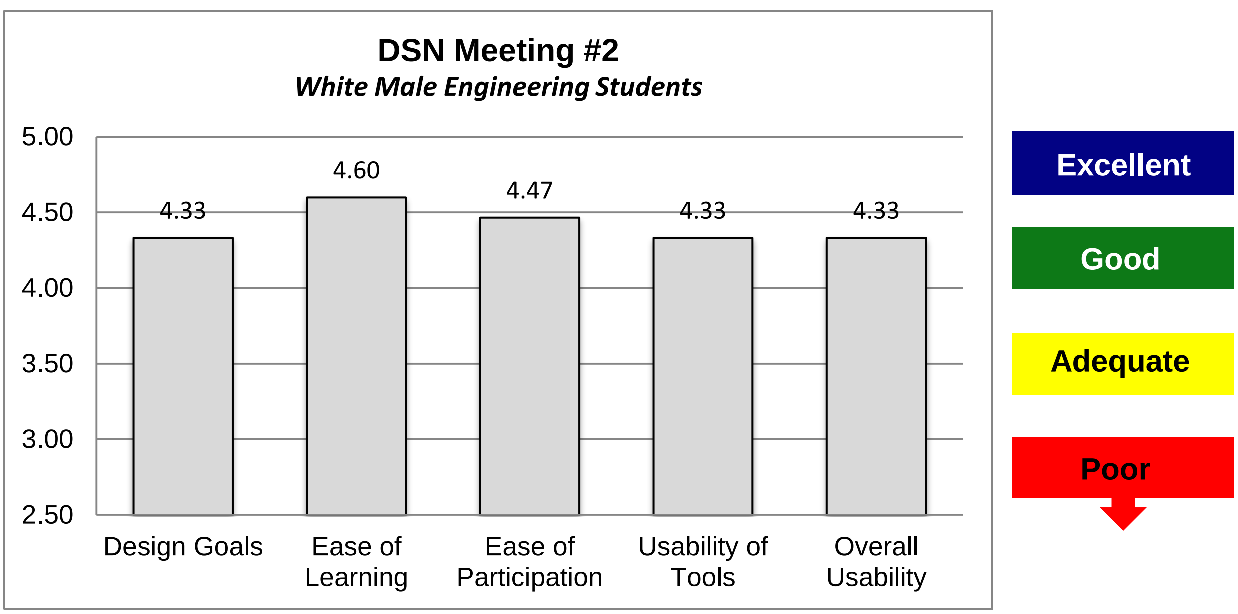


Figure 4-7: Usability Ratings for DSN Meeting #2 – White Male Engineering Students

Similar to the URM DSN meeting, the White male engineering students remarked that the functional decomposition process and the group collaboration were effective. One student stated that "*The hierarchy system and its systematic and rigorous method was effective*." Another student expressed that because of the process "*I was easily able to explain my needs*." In reference to the group collaboration, one student reported that "*Brainstorming with other engineering students was effective.*"

With respect to problems encountered, only two students provided a comment. The first comment related to clarifying the definition of "environmental success factor" because the student was "*confused by the definition of environmental (factor).*" Another student noted that "*I think that the further along we progressed into the meeting the more productive it became. We had a rough start with the green cards (i.e., the first discussion question)*." The only improvement that was recommended by these two students was to use better adhesive for the Post-its. Thus, the recommended improvements in Table 4-5 also include feedback from the problems encountered.

Table 4-5: Design Changes to Improve DSN Meeting #2 based on Recommendations

Attribute	Recommendations	Design Changes
Clarifying the Process	• Clarify the definitions of the student success factors	The definitions of the student success factors were provided.
Clarifying the Process	• Clarify the first discussion question. • Help to clarify functional decomposition process so that students can have a clear understanding of the process at the start of the meeting.	Initially, the first discussion question was to create the categories using the green Post-it notes. The rationale was to allow the participants to create categories without being biased from the categories developed by the researcher. This question was placed after the students identified the enablers/ hinderers, making it the second discussion question.
Equipment	• Use Post-it notes that will remain on the wall throughout the meeting	A new brand of Post-it notes were used for the next meeting.

4.2.2.6.3 DSN Meeting #3 – Asian Engineering Students

The recommendations from DSN Meeting #2 were incorporated into the third DSN meeting, which was held with three Asian engineering students. As shown in Figure 4-8, the ratings for the usability dimensions were the highest in comparison to the other groups for each dimension. The ratings ranged from 4.78 (Design Goals, Ease of Learning, Ease of Participation) to 4.89 (Usability of Tools and Overall Usability), which indicated that the design process and the outcome of the DSN were rated "Excellent" by Asian engineering students.

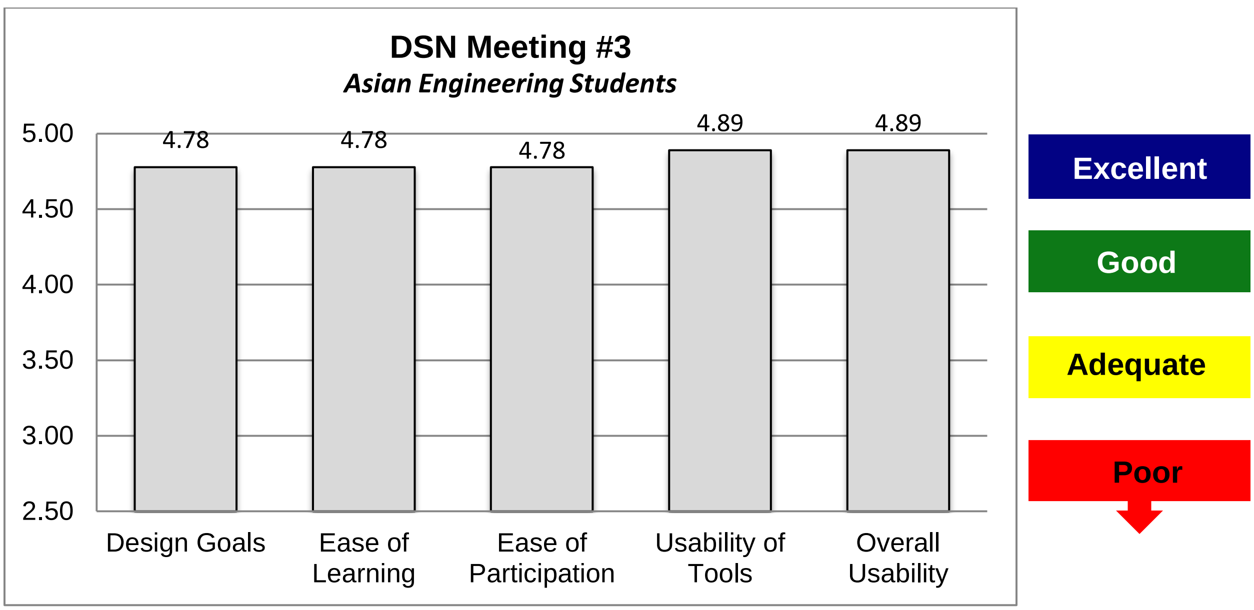


Figure 4-8: Usability Ratings for DSN Meeting #3 – Asian Engineering Students

Similar to the URM and White male group, the Asian engineering students noted that the functional decomposition process and the group collaboration were effective. One student indicated that "*I like the broad categories that were shown initially and I was able to learn about some of the things I haven't thought of.*" In reference to the group collaboration, another student commented that "*Everything went like clockwork. Conversing over pizza helped loosen everyone up.*" That same student attributed the effectiveness of the meeting to the group size.

Only one student encountered problems, indicating that the "*Post-it format with green notes was a little slow to get rolling but after a while it worked well.*" None of the students provided any specific recommendations to improve the meeting. While the mean responses for each dimension were well above the threshold where improvements needed to be made, the researcher decided to incorporate the feedback from the students. As a result, the single recommendation shown in Table 4-6 was devised by the researcher as a result of the feedback from the problems encountered.

Table 4-6: Design Changes to Improve DSN Meeting #3 based on Recommendations

Attribute	Recommendations	Design Changes
Clarifying the Process	• Clarify the second discussion question (grouping the enablers/hinderers into major categories using the green Post-it notes)	• Deleted the eating healthy food example. Allowed participants to work together as one team first to understand each discussion question. Participants then worked individually to answer discussion question #1, and were divided into smaller teams of 2 or 3 to answer the remaining discussion questions.

4.2.2.6.4 DSN Meeting #4 – White Female Engineering Students

The fourth DSN meeting was held with seven White female engineering students. The meeting protocol was updated with the recommended design changes from DSN meeting #3. As shown in Figure 4-9, the ratings for the usability dimensions ranged from 4.38 (Design Goals) to 4.81 (Ease of Participation), which indicated that the design process and the output of the DSN meeting was rated "Excellent" by White female engineering students.

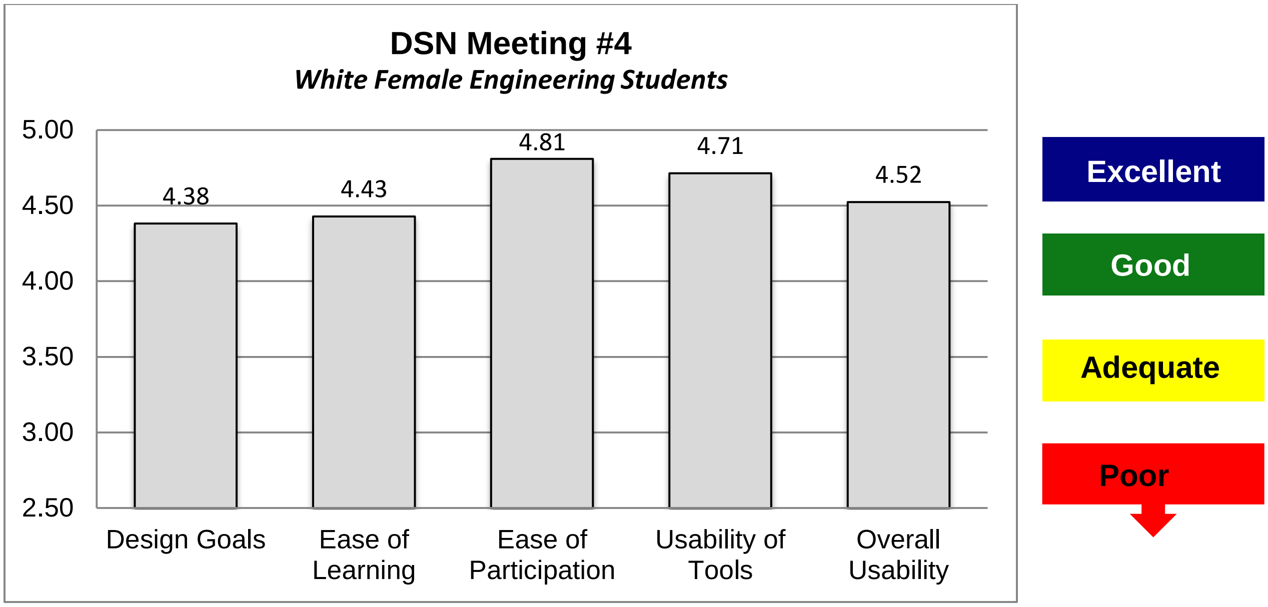


Figure 4-9: Usability Ratings for DSN Meeting #4 – White Female Engineering Students

The White female engineering students commented that the functional decomposition process, group collaboration, and the group size were effective. The majority of comments (a total of 7) were made about the functional decomposition process, in which one student indicated that "*The meeting was effective in really allowing me to identify my needs*." In reference to group collaboration, another student noted that *"It was interesting to work collaboratively to create a lot of needs."* Another student commented that "*It allowed me to bounce my ideas off others very well*." Similarly, another student suggested that "*It is easier to come up with ideas/thoughts when you are talking to others*." Finally, one student summarized each of the three effective areas, as follows: "*Sticky notes on wall was great (,) small group size (,being able to) bounce ideas off each other, and still be (able) to get a word in edge wise."*

A majority (5 out of 7) of the White female engineering students indicated that they did not encounter any problems. In fact, one student noted that "*The study was clear and thorough*," which echoed another student's assessment that the "*format was simple easy to work with*." Of the two students who indicated problems, one student noted that "*At first, I was very confused, but once the process developed I was much more able to participate and share*." The other student commented on the group collaboration, indicating that "*It was better working as a group to come up with ideas than individually*." While the ratings for each usability dimension were well above the threshold where modifications needed to be made, the researcher decided to incorporate the feedback from the students. To address these concerns, the following three recommendations were made by the students (Table 4-7). Since this was the final DSN meeting conducted for this research, the actions taken by the researcher are discussed in the Future Research section.

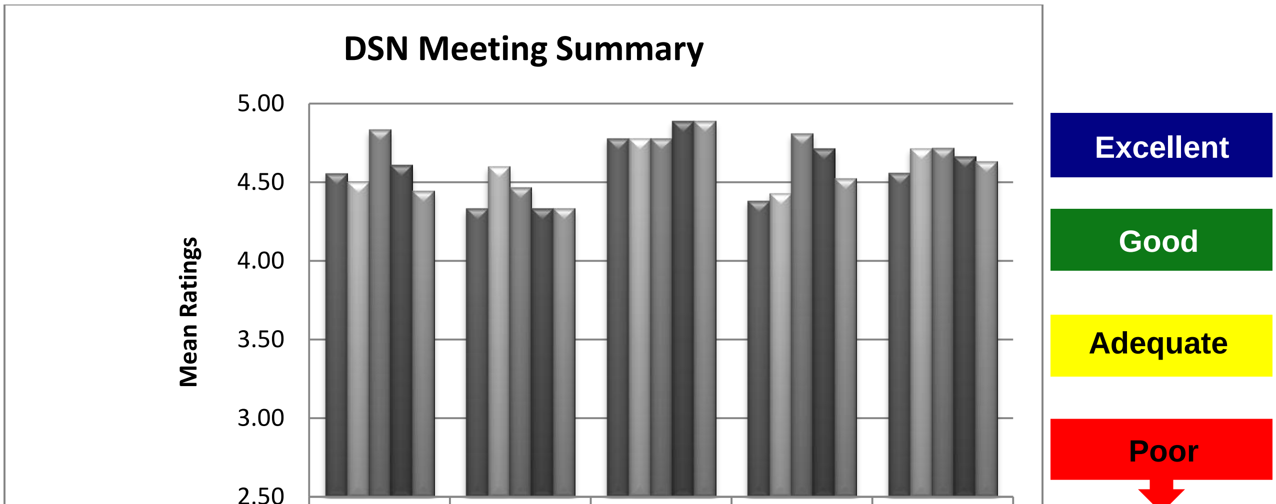
Table 4-7: Design Changes to Improve DSN Meeting #4 based on Recommendations

Attribute	Recommendations	Design Changes
Clarifying the Process	• Provide more examples to help participants understand the scope of the meeting • Examples should be done as a group versus individually	The meeting protocol was updated to clarify terms, objectives, discussion questions, and examples. The updated meeting protocol is included in Appendix A
Time	• Add more time to the meeting	Addressed in Future Research

4.2.2.6.5 DSN Formative Evaluation Discussion and Future Research

Four DSN meetings were conducted with a total of 21 participants to comprehensively identify the student success needs of engineering students. Every student completed formative evaluations and Figure 4-10 summarizes the ratings from the DSN meetings. Overall, the DSN meetings were shown to be effective based on the students' evaluations, which indicated that the design process and the output of the DSN meetings were "Excellent." This assessment is corroborated by the ratings for each of the usability dimensions (Figure 4-10), which ranged from 4.56 (Design Goals) to 4.72 (Ease of Participation).

Although the usability ratings were deemed “Excellent,” the researcher decided to incorporate the suggestions from the open-ended comments to improve the meeting protocol of the subsequent DSN meetings. Specifically, throughout the four DSN meetings, the researcher focused on clarifying the functional decomposition process while effectively facilitating the meeting to ensure that it was conducted in the two-hour time frame. Based on these recommendations, the DSN meeting was improved. Despite these improvements, the participants in the fourth and final DSN meeting (with White female engineering students) reported that more time and clarification of the functional decomposition process was needed. Therefore, the following aspects can be considered for additional research.



	URM N=6	Male N=5	Asian N=3	Female N=7	All Students N=21
Design Goals	4.56	4.33	4.78	4.38	4.56
Ease of Learning	4.50	4.60	4.78	4.43	4.71
Ease of Participation	4.83	4.47	4.78	4.81	4.72
Usability of Tools	4.61	4.33	4.89	4.71	4.67
Overall Usability	4.44	4.33	4.89	4.52	4.63

Figure 4-10: DSN Meeting Summary

First, an additional 15-20 minutes could be incorporated into the meeting to thoroughly explain the functional decomposition process with detailed examples that are related to the actual DSN meeting. Even though participants were given an explanation of the functional decomposition process, a more detailed review of the process may help to clarify the confusion that was reported by the participants early on in the process. Furthermore, the examples should be used as the starting point for the DSN meetings. It should also be noted that initially an eating healthy food example was used so that it would not bias the type of input that was gathered from the participants. However, this food-based example was considered confusing because it didn't relate to the task at hand (i.e., student success needs).

Despite the fact that time added to the meetings might help elucidate concepts, there are two drawbacks to longer meetings: (1) adding additional time may fatigue the participants, and (2) asking students to carve out a greater period of time for a longer meeting could reduce the available participant pool. There is the option of scheduling a pre-meeting to inform the participants about the meeting's protocol, but this option has cost and scheduling implications as well. Therefore, the second recommendation for future research relates to investigating the effectiveness of the DSN meeting. Dimensions of effectiveness many include (but are not limited to) length of meeting time, number of participants, and the trade-offs for including a detailed pre-meeting.

4.3 Specify Sample Questionnaire Items

As a result of the DSN meetings, the typology of student success factors from the literature was used to identify enablers and hinderers of student success. These enablers and hinderers were translated into a comprehensive pool of student need categories and student need statements (Figure 4-5) for each student success factor. As discussed earlier, Table 4-3 details the final dimensions of student success needs that resulted from the DSN meetings. The final dimensions of student success needs and the associated need statements were used as the basis for developing the initial pool of questionnaire items.

Based on the output of the DSN meetings, the researcher identified a comprehensive pool of questionnaire items for possible inclusion in the ESNQ. This step also incorporated the work of Clark and Watson (1995), who provided basic principles for developing a questionnaire and related items.

- A questionnaire must be grounded in a theoretical framework.
- A thorough literature review should be conducted to understand how others have approached the same problem.
- The domain and the dimensions of the construct should be carefully defined so that all content is relevant to the theoretical domain of the construct.
- Items should be broad and more comprehensive (i.e., overinclusive) so that the construct domain is represented.
- The language of the items should be simple, straightforwad, and appropriate for the target audience in order to avoid the use of trendy expressions, colloquialisms and doubled barreled items that assess more than one characteristic.
- Items should be written in such a way to ensure variability in the responses.

Since these guidelines were also incorporated into DSN Analysis Method, the final output of the DSN meetings provided the foundation for generating the sample of questionnaire items. Figure 4-11 provides a sample of the items that were generated for the Teaching and Learning Dimension based on the coding scheme developed in DSN Part E- Evaluate Results.

Once the output from each of the DSN meetings was consolidated, questionnaire items (top row of Figure 4-11) were specified and cross-checked with the literature to ensure that the domain was comprehensively covered. Table 4-8 summarizes existing questionnaires from both undergraduate education and engineering education that provided a knowledge base for related scales that address student success. This table also highlights the questionnaires and their associated dimensions. The *italicized*** dimensions reflect similar dimensions that were included in the engineering ESNQ.

	01-1 Being challenged and intellectually stimulated in class	**01-2 Being adequately prepared for future courses**	**01-3 Providing links between what I have learned and how it all fits**	**01-4 To understand what I am learning and how to apply (e.g, HW, exams, labs)**	**01-5 To connect what I am learning to the real world**
Teaching and Learning (TL)	I_C_03 Engage students in course material	I_A_04 Synchronize courses to ensure universal foundation	II_A_03 To have clear and comprehensive course work		II_C_06 To have real world projects and work
	I_B_09 Courses that tie into my	III_B_01 To have grades reflect learning	I_A_02 Course material should be aligned with books, tests, hw (assignments)		II_C_06 To have real world projects and work
	III_A_03 To stimulate you to learn		II_A_02 To have text books connected to the material		IV_E_04 To have real world examples
	III_B_06 To have a challenging curriculum		II_A_04 To simplify work to include only what is needed and useful		III_B_02 To apply course material to the real world
			II_C_05 To apply course material (HW)		
			II_C_08To have real world examples in class (class demonstrations)		
			IV_F_03To have explicit and clear textbooks		
			II_B_02 To know why I am learning and how to apply		
			III_B_04 To learn how to solve unfamiliar problems (being able to apply what you have learned and relate it to other concepts		
			To see outside the engineering 'bubble'		

Figure 4-11: A sample of the consolidated output from the DSN Meetings

However, questionnaire items could not be taken directly from the literature because the ESNQ was designed uniquely to provide actionable need statements. Similar to requirements, these need statements are short phrases that describe the functionality or actions that institutional practices should deliver in order to help students succeed. Furthermore, these statements describe actions that institutions can directly impact. As a result, psychological factors (e.g., self-efficacy, confidence, motivation) and general impressions and attitudes are outside the scope

Table 4-8: Existing Student Success Scales

Pittsburgh Freshman Engineering Attitudes Survey (PFEAS)	• General Impressions of Engineering • Perception of How Engineers Contribute to Society • Engineering Compatibility • Perception of the Work Engineers Do and The Engineering Profession	• Enjoyment of Math and Science Courses • Engineering Perceived as Being and "Exact" Science • Family Influences to Studying Engineering • *Working in Groups*** • *Adequate Study Habits*	• *Confidence in Communication and Computer Skills*** • *Problem Solving Abilities*** • *Confidence in Basic Engineering Knowledge and Skills* ** • *Financial Influences for Studying Engineering* **
Source: http://www.engr.pitt.edu/~outcomes/#			
Course Experience Questionnaire	• *Student Support Scale* • Graduate Quality Scale	• *Learning Resources Scale* • Intellectual Motivation	• *Learning Community Scale*
Source: Eris (2005)			
Engineering Fields Questionnaire	• Milestone self-efficacy • Coping efficacy	• Outcome expectations • *Environmental supports***	• *Goal progress*** • *Satisfaction***
Source: Lent et al. (2005)			
National Survey of Student Engagement	• *Level of Academic Challenge*** • *Active and Collaborative Learning***	• *Student-Faculty Interaction*** • *Supportive Campus Environment***	• *Enriching Educational Experiences***
Source: http://nsse.iub.edu/			
Student Satisfaction Inventory	• *Academic Advising Effectiveness*** • *Campus Climate*** • Campus Support Services • *Student Centeredness***	• *Responsiveness to Diverse Populations* ** • Safety and Security • Service Excellence • *Concern for the Individual***	• *Instructional Effectiveness*** • *Admissions and Financial Aid Effectiveness*** • Registration Effectiveness
Source: https://www.noellevitz.com/			
Institutional Integration Scales	• *Peer Group Interactions*** • *Academic and Intellectual Development***	• *Interactions with Faculty* ** • *Institutional and Goal Commitment* **	• *Faculty Concern for Student*** • *Development and Teaching***
Source: Pascarella and Terenzini (1980)			

of the ESNQ because they can be attributed to other factors (e.g., personality) that are outside of the institution's control. Section 4.1 has also delimited the scope to include only the post-college aspects that are within the typology of student success factors. Therefore, the scope of the ESNQ does not include the physical and administrative services (e.g., campus support services, registration effectiveness), which are important to students; however, fall outside the scope of the typology of student success factors.

4.3.1 Specify Questionnaire Format

The ESNQ involved an examination of student perceptions of the importance of their needs, as well as their satisfaction level with the performance of the institution in meeting their needs. While traditional methods tend to examine satisfaction and importance independently, these concepts were merged and used together in the ESNQ, which is included in Appendix B. Similar to the Noel Levitz Student Satisfaction Inventory (Elliott, 2002), the ESNQ uses a 7-point Likert-type scale to capture both the importance and the satisfaction.

4.4 Perform Expert Review

The expert review was the first phase of the questionnaire validation process. Content validity was ensured when expert judges agreed that the items were reflective of the overall construct, and that the items were representative of the domain and facets of the construct (Netemeyer et al., 2003). Following the questionnaire development process, the instrument underwent two rounds of expert reviews, after which a refined instrument emerged for the pilot testing stage of this research.

4.4.1 Participants

The expert panel consisted of both academic practitioners as well as students. A criterion sampling strategy was used in order to develop a purposeful sample. Table 4-9 describes the criteria, which were used to select participants for the expert review panel.

Table 4-9: Selection Criteria for Expert Review Panel Participants

Panel #	Participants	Criteria
1	4 Students	Undergraduate Student
		Engineering Major
2	8 Administrators / Professors	Plans, implements and/or evaluates student success practices.
		Leads, develops and/or operates student success programs.
		Writes reports, publishes articles, and/or writes proposals to document, evaluate, and/or fund student success initiatives.

4.4.2 Student Expert Review Panel

A focus group meeting to carry out the student expert panel review was conducted with 4 undergraduate engineering students, who were considered experts based on their knowledge about the undergraduate engineering experience. Students were asked to complete the questionnaire; at the same time they were instructed to edit the questionnaire items to ensure appropriateness of language, clarity, and readability.

Additionally, a modified Q-sort procedure was used to improve the construct validity of the first round of the expert review with students (Moore & Benbasat, 1991). This procedure involved a bottoms-up categorization process that essentially instructed expert judges to group student need questionnaire items into homogeneous dimensions of student success needs (i.e., constructs). The modified version of the Q-Sort was used, which instructed the expert judges to utilize a forced-choice model so that participants would be forced to assign an item to a pre-defined category (Barnard & Ehrenberg, 1990). Figure 4-12 provides a sample to illustrate how the first part of the student expert panel review (Part A) was carried out.

How important is this need to you?								**Need**	***How satisfied are you with this need being met?***								***Clarity***	***Category***
1	2	3	4	5	6	7	N/A		1	2	3	4	5	6	7	N/A		
						X		A.1: ~~Being~~ To be challenged and intellectually stimulated in class.						X			6	TL
					X			E.3: To cope with the educational demands			X						6	W
						X		I.7: Developing my Math Ability						X			6	S

Figure 4-12: Part A - Expert Panel Review

Once participants completed the questionnaire individually, then they were asked to fill out Part B (Figure 4-13) to indicate the categories that each questionnaire item was assigned. A group discussion followed, which allowed the participants collectively to determine whether 1) additional categories should be added or renamed, 2) additional items should be added to a particular category, or 3) and if any improvements should be made to the questionnaire.

As shown in Figure 4-13, the group made recommendations to edit the items (need statements). Items with a clarity score < 5 (from Part A) were edited; however, scores > 5 were edited in some cases if recommendations further improved the clarity of items. Based on the results of Part B, a revised questionnaire was prepared for the practitioner expert panel review (Appendix B).

Category	#	Item Description	Assigned #
A_Teaching and Learning (TL)	A.1	~~Being~~ To be challenged and intellectually stimulated in class	TL
	~~A.2~~	~~Providing links between what I have learned and how it all fits together~~	TL/S
	~~A.3~~	~~Being adequately prepared for future courses~~	TL
	A.4	~~To understand what I am learning and how to apply (e.g., HW, exams, labs)~~ To have opportunities to practice what I have learned	TL
	A.5	To connect what I am learning to the real world	S
	A.6	To have course concepts communicated in a manner that I comprehend	TL
	A.7 ~~B.2~~	To understand course material	TL

Figure 4-13: Part B - Student Expert Panel Review

4.4.3 Practitioner Expert Review Panel

A second expert panel review (Appendix D) consisted of eight student success researchers and practitioners. A worksheet was emailed to the expert reviewers, which was returned to the researcher electronically. The goals of the practitioner expert panel review were the same as the student panel review—to review the questionnaire and provide feedback to ensure that the questionnaire comprehensively and concisely addressed those needs that are critical to engineering student success. However, the distribution format was different to accommodate a review from participants that were in distributed locations.

Similar to the student review panel, the expert participants were asked to indicate whether each questionnaire item was representative of the dimensions of student success needs. They also provided comments on the appropriateness of language, clarity, and readability of the individual items and the questionnaire as a whole. Based on the responses from the practitioner expert panel, a revised questionnaire (Appendix B) was prepared for the pilot study.

4.5 Pilot Study

Once the two rounds of expert reviews were completed by the students and the practitioners, the questionnaire was administered as a pilot test to a sample of students as the next step in the questionnaire validation process. The pilot study provided an opportunity to collect actual data to purify the measure prior to its final administration. Additionally, a trial run of the administration procedures was also carried out to remove any ambiguities in the administration process (Malhorta, 1998). Moreover, by administering the pilot questionnaire, actual data was collected and then subjected to reliability and validity tests, which provided information concerning deficiencies as well as suggested ways to improve the instrument.

4.5.1 Participants

For the pilot study, the questionnaire was completed by 241 undergraduate engineering students at a large southeastern doctoral granting institution.

4.5.2 Administration Procedures

The questionnaire was administered using Qualtrics, which is an online survey tool (http://www.qualtrics.com/) that has been approved by the researcher's institutional review board. An electronic invitation to participate in the survey was sent to 3 undergraduate engineering classes, two departmental list serves, and one MEPs list serve. The invitation contained an electronic link that directed participants to the questionnaire which was completed via the internet. Prior to completing the questionnaire, the participants were instructed to provide demographic information including major, gender, ethnicity, class level, and international student status.

4.6 Assess Reliability and Validity – Pilot Study

Once the questionnaire was administered and responses were collected and tabulated, an assessment was carried out to ensure that the questionnaire was both reliable and valid. For a measure to be considered valid, it had to exhibit dimensionality and reliability. While dimensionality is concerned with the homogeneity of items, reliability is concerned with a measure yielding consistent results. First, Exploratory Factor Analysis (EFA) was used to explore the underlying structure of the constructs and to assess the dimensionality of the scale. Additionally, the most widely used internal consistency reliability test, Cronbach's Alpha coefficient, was used to assess the reliability of the various dimensions of student success needs identified as a result of the factor analysis (Netemeyer et al., 2003).

EFA was used to discover the underlying dimensions of student success needs for the set of student need statements (i.e., questionnaire items) from the ESNQ (Netemeyer, et al., 2003; DeVellis, 2003). While the DSN Analysis Method provided a qualitative method to categorize the dimensions of student success needs and their associated need statements, EFA provides a quantitative statistical approach in order to assess the construct validity of the ESNQ.

In order to conduct EFA, a factor extraction model, a fit rotation method, and the number of factors to retain for rotation need to be determined. The extraction model was principal components analysis (PCA) using the varimax (orthogonal) rotation method because it is the most commonly used method (Costello & Osborne, 2005). To determine the number of components to retain, the eigenvalue-greater-than-one rule was employed. In applying this rule, the number of components retained is equal to the number of eigenvalues that exceed one. The rationale is that a factor must account for at least as much of the variance that can be accounted for by single questionnaire item or variable (Netemeyer et al., 2003).

4.6.1 Results

The results of this analysis are described in Table 4-10. Adhering to criteria advocated in the psychometric literature, factor loadings greater than 0.40 were retained and factor loadings greater than 0.90 were deleted (Comrey & Lee, 1992). Furthermore, a Cronbach's Alpha coefficient of 0.7 or greater indicated a reliable, internally consistent dimension.

Principal components analysis (Table 4-10) revealed the presence of 9 components with eigenvalues exceeding 1. However, the variances explained by the 8th and 9th components were less than 5% (Hair et al., 1998); so they were dropped from the analysis. The resultant 7 components were retained, explaining a total of 58.4% of the variance.

Cronbach's alpha coefficients were calculated to estimate the internal consistency of each component. The reliability assessment yielded Cronbach Alpha coefficients of 0.7 or greater for the components, with the exception of component 5 ($\alpha = 0.69$) and 6 ($\alpha = 0.62$). While the standard is indicative of high reliability, components 5 and 6 were retained because they are indicative of moderately high reliability.

Table 4-10: Reliability and Validity Assessment

Pilot Questionnaire	#	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Classroom Learning (5 items)	01_1	0.09	0.10	0.14	0.10	0.07	0.09	**0.70**	0.00	0.37
	01_4	0.01	0.19	0.18	0.00	0.00	0.11	**0.74**	0.06	-0.03
	01_5	0.04	0.25	0.10	0.19	0.21	0.31	**0.55**	0.06	-0.20
	01_6	-0.01	0.56	0.19	0.10	0.19	-0.12	**0.44**	0.31	-0.04
	01_7	-0.07	0.55	0.32	0.14	0.21	-0.07	**0.41**	0.15	-0.23
Faculty Interaction (4 itmes)	02_1	0.14	0.10	**0.71**	0.18	0.22	-0.07	0.16	0.01	0.08
	02_4	0.12	0.10	**0.81**	0.11	0.09	0.09	0.10	0.13	0.01
	02_5	0.31	0.08	**0.67**	0.01	0.00	0.17	0.14	0.25	0.23
	02_6	0.03	0.13	**0.64**	-0.14	0.02	0.27	0.13	-0.21	-0.16
Sense of Community (7 items) ~~Student Interactions~~	08_1	**0.55**	0.29	0.31	-0.06	0.01	0.16	0.29	0.24	-0.04
	08_3	**0.49**	0.05	0.13	0.13	0.18	0.02	0.27	0.47	0.22
	08_4	0.32	0.24	0.29	0.05	0.11	0.31	0.11	0.09	0.12
	08_5	**0.81**	0.04	0.19	0.00	0.12	0.01	-0.06	0.02	0.10
	07_1	**0.77**	0.12	0.08	0.25	0.03	0.18	0.04	-0.05	0.05
	07_2	**0.75**	0.16	0.05	0.19	0.06	-0.06	0.04	-0.04	0.15
	07_3	**0.59**	0.12	-0.01	0.18	0.34	0.08	-0.09	0.08	-0.37
	07_4	**0.57**	-0.04	0.05	0.23	0.18	0.24	0.01	0.37	-0.20
Financial (4 items)	06_1	0.04	0.12	0.13	**0.82**	-0.03	0.11	0.02	0.05	0.06
	06_2	0.18	0.20	0.18	**0.68**	0.17	0.12	0.02	-0.03	-0.16
	06_3	0.21	0.02	-0.12	**0.76**	0.19	0.18	0.03	0.14	-0.13
	06_4	0.19	0.01	-0.01	**0.78**	0.00	0.12	0.15	0.10	0.16
Skill (4 items)	09_1	0.06	0.27	0.02	0.02	**0.64**	0.08	0.04	0.20	-0.22
	09_2	0.19	0.02	0.17	0.15	**0.74**	0.19	0.01	0.05	0.02
	09_3	0.33	0.09	0.14	0.04	**0.60**	0.18	0.04	0.14	0.20
	09_4	0.23	0.33	0.12	-0.06	0.29	0.19	0.07	0.06	0.65
	09_5	-0.03	0.19	0.08	0.05	**0.63**	0.11	0.23	-0.16	0.30
Professional Development (3 items)	09_6	0.00	0.11	0.05	0.21	0.20	**0.68**	0.19	0.08	0.22
	09_9	0.23	0.08	0.06	0.11	0.40	**0.51**	0.09	0.03	0.10
	04_1	-0.07	0.17	0.20	0.31	0.20	**0.52**	0.12	0.03	-0.23
Resource (4 items)	04_2	0.26	0.28	0.17	0.18	0.06	0.55	0.02	0.10	-0.01
	04_3	0.05	0.17	0.05	0.12	0.04	0.14	0.07	0.81	-0.01
	04_4	0.02	0.47	0.39	0.11	0.29	-0.02	0.07	0.41	0.06
	04_5	0.19	0.46	0.29	0.11	0.19	0.28	-0.08	0.24	0.25
Workload Management (4 items)	05_1	0.09	**0.72**	0.10	0.08	0.14	0.12	0.00	0.13	0.18
	05_2	0.09	**0.80**	0.15	0.07	0.02	0.09	0.12	-0.12	0.05
	05_3	0.18	**0.69**	-0.06	0.02	0.08	0.21	0.19	0.03	-0.04
	05_4	0.24	**0.58**	0.02	0.15	0.08	0.35	0.21	0.13	0.08
Cronbach's Alpha		0.85	0.80	0.73	0.80	0.69	0.62	0.77		
Initial Eigenvalue		10.36	2.96	2.30	1.77	1.65	1.42	1.27		
% Variance Explained		28.00	8.00	6.23	4.79	4.46	3.83	3.43		

4.7 Conceptual Research Model

Based on the results, the pilot version of the ESNQ (Appendix B) demonstrated both reliability and validity. Furthermore, this assessment provided a statistically verified conceptual research model of engineering student success needs. The model in Figure 4-14 serves to define the initial variables, which were refined into a research model and tested in Chapter 6 (Phase II of the S^2OSD methodology).

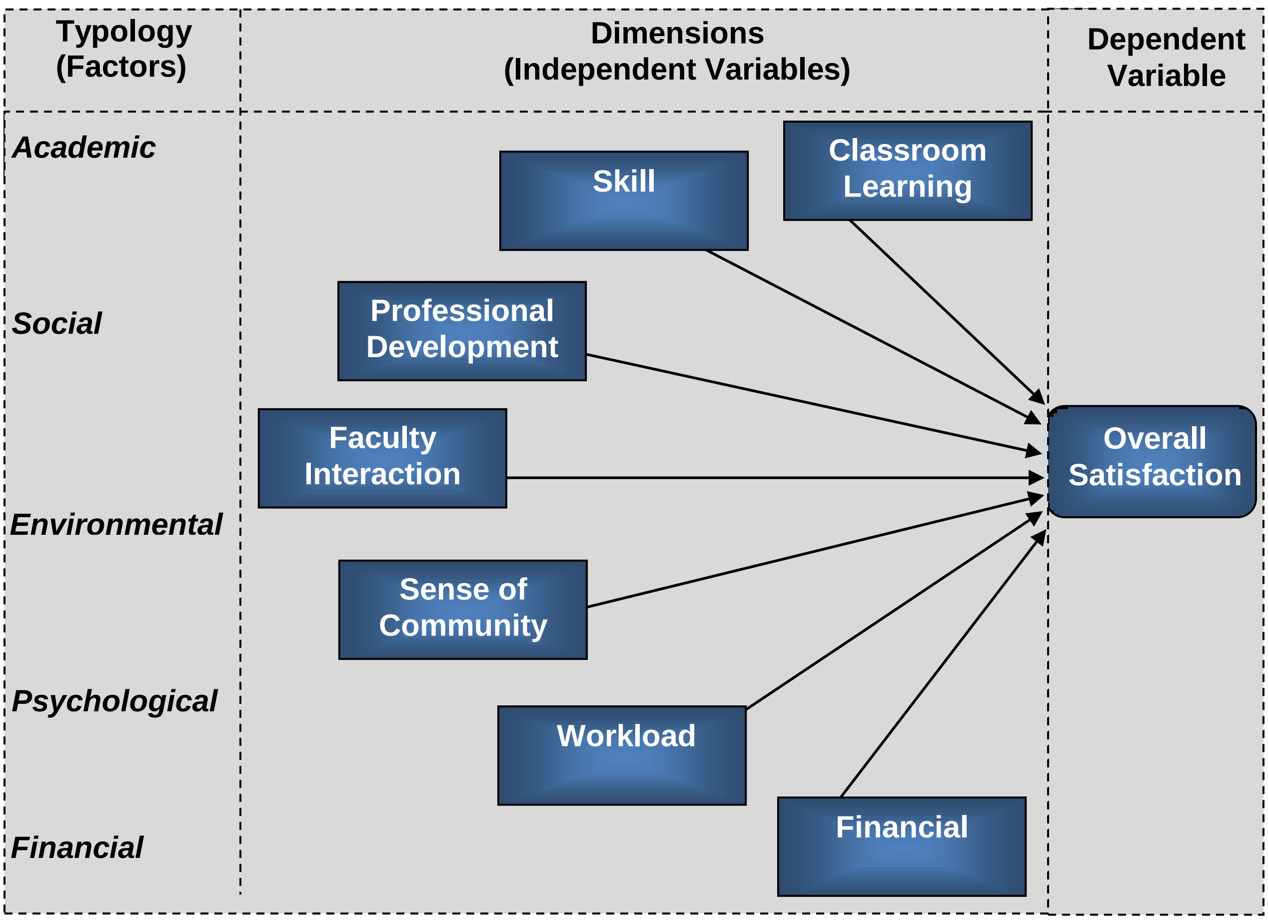


Figure 4-14: Conceptual Research Model: Engineering Student Success Needs

The basic premise of the model is that there are academic, psychological, environmental, financial, and social factors that impact student success. Based on these factors, the seven dimensions of student success needs—i.e., the dependent variables—were defined. Overall satisfaction, which is the independent variable, was used to measure student success. The seven conceptual research model dependent variables are described below:

- *Classroom Learning needs*: This variable describes the extent to which students are satisfied with the institution's efforts in providing a classroom experience that enhances their ability to acquire knowledge in their field of study.
- *Skill needs*. This variable describes the extent to which students are satisfied with the institution in developing requisite engineering and professional skills.
- *Professional Development needs*: This variable describes the extent to which students are satisfied with the institution's efforts to provide practical experiences.
- *Faculty Interaction needs*: This variable describes the extent to which students are satisfied with the institution in providing opportunities to have quality interactions with faculty members.
- *Sense of Community needs*: This variable describes the extent to which students are satisfied with the institution's efforts to create a welcoming environment, such that students experience a sense of belonging with the other students and the engineering community on campus.
- *Workload Management needs:* This variable describes the extent to which students are satisfied with the institution in helping them to cope with the demands of their engineering major.
- *Financial needs*: This variable describes the extent to which students are satisfied with the institution in providing accessible financial assistance.
- *Overall Satisfaction*: This variable describes the extent to which students are satisfied with their overall college experience.

4.8 Summary

This chapter described the development and validation of the ESNQ. The development process consisted of three steps. First, the domain of constructs was determined using the typology of student success factors defined in Chapter 2 (Literature Review). Second, the S^2OPD method was used to conduct four DSN meetings with 21 students. Based on the results of the DSN meetings, the final step in the development process consisted of creating the questionnaire layout and initial pool of questionnaire items was developed to specify actionable need statements. Furthermore, the questionnaire layout was designed to assess the students' importance and satisfaction with the institution in meeting their needs.

Then, the questionnaire validation process was presented to assess both the validity and reliability of the ESNQ. Two expert panel reviews were conducted with four students and eight student success practitioners, respectively, to purify the instrument. As a result of these reviews, a final questionnaire emerged for pilot testing. A pilot test was conducted with 241 participants to collect data in order to assess the reliability and validity of the ESNQ. As a result of these steps, a conceptual research model emerged that defined the initial variables, which were subsequently refined into a research model and tested in Chapter 6 (Phase II of the S^2OSD methodology).

CHAPTER 5 PHASE I: DIAGNOSE THE BASELINE

The S^2OSD methodology offers a top-down approach that begins with the highest level of the institutional unit at which decision-making occurs, and then works down to lower levels of the program (i.e., the students) in the next step to clarify and document the current practices and desired improvements. Since the most critical step in creating a solution is to first define the problem to be solved (Blanchard & Fabrycky, 2006), the first phase of the S^2OSD methodology began with defining and diagnosing the baseline of the institutional unit (e.g., program, department) under study.

To begin with, program documentation was reviewed to provide the researcher with an overview of the current state of affairs (i.e., the program, its goals and objectives). After that, utilizing the Diagnose the Baseline (DB) Method, the S^2OPD meeting process was used to guide institutional leaders through a diagnosis of their current state, and to define their desired state of practices. The following hypothesis was tested to address research question 2.1:

RQ 2.1: *How can decision makers assess their current state and define how to satisfy engineering student success needs in the future?*

H2.1: *Phase I of the S^2OSD methodology can be used to assess and understand how to satisfy the engineering student success needs.*

5.1 Participants

Institutional leaders from the MEP and WIE program participated in Phase I of the S^2OSD methodology. A criterion sampling strategy was employed to select the purposeful sample of institutional decision makers that participated in Phase I based on the criteria described in Table 5-1.

.

Table 5-1: Selection Criteria for the 'Diagnose the Baseline' Meeting Participants

Program	# of Participants	Selection Criteria
Women in Engineering Program	3	• Responsible for planning, implementing and/or evaluating student success practices • Leads, develops and/or operates student success programs • Writes reports, publishes articles, and/or writes proposals to document, evaluate, and/or fund student success initiatives.
Minorities in Engineering Program	5	

5.2 DB Methods, Process, and Tools

To reiterate, the DB method was developed to help decision makers systematically think through key aspects of their organization that are critical to student success. As a result, the perceptions of these individuals can help define current student success practices and the desired areas that need improvements. Figure 5-1 summarizes the steps in the DB meeting process that was used in this study.

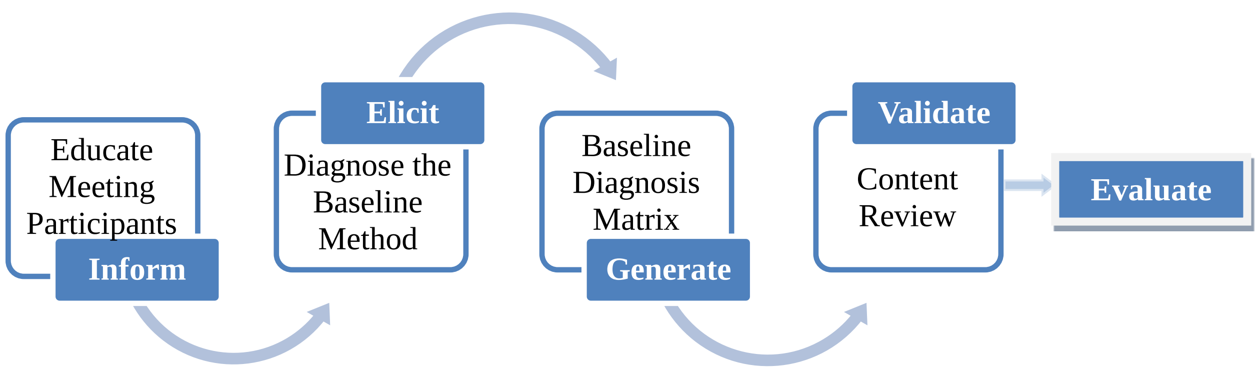


Figure 5-1: Diagnose the Baseline Meeting Process

Specifically, two DB Meetings were carried out using the S^2OPD meeting process, during which participants were asked to share their experiences in a group discussion that was guided by the researcher over a 2-hour period. The meeting process began with the *Inform* step, in which the researcher educated the meeting participants about the scope of the meeting. During the *Elicit* step, the DB method was used to elicit the ideas of the group in a structured manner. The *Generate* step then organized the information resulting from the elicit step in order to generate the Baseline Diagnosis Matrix. The participants then reviewed the content to ensure that the matrix addressed the meetings goals and objectives during the *Validate* step. Finally, the results of the meeting were discussed and evaluated by the MEP and the WIE program administrators.

The DB Method integrated the performance improvement body of knowledge with the student success theoretical perspectives, in which six key performance areas have been identified from Chapter 2. By linking the six performance areas (Figure 5-2), the DB Method was used to brainstorm and document how decision makers satisfy student needs within the context of their program's environment.

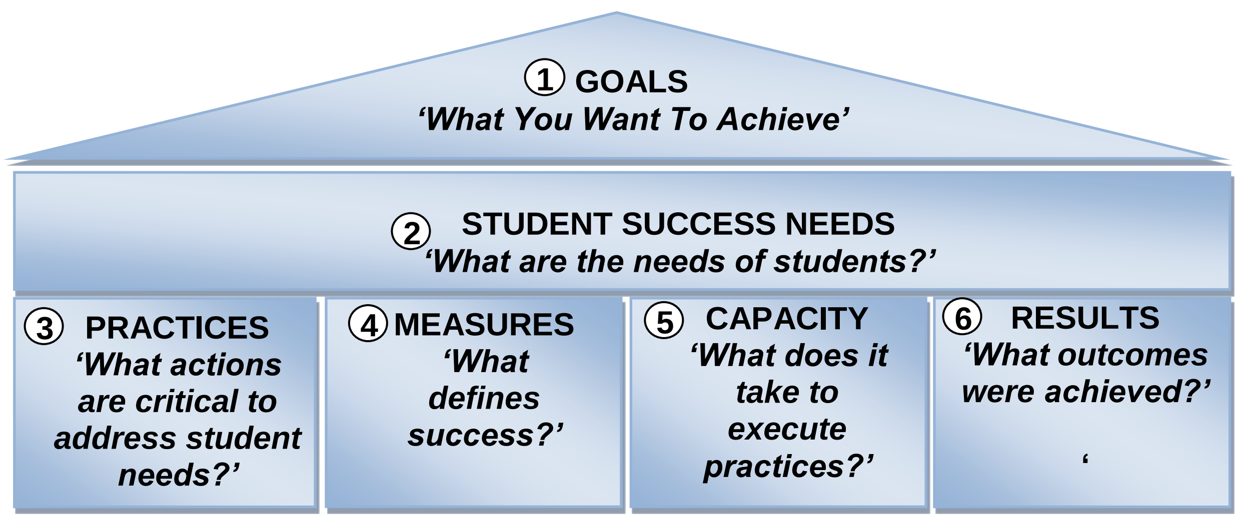


Figure 5-2: Baseline Diagnosis Method: Key Performance Areas

In order to guide the discussion, series of pre-planned questions were used to help decision makers think through each of the performance areas. The *Goals* area allowed participants to first consider what they wanted to achieve. Then, the *Needs* area was used to highlight needs that are critical to undergraduate engineering student success. The *Practices* area allowed the participants to think through how current practices address student needs. In the *Capacity* area, participants considered what is required to implement the student success practices. The *Results* area defined the outcomes of student success practices. For each of these areas, decision makers were also asked to consider how success is defined in the *Measurement* area.

5.2.1 DB: PART A - INFORM

The first step of the meeting consisted of informing the participants about the scope of the meeting, its goals and objectives, the procedures, and the roles and responsibilities of the participants. These goals and objectives (Table 5-2) ensured that the meeting was focused on diagnosing the baseline in the context of the student success theoretical perspectives.

Table 5-2: DB Meeting's Goals and Objectives

Goal #1: To baseline current undergraduate engineering practices	***Goal #2: To identify areas that are in need of improvement***
Objective #1: To define practices in the context of student success.	***Objective #2: To include only factors that the institution can directly impact.***

5.2.2 DB: PART B - ELICIT

The DB Method was developed to diagnose the current baseline of practices in order to identify areas needing improvement. Specifically, discussion questions were used to guide participants through each element of the DB method, after which the elements were utilized to help decision makers identify areas that needed improvement.

First, participants were guided through discussion questions (Table 5-3) to systematically evaluate the current state for each of their student success practices. Using the six key performance areas, participants were able to systematically consider elements of their program that facilitated student success. Second, the decision makers assessed the strengths and weaknesses of existing practices, which enabled them to leverage the strengths, and improve upon the weaknesses. Finally, participants were able to identify areas that were in need of improvement based on the information generated from the discussion questions.

Table 5-3: Elements of the DB Method

Element	Key Performance Area	Discussion Questions
I. Current State	Mission/Goals	• Discussion Question # 1a: What are the goals of the program? • Discussion Question # 1b: How does the program define success in achieving the goals?
	Student Success Needs	• Discussion Question # 2a: What are the needs of undergraduate engineering students that should be met in order for them to succeed? • Discussion Question # 2b: How does the program meet the 'student success' needs of their undergraduate engineering students? • Discussion Question # 2c: How does the program define and measure success for meeting student needs?
	Capacity	• Discussion Question # 3: What infrastructure is needed to meet the needs of the students?
	Measurement	• Discussion Question # 4: How is success defined and measured?
	Results	• Discussion Question # 5: What are the outcomes of the current practices (red- needs improvement, yellow – adequate, green – good, blue – excellent)?
II. Strengths and Weaknesses	Practices	• Discussion Question # 6: What are the strengths of practice X? • Discussion Question # 7: What aspects of practice X need to be improved?
III. Desired State		• Discussion Question # 8: Where are opportunities for desired improvements? • Discussion Question # 9: What barriers can impede progress toward improvements?

5.2.3 DB: PART C - GENERATE

As a result of the discussion questions from the Elicit step, the final output of the meeting was generated based on the completion of the Baseline Diagnosis Matrix (Figure 5-3). Each of the discussion questions were intended to guide the completion of this tool.

5.2.4 DB: PART D - VALIDATE

During the *Validate* Step, the final discussion question allowed the team to review the meeting's goals and objectives to ensure that they were met. A final review of the Baseline Diagnosis Matrix developed in the *Generate* step was examined to ensure that there was agreement among the meeting participants with respect to its ability to meet the stated objectives. If open issues remained, the group repeated the meeting process to elicit, generate, and validate the output. The meeting participants repeated the validation step until no unresolved issues remained.

Discussion Question #10*: Does the Baseline Diagnosis Matrix address the program's current state and define how to satisfy engineering student success needs in the future?*

5.2.5 DB: PART E – EVALUATE RESULTS

The results of the meeting were largely developed and assessed during the DB meeting. Again, the S^2OPD method was designed such that the analysis of the results could be developed and evaluated during the meeting. Based on the results of the *Validate* step, a number of priorities were established for the next year at the organizational level. As such, the results for Phase III's MEP and WIE program consisted of a completed DB tool and priority areas identified for improvement.

Figure 5-3: Diagnose the Baseline Tool – WIE Program

Current State: Living and Learning Community		**Current Goals: The retention of undergraduate female engineering students.**		
Dimensions of Student Success Needs	**Practices**	**Measures of Success**	**Desired State (Opportunities)**	**Threats**
Classroom Learning	1-credit seminar course clustering in core courses	Grades, Retention, Satisfaction		
Workload Management	Time management, advising, tutoring, studying			
Skills	Provides engineering technical skills Communication skills, Job skills		Incorporate Corporate Sponsors	
Faculty Interaction	Provides mentors/role models		Involve women faculty	Time
Sense of Community /Student Interaction	Connects peers, Residential Component, Student Organizations, Social Activities			
Financial	Information about scholarships, internships, co-ops		Provide scholarships	Funding
Capacity	1 program admin/1 grad student Serves 45 students 6th floor Elliott Hall Student Lounge – tutoring center		Expand beyond 1st year Get minority female student participation	Funding, Staffing Negative Peer Perceptions
Results	Course evaluations, Comprehensive Evaluations, Executive Board bi-Weekly, Grad Assistant Meetings			
Strengths	Strong retention rates, Awareness, Effective Clustering, Develops intimate sense of community, Good relationship with residential life, Proven curriculum			
Weaknesses	Negative perceptions by peers of involvement in special program, resources, staffing, funding, time			

These results were then revisited in Phase II. An action grid was developed to reconcile the areas identified from the decision makers' perspective with areas identified from the students' perspective. Therefore, the resulting gap between the initial baseline diagnosis and the results of the questionnaire from the students' responses allowed program administrators to consider how to better meet the needs of their students.

5.2.5.1 Phase I Results: WIE Program

The WIE program participants completed a Baseline Diagnosis Matrix in the following areas: Living and Learning Community, Teaching Opportunities, Research Opportunities, and the Mentoring Student Success Practices. A sample of the output is illustrated in Figure 5-3, which describes the completed Baseline Diagnosis Matrix for the Living and Learning Community. Based on this analysis, a number of priorities were established at the strategic level:

- *Faculty Interaction Need*: Involve and engage female faculty
- *Financial Need*: Provide scholarships
- *Sense of Community Need*: Enhance diversity
- *Capacity Area:* Augment corporate sponsorships and funding in order to reach more students

5.2.5.2 Phase I Results: MEP

The MEP administrators completed a Baseline Diagnosis Matrix for the following student success practices: Advising, Summer Bridge Program, and Research Opportunities. A sample of the output is illustrated in Figure 5-4, which describes the completed Baseline Diagnosis Matrix for Advising. Based on the analysis of the individual student success practices, a number of priorities were established at the strategic level:

Figure 5-4: Baseline Diagnosis Matrix – MEP

Current State: Advising		**Current Goals: To help students navigate through their undergraduate engineering experience.** ①			
Dimensions of Student Success Needs ②	**Practices** ③	**Measures of Success** ④	**Results** ⑥	**Desired State (Opportunities)**	**Threats**
Classroom Learning	Tracks academic progress	Annual retention rates, graduation rates, grades			
Workload Management	Provide advice on balancing workload				
Skills	N/A				
Faculty Interaction	Encourages faculty interaction				
Sense of Community /Student Interaction	N/A				
Financial	Provide information regarding financial opportunities				
Capacity ⑤	All staff and all students Assigned academic advisors			Focusing on advising special populations (first year, transfer, and students on probation), Funding	Funding Perceptions that only faculty should be advising
Strengths	Interaction with students Able to catch potential problems				
Weaknesses	Small staff with many responsibilities				

- *Faculty Interaction Need*: To expand faculty network (interact with new group of faculty)
- *Skill Need*: To enhance the leadership, professional development, course preparation, study skills of students
- *Capacity Area*: To expand student participation
- *Measurement Area*: To develop additional means to understand needs and measure success
- *Capacity Area*: To maintain existing staff and to increase funding

5.2.6 DB: EVALUATE USABILITY

The DB formative evaluations were conducted to determine if the established methods, processes, and tools were able to successfully guide institutional leaders through the process of diagnosing the current baselines and identifying areas that needed to be improved. Two DB meetings were conducted with eight institutional leaders, who provided feedback to improve the usability of the DB meeting during Phase I of this research. The performance-based evaluation framework is described in Chapter 9, and the questionnaire for the DB meeting is included in Appendix E (Part E). The results of the questionnaire are presented for the MEP and the WIE programs; and then summarized collectively in the DB discussion and future research section.

5.2.6.1 DB Meeting #1 – WIE Program Administrators

The DB meeting was first held with three of the program administrators from the WIE program. As shown in Figure 5-5, the ratings for the usability dimensions ranged from 2.83 (Overall Usability) to 3.33 (Ease of Learning). These results indicated that the design process and the outcome of the DB were rated “Adequate” by the program administrators—with the exception of the Design Goals dimension, which was rated “Poor” by the program administrators.

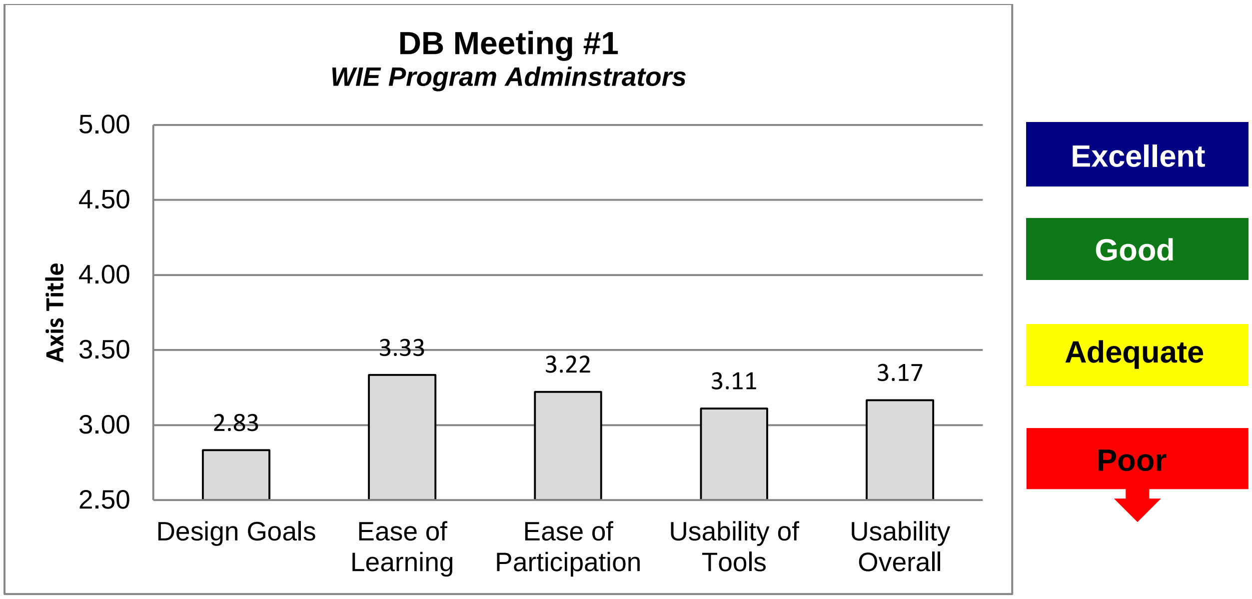


Figure 5-5: Usability Ratings for DB Meeting #1 – WIE Program Administrators

In terms of these lower ratings, the program administrators reported issues with the meeting for several reasons. To begin with, the WIE program's organization was characterized by a centralized decision-making model. The program director reported that

> *"One of the issues is that you requested individuals who are involved in the decision-making processes for WIE retention activities and for the WIE retention programs that is basically a one person decision maker – me. In addition, many student support programs like mine have very small staffs [in some cases it is just one]. Therefore, this would need to be adapted slightly. I really didn't see the value of the group in this situation as a result of the facilitation process."*

As a result, the program administrators did not feel equipped to comment on aspects of the program outside of their job responsibilities. One program administrator indicated that "*Retention isn't my area so I felt less useful as we discussed the current state."*

Another issue was that the need-based format framed the meeting from a discrepancy point of view. In other words, the meeting was approached from the perspective of identifying deficiencies in the program, and making recommendations based on areas where the needs of the students were not being met. This discrepancy-based perspective was described by program administrators as "*a daunting task*." Another program administrator stated that "*I felt drained after the meeting because it felt like we were not doing anything right.*"

The program director also reported that "*Some of the instructions while they seemed clear at the time they were given, when it came time to implement the activity, it wasn't clear what was really required.*" Furthermore, "*When I was completing the framework, it seems there were a few redundancies in the interpretation of the terms. Other terms were not very clear without relying on the example to consider*." As a result, the following design changes (Table 5-4) were made to improve the usability of the DB meeting based on the feedback from the program administrators.

5.2.6.2 DB Meeting #2 – MEP Administrators

The second DB meeting was held with 5 of the institutional decision makers from the MEP. As shown in Figure 5-6, the ratings for the usability dimensions ranged from 3.00 (Overall of Tools) to 4.25 (Ease of Learning). These results indicated that the design process and the outcome of the DSN were rated "Adequate" by the program administrators—with the exception of the Ease of the Learning and the Ease of Participation dimensions. These dimensions were rated "Good" by the program administrators.

Table 5-4: Design Changes to Improve DB Meeting #1 based on Recommendations

Attribute	Recommendations	Design Changes
Transforming the Process	• Transform the process from a discrepancy-based perspective to emphasizing positive	• Since the premise of this research incorporated needs into the improvement process, the discrepancy-based perspective could not be changed. However, holding a pre-meeting prior to the DB meeting with the program director to discuss the importance of a needs-based approach helped the decision makers understand the expectations more clearly.
Transforming the Process	• To have a better understanding of the purpose of the meeting	• Changed the "System Design" performance area, which focused on what actions should be taken to ensure that results are achieved, to the Results performance area. • By focusing on the "Results" performance area, the purpose of the meeting was centered on how the program met the needs of its students. • A color-coding scheme was used to evaluate current results. Program administrators used the following color scheme to determine how they were meeting the needs of their students: ▪ Blue – Excellent ▪ Green – Good ▪ Yellow – Adequate ▪ Red – Poor
Time	• Add more time to the meeting	Identify high-impact initiatives to limit the number of programs reviewed in this research during the pre-meeting

Once the modifications were implemented in Meeting #2, each of the usability dimensions showed an increase in ratings ranging from 0.46 (Usability Overall) to 1.04 (Design

Goals) between DB meetings #1 and #2. This suggested that the design changes recommended by program administrators during DB meeting #1 improved the outputs and the design process for each dimension in DB meeting #2.

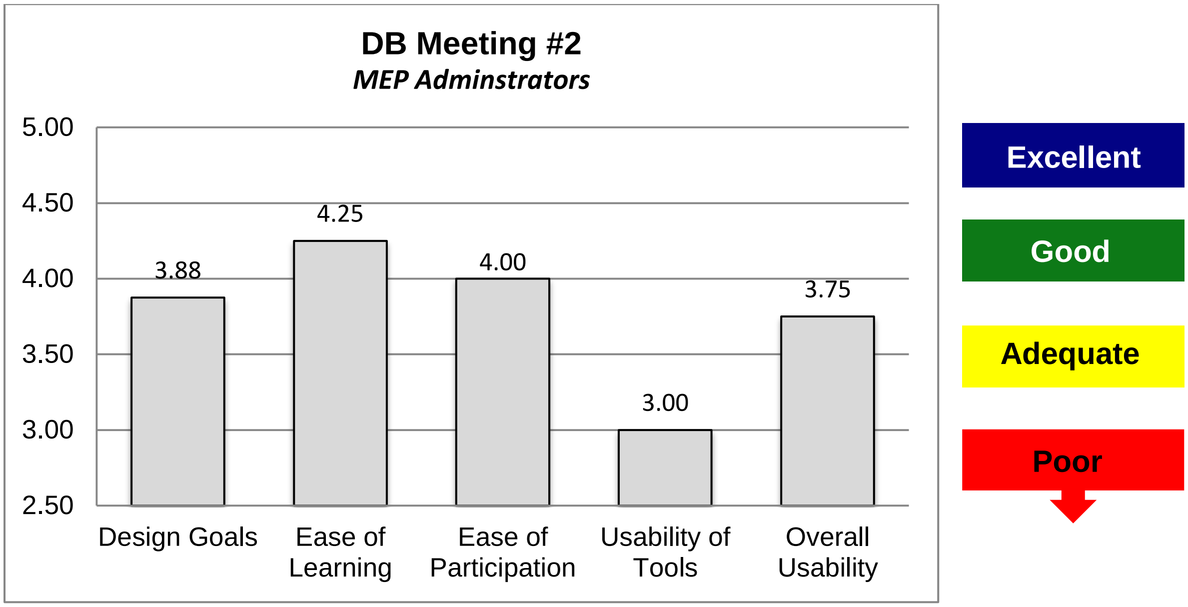


Figure 5-6: Usability Ratings for DB Meeting #1 – MEP

Overall, the program administrators reported that the meeting was effective in helping the decision makers consider areas to improve the program. One program administrator reported that "*The process was a good way to help evaluate our programs*."

With respect to drawbacks, the program administrators reported that problems were encountered with the usability of the tools. During the meeting, four Diagnose the Baseline worksheets were initially used to evaluate each student success practice. One program administrator commented that "*There was too much paperwork*." Additionally, a program administrator noted that the evaluation of the Results performance area provided subjective evaluations of the program's results. To address the problems encountered, the following design changes in Table 5-5 were made to improve the DB meeting

Table 5-5: Design Changes to Improve DB Meetings based on Recommendations

Attribute	Recommendations	Design Changes
Usability of Tools	• Reduce the amount of paperwork to complete the Diagnose the Baseline Tool	Consolidate the DB tool to fit on one page (which was updated and shown in Part E-Evaluate Results).
Time	• Add more time to the meeting	Addressed in Future Research
Objective Results	• The color coding scheme to address the results can use actual data to diagnose the results of the current state	Addressed in Future Research

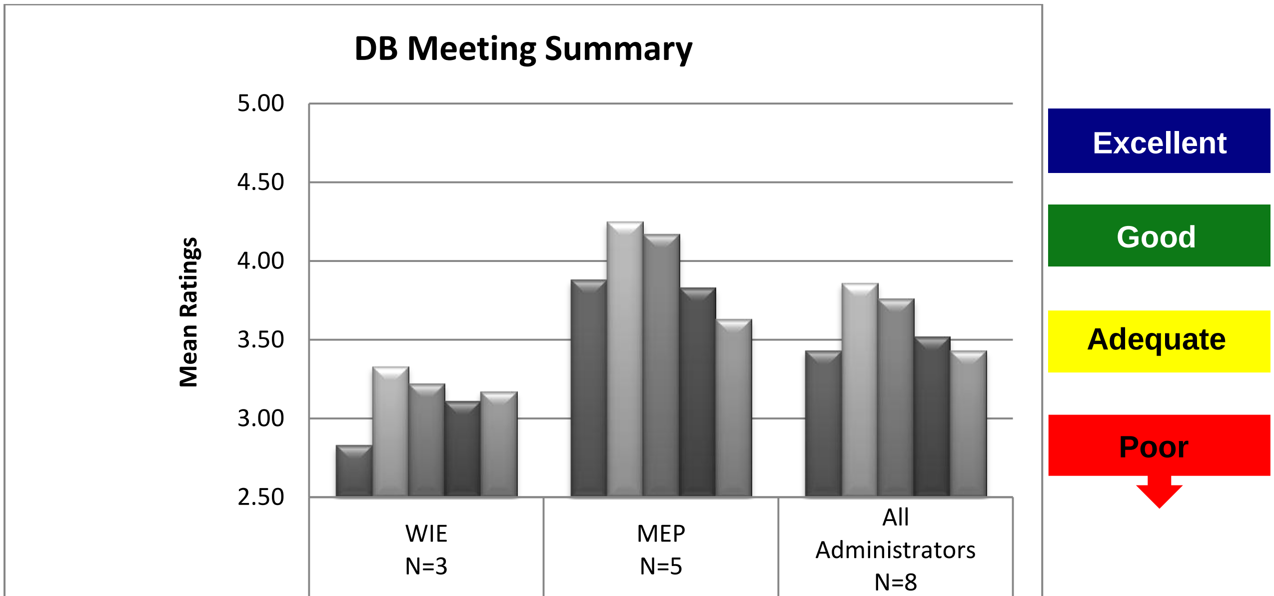
5.3 Summary of Phase I: Diagnose the Baseline

The DB method was used to (1) assess the MEP and WIE programs' current state, and (2) define how to satisfy the needs of their engineering students. Two meetings were conducted with five program administrators from the MEP and three program administrators from the WIE program. The DB method, which employed the S^2OPD meeting process, consisted of three elements to help decision makers systematically diagnose their program's baseline.

The first element of the DB method allowed the team to review the current state of their organization. Based on that diagnosis, the second element facilitated the identification of the strengths, weaknesses, and opportunities for the individual programs. In validating the diagnosis for the individual programs, the team was then able to collectively identify areas that were in need of improvement.

Overall, the DB meetings were shown to be moderately effective based on the institutional leaders' evaluations, which indicated that the design process and the output of the DB meetings were "Adequate." This assessment was verified by the ratings for each of the usability dimensions (Figure 5-7), which ranged from 3.43 (Design Goals and Usability Overall) to 3.86 (Ease of Learning) for all administrators.

Although the usability ratings were deemed "Adequate," the DB meetings were improved as a result of the formative evaluations. Each of the usability dimensions showed an increase in ratings ranging from 0.46 (Usability Overall) to 1.04 (Design Goals) between DB meetings #1 and #2. While the increases were substantial, future research areas were defined to improve the DB meetings, as discussed below.



	WIE N=3	MEP N=5	All Administrators N=8
Design Goals	2.83	3.88	3.43
Ease of Learning	3.33	4.25	3.86
Ease of Participation	3.22	4.17	3.76
Usability of Tools	3.11	3.83	3.52
Overall Usability	3.17	3.63	3.43

Figure 5-7: DB Meeting Summary

First, the updated Diagnose the Baseline Tool, which consolidated the information from the six performance areas, was merged into one worksheet. (Initially, the tool used three worksheets, which consisted of a current state matrix, a SWOT matrix, and a desired state matrix.) The researcher determined that the updated matrix had the potential to streamline the meeting and provide institutional leaders with a more concise understanding of the purpose of the meeting. Therefore, future research should be devoted to utilizing the consolidated matrix, and determining if the usability ratings for each dimension improved as a result of the implemented changes. Additionally, the DB meetings were limited in the amount of time that the institutional leaders had to devote to diagnosing the baseline of their current practices. Therefore, future research should be devoted to investigating the impact of adding additional time.

Furthermore, future research should be devoted to determining how to incorporate an analysis of actual data that has been collected to assess the results of current practices. Instead of subjectively assessing the Results performance area, actual data could be used to inform decision making in the Results performance area. Therefore, future research should be devoted to whether this change improves usability ratings.

In summary, strategic performance improvement areas were identified, which will be further assessed in Chapter 6. Furthermore, the DB meetings were shown to be reasonably effective based on the institutional leaders' evaluations. As a result, H2.1 was moderately supported, namely: *Phase I of the S^2OSD methodology can be used to assess and understand how to satisfy the engineering student success needs.*

CHAPTER 6 PHASE II: IDENTIFY NEEDS

While Phase I focused on identifying student needs from the institutional leaders perspective, Phase II of the S^2OSD methodology consisted of understanding needs from the students' perspective. Specifically, the purpose of Phase II was to capture the Voice of the Student, and translate it into an actionable set of critical needs that were not being met by the institution. In order to achieve this purpose, the Student Needs Identification Method (SNID) was developed to guide institutional leaders through the process of understanding, identifying, and prioritizing the true needs of their students.

The main study had to be completed to validate the conceptual model from the pilot study described in Chapter 4. Through an assessment of reliability and validity, a final model emerged that provided a statistically-verified research model for engineering student success needs, which was then used to test the hypotheses for this research. The results of the main study lead to a validated ESNQ that was used to conduct the SNID method. Based on this activity sequence, Chapter 6 is organized into the following sections to address Research Question 2.2:

- 6.1 – Reliability and Validity Assessment (Main Study)
- 6.2 – Research Model
- 6.3 – Phase II Research Sub-Questions and Hypotheses
- 6.4 – Student Needs Identification Method, Processes, and Tools
- 6.5 – Summary

RQ 2.2*: What are the needs of engineering students that facilitate student success?*

Broad Hypothesis 2.2: *Phase II of the S^2OSD methodology can be used to identify and prioritize the needs of engineering students.*

6.1 Reliability & Validity Assessment (Main Study)

Once the questionnaire was administered and responses were collected and tabulated, the main study was undertaken to examine the validity of the conceptual model that was developed as a result of the pilot study. EFA and Cronbach's Alpha coefficients were calculated to assess its reliability and validity.

6.1.1 Participants

The population from which study participants were drawn included all undergraduate engineering students at the applied research site. Although the S^2OSD methodology in its entirety was applied to URM and female engineering programs, a maximum variation (heterogeneity) sampling strategy was employed to capture and describe the central themes that cut across a great deal of variation (i.e., all student subgroups). In so doing, this approach provided decision makers with an understanding of the needs that are likely to be germane to all students, as well as highlighting the unique needs of these subgroups (Patton, 2002). Consequently, all engineering students were recruited to participate in the main study. Flyers were posted in the engineering buildings, emails were sent to engineering list serves, and student organizations were also solicited to participate in the survey.

Table 6-1 summarizes the demographic characteristics of the engineering students at the applied research site that participated in the main study. Approximately half of the respondents were female (49.3%) and half were male (50.7%). Most of the respondents were white (56.3%) and were not international students (i.e., they were U.S. born) (92.0%). Furthermore, the largest group of students (30.0%) reported that most of their grades were A's, while the next largest group (22.5%) reported that the majority of their grades were a C- or lower. Additionally, there was a distribution of students from the various class levels.

Table 6-1: Demographic Profile of Respondents (Main Study)

Demographic Variables	Frequency	Percent
Gender		
Female	105	49.3
Male	108	50.7
Ethnicity/race		
Asian	37	17.4
Black	39	18.3
Hispanic	7	3.3
Native American	1	0.5
White	120	56.3
Other	9	4.2
International Student		
Yes	17	8.0
No	196	92.0
Grades		
A	64	30.0
A-	28	13.1
B+	42	19.7
B	20	9.4
B-	7	3.3
C+	4	1.9
C- or lower	48	22.5
Class Level		
Freshman	41	19.2
Sophomore	43	20.2
Junior	66	31.0
Senior	63	29.6

6.1.2 Administration Procedures

The validated ESNQ (Appendix B) from the pilot study was administered using Qualtrics, which is an online survey tool (http://www.qualtrics.com/) that was used during the pilot study. An electronic invitation to participate in the survey was sent to the undergraduate engineering list servs. The invitation contained an electronic link that directed participants to the online questionnaire, which included a request for relevant demographic information. Additionally, a website (www.esnq.net) was developed to allow participants to access the questionnaire electronically. Finally, participants were asked to voluntarily submit their email addresses to be entered into a raffle for a single $25 gift card.

6.1.3 Exploratory Factor Analysis missing

Once the questionnaire (see Appendix B) was administered, the data was collected for the main study and downloaded into PAWS SPSS 18.0. The first test for construct validity was to perform an exploratory principal component factor analysis on the validated instrument from the pilot study. Initially, the data was examined to determine if factor analysis was a suitable method.

To do so, Pearson product moment correlations were performed for each item in the student success needs conceptual model. The purpose of the correlation analysis was to assess the strength of the relationships between items within each dimension. As argued by Tabachnick and Fidell (2007), the correlation matrix should be examined to reveal the presence of coefficients greater than 0.30.

The results of the correlation analysis for all of the items in the conceptual model are shown in Table 6-2. The highest value was between items #06_1 and #06_4, $r = .73$, $n = 22$, $p = .00$. These results indicate that there was a strong positive relationship between easing a student's financial burden and having financial assistance available to students. In fact, the results of the correlation analysis revealed that the items in the *Financial* needs dimension possessed the strongest relationships in comparison to all other dimensions.

Table 6-2: Main Study: Correlation Matrix (Items)

#	01_1	01_4	01_5	01_6	01_7	02_4	02_5	02_6	02_7	08_1	08_3	08_4	08_5	06_1	06_2	06_3	06_4	07_1	07_2	07_3	09_1	09_2	09_3	09_4	09_5	09_6	09_9	04_1	04_2	04_3	04_4	04_5	05_1	05_2	05_3	05_4
01_1	1	.284**	.249**	.258**	.266**	.211**	.179**	.122*	0.08	0.11	.206**	0.01	0	0.1	0.02	0.01	0.09	0.11	0.1	0.04	0.03	.154*	0.12	.163*	0.12	0.08	.204**	-0.02	0.07	.165*	.291**	.191**	.270**	.296**	.243**	.218**
01_4	.284**	1	.240**	.308**	.212**	0.11	0.08	0.1	.121*	0.1	0.11	-0.01	-0.01	0.04	0.02	0.08	0.07	0.03	0.04	0	-0.06	.147*	0.13	-0.03	0	-0.05	0.08	-0.02	0.07	.137*	.218**	.165*	.290**	.136*	.146*	.162*
01_5	.249**	.240**	1	.376**	.433**	.375**	.358**	.414**	.275**	.400**	.323**	.399**	.466**	.255**	.254**	.212**	.273**	.262**	.306**	.193**	0.03	.174*	.299**	.303**	.242**	.210**	.352**	.258**	.249**	0.08	.286**	.313**	.178**	.354**	.283**	.340**
01_6	.258**	.308**	.376**	1	.707**	.289**	.367**	.388**	.352**	.379**	.183**	.236**	.225**	.327**	.185**	.225**	.304**	.172*	.194**	.156*	0.03	.275**	.210**	.157*	.247**	.209**	.280**	.242**	.191**	0.03	.306**	.157*	.271**	.325**	.184**	.287**
01_7	.266**	.212**	.433**	.707**	1	.385**	.453**	.421**	.387**	.419**	.227**	.347**	.296**	.321**	.203**	.241**	.292**	.176**	.278**	.177**	-0.01	.343**	.269**	.270**	.340**	.221**	.348**	.162*	.282**	0.07	.422**	.264**	.350**	.403**	.305**	.427**
02_4	.211**	0.11	.375**	.289**	.385**	1	.666**	.532**	.329**	.487**	.318**	.410**	.477**	.259**	.278**	.250**	.241**	.377**	.345**	.232**	.176**	.273**	.174**	.200**	.265**	.327**	.365**	.209**	.259**	.231**	.253**	0.05	.160*	.140*	.256**	.345**
02_5	.179**	0.08	.358**	.367**	.453**	.666**	1	.624**	.444**	.523**	.319**	.470**	.458**	.353**	.277**	.296**	.287**	.377**	.481**	.264**	0.1	.492**	.331**	.311**	.374**	.333**	.378**	.397**	.349**	0.13	.209**	0.1	0.12	.270**	.291**	.304**
02_6	.122*	0.1	.414**	.388**	.421**	.532**	.624**	1	.477**	.567**	.253**	.437**	.484**	.308**	.226**	.243**	.304**	.384**	.474**	.328**	.150*	.338**	.298**	.377**	.382**	.373**	.376**	.361**	.323**	0.07	0.09	0.08	0.01	.165*	.226**	.189**
02_7	0.08	.121*	.275**	.352**	.387**	.329**	.444**	.477**	1	.419**	.132*	.311**	.356**	.293**	.168*	.218**	.264**	.225**	.354**	.213**	-.146*	.328**	.153*	.211**	.314**	.173*	.289**	.215**	.233**	-0.08	0.04	0.04	0.04	.210**	.196**	.248**
08_1	0.11	0.1	.400**	.379**	.419**	.487**	.523**	.567**	.419**	1	.416**	.585**	.430**	.345**	.296**	.342**	.365**	.470**	.502**	.316**	0.08	.406**	.329**	.305**	.381**	.300**	.382**	.264**	.313**	.186**	0.1	0.02	0.1	.227**	.292**	.388**
08_3	.206**	0.11	.323**	.183**	.227**	.318**	.319**	.253**	.132*	.416**	1	.430**	.445**	.279**	.291**	.293**	.279**	.382**	.384**	.320**	.210**	.305**	.264**	0.13	.190**	.215**	.236**	.217**	0.12	.340**	.228**	.233**	.269**	.321**	.299**	.320**
08_4	0.01	-0.01	.399**	.236**	.347**	.410**	.470**	.437**	.311**	.585**	.430**	1	.442**	.367**	.359**	.355**	.329**	.347**	.419**	.243**	0.1	.272**	.254**	.240**	.282**	.302**	.337**	.317**	.240**	-0.01	0.07	0.01	0.04	.204**	.266**	.330**
08_5	0	-0.01	.466**	.225**	.296**	.477**	.458**	.484**	.356**	.430**	.445**	.442**	1	.350**	.372**	.404**	.386**	.455**	.492**	.412**	.193**	.280**	.274**	.237**	.259**	.324**	.348**	.358**	.314**	.205**	.228**	.222**	.187**	.294**	.260**	.279**
06_1	0.1	0.04	.255**	.327**	.321**	.259**	.353**	.308**	.293**	.345**	.279**	.367**	.350**	1	.646**	.642**	.725**	.398**	.399**	.344**	0.05	.275**	.143*	.165*	.275**	.257**	.297**	.270**	.209**	0.04	0.13	-0.02	0.01	0.13	.187**	.272**
06_2	0.02	0.02	.254**	.185**	.203**	.278**	.277**	.226**	.168*	.296**	.291**	.359**	.372**	.646**	1	.686**	.563**	.383**	.353**	.337**	0.12	.317**	.217**	.228**	.220**	.280**	.332**	.310**	.215**	0.07	0.13	-0.02	0.12	0.12	.236**	.235**
06_3	0.01	0.08	.212**	.225**	.241**	.250**	.296**	.243**	.218**	.342**	.293**	.355**	.404**	.642**	.686**	1	.720**	.407**	.342**	.350**	.157*	.312**	.251**	.185**	.209**	.293**	.221**	.222**	.291**	0.1	.194**	0.07	.179**	0.13	.210**	.246**
06_4	0.09	0.07	.273**	.304**	.292**	.241**	.287**	.304**	.264**	.365**	.279**	.329**	.386**	.725**	.563**	.720**	1	.369**	.396**	.270**	0.13	.309**	.154*	.196**	.282**	.245**	.276**	.243**	.243**	0.1	.148*	0.07	.177**	.219**	.246**	.256**
07_1	0.11	0.03	.262**	.172*	.176**	.377**	.377**	.384**	.225**	.470**	.382**	.347**	.455**	.398**	.383**	.407**	.369**	1	.634**	.603**	.253**	.352**	.225**	.217**	.303**	.296**	.361**	.261**	.251**	0.12	0.12	0.03	.149*	.169*	.302**	.305**
07_2	0.1	0.04	.306**	.194**	.278**	.345**	.481**	.474**	.354**	.502**	.384**	.419**	.492**	.399**	.353**	.342**	.396**	.634**	1	.606**	0.08	.393**	.430**	.288**	.410**	.353**	.412**	.285**	.291**	0.1	0.04	0.01	0.04	.177**	.276**	.226**
07_3	0.04	0	.193**	.156*	.177**	.232**	.264**	.328**	.213**	.316**	.320**	.243**	.412**	.344**	.337**	.350**	.270**	.603**	.606**	1	0.13	.298**	.305**	.231**	.301**	.301**	.229**	.213**	.235**	.184**	0.13	0.05	0.11	.143*	.253**	.239**
09_1	0.03	-0.06	0.03	0.03	-0.01	.176**	0.1	.150*	-.146*	0.08	.210**	0.1	.193**	0.05	0.12	.157*	0.13	.253**	0.08	0.13	1	.221**	0.05	0.11	0.12	0.1	0.12	.148*	0.07	.273**	.174*	0.11	.202**	0.12	.221**	0.07
09_2	.154*	.147*	.174*	.275**	.343**	.273**	.492**	.338**	.328**	.406**	.305**	.272**	.280**	.275**	.317**	.312**	.309**	.352**	.393**	.298**	.221**	1	.448**	.327**	.416**	.279**	.335**	.179**	.206**	.175*	.243**	.177**	.295**	.331**	.480**	.351**
09_3	0.12	0.13	.299**	.210**	.269**	.174**	.331**	.298**	.153*	.329**	.264**	.254**	.274**	.143*	.217**	.251**	.154*	.225**	.430**	.305**	0.05	.448**	1	.400**	.387**	.310**	.307**	0.12	.291**	.148*	.187**	.222**	.229**	.227**	.328**	.170*
09_4	.163*	-0.03	.303**	.157*	.270**	.200**	.311**	.377**	.211**	.305**	0.13	.240**	.237**	.165*	.228**	.185**	.196**	.217**	.288**	.231**	0.11	.327**	.400**	1	.549**	.280**	.410**	.268**	.403**	0.06	.170*	.161*	0.06	0.1	.364**	.239**
09_5	0.12	0	.242**	.247**	.340**	.265**	.374**	.382**	.314**	.381**	.190**	.282**	.259**	.275**	.220**	.209**	.282**	.303**	.410**	.301**	0.12	.416**	.387**	.549**	1	.433**	.521**	.372**	.420**	-0.07	0.06	0.05	0.04	0.11	.279**	.277**
09_6	0.08	-0.05	.210**	.209**	.221**	.327**	.333**	.373**	.173*	.300**	.215**	.302**	.324**	.257**	.280**	.293**	.245**	.296**	.353**	.301**	0.1	.279**	.310**	.280**	.433**	1	.500**	.275**	.360**	0.13	0.13	0.13	0.11	0.11	.198**	.197**
09_9	.204**	0.08	.352**	.280**	.348**	.365**	.378**	.376**	.289**	.382**	.236**	.337**	.348**	.297**	.332**	.221**	.276**	.361**	.412**	.229**	0.12	.335**	.307**	.410**	.521**	.500**	1	.402**	.364**	0.01	.151*	-0.04	0.09	.210**	.313**	.368**
04_1	-0.02	-0.02	.258**	.242**	.162*	.209**	.397**	.361**	.215**	.264**	.217**	.317**	.358**	.270**	.310**	.222**	.243**	.261**	.285**	.213**	.148*	.179**	0.12	.268**	.372**	.275**	.402**	1	.432**	0.01	0.08	0.03	-0.04	.152*	.143*	0.13
04_2	0.07	0.07	.249**	.191**	.282**	.259**	.349**	.323**	.233**	.313**	0.12	.240**	.314**	.209**	.215**	.291**	.243**	.251**	.291**	.235**	0.07	.206**	.291**	.403**	.420**	.360**	.364**	.432**	1	0.11	.192**	0.08	0.11	0.03	.147*	.154*
04_3	.165*	.137*	0.08	0.03	0.07	.231**	0.13	0.07	-0.08	.186**	.340**	-0.01	.205**	0.04	0.07	0.1	0.1	0.12	0.1	.184**	.273**	.175*	.148*	0.06	-0.07	0.13	0.01	0.01	0.11	1	.379**	.309**	.386**	.198**	.342**	.153*
04_4	.291**	.218**	.286**	.306**	.422**	.253**	.209**	0.09	0.04	0.1	.228**	0.07	.228**	0.13	0.13	.194**	.148*	0.12	0.04	0.13	.174*	.243**	.187**	.170*	0.06	0.13	.151*	0.08	.192**	.379**	1	.567**	.608**	.439**	.353**	.409**
04_5	.191**	.165*	.313**	.157*	.264**	0.05	0.1	0.08	0.04	0.02	.233**	0.01	.222**	-0.02	-0.02	0.07	0.07	0.03	0.01	0.05	0.11	.177**	.222**	.161*	0.05	0.13	-0.04	0.03	0.08	.309**	.567**	1	.513**	.435**	.300**	.239**
05_1	.270**	.290**	.178**	.271**	.350**	.160*	0.12	0.01	0.04	0.1	.269**	0.04	.187**	0.01	0.12	.179**	.177**	.149*	0.04	0.11	.202**	.295**	.229**	0.06	0.04	0.11	0.09	-0.04	0.11	.386**	.608**	.513**	1	.569**	.507**	.377**
05_2	.296**	.136*	.354**	.325**	.403**	.140*	.270**	.165*	.210**	.227**	.321**	.204**	.294**	0.13	0.12	0.13	.219**	.169*	.177**	.143*	0.12	.331**	.227**	0.1	0.11	0.11	.210**	.152*	0.03	.198**	.439**	.435**	.569**	1	.538**	.585**
05_3	.243**	.146*	.283**	.184**	.305**	.256**	.291**	.226**	.196**	.292**	.299**	.266**	.260**	.187**	.236**	.210**	.246**	.302**	.276**	.253**	.221**	.480**	.328**	.364**	.279**	.198**	.313**	.143*	.147*	.342**	.353**	.300**	.507**	.538**	1	.564**
05_4	.218**	.162*	.340**	.287**	.427**	.345**	.304**	.189**	.248**	.388**	.320**	.330**	.279**	.272**	.235**	.246**	.256**	.305**	.226**	.239**	0.07	.351**	.170*	.239**	.277**	.197**	.368**	0.13	.154*	.153*	.409**	.239**	.377**	.585**	.564**	1

* Correlation is significant at the 0.05 level (2-tailed)

** Correlation is significant at the 0.01 level (2-tailed)

In contrast, the *Resource* needs dimension had the weakest relationships, in which the lowest value was between item # 04_2 and #04_4, r= .19, n =213, p < .005. This suggested that there is a weak relationship between students getting help with academic planning (e.g., degree requirements, course scheduling, etc.) and getting help with mastering course concepts. As Cohen (1988) suggested, correlations of 0.5 is large, 0.3 is moderate, and 0.1 is small. While the lowest values were small, they are not trivial and were retained for factor analysis.

Using Cohen's (1988) thresholds, the correlation analysis also indicated that items within the dimension of *Student Interaction* needs have strong relationships; and the *Faculty Interaction, Sense of Community,* and *Workload Management* needs indicated strong to moderate relationships. However, some items in the *Classroom Learning*, *Skill*, and *Resource* needs dimensions are problematic, and will be considered for deletion as a part of the factor analysis.

Once the strength of the relationship among the items was determined, then the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy and the Bartlett's test of sphericity was also needed to determine the suitability of factor analysis. The KMO value of 0.87 exceeds the recommended value of .6 (Kaiser, 1970), and Bartlett's test of sphericity was significant, $\chi2$ (630) = 3779, p < .001 (Bartlett, 1954). Based on the results of the correlation analysis, KMO measure, and Bartlett's test of sphericity, the ESNQ was considered suitable for factor analysis.

As a result, a principal component analysis was conducted using varimax rotation. The scree plot was used in order to determine the number of components to retain for analysis. As shown in Figure 6-1, the point of inflection (i.e., the elbow) on the scree plot suggested the presence of 3 principal components. Based on the proportion of the total variance, these factors only accounted for 31% of the variance, which is too limited. Therefore, the eigenvalue greater than 1 rule was used to determine the number of components. Nine components had an eigenvalue greater than 1. However, the 7th, 8th, and 9th component account for less than 5% of the variance respectively (Hair et al., 1998). As a result, a six component model solution was retained for rotation.

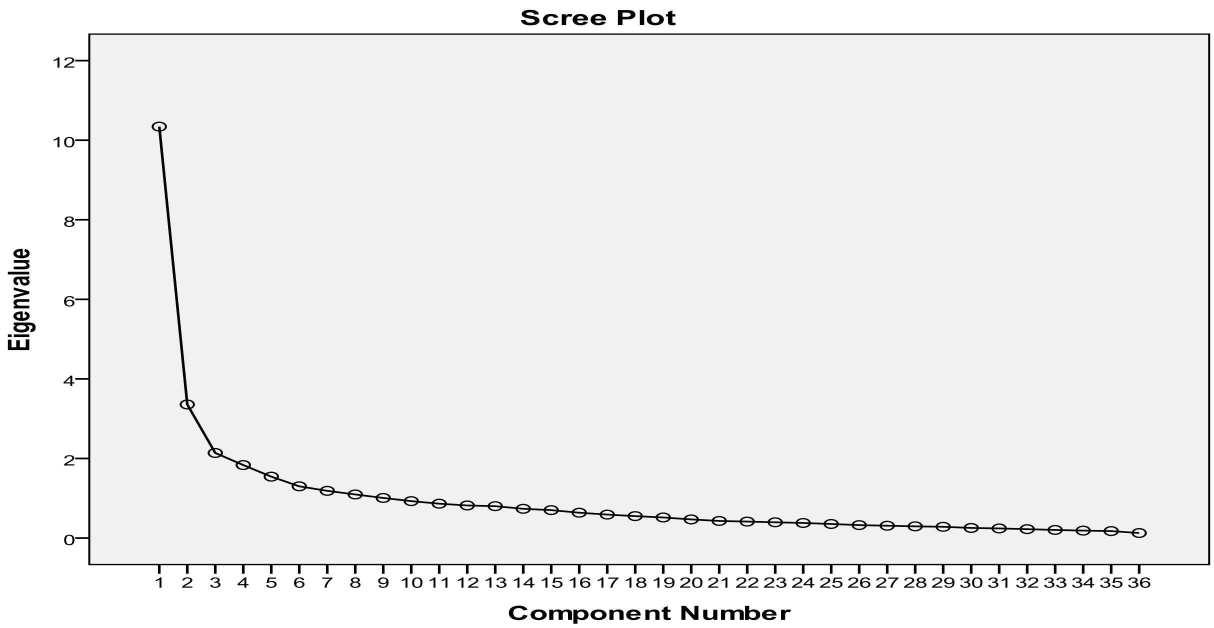


Figure 6-1: Main Study – Scree Plot

Table 6-3 shows the factor loadings, eigenvalues, % variance explained, and the cumulative variance explained by the principal components analysis for the rotated factor solution. As illustrated, five components initially best represented the data in terms of variance explained (51%). The dimensions of *Resources* and *Professional Development* needs were deleted from the analysis. Furthermore, *Faculty Interaction/Sense of Community* needs were divided into two separate dimensions, as well as *Classroom Learning/Workload Management* needs. Conceptually, these dimensions represented unique aspects of student success. Moreover, these dimensions loaded on separate components in the pilot study. As a result, the revised dimensions for the ESNQ are shown in Table 6-3.

Table 6-3: Results of Factor Analysis from the Main Study

Main Questionnaire	#	1	2	3	4	5	6
Classroom Learning (4 items)	01_1	0.09	**0.51**	0.07	-0.06	0.07	-0.04
	01_4	0.10	**0.49**	-0.09	0.03	-0.05	-0.12
	01_5	0.51	0.38	0.20	0.13	-0.02	0.04
	01_6	0.41	**0.53**	0.16	0.22	-0.14	-0.24
	01_7	0.43	**0.61**	0.24	0.17	-0.05	-0.19
Faculty Interaction (4 itmes)	02_1	**0.72**	0.15	0.12	0.07	0.07	0.19
	02_4	**0.70**	0.17	0.29	0.09	0.16	0.03
	02_5	**0.73**	0.06	0.33	0.06	0.12	-0.02
	02_6	**0.52**	0.20	0.15	0.12	0.16	-0.38
Sense of Community (4 items)	08_1	**0.66**	0.13	0.17	0.17	0.34	-0.04
	08_3	**0.40**	0.20	-0.05	0.19	0.35	0.37
	08_4	**0.60**	0.03	0.13	0.25	0.22	0.01
	08_5	**0.59**	0.06	0.17	0.28	0.17	0.34
Student Interactions (3 items)	07_1	0.38	-0.04	0.12	0.32	**0.55**	0.20
	07_2	0.45	-0.05	0.24	0.24	**0.59**	0.01
	07_3	0.24	-0.05	0.16	0.27	**0.57**	0.17
Financial (4 items)	06_1	0.25	0.08	0.11	**0.81**	0.13	-0.10
	06_2	0.14	0.02	0.18	**0.78**	0.17	0.08
	06_3	0.14	0.08	0.14	**0.84**	0.14	0.12
	06_4	0.18	0.15	0.13	**0.81**	0.12	0.01
Skill (4 items)	09_1	0.05	-0.03	0.13	0.07	0.11	0.60
	09_2	0.16	0.33	0.31	0.15	0.52	0.01
	09_3	0.09	0.23	0.46	0.02	0.42	0.05
	09_4	0.08	0.13	**0.72**	0.02	0.21	0.00
	09_5	0.18	0.07	**0.73**	0.09	0.29	-0.15
	09_6	0.24	0.01	**0.55**	0.17	0.13	0.16
	09_9	0.30	0.13	**0.59**	0.15	0.21	-0.07
Resource (4 items)	04_1	0.36	-0.08	0.50	0.22	-0.11	0.14
	04_2	0.24	0.03	0.66	0.17	-0.11	0.14
	04_3	0.09	0.26	-0.05	-0.01	0.12	0.67
	04_4	0.04	0.68	0.13	0.11	-0.11	0.42
	04_5	-0.03	0.59	0.11	-0.05	-0.07	0.43
Workload Management (4 items)	05_1	-0.08	**0.73**	0.00	0.08	0.13	0.38
	05_2	0.12	**0.70**	-0.01	0.05	0.26	0.13
	05_3	0.04	**0.53**	0.21	0.07	0.51	0.20
	05_4	0.19	**0.56**	0.09	0.15	0.36	0.01
Total		4.76	4.18	3.42	3.41	2.65	2.10
% Variance		13.21	11.61	9.50	9.49	7.36	5.83
Cumulative %		13.21	24.82	34.31	43.80	51.16	56.98

Additionally, the three dimensions (i.e., *Classroom Learning, Resource, and Skill* needs) that were problematic in the correlation analysis were also problematic in the factor analysis. As a result, a number of items were eliminated, which were grayed out in Table 6-3. *Classroom Learning* need (#01-5) and Skill needs (# 09-1, 09-2, 09-3) were deleted because these items failed to meet the minimum criteria of having a primary factor loading of 0.4 or higher. Furthermore, the *Resource* needs dimension, which was also problematic in the pilot study, was deleted from the final ESNQ. Further consideration of these items could attribute the problems with the *Resource* needs dimension to the fact that these items could be considered solutions rather than needs. As a result, these solutions appear to cut across a number of dimensions, and did not load cleaning on a single dimension.

6.1.4 Reliability Analysis

The second test of construct validity was to ensure that the instrument demonstrated empirical estimates of reliability. To address this need, Cronbach's Alpha coefficient was used to assess the reliability of the revised dimensions of student success needs. Following convention, a Cronbach Alpha coefficient of 0.7 or greater was the threshold for an internally-consistent, reliable dimension (Nunnally, 1978). If the dimension did not meet the threshold, the effect of removing each item in the dimension was investigated using the "if item deleted method." Table 6-4 depicts the results of the reliability assessment. Six of the alpha coefficients were above the 0.7 threshold, ranging from 0.76 to 0.89. However, the *Classroom Learning* needs dimension was slightly below the threshold ($\alpha = 0.62$).

Table 6-4: Cronbach Alpha coefficient values for each Dimension

Dimensions of Student Success Needs	# of items	α
Classroom Learning	4	0.62
Faculty Interaction	4	0.81
Sense of Community	4	0.77
Student Interaction	3	0.82
Financial	4	0.89
Skill	4	0.76
Workload Management	4	0.81

The "if item deleted method" was examined for this dimension; however, the largest increase resulted from deleting item #01-4 (α=0.69), which still did not meet the threshold. Therefore, none of the four items were deleted from this dimension. While this is less than the desired threshold, Devillis (2003) suggested that 0.6 is still acceptable for newly-developed scales. As a result, the four items were retained in this analysis for the *Classroom Learning* needs dimension. Furthermore, the results in Table 6-4 indicate that the dimensions of student success needs for the ESNQ are reliable and demonstrate an acceptable degree of internal consistency.

6.2 Research Model

Based on these results, evidence of construct validity was demonstrated for the reliability and validity assessment. This indicated that the final ESNQ (Appendix B) measured what it was intended to measure. Furthermore, this assessment provided a statistically verified research model of engineering student success needs (Figure 6-2).

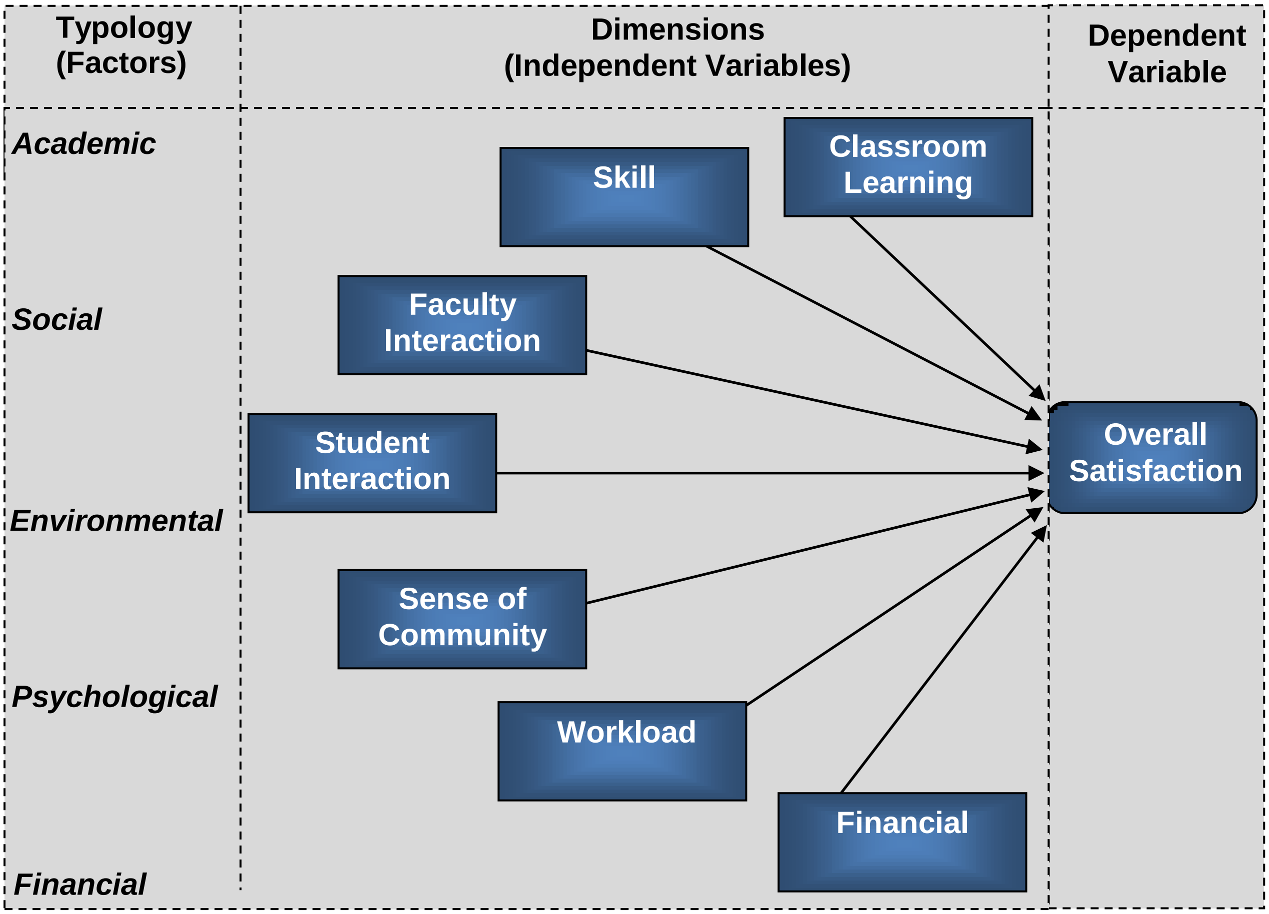


Figure 6-2: Research Model: Engineering Student Success Needs

This model served as the foundation for the S^2OSD methodology, and was subsequently used to test the hypothesized relationships between the independent and dependent variables. The basic premise of the model is that there are academic, psychological, environmental, financial, and social factors that impact student success. Based on these factors, the seven dimensions of student success needs—the dependent variables— have been refined as a result of the main study. The *Professional Development* need dimension from the conceptual research model has been deleted, and the *Student Interaction* need has been added to the research model in Figure 6-2. Overall satisfaction, which is the independent variable, was used to measure student success. The independent variable and the seven dependent variables for the research model are defined below:

- **Classroom Learning needs**: This variable describes the extent to which students are satisfied with the institution's efforts in providing a classroom experience that enhances their ability to acquire knowledge in their field of study.
- **Skill needs**. This variable describes the extent to which students are satisfied with the institution in developing requisite engineering and professional skills.
- **Faculty Interaction needs**: This variable describes the extent to which students are satisfied with the institution in providing opportunities to have quality interactions with faculty members.
- **Student Interaction needs**: This variable describes the extent to which students are satisfied with the institution in providing opportunities to have quality interactions with other students.
- **Sense of Community needs**: This variable describes the extent to which students are satisfied with the institution's efforts to create a welcoming environment, such that students experience a sense of belonging with the engineering community on campus.
- **Workload Management needs**: This variable describes the extent to which students are satisfied with the institution in helping them to cope with the demands of their engineering major.
- **Financial needs**: This variable describes the extent to which students are satisfied with the institution in providing available and accessible financial assistance.
- **Overall Satisfaction**: This variable describes the extent to which students are satisfied with their overall college experience.

6.3 Phase II Research Sub – Questions and Sub – Hypotheses

Based on the research model in Figure 6-2, additional sub-questions and hypotheses were investigated to assess the needs of engineering students in Table 6-5. Four separate statistical techniques were performed to test the research hypotheses. For research question 2.2_a, Pearson correlations were performed to assess the relationship between the dependent and independent variables. This provided an indication of the relationship within each dimension, as well as the relationship between each of the dimensions of student success needs. For research question 2.2_b, a hierarchical multiple regression analyses was performed to examine the relationships between the independent and dependent variables. Both of these analyses were performed to examine the empirical estimates of nomological validity.

While the first two research sub-questions examined the relationships between model variables for the entire sample, the remaining research sub-questions examined the URM and female engineering student sample. Even though a number of statistical techniques could have been used to identify the needs of the female and URM students, the statistical techniques the researcher eventually employed were intended to demonstrate the applicability of Phase II. As a result, Research Questions $2.2_{c,\ d,\ \&\ e}$ explored mean differences using a two-way Analysis of Variance (ANOVA) to highlight the unique needs of female students with respect to their peers. Three hypotheses were tested to address these research questions. For the WIE program's SNID method, a two-way ANOVA was used to examine the main effect of gender ($H2.1_c$), the main effect of race ($H2.1_d$), and the interactive effects between gender and ethnicity/race ($H2.1_{e1}$).

Table 6-5: Phase II – Research Sub-Questions and Hypotheses

<table>
<tr><td colspan="4">RQ 2.2: What are the needs of engineering students that facilitate student success?

Broad Hypothesis 2.2: Phase II of the S^2OSD methodology can be used to identify and prioritize the needs of engineering students.</td></tr>
<tr><th>Research Sub – Questions</th><th>Sub-Hypotheses</th><th>Data Analysis</th><th>Document Section</th></tr>
<tr><td>RQ 2.2_a: What is the relationship between the dimensions of student success needs?</td><td>H 2.2_a: There is a significant positive relationship between the dimensions of student success needs.</td><td>Pearson Correlation</td><td>6.3</td></tr>
<tr><td>RQ 2.2_b: What is the relationship between the dimensions of student success needs and overall satisfaction?</td><td>H 2.2_b: There is a significant negative relationship between the dimensions of student success needs and overall satisfaction.</td><td>Hierarchical Linear Regression</td><td>6.3</td></tr>
<tr><td>RQ 2.2_c: How do the dimensions of student success needs differ by gender?</td><td>H 2.2_c: There is a main effect of gender on the dimensions of student success needs.</td><td rowspan="3">Two-way ANOVA, Descriptive Statistics</td><td>6.4.1 WIE Program SNID Method</td></tr>
<tr><td>RQ 2.2_d: How do the dimensions of student success needs differ by gender and ethnicity/race?</td><td>H 2.2_d: There is an interaction effect between gender and ethnicity/race for the dimensions of student success needs.</td><td>6.4.1 WIE Program SNID Method</td></tr>
<tr><td rowspan="2">RQ 2.2_e: How do the dimensions of student success needs differ by ethnicity/race?</td><td>H 2.2_{e1}: There is a main effect of ethnicity/race on the dimensions of student success needs.</td><td>6.4.1 WIE Program SNID Method</td></tr>
<tr><td>H 2.2_{e2}: There is a significant difference for the dimensions of student success needs between minority and non-minority students.</td><td>One-way ANOVA, Descriptive Statistics</td><td>6.4.2 MEP SNID Method</td></tr>
<tr><td>RQ 2.2_f: How do the dimensions of student success needs differ between class level for URM students?</td><td>H 2.2_f: There is a significant difference for the dimensions of student success needs by class level.</td><td>One-way ANOVA, Descriptive Statistics</td><td>6.4.2 MEP SNID Method</td></tr>
</table>

For the URM students, the differences among minority/non-minority sub-groups were further investigated (Research Question 2.2_e) using a one-way ANOVA. Finally, research Question 2.2_f used a one-way ANOVA to investigate differences in dimensions of student success needs by class level. Hypotheses $2.2_{b\text{-}f}$ each purported that significant differences exist, which supports a fundamental premise of this dissertation—namely, that the needs of students are different and should not be considered homogeneous.

6.3.1 Hypotheses Testing and Model Refinement

The third and final assessment of construct validity consisted of examining the theoretical relationships and empirical estimates of nomological validity. Research Questions 2.2a (*What is the relationship between the dimensions of student success needs?)* and 2.2b (*What is the relationship between the dimensions of student success needs and overall satisfaction?*) were intended to further refine the research model.

Research Question #2.2a

Pearson correlations were performed for each dimension in the student success needs research model. The purpose of the correlation analysis was to assess the strength of the relationships between the independent (i.e., Overall Satisfaction) and dependent variables (i.e., Unmet Needs Scores for the dimensions of student success needs). The results of the correlation analysis as well as descriptive statistics for each variable are shown in Table 6-6.

Based on a significance level of 0.01, significant correlations were found for all of the dependent variables. However, the relationships between the dependent and independent variables were mixed. Moderate significant correlations were found between overall satisfaction and the dimensions for *Classroom Learning* (r= -.39, n=213, p = .00) and *Workload Management* (r= -.34, n= 213, p= .00) needs. Small significant correlations were found between *Overall Satisfaction* and the following needs dimensions: *Faculty Interaction* (r= -.21, n= 213, p= .00), *Sense of Community* (r= -.23, n= 213, p=.001), and *Skill* (r= -.25, n= 213, p= .00). However, there were no statistically significant correlations between *Overall Satisfaction* and the dimensions of *Student Interaction* (r= -.10, n= 212, p= .15) and *Financial*(r= -.12, n= 212, p= .09) Needs.

Table 6-6: Pearson Correlation Matrix for the ESNQ's Dimensions

	CL	FI	SC	SI	F	S	WM	OS
Classroom Learning	1	**.46****	**.36****	**.21****	**.27****	**.33****	**.47****	**-.39****
Faculty Interaction	**.46****	1	**.62****	**.49****	**.39****	**.52****	**.32****	**-.21****
Sense of Community	**.36****	**.62****	1	**.58****	**.51****	**.51****	**.42****	**-.23****
Student Interaction	**.21****	**.49****	**.58****	1	**.48****	**.50****	**.30****	-.10
Financial	**.27****	**.39****	**.51****	**.48****	1	**.38****	**.27****	-.12
Skill	**.33****	**.52****	**.51****	**.50****	**.38****	1	**.36****	**-.25****
Workload Management	**.47****	**.32****	**.42****	**.30****	**.27****	**.36****	1	**-.34****
N	265	265	265	223	223	218	214	213
Mean	1.43	0.66	0.36	-0.12	0.33	0.54	1.19	6.18
Std. Deviation	0.94	1.37	1.36	1.39	1.82	1.05	1.40	1.95

***p< 0.01*

Greater unmet need scores suggest that the institution was not meeting the needs of students. Based on this premise, it was expected that overall satisfaction would decrease as the unmet need scores increased. The correlation analysis also supports the notion that there is an inverse relationship between the dependent and independent variables, which is illustrated by the negative correlations with overall satisfaction. In other words, increases in unmet need scores would correspond to decreases in overall satisfaction, and vice versa.

Research Question #2.2b

A hierarchical multiple regression analysis was used to understand how the dimensions of student success needs impact the students' overall satisfaction with their college experience. Before the analysis was conducted, a number of assumptions were tested to ensure that there were no errors in the model specification. First, multicollinearity—which occurs when the variables in a regression model are highly correlated—was assessed. An inspection of the correlation matrix (Table 6-6) revealed that no two variables were highly correlated. Second, the collinearity of the independent variables was measured by the tolerance and variance inflation factor (VIF), which is the inverse of the tolerance. These measures were calculated in Table 6-6 to determine the extent to which the variability of a given independent variable could not be explained by the other independent variables in the model.

Table 6-7: Tolerance and VIF values for Independent Variables

Dimensions of Student Success Needs	Tolerance	VIF
Classroom Learning	0.66	1.52
Faculty Interaction	0.50	2.01
Sense of Community	0.45	2.25
Student Interaction	0.56	1.79
Financial	0.68	1.48
Skill	0.61	1.64
Workload	0.68	1.46

Following convention, a commonly used cut-off point for determining the presence of multicollinearity is a VIF value greater than 10 (Meyer, 1990) and a tolerance below .2 (Mennard, 1995). Next outliers, normality, linearity, and homoscedasticity assumptions were explored to ensure that there were no errors in the model specification. The residual scatterplots, outliers, and statistics were used, which confirmed that these assumptions were not violated (Tabachnick & Fidell, 2007). Therefore, a hierarchical multiple regression analysis was then used to test the hypothesized relationships in the research model, while controlling for background variables.

Table 6-8: Results of the Multiple Regression Analysis

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	SE	Beta	T	*P*
1	(Constant)	5.87	1.25		4.70	0.00
	Gender	0.07	0.27	0.02	0.27	0.79
	Ethnicity/Race	0.13	0.14	0.06	0.89	0.37
	Grades	-0.07	0.05	-0.09	-1.27	0.20
	Class Level	-0.03	0.12	-0.02	-0.27	0.79
	International	0.04	0.51	0.01	0.07	0.95
2	(Constant)	7.32	1.18		6.19	0.00
	Gender	-0.10	0.26	-0.03	-0.39	0.70
	Ethnicity/Race	0.19	0.13	0.09	1.41	0.16
	Grades	-0.01	0.05	-0.02	-0.27	0.79
	Class Level	0.04	0.12	0.02	0.34	0.74
	International	-0.28	0.49	-0.04	-0.58	0.57
	Classroom Learning	**-0.67**	**0.21**	**-0.27**	**-3.25**	**0.00****
	Workload Management	**-0.26**	**0.11**	**-0.19**	**-2.38**	**0.02***
	Faculty Interaction	0.03	0.13	0.02	0.22	0.82
	Sense of Community	-0.10	0.14	-0.07	-0.75	0.45
	Student Interaction	0.10	0.12	0.08	0.88	0.38
	Financial	0.04	0.09	0.03	0.41	0.68
	Skill	-0.20	0.14	-0.11	-1.41	0.16

*$p < 0.05$, **$p < 0.001$

First, the set of background variables (Gender, Ethnicity, Race, Grades, Class Level, and International Student Status) were entered into block 1 in order to statistically control for these variables. Then the dimensions of student success needs, the independent variables, were entered into block 2 to determine the relationship between the dimensions of student success needs and overall satisfaction after the potential confounding relationships were removed from block 1(Cohen, 2003). The results of the hierarchical regression model are summarized in Table 6-8.

The background variables were entered into block 1, which explained only 1.4% of the variance in overall satisfaction. The dimensions of student success needs were then entered into block 2, which explained 20.2% of the variance. As result, the model as a whole accounted for 21.6% of the variance in Overall Satisfaction, $F(12, 199) = 4.19, p = .00$. However, there were only two significant predictors of Overall Satisfaction, in which the beta weights were used to determine the relative weights of the dimensions in the regression model. In order of importance, the needs dimensions of *Classroom Learning* (beta = -.27, $p < .001$) and *Workload Management* (beta = -.19, $p < .05$) were significant predictors of overall satisfaction. However, no other dimensions had a statistically significant contribution to the model at $p < .05$. Figure 6-3 summarizes the results of the hierarchical multiple regression analysis.

Based on these results, $H2.2_b$ was partially supported. There was a negative relationship between the dimensions of *Classroom Learning* and *Workload Management* needs with Overall Satisfaction. However, the needs dimensions of *Faculty Interaction, Sense of Community, Student Interaction*, *Financial,* and *Skill* needs did not demonstrate a statistically significant relationship with Overall Satisfaction. While these dimensions were not statistically significant, they were still considered meaningful to student success research. Since this analysis only considered one aspect of student success, future research could explore the relationship between the seven dimensions of student success needs and additional measures of student success (e.g., GPA, retention rate, graduation rate). As a result of this limitation, all seven dimensions were retained for applications of SNID method.

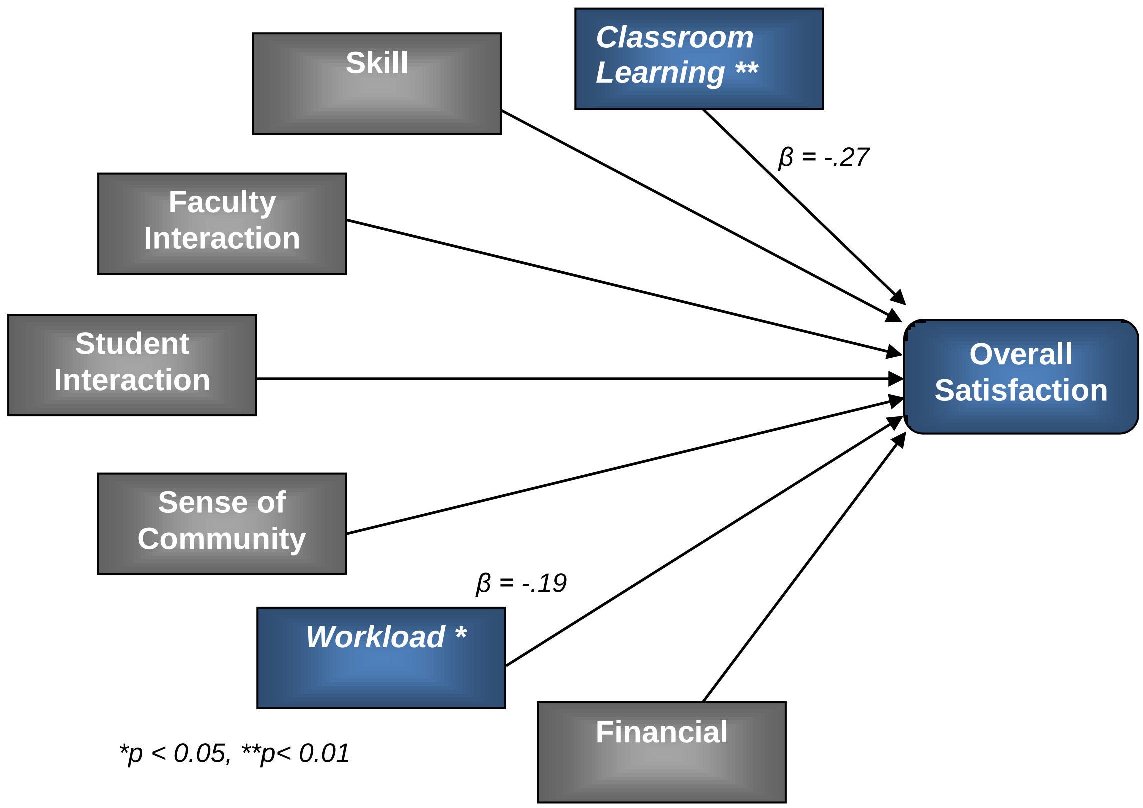


Figure 6-3: Multiple Regression Model of Overall Satisfaction with the Dimensions

6.4 Student Needs Identification Method, Process, and Tools

In an effort to identify the needs of engineering students, the customer needs identification method advocated by Urlich and Eppinger (2008) was adapted for the development of the SNID method. Despite the fact that identifying customer needs is germane to most engineering design efforts, Quinn et al., (2009) noted that any technique used in industry has been met with reluctance in higher education—especially since this particular method was designed for product development. Therefore, researchers have emphasized the importance of adapting industry approaches to fit within the context of higher education.

Ulrich and Eppinger (2008) defined the following five-step process to help overcome the complexities associated with understanding the real needs of customers: 1) gather raw data, 2) interpret the data in terms of needs, 3) organize the needs into a hierarchy, 4) establish the relative importance of the needs, and 5) reflect on the results of the process. Keeping these steps in mind, the researcher tailored the SNID method to guide institutional leaders through the process of gathering, organizing, assessing, and establishing the relative importance of results in order to identify the specific needs of engineering students. As a result, this section describes the development of the SNID method and its application to the MEP and WIE program. Figure 6-3 describes the process and tools that were developed to implement the SNID, which as noted was adapted from Ulrich and Eppinger's (2008) Customer Needs Identification method (denoted within the dotted line box).

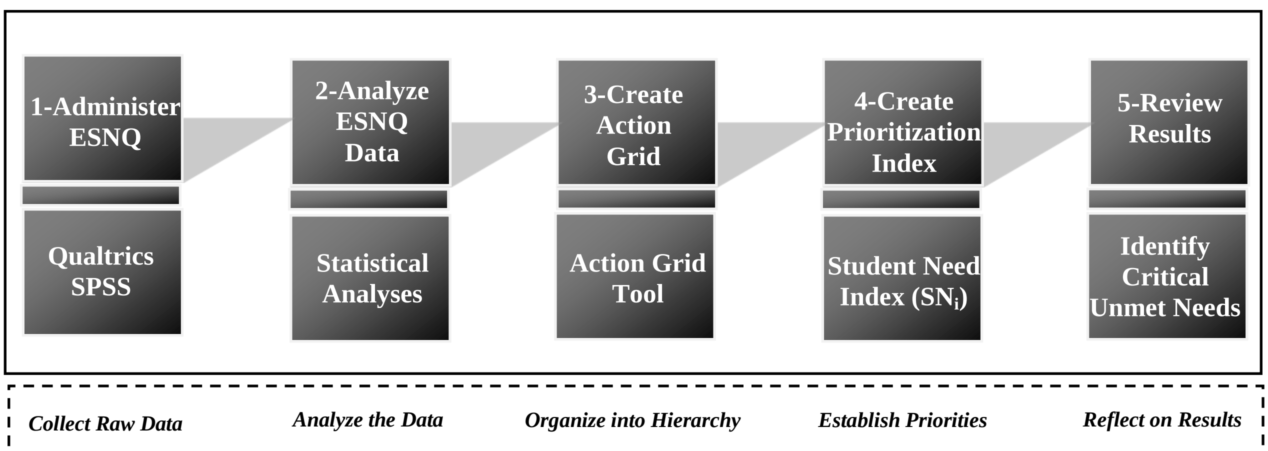


Figure 6-3: Student Needs Identification Method, Process, and Tools

6.4.1 WIE Program Student Needs Identification Method

The five-step process in Figure 6-3 was undertaken to identify the needs of female engineering students at the applied research site. While a number of research questions and statistical approaches could have been employed, this method focused on three research sub-questions to demonstrate the applicability of the SNID for the WIE program.

RQ 2.2$_c$: How do the dimensions of student success needs differ by gender?

RQ2.2$_d$: How do the dimensions of student success needs differ by gender and ethnicity/race?

RQ 2.2$_e$: How do the dimensions of student success needs differ by ethnicity/race?

Since WIE programs exists to help female engineering students overcome the challenges that are unique to their underrepresentation in college of engineering, the research questions investigated the unique needs of the female engineering students. To do so, RQ2.2$_c$ was used to explore the differences between female engineering students and their male peers. It should also be noted that program administrators stressed the need to improve diversity during Phase I. Thus, RQ2.2$_{d \& e}$ investigated the differences among the ethnicities/races for female engineering students.

6.4.1.1 Step #1: Administer ESNQ

The data was collected via the ESNQ, which was administered to all engineering students. However, WIE Program decision makers were particularly interested in the unique needs of the female engineering students at the applied research site. Therefore, a description of the data collection procedures and all participant information is described in Section 6.1, while a description of the female engineering students is provided in Table 6-9 and is summarized in the following paragraph.

A total of 105 female engineering students completed the questionnaire. A majority of the respondents were white (58.1%) and were not international students (i.e., foreign-born) (95.2%). The largest percentage of respondents reported receiving "A" grades (27.6%), and the second largest percentage reported receiving "C- or lower" grades (26.7%). Approximately one-third of the female engineering students were juniors (33.3%), 29.5% were seniors, 21.9% were freshmen, and 15.2% were sophomore. Furthermore, all nine engineering majors participated in the questionnaire for URM. As shown in Figure 6-4, the largest representation was from the bioengineering majors (30%).

Table 6-9: Demographic Profile of Female Engineering Students

	Frequency	Percent
Ethnicity/race		
American Indian or other Native American	1	1.0
Asian, Asian American, or Pacific Islander	26	24.8
Black or African American	10	9.5
Hispanic or Latino	4	3.8
White (non-Hispanic)	61	58.1
Other	3	2.9
International Student		
Yes	5	4.8
No	100	95.2
Grades		
A	29	27.6
A-	15	14.3
B+	16	15.2
B	11	10.5
B-	3	2.9
C+	3	2.9
C- or lower	28	26.7
Class Level		
Freshman	23	21.9
Sophomore	16	15.2
Junior	35	33.3
Senior	31	29.5

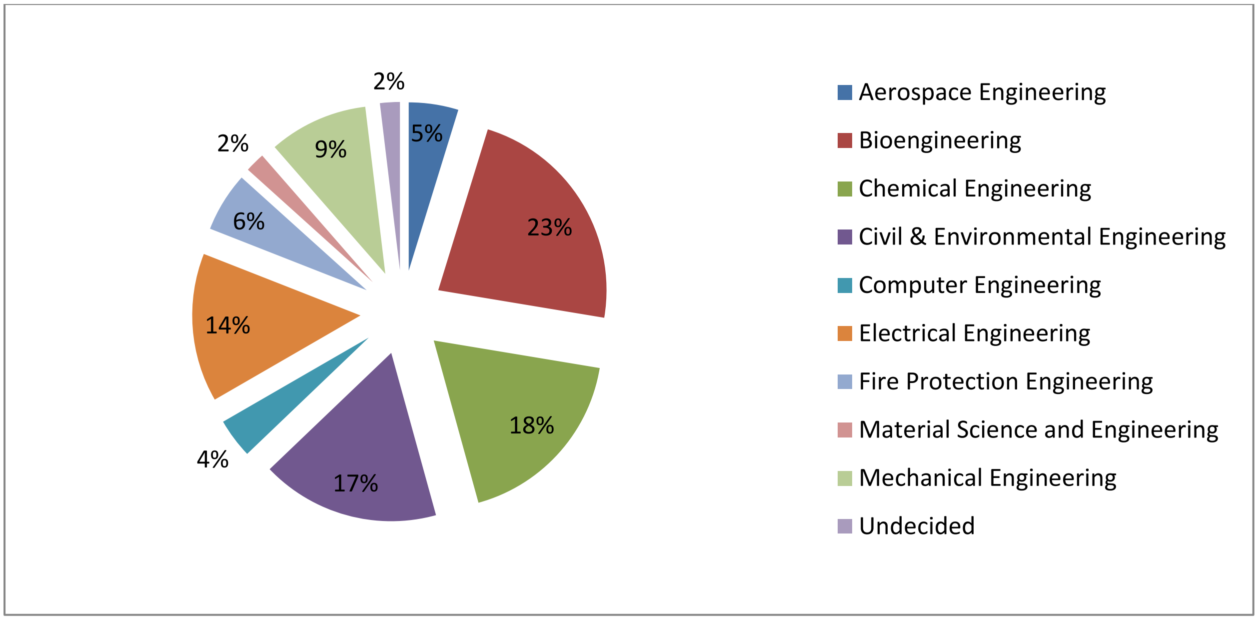


Figure 6-4: Engineering Majors for Female Students

6.4.1.2 Step #2: Analyze ESNQ data

Once the data was collected from the ESNQ, an *Importance* score, a *Satisfaction* score, an *Unmet Need* score, and an *Unmet Student Need Index* (USN_i) were calculated for each questionnaire item, as well as the means scores for each dimension. The *Importance* score and the *Satisfaction* score indicated the student's level of satisfaction and importance with the dimensions of student success needs. The *Unmet Need* score was calculated by subtracting the satisfaction score from the importance score (*Unmet Need* score = *Importance* score – *Satisfaction* score).

The *Unmet Need* score provided critical information to decision makers. This score specified how the needs of students were being fulfilled. A large unmet need score indicated that the institution was not meeting the needs of its students. Conversely, a smaller unmet need score suggested that the institution was meeting the needs of its students. Furthermore, a negative unmet need score implied that the institution was exceeding the needs of the students. Relevant descriptive statistics are presented in Appendix F-1, which provides the mean *Unmet Need* scores for each dimension of student success needs (i.e., dependent variable), the standard deviations, and the N for each subgroup (i.e., by gender and ethnicity/race).

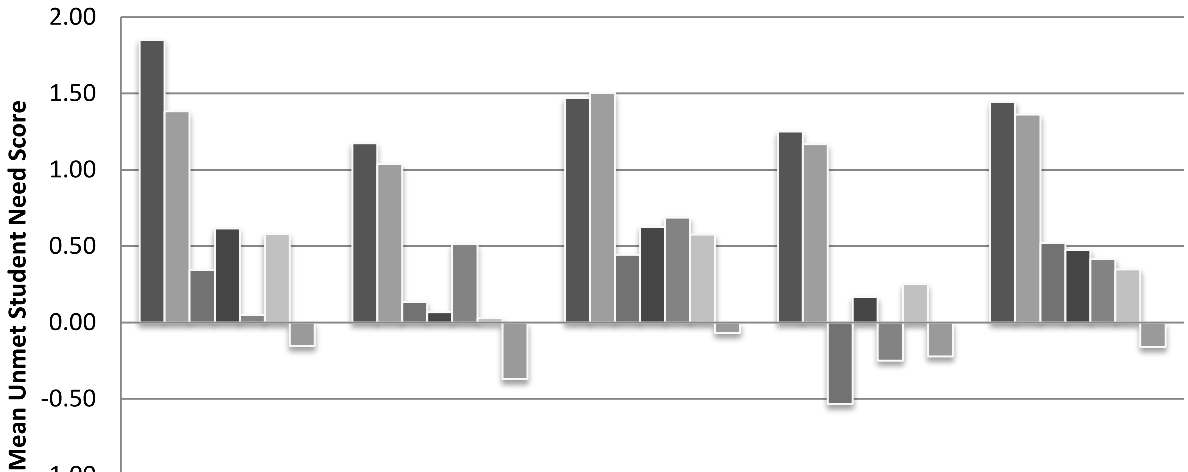
Research Question 2.2_c, $2.2_{d,\ and}$ 2.2_e

Once the scores were calculated, a series of two-way analysis of variance (ANOVA) procedures were conducted to determine whether the dimensions of student success needs (i.e., dependent variables measured by the *Unmet Need* scores) differed as a function of gender and ethnicity/race (i.e., independent variables). The analysis was conducted to address Research Question 2.2_c (*How do the dimensions of student success needs differ by gender*?), Research Question 2.2_d (*How do the dimensions of student success needs differ by gender and ethnicity/race?*), and Research Question 2.2_e (*How do the dimensions of student success needs differ by ethnicity/race*?).

It was hypothesized that there would be both a main effect of gender (H2.2_c), a main effect of race (H2.2_e), and an interaction effect between race and gender (H2.2_d) for the dimensions of student success needs. To test these hypotheses, a series of two-way analyses were conducted. For the analysis, statistical significance was set at a level of 0.05. The Levene's Test of Equality of Error Variance for each analyses revealed ($p > 0.05$) that the homogeneity of variance assumption had not been violated for each test. The results of the two-way ANOVA (Appendix F-2) indicated that the interaction effect between gender and race for each dimension of student success needs was not significant. Furthermore, there was no main effect of gender or ethnicity/race for each of the dimensions of student success needs.

The results of the two-way ANOVA suggest that the needs of both male and female engineering students were being met in similar areas. While these findings do not support H$2.2_{c,}$

H2.2$_d$, and H2.2$_e$, descriptive statistics in Figure 6-4 were meaningful for decision makers to understand how the needs of their female engineering students were being met.



	URM Females	Asian Females	White Females	Other Females	All Females
CL	1.85	1.17	1.47	1.25	1.45
WM	1.38	1.04	1.50	1.17	1.36
S	0.34	0.13	0.44	-0.53	0.52
FI	0.62	0.07	0.63	0.17	0.47
F	0.05	0.52	0.69	-0.25	0.42
SC	0.58	0.03	0.58	0.25	0.35
SI	-0.16	-0.37	-0.07	-0.22	-0.16

Figure 6-5: Mean Unmet Need Scores (Gender * Ethnicity/Race)

As shown in Figure 6-5, which summarizes the mean *Unmet Need* scores (from Appendix F-2), all female engineering students reported the highest unmet need scores for the dimensions of *Classroom Learning*, (*M*=1.45, *SD*=0.98) and *Workload Management*, (*M*=1.36, *SD*=1.24). These scores indicate that these needs required the greatest attention because they were not being met by the institution. Conversely, the lowest unmet need score for female engineering students—indicating that the institution was meeting the needs of female engineering students—was the *Student Interaction Needs* (*M*= - 0.16, *SD*= 1.43). Moreover, the aggregated results held true across all of the subgroups. The highest unmet need scores were reported by White female engineering students for *Workload Management* (*M= 1.50, SD= 1.13*). All subgroups reported high unmet need scores for *Workload Management*; however, the highest reported score for URM female engineering students was *Classroom Learning* (*M = 1.85, SD= 1.18*).

6.4.1.3 Step #3: Create Action Grid

Once the questionnaire was analyzed, the next step was to structure the needs into a hierarchy using an Action Grid. The Importance–Satisfaction Analysis Method described in Chapter 2 was used to develop a 2x2 action grid, which has been adapted from Graf et al. (1992) and Yang et al. (2003, 2009).

This action grid served as a diagnostic tool, in which the mean importance scores for each dimension of student success needs were plotted on the vertical axis and mean satisfaction scores were plotted on the horizontal axis. A hierarchy of needs was then specified based on the coordinates, which were divided into the following four quadrants described as follows:

- *Quadrant I:* High Priority: The needs located in this area were considered to be very important to students, but were not being met. As such, they required immediate attention, and represented the first priority for improvement efforts.
- *Quadrant II:* Low Priority: The needs located in this area were considered a low priority because they were not important to the student. Both the low levels of satisfaction and importance make these needs less influential.
- *Quadrant III:* Surplus Area: The needs located in this area were not very important to students, but they were rated high in satisfaction. A high level of satisfaction on unimportant needs provided a surplus area. If the program needed to cut back, they would target this area.

- *Quadrant IV:* Excellence Area: This area was meeting the needs of the students because they were evaluated high in both satisfaction and importance. The program should strive to maintain good performance for these needs.

By plotting the importance and satisfaction scores for each dimension of student success needs, Figure 6-6 structures the dimensions into four quadrants: high priority, low priority, surplus, and excellence areas.

*****Areas Identified in for Improvement from Phase I***

EXCELLENCE Student Interaction	**SURPLUS** ***Financial ***** ***Sense of Community*****
LOW PRIORITY Skill ***Faculty Interaction*****	**HIGH PRIORITY** Classroom Learning Workload Management

Figure 6-6: Action Grid for Female Engineering Students

6.4.1.4 Step #4: Calculate Index for Prioritization

Once the needs were structured into the action grid, the next step was to calculate an USN_i (Table 6-10), which was used to prioritize the individual student need items within each dimension. While the *Unmet Need* score was useful in identifying areas where needs were not being fulfilled, prioritizing based solely on this score yielded inconsistent results. Therefore, an index was needed to overcome the limitations of using the *Unmet Need* score to prioritize opportunities for improvement.

Table 6-10: WIE Program USN_i

#	ESNQ Item Description	USN_i	Rank
01_1	To have classes that stimulate interest in my field of study	24.83	***1***
05_2	To have a manageable workload	22.61	***2***
01_7	To have class concepts communicated in a manner that I understand	18.76	***3***
05_4	To have a balanced social, personal, and academic experience	18.52	***4***
01_4	To have relevant assignments (e.g., HW, labs, exams, etc.) that reinforce what I am learning in class	16.54	***5***
09_9	To develop job or work-related skills and experiences	16.47	***6***
05_1	To keep up with the pace of my courses	15.80	***7***
01_6	To comprehend class material	13.37	***8***
05_3	To cope with stress	13.20	***9***
09_6	To develop technical skills (e.g., programming languages, software applications, etc.)	4.63	***10***
08_3	To have a supportive group of people who provide help and encouragement	4.52	***11***
08_4	To have an environment where I receive fair and unbiased treatment	4.26	***12***
09_4	To develop communication skills (e.g., verbal and written)	3.65	***13***
02_1	To have approachable faculty members that I can discuss issues of interest and importance to me	3.01	**14**
09_5	To develop problem solving skills	2.56	**15**

#	ESNQ Item Description	USN_i	Rank
09_5	To develop problem solving skills	2.56	**15**
02_5	To have faculty members who are interested in engaging me in their fields	0.76	**16**
02_4	To have faculty members who demonstrate flexibility and responsiveness to my needs	-2.18	**17**
06_1	To have financial assistance available to me (e.g., scholarships, grants, etc.)	-2.50	**18**
02_6	To receive timely feedback from faculty members (e.g., grades, homework, exams)	-3.61	**19**
06_2	To have opportunities to cultivate close personal relationships with students who share my interests	-6.15	**20**
07_1	To ease my financial burden	-8.10	**21**
08_1	To have a welcoming environment where I feel a sense of belonging	-9.73	**22**
08_5	To have opportunities outside of class to cultivate relationships with the engineering community on campus	-9.94	**23**
06_3	To have opportunities to exchange ideas and gain knowledge from other students	-16.81	**24**
07_2	To have opportunities to earn money in order to offset my expenses (e.g., jobs, work study, etc.)	-18.98	**25**
07_3	To be informed about financial assistance opportunities	-22.76	**26**
06_4	To have opportunities to socialize with students from diverse backgrounds	-33.52	**27**

For example, an *Unmet Need* score (*Important – Satisfaction*) of 1 could be calculated for two respondents whose needs were not being fulfilled in the same manner. Consider Respondent A, who has indicated an importance score of 7 and a satisfaction score of 6—and Respondent B, who has indicated an importance score of 2 and satisfaction score of 1. Even though their unmet need score is the same (i.e., 1), Respondent A is satisfied with the institution in meeting a very important need—in comparison to Respondent B, who is very dissatisfied with an unimportant need.

To overcome this limitation, Yang's (2009) improvement index was modified to prioritize the critical student needs that were not being met by the institution. USN_i for each student need is defined as:

$$USN_i = \frac{\text{Unmet Need score}}{\text{Importance score}} \quad (5)$$

Essentially, the USN_i divides the unmet need score by the importance score (which Yang et al. (2009) subtracted the Importance Score from the Satisfaction Score in the numerator to develop an Improvement Index). The results of the USN_i are described in Table 6-10.

6.4.1.5 Step #5: Review Results

The SNID method was developed and applied to the WIE program at the applied research site. This method features a five-step process that was intended to 1) identify areas where female engineering student needs were not being fulfilled, 2) place those needs into priority order, and 3) select the highest priority for improvement. This process began with Step 1, namely, utilizing the ESNQ to collect data from the female engineering students at the applied research site. In Step 2, the questionnaire data was analyzed using descriptive statistics and a series of two-way ANOVAs to simultaneously investigate the effects of both gender and ethnicity/race on each of the dimensions of student success needs for female engineering students. Although there were no significant differences by gender or between gender and ethnicity/race, the descriptive statistics were used to provide meaningful insights into specific needs that should be targeted for improvement.

Based on the results of the statistical analysis, the action grid tool was used to structure the needs into a hierarchy in Step 3. The needs dimensions of *Classroom Learning* and *Workload Management* were identified as areas that required the greatest attention for all students, including the URM female engineering students. Subsequently, Step 4 developed an USN_i to prioritize those needs requiring the greatest attention for female engineering students. In reviewing the results (Step 5), the top-prioritized needs were then considered for design improvements in Phase III. Based on results from calculating the USN_i, the top five areas where the female engineering students indicated that they were not satisfied with very important needs not being met are described in Table 6-11.

Table 6-11: Phase II Results

Rank	Dimension	Item #	Item	Index Score
1	Classroom Learning	01_1	To have classes that stimulate interest in my field of study	24.83
2	Workload Management	05_2	To have a manageable workload	22.61
3	Classroom Learning	01_7	To have class concepts communicated in a manner that I understand	18.76
4	Workload Management	05_4	To have a balanced social, personal, and academic experience	18.52
5	Classroom Learning	01_4	To have relevant assignments (e.g., HW, labs, exams, etc.) that reinforce what I am learning in class	16.54

6.4.2 MEP Student Needs Identification Method

The five-step process described for the WIE program was also replicated for the URM engineering students at the applied research site. While the method used with the WIE program focused on gender-specific needs, the MEP's method focused on minority-specific needs. Additionally, program administrators also indicated in Phase I that they wanted to better serve the needs of their minority students beyond the freshmen year. As a result, the following research questions were addressed:

RQ2.2$_e$: How do the dimensions of student success needs differ by ethnicity/race (i.e., between minorities and non-minorities)?

RQ2.2$_f$: How do the dimensions of student success needs differ by the class level of URM students?

6.4.2.1 Step #1: Administer Questionnaire

The SNID method was initiated by administering the ESNQ to all engineering students. A description of the data collection procedures and participants are described in Section 6.1. Since the number of underrepresented minority students was low, this population of students was combined into the URM subgroup, which consisted of Hispanic or Latino, Black or African American, and American Indian or other Native American engineering students. A profile of the URM engineering students that participated in the assessment is included in Table 6-12.

As described in Table 6-12, a total of 47 URM students completed the ESNQ. In terms of demographics, the majority of respondents were male (68.1%); most of the respondents were Black or African American (83.0%) and not international students (80.9%). Additionally, more than half of the URM engineering students reported grades in the B range, and the students were relatively distributed across the grade levels. Furthermore, all nine engineering majors participated in the questionnaire for URM engineering students. As shown in Figure 6-7 the largest representation was from the electrical engineering students (30%).

Table 6-12: Demographic Profile of Underrepresented URM students

	Frequency	Percent
Gender		
Female	15	31.9
Male	32	68.1
Ethnicity/race		
American Indian or other Native American	1	2.1
Black or African American	39	83.0
Hispanic or Latino	7	14.9
International Student		
Yes	9	19.1
No	38	80.9
Grades		
A	8	17.0
A-	4	8.5
B+	12	25.5
B	12	25.5
B-	3	6.4
C+	1	2.1
C- or lower	7	14.9
Class Level		
Freshman	10	21.3
Sophomore	11	23.4
Junior	14	29.8
Senior	12	25.5

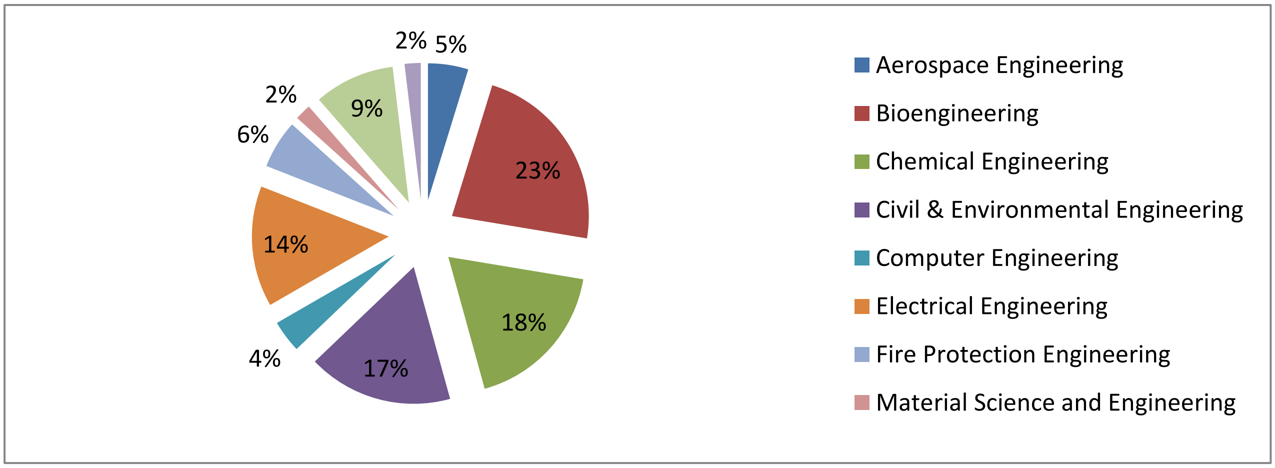


Figure 6-7: Engineering Majors for Underrepresented Minority students

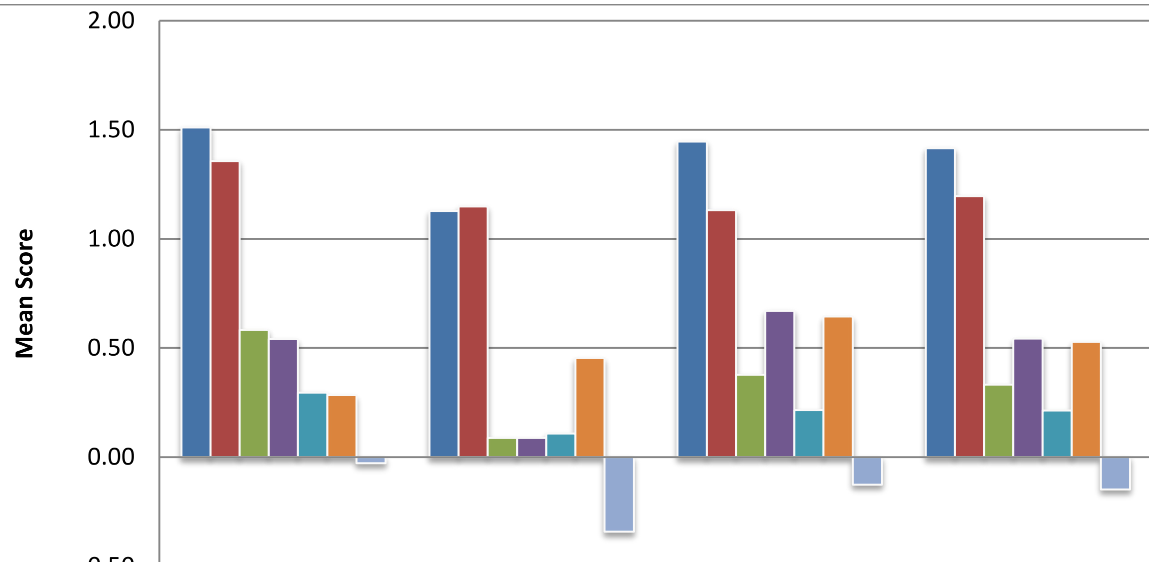
6.4.2.2 Step #2: Analyze Questionnaire Data

As a result of the questionnaire administration in Step 1, the data was collected and downloaded into PAWS (SPSS 18.0). The file was filtered by ethnicity/race. First, the following four scores were computed: 1) an *Importance* score, 2) a *Satisfaction* score, 3) an *Unmet Need* score, and 4) an *Unmet Student Need Index* score. Appendix F-4 details these scores for the URM engineering students' responses to each questionnaire item.

Research Question 2.2_e

First, Research Question 2.2_{e2} (*How do the dimensions of student success needs differ by ethnicity/race?*) was examined to explore the differences between minority and non-URM students. It was hypothesized ($H2.2_{e2}$) that there would be significant differences for the dimensions of student success needs across ethnicities/races. A one-way ANOVA was conducted to test $H2.2_{e2}$. Even though no significant effects were found (Appendix F-6), descriptive statistics was used to help program administrators understand the needs of URM engineering students. Descriptive statistics were computed (Appendix F-5) to provide the mean unmet need scores for each dimension of student success needs, the standard deviations, and the N for each subgroup.

From Appendix F-5, the mean unmet need scores for each dimension are summarized and plotted for the engineering students by ethnicity/race in Figure 6-8. As illustrated, each group reported that their needs were not being fulfilled in the needs dimensions of *Classroom Learning* and *Workload Management*. Among the ethnicities/races, URM students reported the highest levels for the needs dimensions of *Classroom Learning* ($M = 1.51$, $SD = 1.07$) and *Workload Management* ($M = 1.36$, $SD = 1.46$). These scores indicate that these needs require the greatest attention, particularly from the MEP because they were not currently being met for URM students. Conversely, the lowest unmet need score for all students was the *Student Interaction* eeds dimension. Although this score indicated that the institution was exceeding in meeting this need for all students, URM students reported the highest levels among the ethnicities/races *(M =-0.03, 1.51)*. Among the ethnicities/races, minorities were the least satisfied with this dimension.



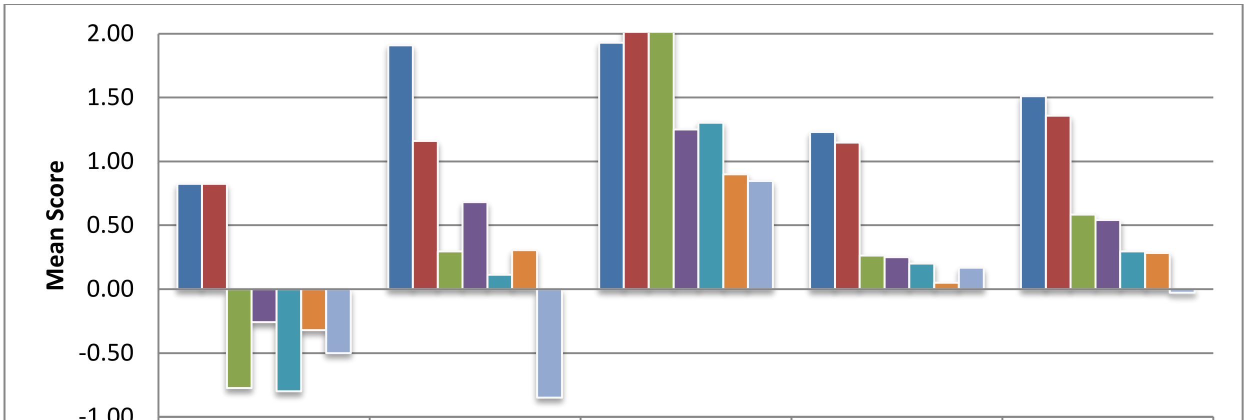
	Minority	Asian	White	All Students
CL	1.51	1.13	1.45	1.42
WM	1.36	1.15	1.13	1.19
F	0.58	0.09	0.38	0.33
FI	0.54	0.09	0.67	0.54
SC	0.30	0.11	0.22	0.21
S	0.28	0.45	0.64	0.53
SI	-0.03	-0.34	-0.13	-0.15

Figure 6-8: Mean Unmet Need Scores (Ethnicity/Race)

Research Question 2.2$_f$

Research Question 2.2$_f$ (*How do the dimensions of student success needs differ by the class level for URM engineering students?*) further examined the unique needs of URM engineering students. It was hypothesized (*H2.2$_f$*) that there were significant differences between the dimensions of student success needs by class level. To test the hypotheses, a series of one-way ANOVAs were conducted.

The descriptive statistics (Appendix F-5) provide the mean unmet need scores for each dimension of student success needs, the standard deviations, and the N for each class level. From Appendix F-5, the mean unmet need scores by class level are plotted for each dimension of student success needs in Figure 6-9. As noted earlier, a large unmet need score indicates that the institution is not meeting student needs—in comparison to a small unmet need score, which indicates that the institution is meeting the needs of students. As shown in Figure 6-9, the institution was exceeding the needs of freshmen URM engineering students in most of the dimensions of student success (with the exception of *Classroom Learning* and *Workload Management*). It should also be noted that freshmen engineering students provided the most favorable responses compared to the all of the upperclassmen. This outcome could be the result of institutional efforts that typically target first-year students, because this is the time where they are most vulnerable (Felder et al., 1998). In comparison, juniors provided the least favorable responses compared to the other class levels, as they have reported the highest unmet need scores.



	Freshmen	Sophomore	Junior	Senior	All
CL	0.83	1.91	1.93	1.23	1.51
WM	0.83	1.16	2.07	1.15	1.36
F	-0.78	0.30	2.17	0.26	0.58
FI	-0.26	0.68	1.25	0.25	0.54
SC	-0.80	0.11	1.30	0.20	0.30
S	-0.32	0.30	0.90	0.05	0.28
SI	-0.50	-0.85	0.85	0.17	-0.03

Figure 6-9: Mean Unmet Need Scores: URM Engineering Students by Class Level

Next, a series of one-way ANOVAs were conducted. For this analysis, statistical significance was set at a level of 0.05. The ANOVA table, which provides the detailed results of each dependent variable is included in Appendix F-7, and is summarized in Table 6-13. The results in this table confirm that $H2.2_f$ was partially supported. Although no significant differences were found for the dimensions of *Workload Management* needs[F (3, 43) = 1.80, p = 0.16] and *Skill* needs [F (3, 43) = 1.87, p = 0.15], significant differences were found for the remaining five dimensions. Post-hoc comparisons using Tukey HSD test were conducted to examine the significant differences, and a graph of the means are presented to explore these differences.

Table 6-13: One-way ANOVA Results by Class Level

Dimension (Dependent Variable)	Class Level
Classroom Learning Needs	***F (3, 43) = 3.32, p = 0.03****
Workload Management Needs	F (3, 43) = 1.81, p = 0.16
Financial Needs	***F (3, 42) = 4.82, p = 0.01*****
Faculty Interaction Needs	***F (3, 43) = 3.00, p = 0.04****
Sense of Community Needs	***F (3, 43) = 6.64, p = 0.00*****
Skill Needs	F (3, 43) = 1.87, p = 0.15
Student Interaction Needs	***F (3, 42) = 3.42, p = 0.03*****

**p < 0.05, *p < 0.01*

Classroom Learning Needs

For *Classroom Learning Needs*, the one-way ANOVA results revealed significant differences between the freshmen and junior URM engineering students, *F (3, 43) = 3.32, p = 0.03*. Post hoc comparisons showed that juniors (*M=0.83, SD=0.72*) reported higher unmet need scores than freshmen (*M=1.93, SD=0.57*) (see Figure 6-10). The results suggested that program administrators should consider how to address the *Classroom Learning Needs* of URM students during their junior year, which Felder et al. (1998) indicated can be one of the most demanding years in a student's university tenure.

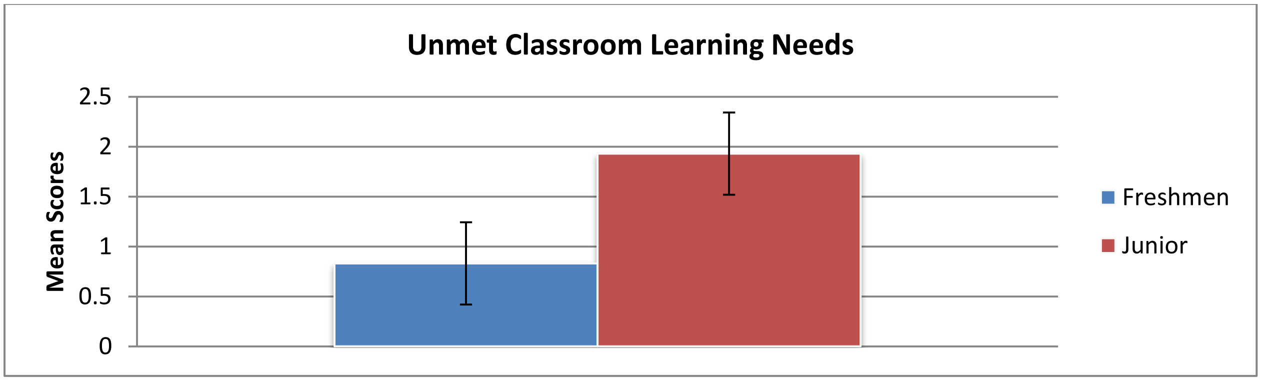


Figure 6-10: Comparison of Significant Unmet Classroom Learning Needs by Class Level (p < 0.05)

Financial Needs

The one-way ANOVA results showed significant differences between the freshmen and junior URM engineering students for the *Financial Needs* dimension, $F(3, 42) = 4.82, p = 0.01$. Post-hoc comparisons indicated that juniors *(M=2.17, SD=1.79)* reported significantly higher unmet need scores than freshmen (*M=-0.78, SD=0.67*) (see Figure 6-11).

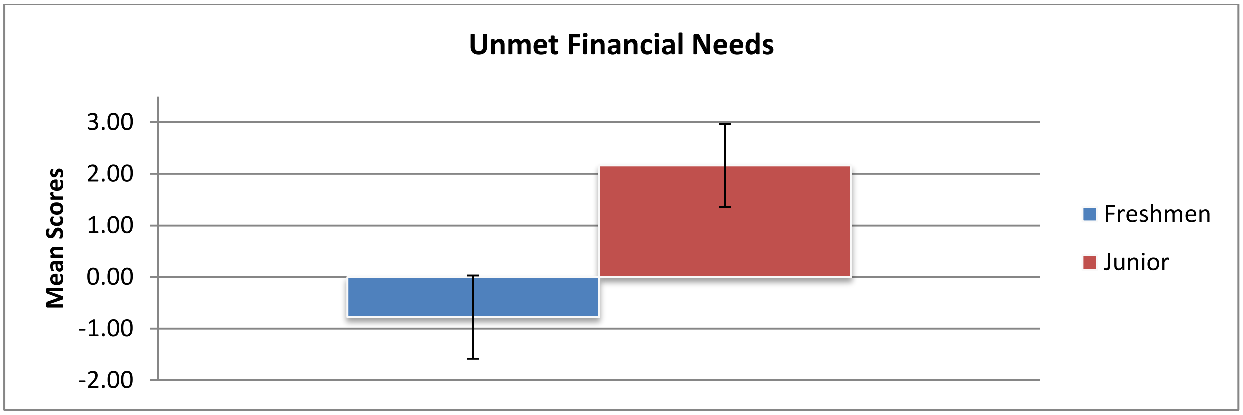


Figure 6-11: Comparison of Significant Unmet Financial Needs by Class Level ($p < 0.01$)

Faculty Interaction Needs

The one-way ANOVA results revealed significant differences between the freshmen and junior URM engineering students for the *Faculty Interaction Needs* dimension, $F(3, 43) = 3.00$, $p = 0.04$. Post-hoc comparisons showed that juniors (*M=-0.26, SD=0.87*) reported higher unmet need scores than freshmen (*M=1.25, SD=1.24*) (see Figure 6-12).

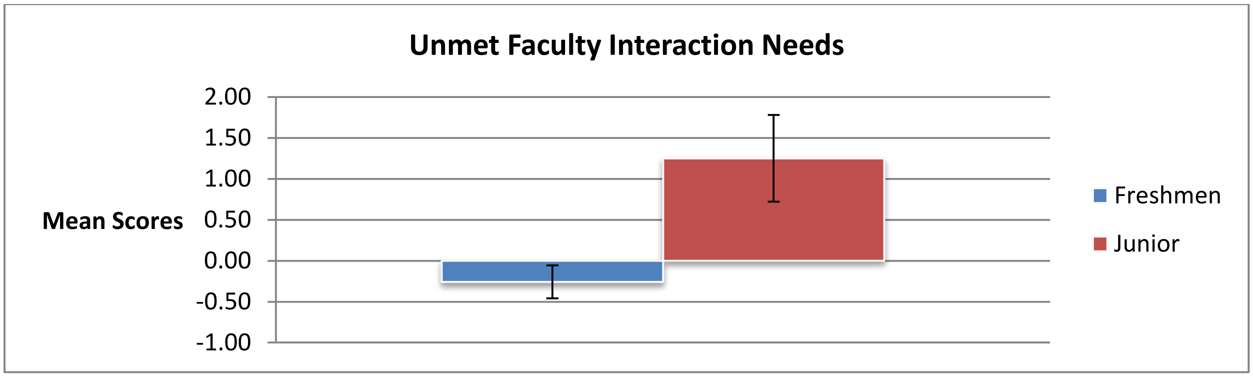


Figure 6-12: Comparison of Significant Unmet Faculty Interaction Needs by Class Level ($p < 0.01$)

Sense of Community Needs

For the *Sense of Community Needs* dimension, the one-way ANOVA results showed significant differences between the freshmen and junior URM engineering students, *F (3, 43) = 6.64, p = 0.00.* Post-hoc comparisons indicated that juniors *(M=-0.80, SD=0.87)* reported significantly higher unmet need scores than freshmen (*M=1.25, SD=1.24*) (see Figure 6-13).

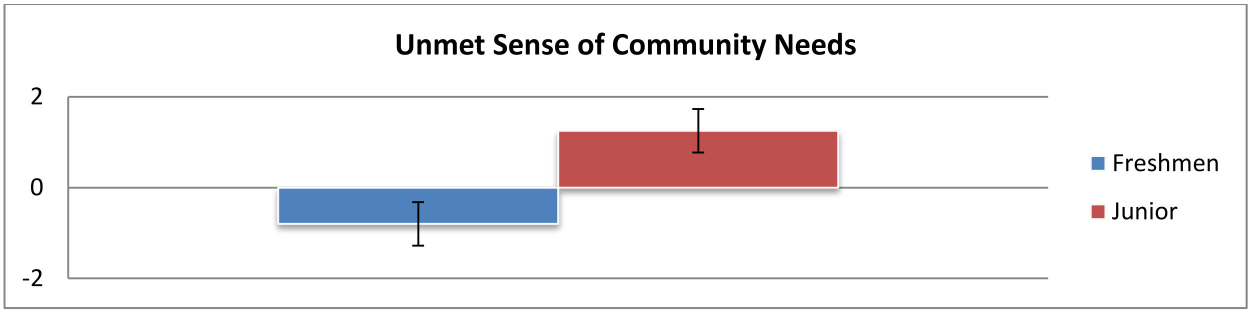


Figure 6-13: Comparison of Significant Unmet Sense of Community Needs by Class Level ($p < 0.01$)

Student Interaction Needs

The one-way ANOVA results revealed significant differences between the freshmen and junior URM engineering students for the *Student Interaction Needs* dimension, *F (3, 42) = 3.42, p = 0.03.* Post-hoc comparisons indicated that juniors *(M*=--0.50, *SD*=1.49*)* reported significantly higher unmet need scores than freshmen (*M*=0.85, *SD*=1.11) (see Figure 6-14).

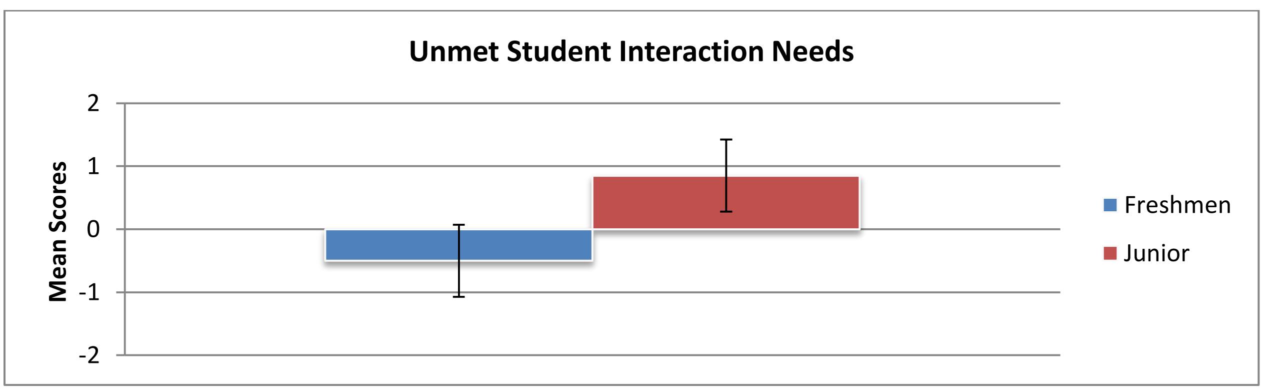


Figure 6-14: Comparison of Significant Unmet Student Interaction Needs by Class Level ($p < 0.05$)

6.4.2.3 Step #3: Create Action Grid

Once the raw data from the questionnaire was analyzed, Step 3 consisted of creating an action grid. The Action Grid tool, described in the WIE Program's SNID, was used to structure the needs into the following four quadrants: high priority, low priority, surplus, and excellence areas (Figure 6-15).

The bold italicized areas have been highlighted to indicate those areas that were identified during Phase I. Both of the dimensions of Classroom Learning and Workload Management needs, which were not initially identified in Phase I by decision makers for improvement, require the greatest attention for all students according to Figure 6-15. Also, the results of the previous phase suggests that the junior year requires the greatest attention from program administrators, as students in the third year have reported the highest level of unmet needs across all of the dimensions of student success needs. Therefore, program administrators should also consider how to better serve the classroom and workload management needs of all students and concentrate on expanding services to junior URM engineering students.

EXCELLENCE Student Interaction	**SURPLUS** Financial Sense of Community
LOW PRIORITY ***Faculty Interaction***** ***Skill*****	**HIGH PRIORITY** Classroom Learning Workload Management

*****Areas Identified in for Improvement from Phase I***

Figure 6-15: Action Grid for URM Engineering Students

6.4.2.4 Step #4: Calculate Index for Prioritization

Once the needs were structured into the action grid, the next step was to calculate an USN_i, which was used to prioritize the individual student need items within each dimension. The results of the USN_i are shown in Table 6-14. Higher index scores indicate those items that required the greatest attention due to the fact that those needs were not being met.

6.4.2.5 Step #5: Review Results

The final step in the process was to review the results of the SNID method, which was applied to the MEP at the applied research site. This method featured a five-step process that was developed to execute Phase II of the S^2OSD methodology in order to: collect the data, interpret raw data, structure a hierarchy of student needs, and prioritize the critical unmet student needs that were considered for design improvements in Phase III.

The MEP process began in Step 1 with utilizing the ESNQ to collect data from the URM engineering students at the applied research site. In Step 2, the questionnaire data was analyzed using a number of statistical techniques. First, a one way ANOVA and descriptive statistics were used to investigate the differences between minorities and non-minorities. Since the ANOVA did not reveal significant differences, descriptive statistics provided meaningful insight into the needs that should be targeted for URM engineering students. Specifically, URM students reported the highest levels of unmet needs among the ethnicities/races for the needs dimensions of *Classroom Learning* and *Workload Management*. Furthermore, descriptive statistics and a series of one-way ANOVAs revealed that program administrators should pay particular attention to students in their junior year due to the fact that these students reported the highest levels of unmet needs.

Table 6-14: MEP USN_i

#	ESNQ Item Description	USN_i	Rank
01_1	To have classes that stimulate interest in my field of study	23.30	***1***
05_2	To have a manageable workload	21.26	***2***
01_7	To have class concepts communicated in a manner that I understand	21.18	***3***
05_1	To keep up with the pace of my courses	18.98	***4***
01_4	To have relevant assignments (e.g., HW, labs, exams, etc.) that reinforce what I am learning in class	17.46	***5***
05_3	To cope with stress	15.20	***6***
01_6	To comprehend class material	14.84	***7***
02_1	To have approachable faculty members that I can discuss issues of interest and importance to me	10.30	***8***
06_1	To have financial assistance available to me (e.g., scholarships, grants, etc.)	9.94	***9***
02_4	To have faculty members who demonstrate flexibility and responsiveness to my needs	9.25	***10***
08_3	To have a supportive group of people who provide help and encouragement	8.15	***11***
05_4	To have a balanced social, personal, and academic experience	8.00	***12***
09_9	To develop job or work-related skills and experiences	5.28	***13***
09_6	To develop technical skills (e.g., programming languages, software applications, etc.)	1.60	**14**
02_6	To receive timely feedback from faculty members (e.g., grades, homework, exams)	-0.04	**15**
08_1	To have a welcoming environment where I feel a sense of belonging	-0.68	**16**
06_2	To have opportunities to cultivate close personal relationships with students who share my interests	-0.72	**17**
02_5	To have faculty members who are interested in engaging me in their fields	-2.01	**18**
09_4	To develop communication skills (e.g., verbal and written)	-2.30	**19**
09_5	To develop problem solving skills	-2.56	**20**
08_4	To have an environment where I receive fair and unbiased treatment	-3.84	**21**
07_1	To ease my financial burden	-6.25	**22**
07_3	To be informed about financial assistance opportunities	-6.96	**23**
06_3	To have opportunities to exchange ideas and gain knowledge from other students	-10.76	**24**
08_5	To have opportunities outside of class to cultivate relationships with the engineering community on campus	-11.01	**25**
07_2	To have opportunities to earn money in order to offset my expenses (e.g., jobs, work study, etc.)	-14.15	**26**
06_4	To have opportunities to socialize with students from diverse backgrounds	-20.87	**27**

Based on the results of the statistical analysis, the action grid tool was used to structure the needs into a hierarchy in Step 3. The needs dimensions of *Classroom Learning* and *Workload Management* were identified as areas that required the greatest attention for URM engineering students. Then, Step 4 calculated the USN_i to prioritize those needs requiring the greatest attention for URM engineering students. Based on the results of calculating the USN_i, the top five areas where the URM engineering students have indicated that they are not satisfied with very important needs not being met are described in Table 6-15.

Table 6-15: Phase II Results

Rank	Dimension	Item #	Item	USN_i
1	Classroom Learning	01_1	To have classes that stimulate interest in my field of study	23.30
2	Workload Management	05_2	To have a manageable workload	21.26
3	Classroom Learning	01_7	To have class concepts communicated in a manner that I understand	21.18
4	Workload Management	05_1	To keep up with the pace of my courses	18.98
5	Classroom Learning	01_4	To have relevant assignments (e.g., HW, labs, exams, etc.) that reinforce what I am learning in class	17.46

6.5 Summary of Phase II: Identify Needs

Phase II of the S^2OSD methodology was designed to capture the voice of engineering students and translate that information into a set of critical needs that were not being met by their institution. This process was four-fold in nature: (1) Develop a statistically-verified model of student success needs, (2) Use that information as the basis for developing the revised ESNQ, (3) Develop the SNID to guide institutional leaders through the process of understanding, identifying, and prioritizing the true needs of their students, and (4) Apply the SNID method to the MEP and the WIE Program at the applied research site.

First, a main study was conducted involving a total of 213 engineering students who completed the ESNQ. The purpose of the main study was to assess the reliability and validity of the conceptual model that was developed as the outcome of the pilot study. As a result of the assessment, a statistically-verified research model for engineering student success needs was used to test the relationships between the dependent (i.e., student success needs) and independent (i.e., overall satisfaction) variables.

To do so, correlation analyses was performed to assess the strength of the relationships between the independent (i.e., Overall Satisfaction) and dependent variables (i.e., unmet needs scores for the dimensions of student success needs). Then, hierarchical linear regression was used to test the relationships between the dimensions of student success needs while controlling for demographic variables. Based on the results, a refined model was developed that identified the needs dimensions of *Classroom Learning* and *Workload Management* as contributing significantly to *Overall Satisfaction*.

Next, the SNID method and related processes/tools was developed to identify the critical student success needs of engineering students. This step involved adapting Ulrich and Eppinger's (2008) customer needs identification method for use in an educational setting. The following five-step process was then applied to the WIE program and the MEP: Administer ESNQ, Analyze ESNQ data, Create Action Grid, Calculate Index for Prioritization, and Review Results.

In applying the SNID method, a series of two-way ANOVAs were used to determine the unique needs of the female engineering students at the research site. The main effect of gender, the main effect of ethnicity/race, and the interaction effect between gender and ethnicity/race were tested to explore the unique needs of female and URM students. While there were no statistically-significant relationships found, descriptive statistics revealed that the needs dimensions of *Classroom Learning* and *Workload Management* (which were also identified as a result of the regression analysis) were not being met by the institution.

Descriptive statistics and a series of one way ANOVAs were used to understand the unique needs of URM engineering students between minorities and non-minorities and by class level. Although the results of the one way ANOVAs did not reveal any significant relationships between minorities and non-minorities, descriptive statistics were useful in identifying the *Classroom Learning* and *Workload Management* needs. These needs are currently not being met, and require program administrators to focus improvement efforts in these dimensions.

For class level, freshmen indicated the most favorable responses, while junior URM engineering students indicated the most unfavorable responses for each dimension of student success needs. Furthermore, the one-way ANOVAs revealed significant differences between freshmen and juniors for five of the seven needs dimensions (*Financial, Faculty Interaction, Sense of Community*, *Skill,* and *Student Interaction*). To determine the needs that would be considered for design improvements during Phase III, an USN_i was created to prioritize the needs that were not being met by the institution.

CHAPTER 7 PHASE III - DESIGN IMPROVEMENTS

The purpose of Phase III was to have students design improvements practices to address the specific student success needs that were identified during Phase II. During this phase of the S^2OSD methodology, a structured idea-generation process was undertaken with the goal of producing the broadest possible set of feasible design practices (i.e., solutions) to satisfy the needs of students. This process relied on a more abstract view to encourage greater access to a wider range of potential solutions. The purpose was, therefore, to guide the students through a thorough exploration of improvements that rely on a different means to ultimately reach the goal of meeting student needs. The following hypothesis was used to investigate research question 2.3:

> ***RQ2.3:*** *How can improvement practices be designed to meet engineering student success needs?*
>
> ***H2.3:*** *Phase III of the S^2OSD methodology can be used to design improvement practices to meet the student success needs of engineering students.*

7.1 Participants

To recruit participants for this study, emails were sent to all of the female and URM engineering students at the applied research site (email addresses were obtained from student organization lists and related program list servs). Flyers describing the study were also posted in the engineering buildings. Students who participated in the study were compensated $20, and also received lunch as an incentive for their participation. Instead of scheduling a specific date for the meetings, students were asked to provide their availability using an online meeting scheduler (www.doodle.com) across a range of dates. The sessions were overbooked by 10 students to account for any last minute cancellations. A description of the 13 participants is provided in Table 7-1.

Table 7-1: Demographic Profile of Phase III Participants

	Minority Engineering Students	Female Engineering Students
Majors		
Bioengineering	1	3
Fire Protection Engineering	1	1
Electrical Engineering	3	3
Material Science & Engineering	1	0
Gender		
Female	4	7
Male	2	0
Ethnicity/race		
Black or African American	3	1
Hispanic or Latino	3	
White	0	6
Activeness in Program		
Very Active	3	1
Moderately Active	2	3
Not Active	1	3
Class Level		
Freshman	0	1
Sophomore	2	1
Junior	1	3
Senior	3	2

7.2 Design Improvements Method, Process, and Tools

Using the S^2OPD meeting process, the Design Improvement (DI) Method was used to carry out Phase III of the S^2OSD methodology. Participants were asked to share their experiences in a group discussion that was guided by the researcher over a 2-hour period. The objective of this meeting was to have students design improvements to address the critical unmet student success needs identified during Phase II.

The DI method adopted a customer-oriented view that incorporated the primary beneficiaries of the college experience (i.e., students) for the purpose of designing improvements that could impact their success. Thus, they were intimately involved in making recommendations for areas that need improvement using the process and tools described in Figure 7-1.

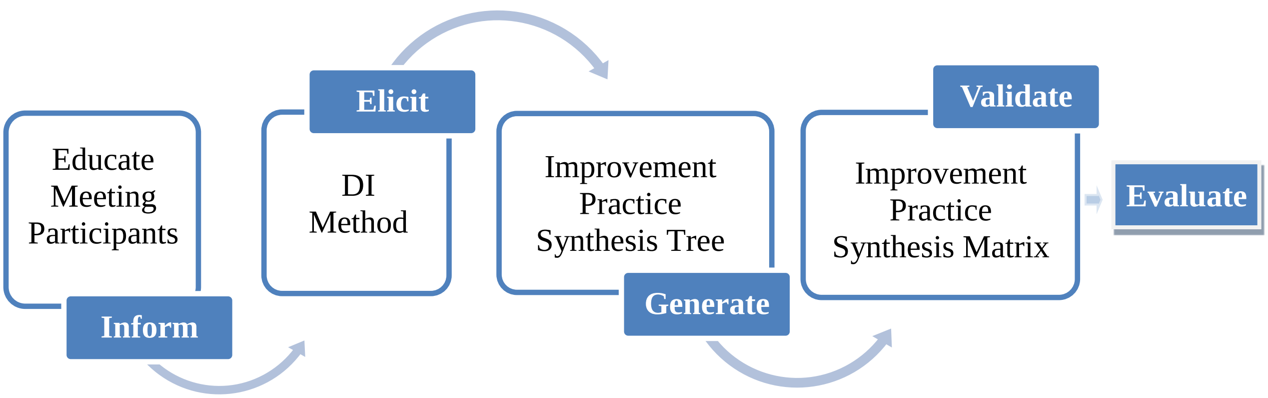


Figure 7-1: DI Meeting Process

The meeting process began with the *Inform* step, in which the researcher educated the meeting participants about the scope of the meeting. During the *Elicit* step, the DI Method was used to elicit ideas from the group in a structured manner. The *Generate* step then organized the resulting information in order to generate the Improvement Practice Synthesis Tree. Next, the participants translated the tree into the Improvement Practice Synthesis Matrix to ensure that the final output addressed the meetings goals and objectives during the *Validate* step. Finally, the results of the meeting were evaluated for the MEP and WIE programs.

Central to the DI method is the utilization of a functional decomposition process that began during the DB meeting. With this in mind, Phase III consisted of identifying the characteristics of institutional practices that contribute to meeting student needs, and transforming these characteristics into improvement practices. Integrating Brainstorming, QFD, SWOT, and the function-means method, the DI method was used to facilitate the functional decomposition process. As illustrated in Figure 7-2, the DI method was embedded into the S^2OPD meeting process, which was used to execute Phase III of the S^2OSD methodology.

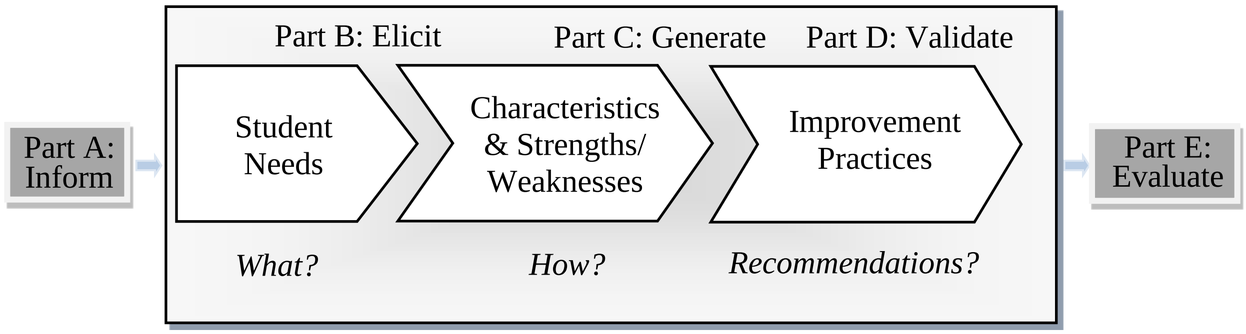


Figure 7-2: DI Method embedded within the S^2OPD Meeting Process

7.2.1 DI: PART A - INFORM

The first step of the meeting consisted of informing the participants about the goals and objectives of the meeting (Table 7-2), which involved a series of pre-determined discussion questions developed by the researcher. First, participants were asked to reflect on their own experiences and answer discussion questions on their own. A color-coding scheme using Post-It notes was used by participants to write down their individual responses, after which they shared the information on their Post-It notes by attaching them to the wall of the conference room. This allowed participants to reflect on their own experiences first, and then engage in a group discussion to generate additional ideas. The following color-coding scheme was used in the remaining steps to track key aspects of this process as follows:

- Green – Unmet Student Success Needs
- Blue – Characteristics
- Yellow – Current Practices

- Purple – Strengths
- Pink – Shortcomings
- White – Proposed Improvements

Table 7-2: DI Meeting Goals & Objectives

Goals	Objectives
1) To review the critical needs of engineering students	1) To use the results of Phase II to review the unmet needs of the students.
2) To define how institutional practices can address the needs of students.	2) To first describe desired characteristics of student success practices, and then to consider the strengths and weaknesses of current student success practices.
3) To recommend how the program can help support these needs.	3) To determine how the strengths and weaknesses of current practices can be used to develop improvement practices that address the desired characteristics of student success practices.

7.2.2 DI: PART B - ELICIT

The DI Method was used in the *Elicit* step to functionally decompose the student needs into desired characteristics of institutional practices, which were then used as the basis for critically examining how existing practices met the needs of students.

Discussion Question #1: *What characteristics of student success practices are required to address the needs?* (Students wrote characteristics on a blue Post-it note.)

The first discussion question required participants to consider the critical needs of students that were prioritized by the USN_i from Phase II. Instead of designing specific improvement practices, abstraction was used to emphasize the essential characteristics of student success practices. Therefore, students were asked to identify design characteristics of student success practices that fulfilled student needs. According to Pahl et al., (2007), this process provides participants an opportunity to search for and develop other solutions that contain the identified characteristics. This approach also supports systematic thinking and creativity, thereby opening up the solution space to allow participants to consider range of ideas without being fixated on traditional ideas.

Discussion Question #2: *What are the current practices that address these characteristics? Describe key aspects.* (Students wrote current practices on a yellow Post-it note.)

- ***Discussion Question #2a:*** *What are the strengths of the current practices?* (Students wrote strengths on purple Post-it note).
- ***Discussion Question #2b:*** *What are the shortcomings of the current practices?* (Students wrote shortcomings on a pink Post-it note).

Once solution-independent characteristics were identified, the next set of discussion questions allowed participants to leverage existing knowledge. The second discussion question and its associated sub-questions helped participants to think through existing practices, for which strengths and weaknesses were assessed.

7.2.3 DI: PART C - GENERATE

The *Generate* step guided participants through the process of synthesizing the information from the previous questions to generate improvements. By assessing strengths and weaknesses, participants were able to leverage the strengths, improve upon the weaknesses, or develop new solutions for characteristics that were not currently being addressed by their program.

Discussion Question #3: *What improvement practices can be created to incorporate the characteristics of institutional practices and address the shortcomings of current practices?*

To address discussion Question #3, the function-means tree was extended to include needs (functions), design characteristics, current practices, and improvement practices (means). By considering design characteristics first, participants were able to broaden their search for improvement practices, which opened up opportunities to think of innovative solutions. Additionally, analyzing existing practices was also useful in stimulating new ideas. Therefore, incorporating these elements into the Improvement Practice Synthesis Tree (Figure 7-3) was intended to guide the team through the process of synthesizing information to develop improvement practices that could address the needs of students.

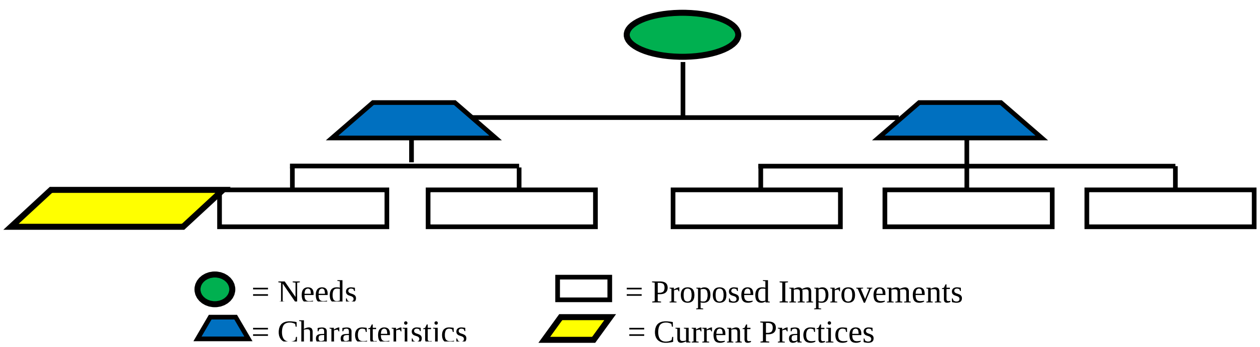


Figure 7-3: Improvement Practice Synthesis Tree

7.2.4 DI: PART D - VALIDATE

Once the Improvement Practice Synthesis Tree (Figure 7-3) was completed, the final step was to validate whether the output of the meeting achieved the goals it set out to achieve. Therefore, the *Validate* step ensured that the improvement practices resulting from the Design Improvements Method actually met the needs of the students.

Discussion Question #4: *Does the proposed improvement practices address the needs of the students?*

To validate the output, the participants were divided into smaller teams of two or three individuals to transform the tree into a matrix format. Strength symbols were then assigned to each improvement practice according to whether it adequately addressed the needs using the following symbols: ☺ (1) – strongly; 😐 (2) adequately; or ☹ (3) poorly. If an improvement practice did not strongly address the needs of students, then the participants iterated through the meeting process to refine that practice to better meet student needs. These smaller team results were then written on large sticky pads that were then addressed as a group. Again, if any practice did not strongly address student needs, then the entire group iterated through the meeting process to achieve better results.

7.2.5 DI: PART E - EVALUATE RESULTS

The DI method was used to design improvements for both the MEP and WIE program to address the critical unmet needs of the students. The S^2OPD meeting process was used to facilitate the students' completion of the Improvement Practice Synthesis Matrix, which represents the final output of the meeting. A number of improvement practices were designed to address the unmet needs that were identified as a result of Phase II. The examples presented herein focus a few improvement practices that were carried forward into Phase IV to demonstrate the usability of the DI method.

7.2.5.1 Phase III Results – WIE Program

Seven female engineering students completed Phase III of the S^2OSD methodology, which consisted of a structured idea generation process to design improvements to satisfy the unmet needs of female engineering students. Table 7-3 illustrates an example of the Improvement Practice Synthesis Matrix that was used to design improvements.

Table 7-3: Improvement Practice Synthesis Matrix for the WIE Program

Need	**To have a manageable workload**				**To have a balanced social, personal, and academic experience**
Characteristics	Work personal life balance	Time management skills	Doable work	Help coping with stress	To have clubs and organizations
Practices	WIE study social events	Advising	Office Hours Informal Study Groups	Advisors/ Mentors Advice	Fraternities social rather than academic (e.g., WIE, SOBE, BES)
Strengths	Academic networking	Advisors typically know average workload of class	Save time by asking questions, Better information with informal interaction	Gain Knowledge from other's experience	
Shortcomings	Program isn't open to everyone	Some people don't care what advisors have to say	Professors are not available, Sometimes it takes longer to get something done with a larger group	Doesn't really address coping with stress directly	No time to participate
Improvements	Expand programs to incorporate multiple years	Require time management seminar	Offer formal tutoring to everyone	Tips sent out over email on how to cope/ stress management workshop	Survey students on what events and where people would actually go
Validation	☺	☺	☺	☺	😐

As shown in Table 7-3, the primary inputs to the DI method were two unmet *Workload Management* needs of the female engineering students from Phase II ("to have a manageable workload," and "to have a balanced social, personal, and academic experience"). The next step in the process was to have the students define characteristics of student success practices that could be used to fulfill each need. For example, to address the unmet need "to have a manageable workload," students indicated that having *help coping with stress* described a characteristic of how this need could be satisfied. Next, students considered the strengths and weaknesses of current practices. For this example, students indicated that their advisors/mentors should provide guidance with managing their workload. Even though students are typically able to gain knowledge and experience from others, the advice *doesn't really address coping with stress directly*. Therefore, the students developed a specific improvement practice—*to have workshops that help with stress management* and *tips sent over email on how to cope*– in order to directly address the "To have a manageable workload" need.

At the bottom of Table 7-3, students validated the final output by assessing the relationship between the unmet needs and the proposed improvement practices. As a result, the students designed a number of practices to meet the needs of female engineering students.

7.2.5.2 Phase III Results - MEP

Six URM engineering students completed Phase III of the S^2OSD methodology. The DI method was used to address the unmet needs (from Phase II) of the students for the dimension *Classroom Learning* needs ("To stimulate interest in your field," and "To have class concepts communicated in a manner that I understand"). Table 7-4 illustrates an example of the Improvement Practice Synthesis Matrix that was used to design improvements.

As shown in Table 7-4, the primary input to the DI method was the unmet needs of the students from Phase II, in which two classroom learning needs are presented as an illustrative example ("to stimulate interest in your field," and "to have class concepts communicated in a manner that I understand"). Next, the students defined characteristics of student success practices that describe how their needs could be fulfilled. For example, to address the unmet need that would "stimulate interest in your field," students indicated that having *real world immersion* was a characteristic that described how that need could be satisfied. Next, students considered the strengths and weaknesses of current practices. For this example, students indicated that the engineering study abroad program provided a good program for real world immersion. However, the program was limited in access to a range of URM engineering students. Therefore, the students developed an improvement practice to expose a wide range of URM engineering students to the research efforts that are taking place on campus.

Finally, students validated the final output by assessing the relationship between the unmet needs and the proposed improvement practices. By doing so, the validation process allowed students to assess the strength of the relationship. As a result, the proposed improvement practice had a number of implications for a variety of dimensions. First, it could expose students to areas within their field that could stimulate interest. Additionally, this practice could also be used as a mechanism to expose URM students to URM faculty. It could also be used as a mechanism to expose students to different *real world immersion* experiences on campus.

Table 7-4: Improvement Practice Synthesis Matrix for the MEP

Need	**To stimulate interest in your field**		**To have class concepts communicated in a manner that I understand**			
Characteristics	Provide more exposure	Real world immersion	Adapting to different learning styles	Beforehand Knowledge on how teachers deliver information	More than 1 professor for a class being able to meet with other professors	Classes should be consistent standard
Practices	Career Fairs Companies coming to campus	Study (Engineering) Abroad	Nothing	Nothing	Nothing	Test, HW Banks
Strengths	Lots and Diverse	Well-Advertised good program well liked	N/A	N/A	N/A	Helps students understand how/what to study
Shortcomings	May not get hired just network	Many students are not able to participate				No central repository
Improvements	Help us (i.e. students) create personal relationships with industry.	Field trips to research labs on campus	Providing a database listing of info on teaching styles, HW, tests of each professor (using students as a reference) similar to course emails	Compiling a list of students who have same major background, etc.	To have special topic lectures that align with courses taught by minority faculty (e.g., .5 day short review	Central repository of test for center and old homework
Validation	☺	☺	☺	☺	☺	☺

7.2.6 DI: EVALUATE USABILITY

The DI formative evaluations helped to determine if the methods, processes, and tools were able to effectively guide students through the process of designing improvements to address the critical needs of engineering students. The performance-based evaluation framework is described in Chapter 9, and the questionnaire for the DI meeting is included in Appendix G (Part E). The results of the questionnaire are presented for the MEP and the WIE Program's DI meeting and then summarized collectively for all students.

7.2.6.1 DI Meeting #1 – Female Engineering Students

The first DI meeting was held with seven female engineering students from the WIE program. As shown in Figure 7-4, the ratings for the usability dimensions ranged from 4.21 (Overall Usability) to 4.57 (Ease of Participation). These results indicated that the design process and the output of the DI meeting were rated "Good" by the female engineering students, with the exception of the Ease of Participation dimension, which was rated "Excellent."

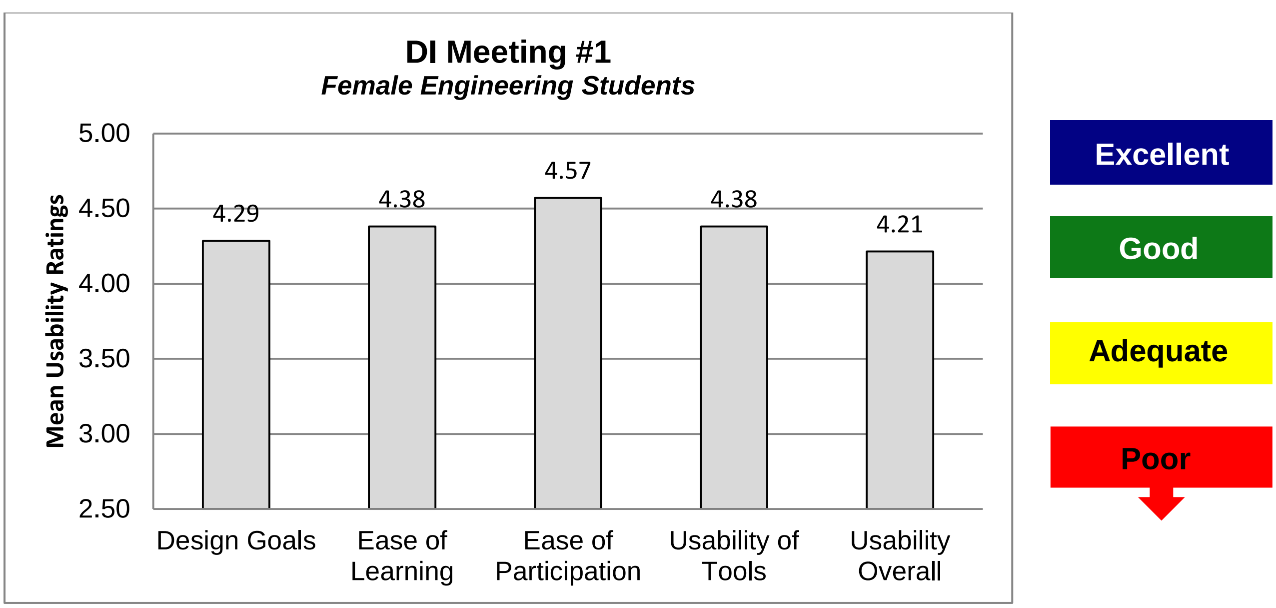


Figure 7-4: Usability Ratings for DI Meeting #1 – Female Engineering Students

The students indicated that the functional decomposition process, group collaboration, group size, and the validation process were effective. Three students commented on the functional decomposition process. One student noted that the "*The decomposition of each need effectively addressed the problem*." Another student added that it was an "*interesting approach definitely a different way of thinking for myself*." Four students provided comments on group collaboration, indicating that the brainstorming ideas with other students were effective. Another student also noted that breaking the students up into "*smaller teams (of 2-3 students) led to more discussion.*" One student also commented on the group size, indicating that the meeting had a "*good group size*." A final comment was made on the validation step, leading a student to state: "*The evaluation of the results as adequate poor or strong created a better selection of solutions.*"

However, students encountered problems with needing clarification about the process and the forced discussion format. One student noted that it was initially confusing to determine how needs should be addressed. Another student commented that the short introduction about the functional decomposition process, which a student described as "*too vague*," could have been more detailed. Two other students commented about the forced discussion model. One student stated that "*Sometimes it was a little difficult to label thoughts in the exact categories.*" Another student added that "*I would prefer a more free form discussion like a focus group*." To address these problems, a number of recommendations were made by the students. These recommendations were translated into design changes as well as the students recommendations are presented in Table 7-5.

Table 7-5: Design Changes to Improve DI Meeting #1 Based on Recommendations

Attribute	Recommendations	Design Changes
Time	Need more time for the meeting	• Focused on a few needs to allow students time to address the needs of students
Clarifying the Process	Informing students about the meeting beforehand	• Although students were not informed about the meeting beforehand, the research allocated an additional five minutes to the meeting in order to convey the functional decomposition process in more detail.

7.2.6.2 DI Meeting #2 – URM Engineering Students

The second DI meeting was held with six of the URM engineering students from the MEP. As shown in Figure 7-5, the ratings for the usability dimensions ranged from 4.50 (Ease of Participation) to 4.92 (Design Goals and Usability Overall). These results indicated that the design process and the outcome of the DI were rated "Excellent" by the URM students.

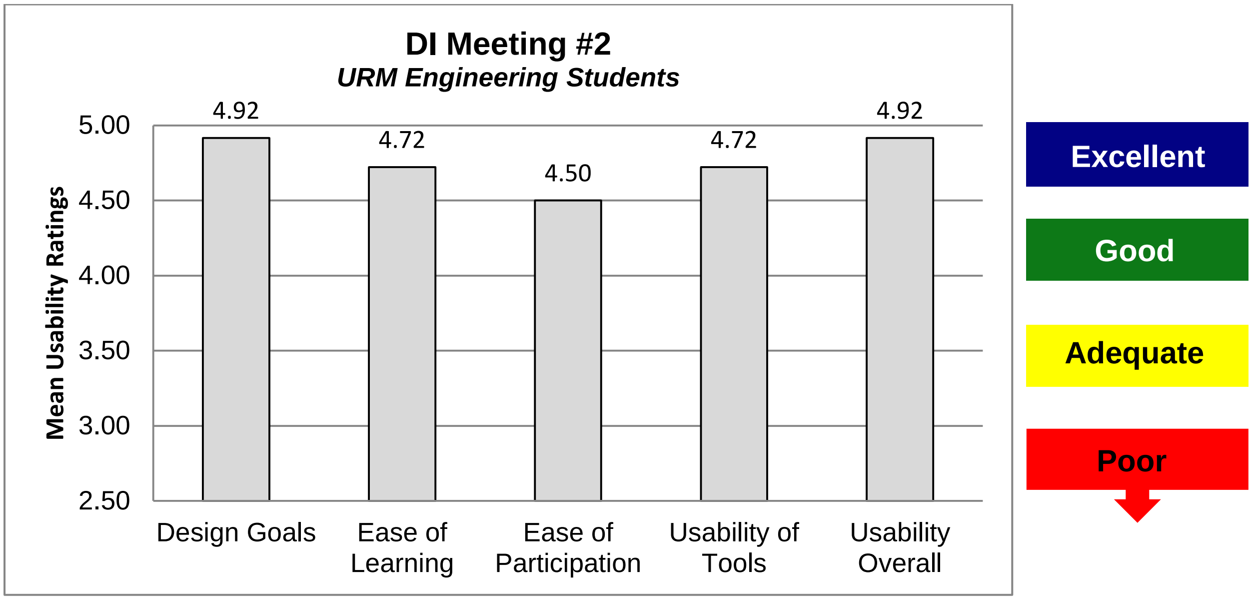


Figure 7-5: Usability Ratings for DI Meeting #2 – URM Engineering Students

All of the URM students reported that the group collaborative format was effective, while three of the students reported that the functional decomposition process was effective. One student noted that the "*small group size (was) more personal*," and another added that the "*topics were discussed in an organized manner.*" Another student asserted that the "*frequent feedback discussion (and the) open environment*" was effective. Conversely, two students encountered problems with the time of the meeting. One student stated that *"I felt tired in the full length maybe a break (is needed)*." Two other students also commented on problems understanding the process. One student noted that "*At first I didn't understand the objective*." As a result, two recommendations were made by the students, which are shown in Table 7-6.

Table 7-6: Design Changes to Improve DI Meeting #2 based on recommendations

Attribute	Recommendations	Design Changes
Time	• Length of the Meeting	• Addressed in Future Research—namely, trying to balance extending the meeting with providing more in depth explanations about the process.
Clarifying the Process	• Clarify the terms	• The meeting protocol was updated to clarify terms, objectives, discussion questions, and examples. The updated meeting protocol is included in Appendix G.

7.3 Summary of Phase III: Design Improvements

This chapter described the development and application of Phase III of the S^2OSD methodology. The DI method, meeting process, and tools were used to design improvements to address the needs of female and URM engineering students. A total of two meetings were conducted with six URM engineering students and seven female engineering students (thirteen students in total) to design improvements that could address the critical unmet needs of students in the MEP and WIE Program.

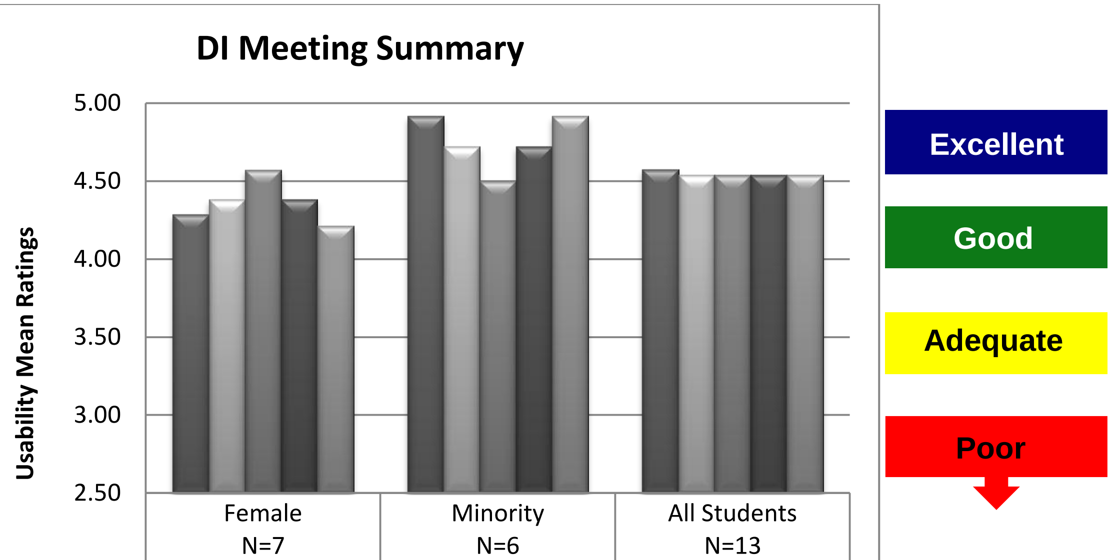
The DI method emphasized the design philosophy that is purported throughout each phase of the S^2OSD methodology. At the core of the DI method is the analysis-synthesis-evaluation principle, which utilized the design skills to help students systematically translate student needs into student success practices. The Improvement Practice Synthesis Tree and Matrix was used as a tool that helped students identify and document desired characteristics of student success practices to address student needs, consider the strengths and weaknesses of current practices, and leverage each aspect of the tree/matrix to design improvements.

The *student orientation* principle was reinforced by placing the needs of the students at the heart of designing improvement practices to help students succeed. The *Vital to Student Success* principle is inherent in this phase because only a few of the critical unmet needs from Phase II were incorporated into Phase III. The *participation* principle was applied in the meeting process, which incorporated the primary beneficiaries of the college experience into the *analysis-synthesis-evaluation* process.

While this phase can be used to holistically design improvements, the results of Phase III did not support the *holistic* principle. Instead, this phase was devoted to demonstrating the usability of the DI method. The results of the DI method, which proposed improvement practices to address the unmet needs of students, were suggested and evaluated by program administrators in Phase IV. The results of the formative evaluation are summarized in Figure 7-6.

Overall, the DI meetings were shown to be very effective based on the evaluations of the URM students, who rated the design process and the outputs of the DI meetings as being "Excellent." This judgment was confirmed by the ratings for each of the usability dimensions (Figure 7-6), which ranged from 4.54 (Ease of Learning, Ease of Participation, Usability of

Tools, and Overall Usability) to 4.58 (Design Goals) for all students. The DI meetings were improved as a result of the formative evaluations. Four of the usability dimensions showed a ratings increase that ranged from 0.34 (Ease of Learning and Usability of Tools) to 0.70 (Usability Overall) between DI meeting #1 and #2. Despite the fact that the DI meetings were deemed 'Excellent,' there remains a need for future research in two areas.



	Female N=7	Minority N=6	All Students N=13
Design Goals	4.29	4.92	4.58
Ease of Learning	4.38	4.72	4.54
Ease of Participation	4.57	4.50	4.54
Usability of Tools	4.38	4.72	4.54
Overall Usability	4.21	4.92	4.54

Figure 7-6: DI Meeting Summary

The first area of future research is related to determining the ideal time length for the meetings. Since the DI meetings required students to be active participants in the design process, a two-hour period was thought to be minimally sufficient to acquire the needed information without exhausting participants (Stewart et al., 2007). However, the participants recommended a thorough description of the functional decomposition process; therefore, future research should investigate how to review the functional decomposition process more thoroughly within an acceptable time allotment. For example, should a pre-meeting be scheduled to review this process? Should more time be added to the meeting to provide a thorough explanation?

The second area of future research should be devoted to understanding how to comprehensively address a large number of needs. For this research, the team covered a few needs to demonstrate the applicability of the framework. In order to be an effective tool for institutional leaders, future research should be devoted to understanding how the meeting can be used to comprehensively address the needs of students.

In summary, the DI meetings were shown to be very effective. As a result, H2.3 was supported. *Phase III of the S^2OSD methodology can be used to design improvement practices to meet the student success needs of engineering students.*

CHAPTER 8 PHASE IV - DEVELOP PLAN OF ACTION

The final phase of the S^2OSD methodology consisted of guiding institutional leaders through the process of deciding on a concrete course of action based on the information generated from the previous phases. Such an exercise facilitated an understanding of how the proposed improvement practices could ultimately address the needs of students in the context of the overall vision and direction of the program. The linkages between program goals, student needs, characteristics of institutional practices, and improvement practices allowed decision makers to visualize how student needs could be taken into account in the action planning process. This phase tested the following hypothesis to address the research question 2.4:

> ***RQ 2.4****: How can the information generated from the previous phases be translated into a plan of action that promotes student success?*
>
> ***H2.4:*** *Phase IV can use the information generated from the previous phases of the S^2OSD methodology to develop a plan of action.*

8.1 Participants

All of the institutional leaders that participated in Phase I of this research were recruited to participate in Phase IV; however, only a total of five participants completed Phase IV. The program director for the WIE program; and the program director, assistant director, program management specialist, and program coordinator from the MEP completed Phase IV.

8.2 Develop Plan of Action Method, Process, and Tools

The fourth and final phase of the S^2OSD methodology consisted of developing a plan of action to address the needs of students. The Develop Plan of Action (DPA) Method was used to carry out Phase III using the S^2OPD meeting process. Participants were asked to share their experiences that were guided by the researcher over the course of a 1.5-hour period. The objective of this meeting was to have institutional leaders evaluate and select a course of action to implement. Figure 8-1 summarizes the steps that were used in the DPA meetings.

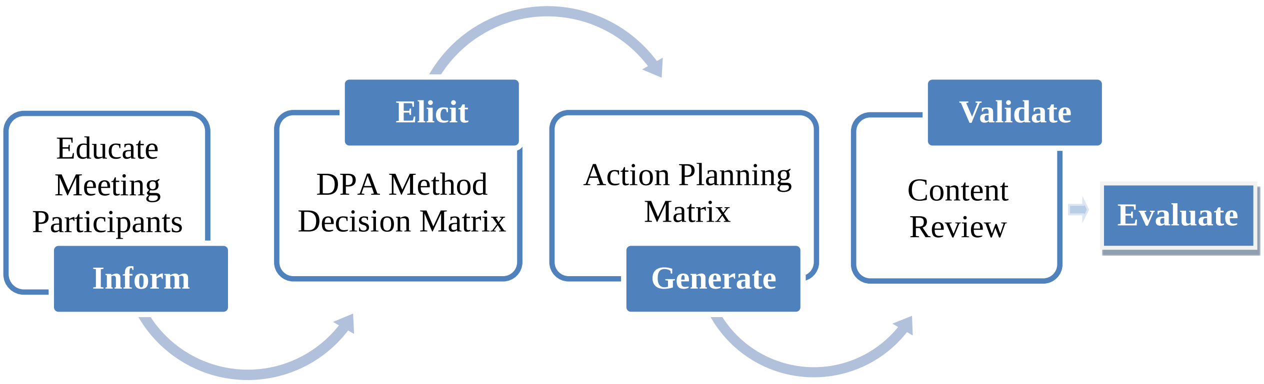


Figure 8-1: DPA Meeting Process

Based on the information learned from the previous phases (I-III) of the S^2OSD methodology, a plan of action was developed using the DPA method in Phase IV. First, the participants were educated about the scope of the meeting during the *Inform* step. Then, the DPA method was used during the *Elicit* step. This step allowed program administrators to complete the Improvement Practice Decision Matrix as a mechanism to obtain the institutional decision makers' evaluation and selection of the most feasible improvement practices to meet the needs of students. A preferred course of action was then developed during the *Generate* step using the Student Success Action Planning Matrix. A content review of the matrix was completed during the *Validate* step to ensure that the output fulfilled the goals and objectives of the meeting. Finally, the results were evaluated, and the usability of the DPA method was assessed during the *Evaluate* step. Based on the results, future research was proposed to improve the usability of the DPA meeting.

8.2.1 DPA: PART A - INFORM

The first step of the meeting consisted of informing the participants about the scope of the meeting, its goals and objectives, the procedures, and the roles and responsibilities of the participants. The following goals and objectives were established for the DPA meetings.

Table 8-1: DPA Meeting's Goals and Objectives

Goals	Objectives
1) To determine the most promising improvement practices	1) To use performance criteria to analyze and select the most feasible improvement practices recommended from Phase III.
2) To translate recommended improvement practices into a plan of action that facilitates student success	2) To use the key performance areas to develop a plan of action.

8.2.2 DPA: PART B - ELICIT

The weighted attribute method (Muller et al., 2003), which is based on the PDM, was used to elicit the judgments of decision makers about the improvement practices designed by the students from Phase III. The first discussion question allowed decision makers to establish a set of performance criteria by which the recommended improvement practices from Phase III could be evaluated.

Discussion Question #1: *What criteria should be used to evaluate the improvement practices?*

To address this question, a number of performance criteria were established by the researcher to allow decision makers to critically evaluate the improvement methods. Based on Sink and Tuttle's (1989) seven performance criteria, the decision makers used the criteria in Table 8-2 to compare and select the most promising improvement practices.

Discussion Question #2: *How should the performance criteria be weighted to capture the relative importance with respect to the other criteria?*

Table 8-2: Performance Criteria for Evaluating and Selecting Improvement Practices

Performance Criteria	Description
Efficiency	The improvement practice can achieve a better result over current practices
Productivity	The results generated from the improvement practice are worth the effort required to implement the improvement practice.
Effectiveness	The Center has the capability/capacity to implement this practice successfully.
Cost-effectiveness	The result of the improvement practice is worth the amount of money needed to implement the practice.
Quality	The improvement practice meets the needs of the student.
Innovation	The improvement practice introduces a new way of satisfying the needs of students

The decision makers used the criteria in as a starting point to address Discussion Question #2, and were then given the opportunity to add or delete criteria. As a result, the final agreed-upon list of performance criteria was added to the first column in Figure 8-2. Then, the decision makers determined a weighting system to capture the relative importance of each criterion with respect to the others. To do so, the criteria were ranked in order of importance, and weighted according to their importance. The weight for each criterion was denoted in the second column of the matrix.

Criteria	Weight	IP_1	IP_2	IP_3	IP_4
#1					
#2					
#3					
Total Score					
Rank					

1 - Strongly Disagree
2 - Disagree
3 - Somewhat Disagree
4 - Neutral
5 - Somewhat Agree
6 - Agree
7 - Strongly Agree

Figure 8-2: Improvement Practices Decision Matrix

Discussion Question #3*: How do the proposed improvement practices satisfy each of the criteria?*

Once the weighting system was determined, each of the improvement practices was then evaluated based on its ability to satisfy each of the criteria. First, the decision makers were asked to determine their level of agreement with each of the statements listed in Table 8-2. For example, decision makers were asked to determine whether "*the improvement practice can achieve a better result over current practices"* for the efficiency criterion. The response was recorded in the body of the matrix in Figure 8-2 based on a seven point likert-type scale (1 – strongly agree to 7 – strongly disagree).

Discussion Question #4: *Which improvement practices should be considered for implementation?*

Based on Discussion Questions # 1-4, the decision matrices were constructed where n = the number of design criteria, w_i = the weight of the ith criterion, and r_{ij} = the rating of the improvement practice j for the ith criterion, and the TS_j = the total score for the improvement practice j was calculated for each improvement practice as follows:

$$TS_j = \sum_{i=1}^{n} r_{ij} w_i \quad (6)$$

A higher numerical rating for each criterion was indicative of better performance. Therefore, the improvement practice with the highest score was selected as the preferred solution for generating a plan of action.

8.2.3 DPA: PART C - GENERATE

The improvement practices were then translated into a preferred course of action. This was accomplished by completing the Student Success Action Planning Matrix, which aligned the programs' goals, student needs, and the plan of action to achieve the goals that address the student success needs. As a result, the planning matrix was used as an alignment tool, which was intended to facilitate a focused execution of program plans (Marhevko, 2007).

Discussion Question #5: *Based on the information gained from the previous phases, what is the plan of action that facilitates student success?*

To address Discussion Question #5, the decision makers completed the Student Success Planning Worksheet. As shown in Table 8-3, the key performance areas from Phase I were identified and described to help decision makers systematically develop a plan of action.

Table 8-3: Student Success Planning Worksheet

Key Performance Areas	Description	Plan of Action
Goals	The goals for the Program	
Student Needs	The "critical" student success needs identified from Phase II (i.e., USN_i)	
Student Success Practices	The practices that will meet the needs of the students	
- Student Success Strategies	The student success improvement strategies that should be implemented.	
Performance Measures	The key metrics that provide measurable goals, which quantify the effectiveness and the efficiency of the actions taken.	
Capacity Owner	The responsible party (ies) for each line item	
Results	The expected outcomes	

For example, improvement goals were used to formulate specific plans to achieve program practices; key metrics were defined to measure performance on the key objectives, and accountable resources were identified to determine who owned the execution of each item. (The performance areas were taken from Phase I.) However, student success improvement strategies were added to further describe how the practices would be implemented. Also, the “capacity” area identified the owners of the line items (vs. tracking the capacity resources). By aligning the key performance areas, the planning matrix was used to facilitate a focused implementation of program plans (Marhevko, 2007).

8.2.4 DPA: PART D - VALIDATE

The final discussion question allowed the group to review the meeting’s goals and objectives to ensure that they were met. A final review of the Student Success Planning Matrix developed in the *Generate* step was examined to ensure that there was agreement among the meeting participants with respect to its ability to meet the stated objectives. If open issues still remained, the group repeated the meeting process to elicit, generate, and validate the output. The meeting participants repeated the validation step until no unresolved issues remained.

Discussion Question #6*: Does the plan of action facilitate student success?*

8.2.5 DPA: PART E - EVALUATE RESULTS

The DPA method was used to develop an action plan to address the critical student success needs that were not being met for the female and URM engineering students at the applied research site. The S^2OPD meeting process was used to facilitate the program administrators' completion of the Improvement Practices Decision Matrix and Student Success Planning Matrix, which was the final output of the meeting. The examples presented herein focused on the evaluation of a few improvement practices to demonstrate the usability of the DI method.

8.2.5.1 Phase IV Results - MEP

The results from Phase I through Phase III were presented to MEP program administrators. A thirty-minute PowerPoint presentation was given to the program administrators to review a sample of the results. Following the presentation, four improvement practices were considered to demonstrate the usability of Phase IV. To evaluate the improvement practices (Table 8-4) designed during Phase III, the Improvement Practices Decision Matrix was completed by the program administrators.

Table 8-4: Improvement Practices - MEP

Need	Improvement Practice
Classroom Learning Faculty Interaction Need	IP_1: To have special topic lectures that align with courses taught by minority faculty (e.g., .5 day short review course – calculus – physics – MATLAB)
Faculty Interaction, Skill Need	IP_2: Field trips to research labs on campus (exposure to minority faculty)
Workload Need	IP_3 : Have standard advising office hours at the Center
Workload Management, Faculty Interaction, Student Interaction Need	IP_4 : Workshops to help with time management and stress management (Developed and presented by minority faculty, undergraduate, graduate students)

Based on the results of the Improvement Practices Decision Matrix in Figure 8-3, improvement practice #4 (IP_4) ranked the highest among the practices. However, the decision makers preferred to implement short review courses as opposed to workload type workshops because the latter had been unsuccessful in the past. As a result, a plan of action was developed for improvement practice #1 – short review courses. As a result, the decision makers were then able to develop and align the program’s goals, practices, strategies, metrics, and capacity owners to develop a plan of action to facilitate the success of minority engineering students in Figure 8-4.

Criteria	**Weight**	**IP_1** Short review courses	**IP_2** Research Lab Field Trips	**IP_3** Standard Advising Hours	**IP_4** Workload Workshops
Quality	0.20	7	5.5	7	7
Efficiency	0.30	6	4	4.5	5
Productivity	0.15	6	4	5.5	5.5
Effectiveness	0.10	5	6	7	7
Cost Effectiveness	0.25	6	7	6	7
Total Score		6.1	5.3	5.8	6.2
Rank		**2**	**4**	**3**	**1**

Figure 8-3: MEP Improvement Practices Decision Matrix

8.2.5.2 Phase IV Results - WIE Program

For the WIE program, the results from Phase I through Phase III were presented to the program director. A thirty-minute PowerPoint presentation was given to the program director to review a sample of the results. Following the presentation, three improvement practices (see Table 8-5) from Phase III were recommended for demonstrating the usability of Phase IV.

Table 8-5: Improvement Practices – WIE Program

Student Success Needs	**Improvement Practices**
Classroom Learning Faculty Interaction Needs	IP_1: To have workshops that help to reinforce learning
Classroom Learning Needs	IP_2 : To have group tutoring/study sessions overseen by a knowledgeable graduate student/TA/
Workload Needs	IP_3: To have workshops that help with time and stress management

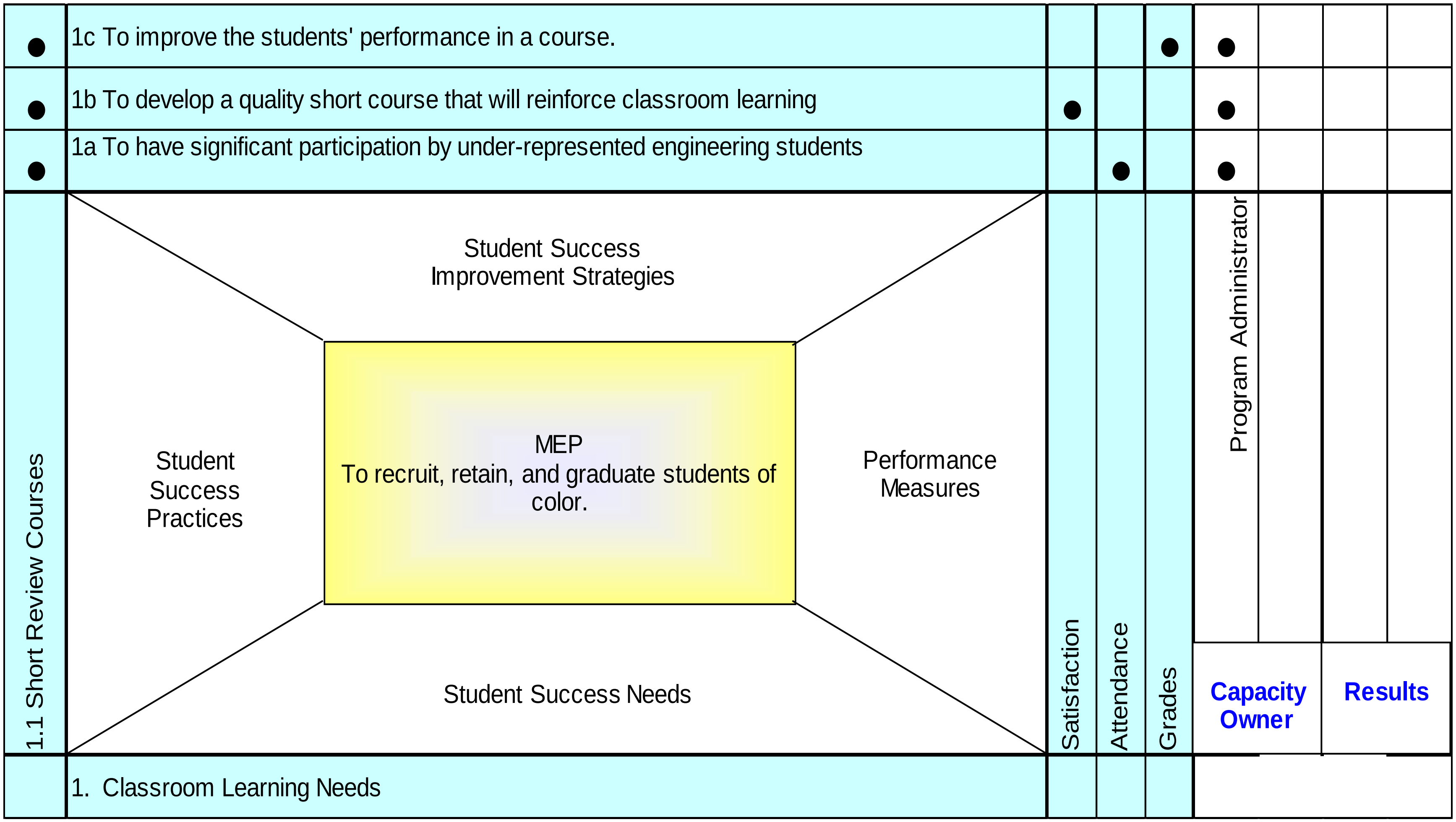


Figure 8-4: MEP Student Success Action Planning Matrix

To evaluate these improvement practices, the Improvement Practices Decision Matrix was completed by the WIE program director. Based on the results in Figure 8-5, improvement practice #1 (IP_1) ranked the highest. As a result, a plan of action was developed for improvement practice #1 – short review courses (see Figure 8-6).

Criteria	**Weight**	**IP_1** Reinforcement Workshops	**IP_2** Student Led Sessions	**IP_3** Workload Workshops
Quality	.2	7	6	1
Efficiency	.2	7	6	4
Productivity	.2	7	7	5
Effectiveness	.2	7	6	4
Cost Effectiveness	.2	5	6	4
Total Score		6.6	6.2	3.6
Rank		**1**	**2**	**3**

Figure 8-5: WIE Improvement Practices Decision Matrix

8.2.6 DPA: EVALUATE USABILITY

DPA formative evaluations were conducted to determine if the methods, processes, and tools were able to guide institutional leaders through the process of designing a plan of action to address the critical unmet student success needs of engineering students. Thus, two DPA meetings were conducted with one WIE program director and four MEP program administrators. The results of the questionnaire are presented for the MEP and the WIE's DPA meeting and then summarized collectively for all students. The performance-based evaluation framework is described in Chapter 9, and the questionnaire for the DPA meeting is included in Appendix H (Part E).

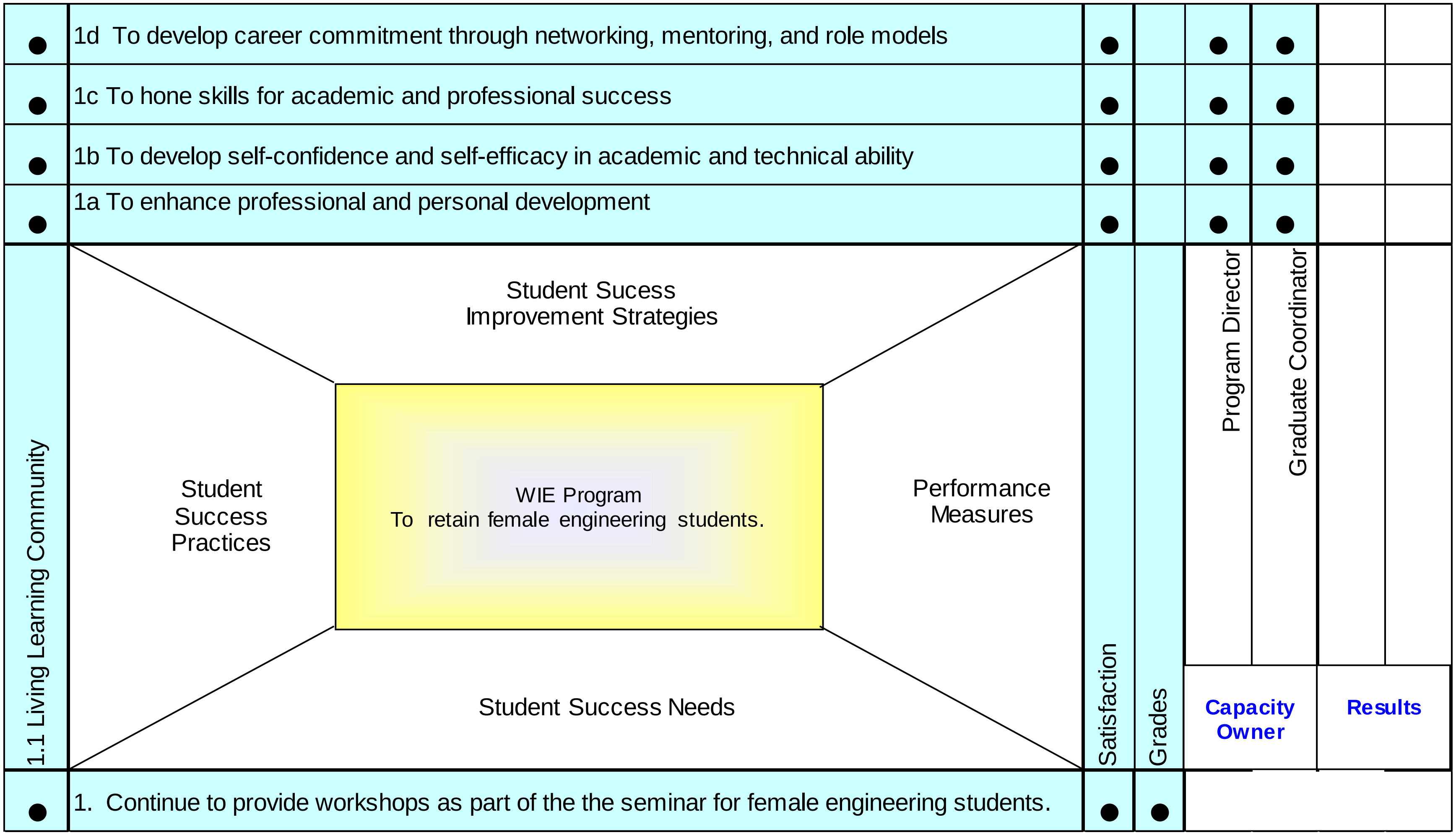


Figure 8-6: WIE Student Success Action Planning Matrix

8.2.6.1 DPA Meeting #1 – MEP

The DPA meeting was first held with the four program administrators from the MEP. As shown in Figure 8-7, the ratings for the usability dimensions ranged from 4.14 (Overall Usability) to 4.52 (Usability of Tools). These results indicate that the design process and the output of the DPA meeting were rated "Good" by the program administrators—with the exception of the Usability of Tools dimension, which was rated "Excellent."

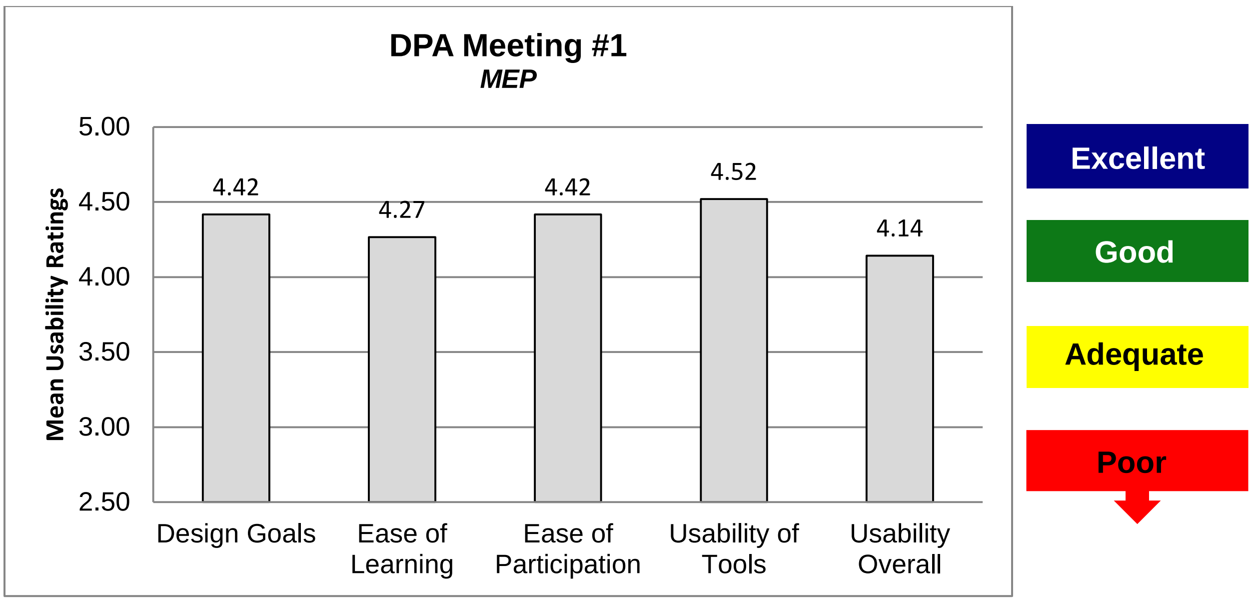


Figure 8-7: Usability Ratings for DPA Meeting #1 – MEP

The program administrators commented that using the tools and learning about the students' perspectives were both very effective. One administrator indicated the importance of "*thinking about the needs of students and how we can help them succeed in school/undergraduate program. This was a great meeting that was very informative.*" Another program administrator added that "*learning how to use the tools*" was an effective part of the DPA meeting. Conversely, problems encountered by the program administrators were related to understanding how to use the tools. One program administrator commented that "*It was a little* *slow at first but we went on some really good information came out.*" Only one recommendation was made, which is featured in Table 8-6.

Table 8-6: Design Changes to Improve DPA Meeting #1 Based on Recommendations

Attribute	Recommendations	Design Changes
Time	Having enough time to devote to the process	Reduced the improvement practices to three instead of four to allow time to thoroughly devote to the process.

8.2.6.2 DPA Meeting #2 – WIE Program

The second DPA meeting was held with the program director of the WIE program. As shown in Figure 8-8, the ratings for the usability dimensions ranged from 3.00 (Overall Usability) to 3.67 (Design Goals). These results indicated that the design process and the outcome of the DPA were rated "Adequate" by the WIE program director.

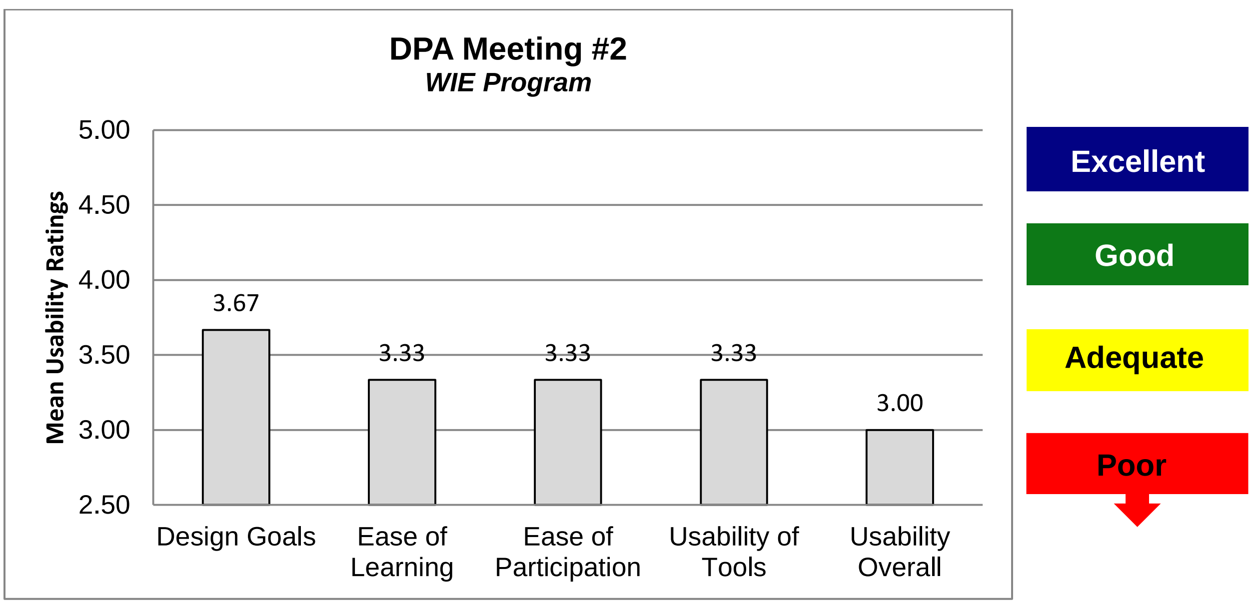


Figure 8-8: Usability Ratings for DPA Meeting #2 – WIE Program

The program director indicated that "*having Tracee (i.e., the researcher/PI) here to explain the tools, learning the students' feedback. Being able to talk through the students'* *perspective vs. what I see as an administrator*" was effective. Conversely, even though the program director did not explicitly state that problems were encountered or provide specific recommendations for improvement, the program director thought that problems would have been encountered if the program was required to complete the DPA meeting without the researcher there to elucidate the process. Therefore, while the S^2OSD methodology was designed to be a facilitator-led approach, the program director supported this design feature by stating:

> *I'm not sure I would have been able to understand this process without Tracee explaining the tools. To adequately get a program admin started with this process may take a facilitator. I do think good results can be found particularly through the student interviews being reconciled with the program administrator's perspective. However, it is important to have an unbiased third party available to represent the student's opinions and discuss issues/ strategies.*

In summary, to address these various concerns, the researcher made the following design changes in Table 8-7.

Table 8-7: Design Changes to Improve DPA Meeting #2 Based on Recommendations

Attribute	Recommendations	Design Changes
Time	• Length of the Meeting	• Addressed in future research
Clarifying the Process	• Clarify the terms • Use examples to facilitate the understanding of how to use the tools.	• The meeting protocol was updated to clarify terms, objectives, discussion questions, and examples. The updated meeting protocol is included in Appendix F.

8.3 Summary of Phase IV: Develop a Plan of Action

This chapter described the development and application of Phase IV of the S^2OSD methodology. The DPA method, meeting process, and tools were used to develop an action plan based on the information generated from the previous phases shown in Figure 8-9. Two meetings were conducted with one program administrator from the WIE program and four program administrators from the MEP.

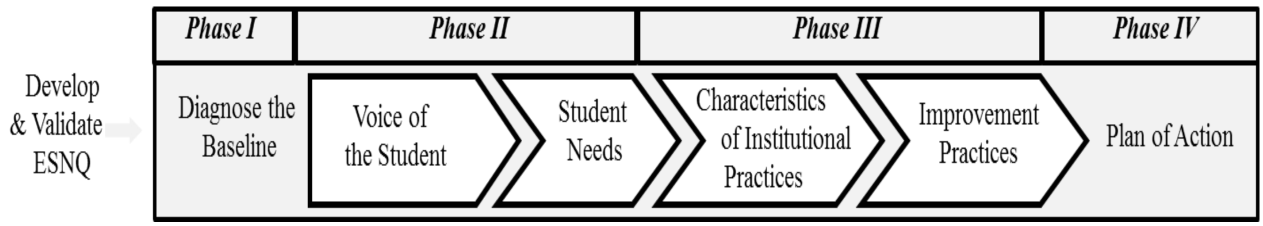
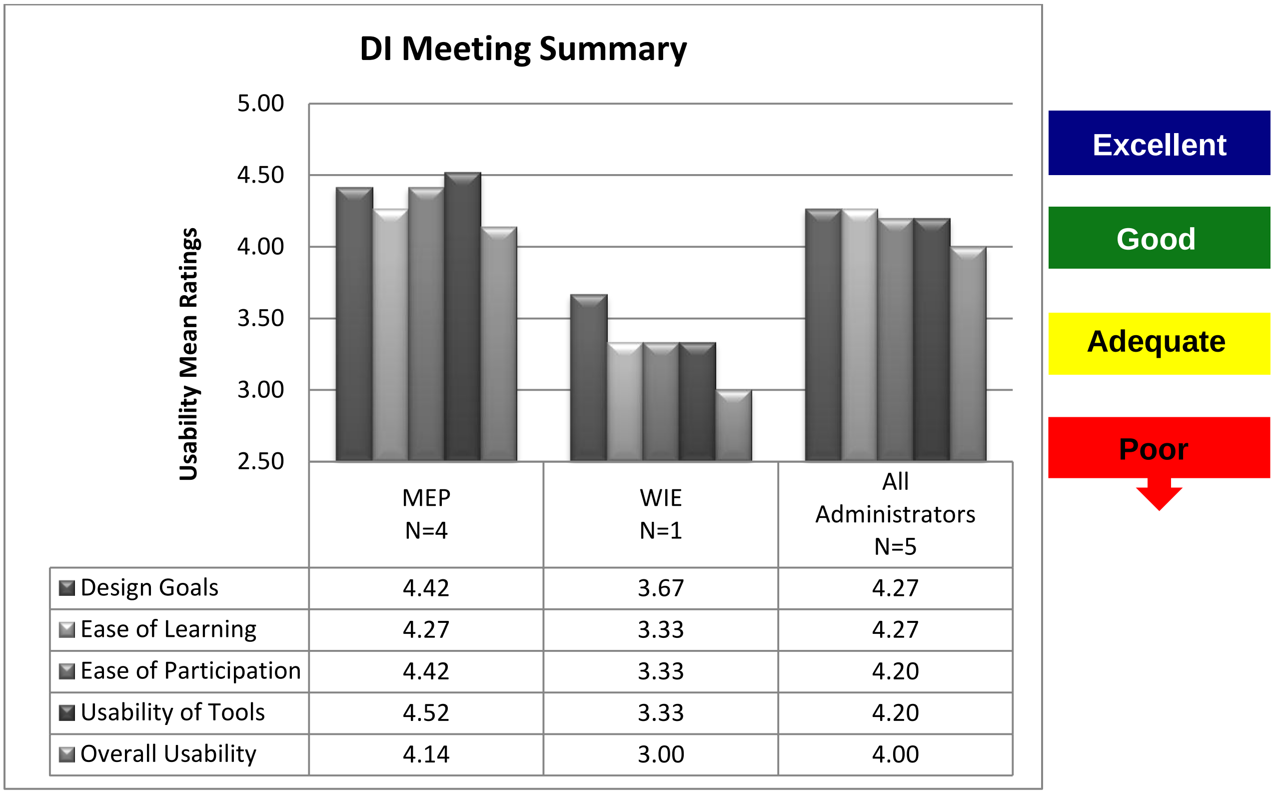


Figure 8-9: Phase IV: Incorporates Information from the Previous Phases

The DPA method emphasized the design philosophy inherent in each phase of the S^2OSD methodology. In other words, at the core of the DPA method is the analysis-synthesis-evaluation principle, which utilizes specific design skills to help program administrators systematically translate student needs into an action plan to facilitate student success. The Student Success Decision Matrix was used as a tool to help program administrators systematically compare and select the most promising improvement practices that resulted from Phase III. Based on the selected improvement practices, a concrete course of action was developed. The Student Success Action Planning Matrix allowed program administrators to align key performance areas (from Phase I) in order to facilitate the focused implementation of program plans.

The *student orientation* principle was reinforced by placing student needs at the heart of the Student Success Action Planning Matrix. The *Vital to Student Success* principle was critical for this phase because the Student Success Decision Matrix helped to prioritize the most promising improvement practices. The *participation* principle was applied in the meeting process, which incorporated a team-based meeting approach into the *analysis-synthesis-evaluation* process. This phase was not intended to holistically develop an action plan. Instead, this phase was devoted to *holistically* completing the conceptual design process and demonstrating the usability of the DPA method. The results of the formative evaluation are summarized in Figure 8-10, in which the usability ratings from the individual DPA meetings as well as for all of the administrators are summarized.



	MEP N=4	WIE N=1	All Administrators N=5
Design Goals	4.42	3.67	4.27
Ease of Learning	4.27	3.33	4.27
Ease of Participation	4.42	3.33	4.20
Usability of Tools	4.52	3.33	4.20
Overall Usability	4.14	3.00	4.00

Figure 8-10: DPA Meeting Summary

Overall, the DPA meetings were shown to be effective based on the program administrators' evaluations, which indicated that the design process and the outcomes of the DPA meetings were "Good". This assessment can be corroborated by the ratings for each of the usability dimensions (Figure 8-10), which ranged from 4.00 (Overall Usability) to 4.27 (Design Goals and Ease of Learning) for all students. Nonetheless, the DPA meetings did not show an improvement between DPA meeting #1 and #2. In fact, all of the usability dimensions showed a decrease in ratings between 0.75 (Design Goals) and 1.19 (Usability of Tools) between DPA meeting #1 and #2. This could be the result of the importance of the DPA meeting as a tool for team-based decision making. For example, the WIE program director decided that Phase IV should be conducted by the sole decision maker of the program. Therefore, these results could suggest that the DPA meeting was less effective for centralized decision making, and more effective for team based decision making.

Based on this hypothesis, future research could be devoted to understanding the determinants of team effectiveness for the DPA meetings. Secondly, additional studies could consider how to comprehensively address a plan of action for the programs. For this research, the team only investigated a few plans to demonstrate the applicability of the framework. In order to be an effective approach for institutional leaders to use on a broader scale, future research should be devoted to applying the methodology more comprehensively.

In summary, the DPA meetings were shown to be effective. As a result, H2.4 was supported. *Phase IV can use the information generated from the previous phases of the* S^2*OSD methodology to develop a plan of action.*

CHAPTER 9 S^2OSD EVALUATION FRAMEWORK

The final stage in this research involved the implementation of a S^2OSD evaluation framework to systematically acquire feedback about its usability. Formative evaluations were conducted during each phase to provide continuous feedback on how to improve the design (Rossi et al., 1999) of the S^2OSD methodology. Furthermore, formative evaluations were used to facilitate the evolution of the S^2OSD methodology. As responses were captured, the next application incorporated that feedback to improve the usability of the S^2OSD methodology.

Additionally, summative evaluations were conducted retrospectively to judge the overall value or worth of the S^2OSD methodology. While formative evaluations aim at forming the methodology throughout each phase, the goal of the summative evaluation is to assess the overall usability of the methodology at the end of the research process (Patton, 2002).

9.1 Participants

The participants of the formative evaluation consisted of the students and institutional decision-makers who participated in the S^2OPD meeting process during the preliminary research and phases of the S^2OSD methodology. However, only the institutional decision-makers that participated in both Phase I and Phase IV of the S^2OSD methodology completed the summative evaluation, since they represent the primary users who will ultimately utilize the output to implement a course of action to address their students' needs.

9.2 Data Collection Procedures

The formative evaluations were completed at the end of each S^2OPD meeting. Paper-based questionnaires were used to conduct both the formative and summative evaluations. However, decision makers had the option to complete the summative evaluations via the web using the Qualtrics survey tool (that was used during the pilot and main study).

9.3 Data Collection Instrument

The formative and summative evaluation questionnaires were designed to collect feedback from the users of the S^2OSD methodology in order to refine and improve it. A performance-based approach to evaluation was used to collect quantifiable information that helped determine if the S^2OSD methodology actually satisfied the goals it set out to achieve. Performance-based evaluations were useful in clarifying the efficacy of the process. As such, a performance-based evaluation was undertaken to ascertain whether the actions taken overall (i.e., summative evaluation) and during each phase (i.e., formative evaluation) produced quality outputs (Norros & Nuutinen 2005, Norros & Savioja, 2004).

Researchers have approached the question of performance by establishing specific evaluation criteria. The ISO Standard's 9241-11 usability definition provides guidance on which aspects of performance need to be considered in the evaluation process. Usability is defined as "the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use" (p. 5). Based on this definition, evaluation criteria can be operationalized into measures of effectiveness, efficiency and satisfaction.

Sink and Tuttle (1989) succinctly described effectiveness as "doing the right things," while efficiency is defined as "doing things right'. Effectiveness has been more formally defined as the "accuracy and completeness with which users achieve specified tasks" (p. 5). Efficiency is defined as the "resources expended in relation to the accuracy and completeness with which users achieve goals" (p. 5). Because ISO's definition of satisfaction is related to comfort, a customer-driven definition of satisfaction was adopted for this research. In other words, satisfaction is defined as an individual's evaluation of their personal experience (Johnson et al., 2001) with the S^2OSD methodology.

Several researchers have defined evaluation criteria for performance-based evaluations. For example, the Halden Reactor Project (HRP) project developed a generic set of performance criteria to evaluate the design process (Miberg-Skjerve & Skraaning, 2003), which was conceptualized based on ISO's measures of effectiveness, efficiency, and satisfaction. The HRP evaluation criteria consisted of three-levels: 1) *user acceptance*, which is the user's judgment or evaluation of the designed system's characteristics and adequacy in relation to the intended functions of the system; 2) *benefits to work process*, which refers to systematic testing of work processes on the individual and team level using realistic versions of the design (e.g., prototypes, mock-ups, etc.); and 3) *benefits to system performance*, which refers to the user's perception of the design solution's capability to enhance the overall performance of the system (i.e., productivity, effectiveness, and safety).

A better known conceptualization comes from Nielsen's (1993) seminal work "Usability Engineering," which was written prior to the ISO standard's development. Nielsen defined criteria for usability based on the following five dimensional quality attributes: 1) *Learnability*: Whether the system is easy to learn; 2) *Efficiency*: Corresponds to the users' steady-state level of performance at the time when their learning curve flattens. 3) *Memorability*: The casual user's ability to use the system, 4) *Error prevention*: Minimum opportunities for users to take incorrect actions, 5) *Satisfaction*: A subjective measure of the users' emotional feelings about the system.

Table 9-1: Design Goals Related to S^2OSD Principles

Phase #	**Design Goals (DG)**	**S^2OSD Principle**
Phase I	To develop a comprehensive view of current practices	(5) Holistic
	To develop a comprehensive view of areas that are targeted for improvement	(5) Holistic
Phase II	To draw out both articulated and unarticulated needs	(2) Analysis-Synthesis-Evaluation
	To transform needs expressed initially as broad ideas into functionally precise statements	(2) Analysis-Synthesis-Evaluation
	To comprehensively define the needs of students that facilitate their success	(4) Vital to Student Success Principle (5) Holistic
Phase III	To translate needs into improvement practices that will facilitate student success	(2) Analysis-Synthesis-Evaluation
	To open up the solution space to include the possibility of unconventional ideas	(2) Analysis-Synthesis-Evaluation
	To increase insights into the critical needs/problems that need to be addressed to help students succeed	(4) Vital to Student Success Principle
	To actively engage students in the design process in order to elicit input that otherwise may not have been gained by decision makers	(3) Participation Principle
Phase IV	To provide a definable course of action that addresses student needs.	(4) Vital to Student Success Principle
	To identify measurable objectives that address student needs, which provide the means to quantify the effectiveness and efficiency of action (i.e., implementation).	(4) Vital to Student Success Principle
	To provide a comprehensive view of the needs of students that facilitate their success	(5) Holistic
	To align needs and improvements in order to facilitate effective decision making (i.e., decisions to address the program's critical problems)	(2) Analysis-Synthesis-Evaluation Principle
	To facilitate the identification of priorities	(4) Vital to Student Success Principle
	To gain additional insight from other meeting participants that could not otherwise be gained alone.	(3) Participation Principle
	To create a framework for internal communication between program personnel	N/A
	To evaluate improvement strategies against requirements	(2) Analysis-Synthesis-Evaluation Principle

Although a number of evaluation frameworks exist—including frameworks that have been applied specifically to learning environments—the existing criteria needed to be adapted to fit into the context of the present study. Evaluation criteria can be grouped into two categories: those designed to evaluate the design process as a process, and those designed to evaluate the output of the design process. The S^2OSD evaluation framework has incorporated both. To evaluate the quality of the output or the outcomes of the S^2OSD methodology, design goals have been developed. Table 9-1 describes the design goals and relates them to the principles of the S^2OSD methodology. Adapting the criteria and definitions from Davis (1989), additional S^2OSD design process dimensions are defined in Table 9-2 to evaluate the design process.

Table 9-2: Design Process Dimensions

Dimension	Definition	Notional Items
Ease of Learning (EL)	The degree to which a person believes the S^2OPD method and tools are not difficult to learn.	• The (Insert Phase) was easy to learn. • My peers could easily learn how to (Insert Process).
Ease of Participation (EP)	The degree to which a person believes that their participation in the S^2OPD meeting was not difficult.	• My role in this (Insert Process) was clear and understandable. • My participation in the (Insert Process) was straightforward. • My peers could participate in (Insert Process) with ease. • I did not encounter problems participating in (Insert Process).
Usability of Tools (UT)	The degree to which a person believes that the tools used to elicit and generate information that is effective, efficient, and satisfactory.	• (Insert Tool) facilitated (Insert Usability description).
Usability Overall (UO)	The degree to which a person believes that using the S^2OSD methodology will facilitate student success.	• I would recommend this approach to faculty and program administrators. • Using the (Insert Process) improves (Insert Outcome).
What aspects of the meeting were effective?		
If you encountered any problems, please explain?		
What needs to be improved?		

The resulting formative and summative evaluations were developed based on the usability dimensions, which included the design goals (Table 9-1) and the design process dimensions (Table 9-2). Additionally, open-ended questions were included to allow participants to provide further recommendations.

9.4 Data Analysis

The responses to the individual items within each usability dimension from the evaluation questionnaire were analyzed to determine the participants' evaluation of the design methods, processes, and tools. To do so, the mean scores for each dimension were calculated. Also, Neale and Nichols' (2001) theme-based content analysis method was used to code the three open-ended questions.

A five-point Likert scale was used to analyze the questionnaire data, in which 1 indicated *Strongly Disagree*, 2 indicated *Disagree*, 3 indicated Neutral, 4 indicated *Agree*, and 5 indicated *Strongly Agree*. To evaluate the usability dimensions, this research adapted Keane and Gilbert's (2007) typology, in which ratings were defined as follows: *Poor* for mean scores below 3, *Adequate* for mean scores between 3 and 4, *Good* for mean scores between 4 and 4.5, and *Excellent* for mean scores between 4.5 and 5. Based on this assessment, mean scores for a dimension that were less than or equal to the midpoint (3) were considered in need of improvement. In cases where the mean score did not meet the threshold, the comments and recommendations from the open-ended questionnaire items were incorporated to refine and improve the various aspects of the S^2OSD methodology. However, the mean scores often met the threshold. In many cases, therefore, the comments were incorporated based on the open-ended questions because they provided insightful recommendations to improve key aspects of the S^2OSD methodology.

9.5 Summary of the Formative Evaluations

Formative evaluations were conducted with the users (i.e., institutional decisions makers and students) at the conclusion of each S^{2}OPD meeting process in order to refine and improve various aspects of this research. Specifically, formative evaluations were completed to evaluate the: DSN method (*Chapter 4*); DB method (*Chapter 5*); the DI method (*Chapter 7*); and the DPA method (*Chapter 8*). The results of the formative evaluations, which are detailed in the aforementioned Chapters, are summarized in Figure 9-1.

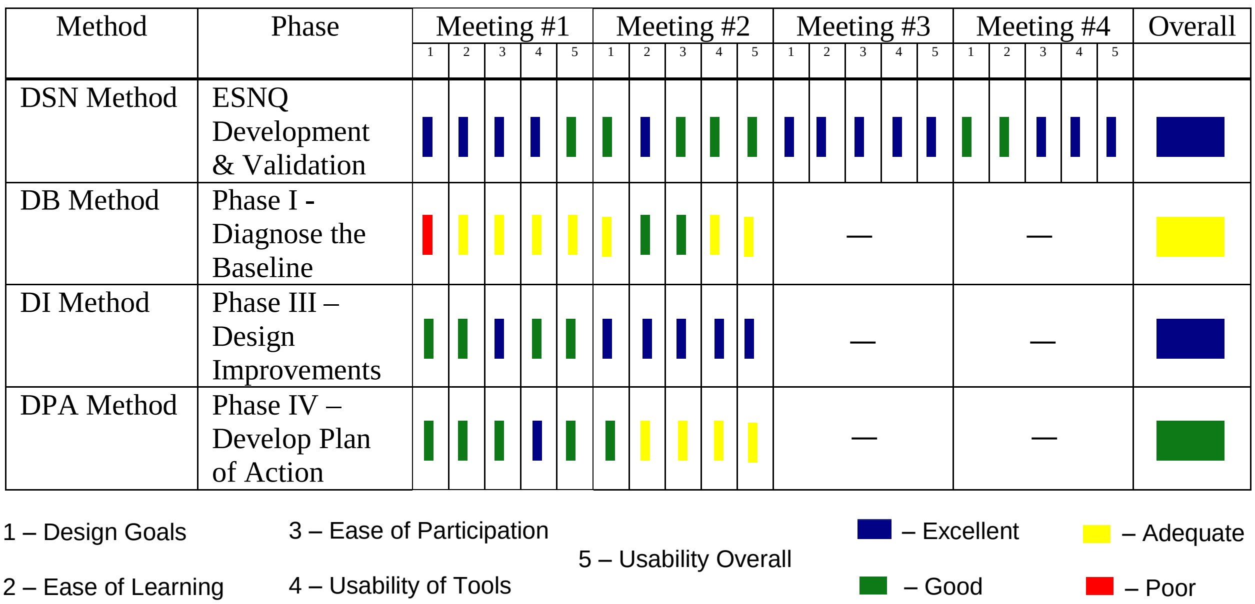


Figure 9-1: Summary of Formative Evaluation Results

The results of the formative evaluation were rated from excellent to poor using the color-coding scheme in Figure 9-1 based on the five usability dimensions. The meetings were rated individually, but also received an overall rating. The four DSN meetings and the two DI meetings received the most favorable ratings overall. Conversely, the two DB meetings and the two DPA meetings received the least favorable ratings overall. Interestingly, the highest-rated meetings were conducted with students, in comparison to the DB and DPA meetings, which were conducted with the institutional leaders.

Also interesting to note is the fact that the two lowest-rated meetings (DB Meeting #1 and DPA meeting #2) were held with the WIE program leaders. This program is characterized by a centralized decision-making structure, such that the program director is the primary decision maker. Therefore, this result could suggest that meetings that are rooted in the participation principle may be less effective for centralized decision making.

Based on the results of the formative evaluations, design changes were made from one meeting to the subsequent meetings. This evolutionary process led to improvements throughout the research process, and the final improved meeting protocols are included in the appendices. As an exception, the ratings improved between DI meeting #1 and DI meeting #2, which was not a consistent pattern across all of the meetings.

9.6 Summative Evaluation

As a result of the formative evaluations, refinements were made to the S^2OSD methodology to address the comments that were provided by users. Following the formative evaluations, a summative evaluation was conducted by the program administrators to retrospectively judge the usability of the refined four-phased S^2OSD methodology. Summative evaluations were conducted for the MEP and WIE program using the usability dimensions in Table 9-1 and Table 9-2. Additionally, the summative evaluations included a S^2OPD meeting process dimension. The performance-based summative evaluation questionnaire is included in Appendix I. The results of the questionnaire are presented for each program and then summarized collectively.

9.6.1 Summative Evaluation – WIE Program

Respondents were asked to assess the design goals and the usability of tools for each phase of the S^2OSD methodology. In the case of the WIE program, the program director was the only WIE representative completing the summative evaluation for this program. As shown in Figure 9-2, the mean ratings for the Design Goals usability dimension ranged from 3.00 (Phase I) to 3.75 (Phase II); and the mean ratings for Usability of Tools dimension ranged from 3.00 (Phase II and Phase IV) to 4.00 (Phase I and Phase III). For each phase of the S²OSD methodology, these results indicated that the Design Goals dimension was rated "Adequate." Furthermore, the Usability of Tools dimension was also rated "Adequate" for Phase II and Phase IV; and "Good" for Phase I and Phase III.

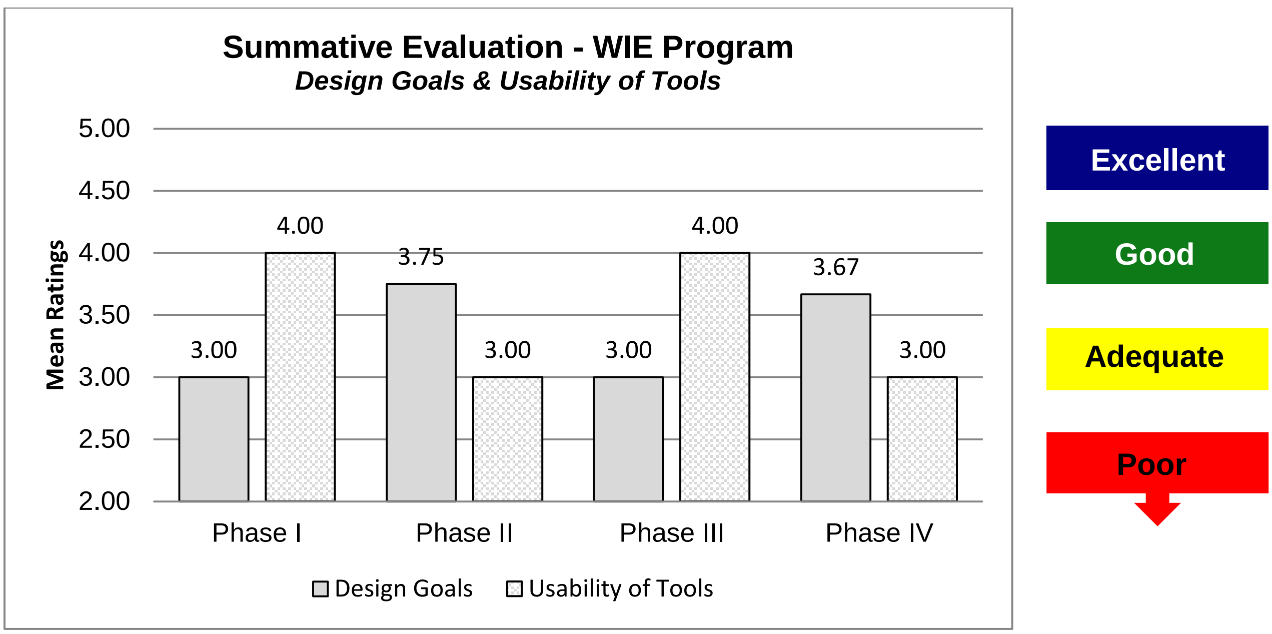


Figure 9-2: Design Goals and Usability of Tools for WIE Program's Phase I – IV

The remaining dimensions are included in Figure 9-3. The mean ratings ranged from 2.5 (S²OPD meeting process) to 2.67 (Ease of Learning, Ease of Participation, Usability Overall), indicating that the design process was rated "Adequate" by the WIE program director – with the exception of the S²OPD meeting process that rated "Poor".

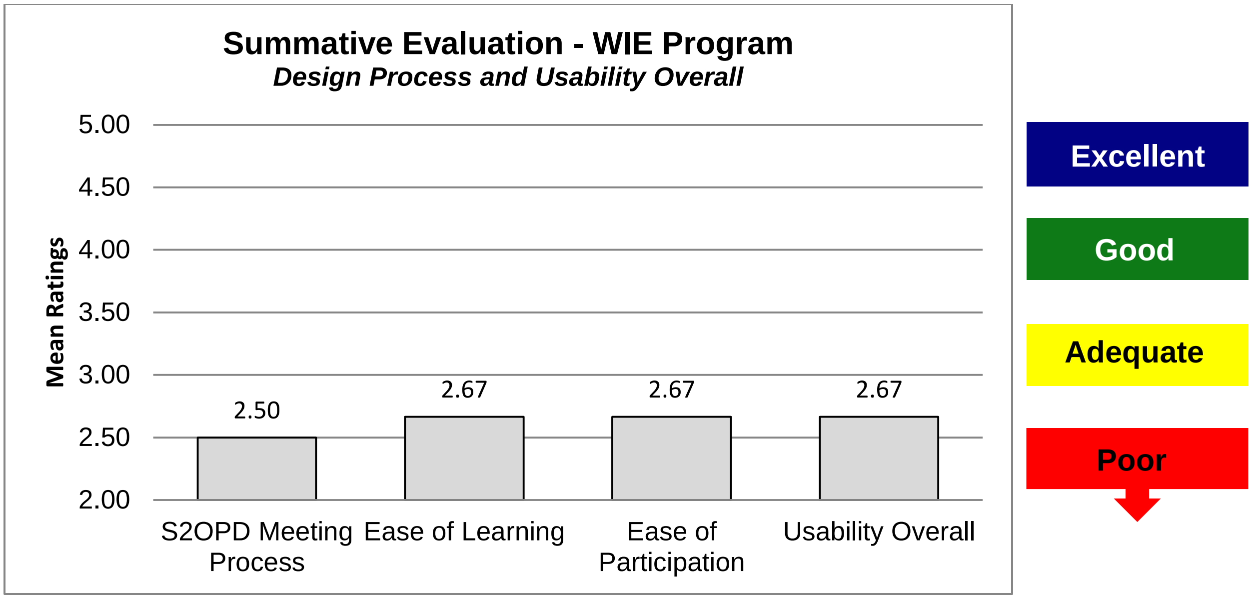


Figure 9-3: Design Process and Usability Overall Ratings for the WIE Program

In terms of specific comments, the program director indicated that the "*feedback from the students was very valuable*." However, the "*approach requires a team to be most effective. Because in my case [there] wasn't a team (so the approach) was very cumbersome*." This feedback supports a fundamental principle of the S^2OSD methodology—namely, the participation principle. The S^2OSD methodology was designed to guide a team through the process of developing a plan of action to address the needs of the students. After Phase I of the S^2OSD methodology, the program director decided that it was ineffective to have the team participate because of the centralized organizational structure of the program.

The program director also commented that "*It was also a little difficult to evaluate the effectiveness of this approach because there has been no time to implement any ideas gained*." The program director recommended that the process should be simplified, more extensive explanations should be provided, and that more time should be added to apply the S^2OSD methodology.

9.6.2 Summative Evaluation - MEP

In comparison to the WIE program's evaluation, four program administrators completed the summative evaluation for the MEP in order to assess the design goals and the usability of tools for each phase of the S^2OSD methodology. As shown in Figure 9-4, the mean ratings for the Design Goals usability dimension ranged from 3.42 (Phase IV) to 4.19 (Phase II); and the mean ratings for Usability of Tools dimension ranged from 3.25 (Phase III) to 4.25 (Phase I). For each phase of the S^2OSD methodology, therefore, these results indicated that the Design Goals dimension were rated "Adequate" for Phase III and Phase IV, and "Good" for Phase I and Phase II. Furthermore, the Usability of Tools dimension was also rated "Adequate" for Phase II, Phase III, and Phase IV; and rated "Good" for Phase I.

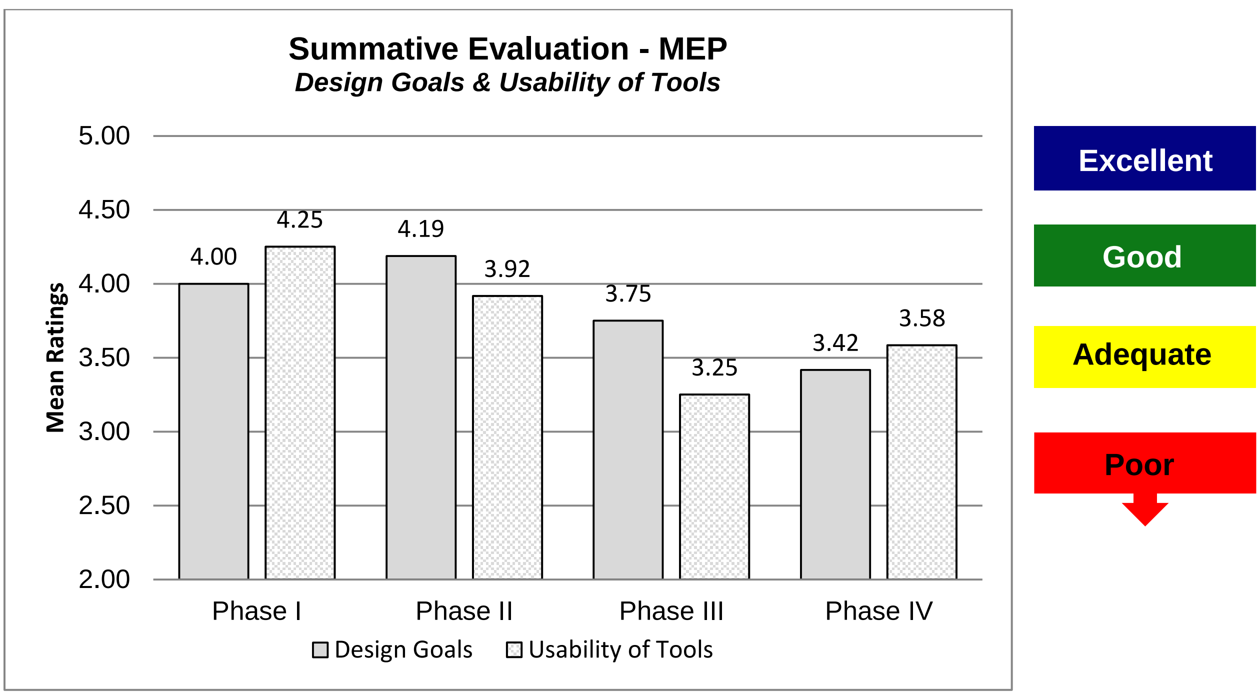


Figure 9-4: Design Goals and Usability of Tools for MEP Phase I – IV

The remaining dimensions are included in Figure 9-5. The mean ratings ranged from 3.67 (Ease of Participation and Usability Overall) to 3.94 (S^2OPD meeting Process), which indicated that the design process and overall usability were rated in the high "Adequate" range by MEP program administrators.

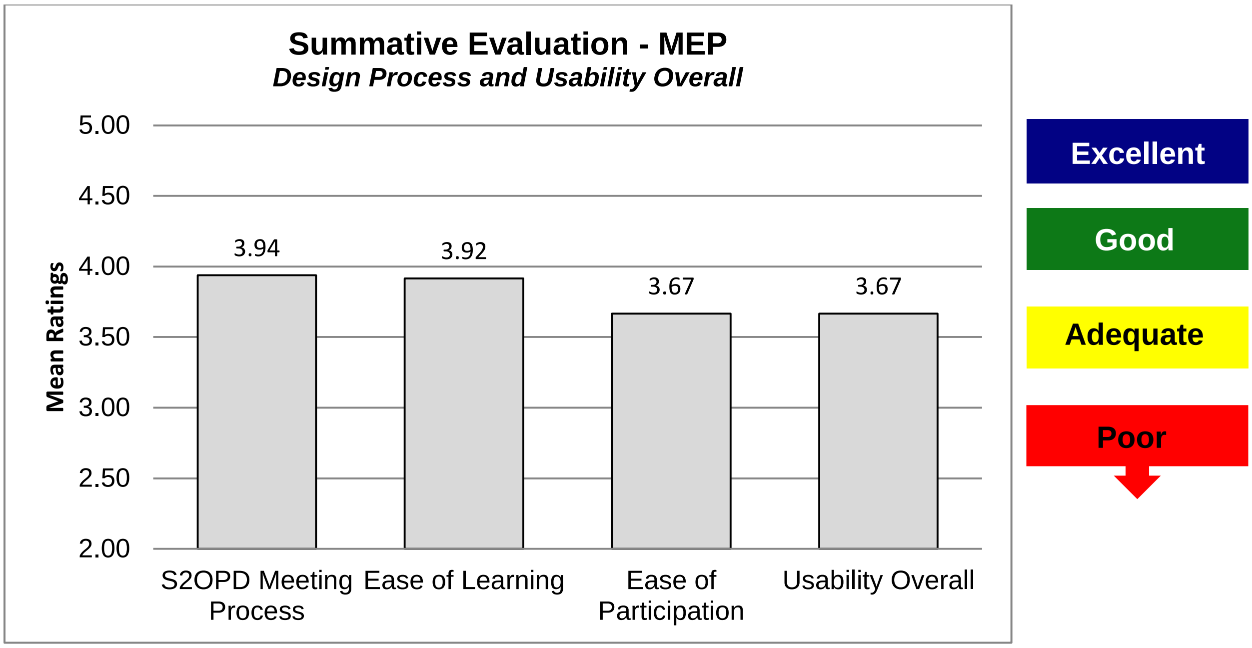


Figure 9-5: Design Process and Usability Overall Ratings for the MEP

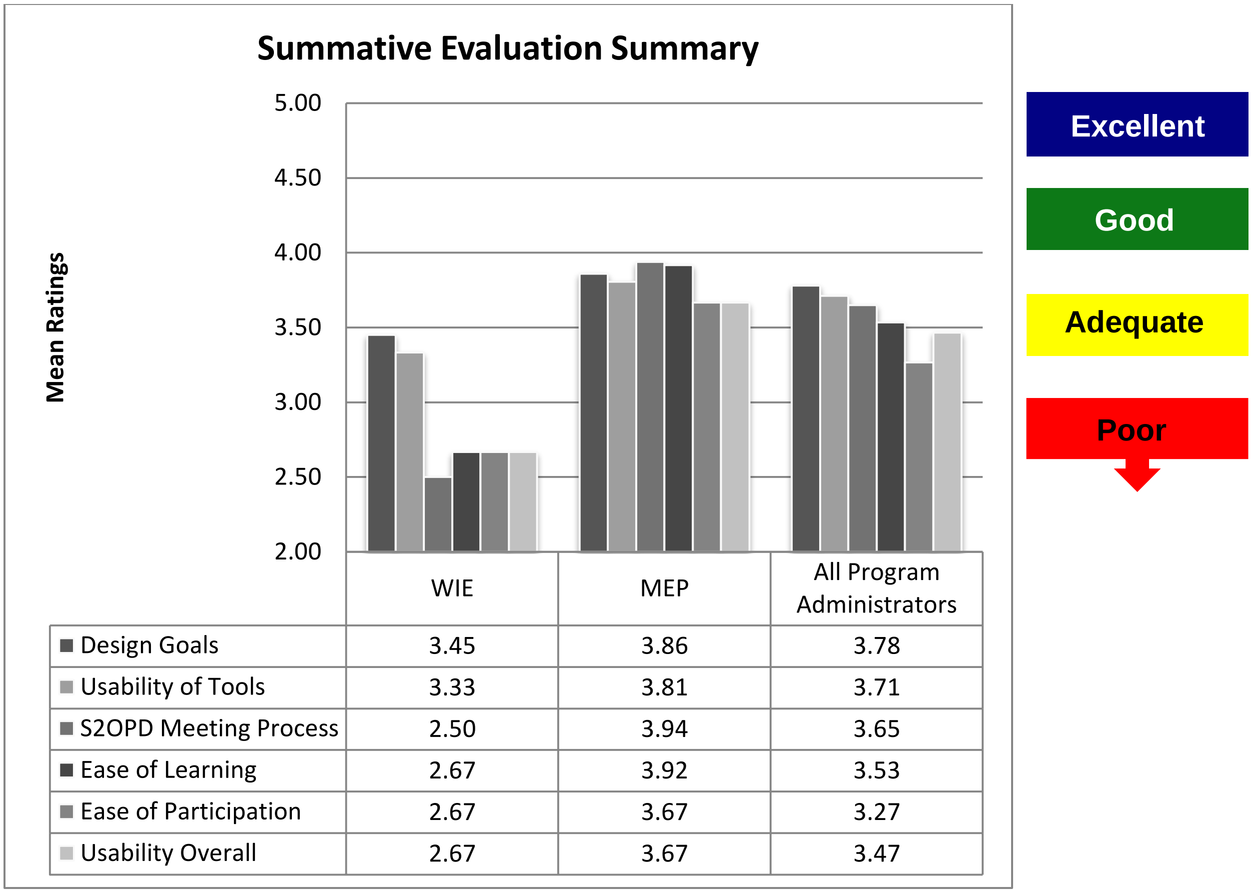
Only three comments were provided by MEP program administrators. One administrator stated that *"I think that the methodology is useful to educators and decision makers who want to provide the best support and/or services to their students by getting their point of view of the services that they would like to receive."* Another program administrator commented that *"Overall, the organizational planning aspect*" was effective. Furthermore, a program administrator commented that *"More examples (are) needed"* to improve the facilitation of the S^2OSD methodology.

9.7 Summary of the S^2OSD Evaluation Framework

Performance-based evaluation questionnaires were developed and used to systematically acquire feedback regarding various aspects of this research. Formative evaluations were completed by the users (i.e., students and institutional leaders) to provide continuous feedback during the preliminary research and the phases of the S^2OSD methodology. Furthermore, summative evaluations were completed by the institutional leaders to retrospectively judge the overall value or worth of the S^2OSD methodology.

Results from the formative evaluations were summarized for each of the S^2OPD meetings that were conducted during preliminary research, Phase I, Phase III, and Phase IV. The results were mixed. The two meetings that were conducted with the students (i.e., DSN and DI meetings) received an overall rating of “Excellent.” For the meetings conducted with the institutional leaders, the DPA meetings received an overall rating of “Good,” while the DB meeting received the least favorable rating of “Adequate.”

As a result of the formative evaluations, improvements were made to the S^2OSD methodology to address the comments that were provided by users. Following the formative evaluations, summative evaluations were retrospectively provided by program administrators to evaluate the usability of the S^2OSD methodology. A total of five program administrators completed the summative evaluations at the applied research site —the program director of the WIE program and four program administrators associated with the MEP. The results of the summative evaluation are summarized in Figure 9-6 for each program individually, as well as collectively for all program administrators.



	WIE	MEP	All Program Administrators
Design Goals	3.45	3.86	3.78
Usability of Tools	3.33	3.81	3.71
S2OPD Meeting Process	2.50	3.94	3.65
Ease of Learning	2.67	3.92	3.53
Ease of Participation	2.67	3.67	3.27
Usability Overall	2.67	3.67	3.47

Figure 9-6: Summative Evaluations Summary

Overall, the S^2OSD methodology was shown to be adequately effective based on the program administrators' evaluations. For the MEP and WIE program, the mean ratings for the Design Goals and Usability of Tools were shown to be "Adequate." Additionally, the S^2OSD Meeting Process, Ease of Learning, Ease of Participation, and Overall Usability were shown to be "Poor" for the WIE program. However, the mean ratings for each of these dimensions increased at least one point for the MEP's evaluation. This suggests, as the WIE program director noted, that the S^2OSD methodology may be more effective in a team-based environment.

Furthermore, Figure 9-6 shows that the summative evaluations were deemed “Adequate” by all program administrators collectively. As a result, a number of areas were identified in future work to improve the usability of the S^2OSD methodology.

CHAPTER 10 SUMMARY AND FUTURE WORK

The objectives of this research were to develop, apply and evaluate the S^2OSD methodology. This methodology was formulated to provide decision makers in higher education with the methods, processes, and tools to design practices in order to meet the needs of engineering students at the applied research site. To achieve these objectives, the first research question and broad hypothesis focused on the developing the S^2OSD methodology, its associated methods and tools, and key outputs of each phase.

> ***(RQ)1:*** *What methods, processes, and tools should be developed to support institutional decision makers in designing practices that meaningfully facilitate student success?*
>
> ***(H)1:*** *From a review of the system design, performance improvement, and student success bodies of knowledge, the phases of the S^2OSD methodology, its associated methods and tools, and key outputs of each phase can be defined.*

Hypothesis 1 was supported. The S^2OSD methodology integrated system design, performance improvement, and the student success theoretical body of knowledge in order to address RQ1. Specifically, this methodology was used to *Diagnose the Baseline* (Phase I) of current student success practices, *Identify Needs* (Phase II) that are currently not being met, *Design Improvements* (Phase III) to address critical unmet needs, and *Develop a Plan of Action* (Phase IV) to implement student success practices.

At the heart of the methodology is a design philosophy that is based on the following five principles:

1. *Student Orientation*: Satisfying the needs of students is the driving force behind each phase.
2. *Analysis-Synthesis-Evaluation Principle*: Provides the basic structure for the design process, which utilizes the design skills of abstraction, persistent questioning,

identifying critical performance areas, and factorization to facilitate the conceptual system design process.

3. *Participation Principle*: Facilitates the participation of key stakeholders (i.e., students and decision makers) in the design process.
4. *Holistic Principle*: Encompasses all of the phases of the conceptual system design process in order to translate student needs into an action plan that facilitates student success.
5. *Vital to Student Success Principle*: Focuses the design process on specific aspects that are critical to student success.

10.1 Summary of Research Findings

In order to develop, apply, and evaluate the S^2OSD methodology, a three-staged approach was used to address the purpose and objectives of this study. In the first stage, preliminary research was conducted to develop a participatory design method to execute the phases of this research. Additionally, preliminary research was conducted to develop and validate the ESNQ. Then, the four-phased S^2OSD methodology was developed and applied to a top university's MEP and WIE program during the second stage. In the third and final stage, the S^2OSD evaluation framework was presented, which was developed to evaluate (both formative and summative) the usability of the S^2OSD methodology. A summary of the research findings for the three stages are described.

10.2 Stage I: Preliminary Research

The first stage of this research consisted of conducting preliminary research 1) to develop a participatory design approach to execute the stages of this research; and 2) to develop and validate a conceptual model of engineering student success needs, which was used as the basis for creating the pilot version of the ESNQ.

10.2.1 Develop S^2OPD Method Summary

The S^2OPD method represents a participatory design approach that actively involved the primary customers (i.e., the students) in the design of student success practices. The S^2OPD method was embedded into the stages of this research in order to facilitate a team-based meeting approach to define student needs (preliminary research – DSN method), diagnose the baseline (Phase I – DB method), design improvements (Phase III – DI method), and develop a plan of action (Phase IV – DPA method) that fosters student success. As a result, the S^2OPD method was initially developed to provide the scope and guidance for realizing the phases of the S^2OSD methodology and to conduct the preliminary research.

Information gathering and participatory design methods were adapted to develop a five-step meeting process ("Inform > Elicit > Generate > Validate > Evaluate") that was used to carry out this research. The structured meeting process was designed 1) to improve the quality of information generated, 2) to provide a self-documenting process, and 3) to utilize the team synergy to conduct qualitative data analysis during the meeting process (which is typically conducted in qualitative studies after a meeting).

The design skills of abstraction, persistent questioning, identifying critical performance areas, and factorization were infused into the meetings to facilitate the analysis-synthesis-evaluation cycle. As a result, the meeting process was structured to capture ideas, which were organized such that tools could be generated to provide actionable information for decision making.

10.2.2 Develop and Validate ESNQ Summary

While the S^2OPD method was used to carry out the preliminary research and Phase I, III, and IV, the ESNQ was used to carry out Phase II (Identify Needs) of the S^2OSD methodology. In order to develop and validate the ESNQ, a conceptual model of student success needs was first developed and tested during preliminary research. To accomplish this goal, a questionnaire development and validation process was undertaken. This began with an extensive literature review (Chapter 2), in which a typology of student success factors was developed. The typology, which was derived from a collection of student success theoretical perspectives, identified the broad elements from the literature that where shown to facilitate student success. Although these factors explained why students decided to leave or stay in college, they did not directly define the needs of students. Furthermore, the factors were not specific to engineering students. As a result, the identified typology was used as the starting point to derive the student success needs of engineering students during the DSN meetings. Based on the results of the DSN meetings, an initial version of the ESNQ was developed.

Following the questionnaire development process, the instrument was initially validated via two rounds of expert reviews—with students during the first round, and with student success researchers and practitioners during the second round. Based on these expert reviews, the ESNQ was revised. As a result, the conceptual model was developed and tested during the pilot study.

The purpose of the pilot study was to examine the validity and reliability of the conceptual model, refine the questionnaire design and administration procedures, and to refine the ESNQ for the main study. To accomplish these goals, exploratory principal component factor analysis using varimax rotation was utilized to assess the quality of the items and the model factors. Then a reliability analysis utilizing Cronbach's Alpha coefficient was used to test the reliability of the factors identified from the EFA. As a result, a statistically verified model of student success needs was developed to address a number of sub-questions and hypotheses. The model consisted of the following 7 dimensions of student success needs: Classroom Learning, Faculty Interaction, Sense of Community, Financial, Skill, Workload Management, and Professional Development needs. Based on the conceptual model, the ESNQ was prepared for the main study in Phase II.

10.3 Stage II: Develop and Apply the S^2OSD Methodology

The second stage of this research consisted of developing and applying the S^2OSD methodology at a large Doctoral-Granting Institution in the Northeast. Specifically, the four phased methodology was applied to both the MEP and WIE program at the applied research site. A summary of the research findings to address Research Question 2 are presented below.

Research Question 2: *What information does the S^2OSD methodology provide institutional decision makers?*

Broad Hypothesis 2: *The S^2OSD methodology provides information to guide decision makers through the process of diagnosing the baseline, identifying needs, designing improvements, and developing a plan of action.*

10.3.1 Phase I: Diagnose the Baseline

The first phase of the S^2OSD methodology consisted of diagnosing the baseline of the MEP and WIE Program. Utilizing the S^2OPD method, institutional leaders were able to systematically think through the current state, and define the desired state of the program during the DB meeting. The following hypothesis was tested to address research question 2.1:

RQ 2.1*: How can decision makers assess their current state and define how to satisfy engineering student success needs in the future?*

H2.1: *Phase I of the S^2OSD methodology can be used to assess and understand how to satisfy engineering student success needs.*

To address Research Question 2.1, Phase I consisted of examining a program's current state, its strengths and weaknesses, and identifying the desired state for the program using the following six key performance areas identified for this research: goals, student success needs, student success practices, capacity, results, and performance measurement. By linking the six performance areas, the DB Method was developed and utilized to brainstorm and document how decision makers satisfy student needs within the context of their program's environment.

Two DB meetings were conducted with program administrators at the applied research site to determine whether Phase I of the S^2OSD methodology could be used to assess and understand the needs of engineering students. To test Hypothesis 2.1, formative evaluations were completed by the program administrators. Overall, the DB meetings were shown to be moderately effective based on the institutional leaders' evaluations, which indicated that the design process and the output of the DB meetings were "Adequate."

10.3.2 Phase II: Identify Needs

The second phase of the S^2OSD methodology consisted of identifying the needs of female and URM engineering students. In order to carry out Phase II, the conceptual model from preliminary research was tested in order to develop a statistically-verified research model. The model was used as the basis for developing the ESNQ. The following hypothesis was used to test to address research question 2.2:

RQ 2.2*: What are the needs of engineering students that facilitate student success?*

Broad Hypothesis 2.2: *Phase II of the S^2OSD methodology can be used to identify and prioritize engineering student success needs.*

In order to address RQ2.2, a number of statistical analyses were employed to empirically test the relationships between model variables (based on the sub-questions and hypotheses in Section 6.3). To begin, correlation analysis was performed to assess the strength of the relationships between the independent (i.e., Overall Satisfaction) and dependent variables (i.e., Unmet Needs Scores for the dimensions of student success needs). Then hierarchical linear regression was performed to assess the relationships between the dimensions of student success needs and overall satisfaction. Based on the results, a refined model was developed that identified the dimensions of *Classroom Learning* and *Workload Management* needs as contributing significantly to *Overall Satisfaction*.

In order to use acquired data to facilitate decision making for the MEP and WIE Program, the SNID method was developed to gather, organize, assess, and establish the relative importance of the student success needs from the ESNQ. Adapted from Ulrich and Eppinger's (2008) customer needs identification method, the following five-step process was then applied to the MEP and WIE programs at the applied research site: Administer ESNQ, Analyze ESNQ data, Create Action Grid, Calculate Index for Prioritization, and Review Results.

The questionnaire was completed by 213 engineering students at the applied research site. For the WIE Program, the data was analyzed for the 105 female engineering students using a series of two-way ANOVAs to investigate the main effect of gender, a main effect of ethnicity/race, and the interaction effect between gender and ethnicity/race. While there were no statistically significant relationships found, descriptive statistics revealed that the dimensions of

Classroom Learning and *Workload Management* needs (which also were identified as a result of the regression analysis) were not being met by the institution.

For the MEP, a series of one-way ANOVAs were used to examine the unique needs of URM students. Statistically significant relationships were found for the *Classroom Learning, Financial, Faculty Interaction, Sense of Community,* and *Student Interaction* needs among the freshmen and junior URM engineering students. Descriptive statistics also revealed that freshmen were the most satisfied URM engineering students and juniors were the least satisfied URM engineering students with regard to their needs being met. This conclusion, therefore, suggests that improvement efforts should be targeted at URM junior engineering students. Additionally, a series of one-way ANOVAs were conducted to investigate the differences between minorities and non-minorities. Although there were no statistically significant relationships found, descriptive statistics provided useful information for decision makers. URM students reported the highest unmet need scores for the dimensions of *Classroom Learning* and *Workload Management* needs. This indicated that these needs required the greatest attention because they were currently not being met for URM students.

For each program, an action grid was created to structure the needs into a hierarchy. The results revealed that the dimensions of *Classroom Learning* and *Workload Management* needs required the greatest attention from program administrators. During this step, program administrators were able to identify gaps between their perspectives from Phase I with the students' perspective from Phase II. Then, an USN_i was created to prioritize those needs that required the greatest attention. Finally, the results of the SNID method were reviewed in order to determine those needs that would be considered during Phase III for improvements.

10.3.3 Phase III: Design Improvements

The third phase of the S^2OSD methodology consisted of designing improvements to address the critical unmet needs of students identified during Phase II. Utilizing the S^2OPD method, students were guided through a structured idea-generation process to design improvements during the DI meetings. The following hypothesis was used to investigate Research Question 2.3:

RQ2.3: *How can improvement practices be designed to meet engineering student success needs?*

H2.3: *Phase III of the S^2OSD methodology can be used to design improvement practices to meet the student success needs of engineering students.*

To address Research Question 2.3, Phase III consisted of utilizing a functional decomposition process that began during the DSN meeting. With this in mind, Phase III consisted of identifying the characteristics of institutional practices that were shown to satisfy student needs, and transforming those characteristics into improvement practices as recommended by program administrators in Phase IV. This approach incorporated design skills, which allowed participants to consider a range of ideas without being fixated on traditional ideas.

Two DI meetings were conducted with students at the applied research site to determine if Phase III of the S^2OSD methodology could be used to design improvements to address the critical unmet needs of engineering students. To test Hypothesis 2.3, formative evaluations were completed by the students. Overall, the DI meetings were shown to be very effective based on the students' evaluations, which indicated that the design process and the outputs of the DI meetings were "Excellent."

10.3.4 Phase IV: Develop Plan of Action

The fourth and final phase of the S^2OSD methodology was designed to guide institutional leaders through the process of deciding on an action plan based on the information generated from the previous phases. During this phase, program administrators from the MEP and WIE program linked key performance areas (from Phase I) of the S^2OSD methodology in order to develop a framework for action that placed the needs of the students at the heart of the process. This phase tested the following hypothesis to address the research question 2.4.

> ***RQ2.4****: How can the information generated from the previous phases be translated into a plan of action that promotes student success?*
>
> ***H2.4:*** *Phase IV can use the information generated from the previous phases of the S^2OSD methodology to develop a plan of action.*

To address Research Question 2.4, Phase IV reviewed the information generated from the previous phases. Using an Improvement Practices Decision Matrix, improvement practices proposed by the students during Phase III were evaluated by program administrators to analyze and select the most feasible improvement practices to meet the unique needs of their students. Based on this analysis, the Student Success Action Planning Matrix was generated as an alignment tool that linked key performance areas in order to facilitate a focused execution of program plans (Marhevko, 2007).

Two DPA meetings were conducted with program administrators at the applied research site for the MEP and WIE program. To determine if Phase IV of the S^2OSD methodology could be used to develop an action plan for facilitating the student success needs of URM and female engineering students, formative evaluations were completed by the program administrators to test Hypothesis 2.4. Overall, the DPA meetings were shown to be effective based on the program administrators evaluations, which indicated that the design process and the output of the DI meetings were "Good."

10.4 Stage III: S^2OSD Evaluation Framework

The final stage in this research developed and utilized the S^2OSD evaluation framework to address Research Question 3. Formative evaluations were conducted to provide continuous feedback on how to improve the design (Rossi et al., 1999) of the S^2OSD methodology. The formative evaluations were used to test the usability of each meeting that used the S^2OPD method (during preliminary research and during Phase I, III, and IV). Additionally, summative evaluations were conducted retrospectively to judge the overall value or worth of the S^2OSD methodology. As such, Hypothesis 3 was affirmed.

***RQ3**: What methods can be used to evaluate the S^2OSD methodology in order to refine and improve it?*

***H3:** Formative and summative evaluation methods can be used to evaluate the S^2OSD methodology in order to refine and improve it.*

This study presented a formative evaluation framework, which provided the evaluation process, criteria, and questionnaires to systematically assess and improve the usability of the S^2OSD methodology. The formative evaluations were used to make design changes based on the feedback received from the users of the S^2OSD methodology. Therefore, the formative evaluations facilitated the evolution of the usability of the S^2OSD methodology. As feedback was gained from each application, the knowledge gained was incorporated into the next application to improve its usability.

The summative evaluations were used to retrospectively evaluate the value and worth of the S^2OSD methodology. Overall, Hypothesis 2 was moderately supported. In other words, the

S^2OSD methodology was shown to be moderately effective based on the program administrators' evaluations, which indicated that the design process and the outputs of the S^2OSD methodology were "Adequate."

10.5 Research Contributions

The multidisciplinary nature of this research provides important contributions to the existing body of customer and student-oriented knowledge—particularly in the areas of system design, performance improvement, participatory design, usability, and student success theoretical research. As such, this dissertation has methodological, theoretical, and practical contributions to research and practice.

Methodological Contributions

The first methodological contribution involved the creation of the proposed **system design** methodology. The S^2OSD methodology focused on the conceptual design stage of the systems engineering lifecycle. Therefore, the methodology provided a framework that began with the assessment of student success needs and progressed through a series of phases to generate a plan of action to satisfy the needs. The major components of the S^2OSD methodology included (1) the four-phased methodology with associated methods, processes, and tools to carry out each phase; (2) a design philosophy with mutually-reinforcing principles; and (3) protocols that a facilitator can use to guide practitioners through the conceptual design of student-success practices. Furthermore, the design skills of abstraction, persistent questioning, identifying critical performance areas, and factorization were infused into each phase in order to simplify the design process. By doing so, practitioners in higher education (many of whom typically don't have an engineering design background) can utilize critical and creative thinking to develop solutions that facilitate student success.

The second methodological contribution is the integration of the **performance improvement** and system design bodies of knowledge. By integrating characteristics of performance measurement systems from the literature, a framework was created that identified six interrelated performance areas. These performance areas were used to guide decision makers through the process of diagnosing performance (Phase I), and developing a plan of action (Phase IV) in areas of higher education that are critical to helping students succeed. Although there have been performance measurement frameworks applied from industry and developed specifically for the education domain, this research represents a unique approach that places student success needs at the heart of the organizational performance improvement framework.

The third methodological contribution involves the **participatory design** body of knowledge. The S^2OPD method was created to provide a facilitated five-step group meeting process that was able to generate tools for decision making. By incorporating the participation of students and decision makers, the design process ensured that the VoS (voice of the student) was captured throughout this research. Furthermore, the qualitative data analysis activities (e.g., developing classification and coding schemes), which are typically conducted by the researcher after the meeting, were incorporated into the meeting process. As a result, the tools generated from the S^2OPD method transformed the massive amounts of data into a structured format that could be used to make decisions and take action to help students succeed.

Finally, the fourth methodological contribution is reflected in the **usability** body of knowledge. A performance-based evaluation framework was developed to evaluate the usability of the S^2OSD methodology. Although a number of evaluation frameworks have been developed in the usability literature, these evaluations tended to focus on efficiency, effectiveness, and satisfaction as it related to human-computer interactions (e.g., software engineering, product quality, or ergonomics). As a result, the S^2OSD evaluation framework developed an evaluation process, usability dimensions, and questionnaires to systematically assess and improve the usability of the S^2OSD methodology in the student success domain.

Theoretical Contributions

Several contributions to the student success theoretical body of knowledge have resulted from this study. From a review of **student success theoretical research**, a typology of student success factors was created to describe the broad factors from the extant literature that contribute to student success. This typology was used as the basis for conducting the empirical research, in which a model of student success needs was developed and validated in order to identify student success needs that relate to the student success outcome (i.e., Overall Satisfaction). This model led to the development of a new ESNQ, which was used to assess the student success needs of engineering students. The empirical aspect of this research shifted the focus from trying to understand *why* students decide to leave/stay in college to *understanding and satisfying the needs of the students*.

Practical Contributions

By integrating student success research with the growing body of system design and performance improvement literature, this research contributed to student success practice. Specifically, by providing actionable information to decision makers, student success practitioners can develop viable programs and policies to help students succeed. Furthermore, this research contributes to the systems engineering discipline by presenting a novel approach to analyzing, designing, and improving the performance of higher education systems.

10.6 Future Work

The S^2OSD methodology was developed, applied, and evaluated at the applied research site. Through its application and evaluation, future research can be conducted in five areas to extend the usability of the methodology.

1. Expanding the Operationalization of Student Success

This research focused on student satisfaction, which is an often-overlooked outcome that is useful in determining the quality of the educational experience (Kuh et al., 2006), as a measure of student success. As Braxton et al. (2006) noted, although there are several measures of student success, the most frequently-cited theories define student success in college in terms of persistence, educational attainment, and obtaining a degree (Kuh et al., 2006). Future research should investigate the relationship between satisfying student needs and additional measures of student success (e.g., attrition rates, persistence rates, GPA, graduation rates).

2. Strengthening the Validity and Reliability of the ESNQ

Although the ESNQ met the recommended thresholds for reliability and validity, additional items can be tested to strengthen the dimensions of Classroom Learning and Skill needs. Additionally, test-retest reliability can also be used (in addition to Cronbach Alpha's coefficient used in this research) to administer the instrument to the same respondents on different occasion. By using this statistical technique to determine if the correlation between the two administrations is high, the reliability of the instrument reliability can be strengthened. Furthermore, the cultural validity of the instrument should be assessed with a larger sample size. By doing so, future research can examine the socio-cultural influences that shape how URM and female engineering students make sense of the ESNQ items and respond to them (Solano-Flores & Nelson-Barber, 2001).

*3. **Transitioning from a Performance Measurement System to Management System***

The application of the S^2OSD methodology embedded a performance measurement system into Phase I and Phase IV. The performance measurement system provided actionable information about critical performance areas within the organizational unit (i.e., the MEP and WIE programs). As a result, decision makers were able to assess the strengths and weaknesses of the organization, determine future initiatives, and provide a basis for assessing progress toward predetermined objectives with the goal of improving organizational performance (Amaratunga & Baldry, 2002).

In order to use the S^2OSD methodology on an ongoing basis (e.g., annually), future research should be devoted to transitioning the measurement system into a management system. The objective of a performance management system is to provide a closed-loop control system, where practices are deployed to all processes, activities, task and personnel, and feedback is obtained through the performance measurement system to enable the appropriate management decisions (Bititci et al., 1997) that stimulate improvement.

4. Further Applying the S^2OSD Methodology and Evaluating its Effectiveness

As a result of the formative and summative evaluations, a number of suggestions and areas for improving the usability of the S^2OSD methodology were provided. In Phases I, III and IV, suggestions from Meeting #1 were incorporated into the process to execute Meeting #2. However, recommendations were also made as a result of Meeting #2. These design changes should be made and further applications should be carried out to improve the usability of the S^2OSD methodology. Furthermore, this research was intended to present selected examples of the S^2OSD methodology to demonstrate its usability. Future work can be devoted to more expansive applications. Moreover, future developments can also benefit from applying the methodology to various levels of the institution (dean, department, and program level).

Although this research evaluated the effectiveness of the methods, processes, and tools of the S^2OSD methodology as a part of the formative and summative evaluations, evaluating outcome effectiveness is also an area that could be explored. By evaluating outcomes, program administrators can then determine if the methodology actually improves student success outcomes.

5. Incorporating Multiple "Customers" into the S^2OSD Methodology

There are multiple stakeholders that provide a range of perspectives on what constitutes student success. For example, Crawley et al. (2007) defined four primary customer groups in the context of engineering education: students, university faculty, industry, and society. While industry (including program alumni working in industry) is the ultimate customer of engineering student success, the immediate customers of engineering education are the students themselves. Since students are being educated because they lack the requisite skills to be successful in their chosen fields, faculty also plays an important role because they create and deliver the knowledge, skills, and attitudes that are needed for students to be successful in engineering education. Additionally, society sets the requirements for engineering education through legislation and accreditation. Therefore, future research should also incorporate these multiple perspectives into the S^2OSD methodology for a more comprehensive view of student success needs.

REFERENCES

Abernathy, M., & Chua, W. (1996). A field study of control system "redesign": the impact of institutional processes on strategic choice. *Contemporary Accounting Research*, 13(2), 569-696.

Abras, C., Maloney-Krichmar, D., Preece, J. (2004). User-Centered Design. In Bainbridge, W. (Ed.), *Encyclopedia of Human-Computer Interaction*. Thousand Oaks: Sage Publications.

Ackoff, R. (1962). *Scientific Method.* New York, NY: John Wiley & Sons.

Adelman, C. (1998). *Women and men of the engineering path: A model analysis of undergraduate careers*. Washington, DC: U.S. Department of Education.

Akao, Y. (2004). *Quality Function Deployment: Integrating Customer Requirements into Product Design.* Cambridge, MA: Productivity Press.

Akao, Y. & G. Mazur (2003). The Leading Edge in QFD: Past, Present and Future. *International Journal of Quality & Reliability Management*, 20 (1), 20-35.

Alexander, C. (1964). *Notes on the Synthesis of Form*. Cambridge, Massachusetts: Harvard University Press.

Aliff, J.V. (1998). *Are students 'customers' of collegiate education? Proceedings of the Annual General Meeting of the Georgia Academy of Science*.

Allen, C. D. , Ballman, D., Begg, V., Miller-Jacobs, H. H., Nielsen, J., Spool, J., & Muller, M. (1993). *User involvement in the design process: Why, When and How? Proceedings in the Conference on Human Factors in Computing Systems*, New York, NY.

Aly, N. & Akpovi, J. (2001). Total quality management in California public higher education. *Quality Assurance in Education*, 9(3), 127-31.

Andersen, B. and Fagerhaug, T., (2002). Eight steps to a new performance measurement system, *Quality Progress*, 35(2), 112.

Anderson, E.W., Fornell, C. & Lehmann, D.R. (1994). Customer satisfaction, market share and profitability: findings from Sweden. *Journal of Marketing*, 58, 53-66.

Anderson, E.W. & Mazvancheryl, S.K. (2004). Customer Satisfaction and Shareholder Value. *Journal of Marketing*, 68, 172–85.

Andersen, T.J. (2000). Strategic planning, autonomous actions and corporate performance. *Long Range Planning*, 33, 184-200.

Appiah-Adu, K. & Singh, S. (1998). Customer Orientation and Performance: A Study of SMEs. *Management Decision*, 36(6), 385–402

Amaratunga, D., & Baldry, D. (2002). Moving from performance measurement to performance management. *Facilities, 20*(5/6), 217- 223.

Armstrong (1982). The value of formal planning for strategic decisions: Review of empirical research. *Journal of Strategic Management*, 3(3), 197-211.

Arthur, J. D. & Groener , M. K. (2005). An operational model for structuring the requirements generation process. *The Requirements Engineering Journal*, 10, 45–62.

Astin, A. W. (1984). Student involvement: A developmental theory for higher education. Journal of College Student Personnel, 25, 297-308

Astin, A. W. (1993). *What matters in college? Four critical years revisited.* San Francisco, CA: Jossey-Bass.

Astin, A. W., & Dey, E. L. (1997). *Causal analytical modeling via blocked regression analysis (CAMBRA): An introduction with examples*. Los Angeles, CA: Higher Education Research Institute.

Astin, A.W., & Denson, N. (2009). Multi-Campus Studies of College Impact: Which Statistical Method is Appropriate? *Research in Higher Education*, 50(4), 354-367.

Astin, A. W., & Oseguera, L. (2005). Pre-college and institutional influences on degree attainment. In A. Seidman (Ed.), *College student retention: Formula for student success* (pp. 245-276). Westport, CT: Praeger.

Attinasi, L. C. (1989). Getting in Mexican Americas' perceptions of university attendance and implications for freshman year persistence. *Journal of Higher Education*, 60, 247-277.

Attinasi, L. C. (1992). Rethinking the study of the outcomes of college attendance. *Journal of College Student Development*, 33, 61-70.

Avison, D.E., & Fitzgerald, G. (2003). Where now for development methodologies? *Communications of the ACM*, 46(1), 78-82.

Azzone, G., Masella,C., Bertele, U. (1991). Design of performance measures for time-based companies, *International Journal of Operations and Production Management*, 11(3), 77–85.

Badri, M.A., Selim, H., Alshare, K., Grandon, E.E., Younis, H., Adsulla, M. (2006). The Baldrige education criteria for performance excellence framework. Empirical test and validation. *International Journal of Quality and Reliability Management*, 23(9), 1118–1157.

Baecker, R.M, Grudin, J., Buxton, & W.A.S., Andgreenberg, S. (1995). *Readings in Human-Computer Interaction: Toward the Year 2000.* San Mateo, CA: Morgan Kaufmann.

Bahill, A. T. & Gissing, B. (1998). Reevaluating Systems Engineering Concepts Using Systems

Thinking. *IEEE Transactions on Systems, Man, and Cybernetics*, 28(4), 516-527.

Bandyopadhyay, J., Lichtman, R. (2007). Six Sigma approach to quality and productivity improvement in an institution for higher education in the United States. *International Journal of Management*, 24 (4), 802-808.

Barnard, N.R., & Ehrenberg, A.S.C.(1990). Robust Measures of Consumer Brand Beliefs. *Journal of Marketing Research*, 27(4), 477–484.

Bartlett, M. S. (1954). A note on the multiplying factors for various x2 approximation. *Journal of the Royal Statistical Society*, 16, 296–298.

Bayus, B.L. (2009). Understanding Customer Needs. In S. Shane (Ed.), *Blackwell Handbook of Technology and Innovation Management* (pp.115-142), Cambridge, MA: Blackwell Publishers.

Bean, J.P. (1980). Dropouts and turnover: The synthesis and test of a causal model of student attrition. *Research in Higher Education*, 12(2) 155-187.

Bean, J. P. (1982). The application of a model of turnover in work organizations to the student attrition process. *The Review of Higher Education*, 6(2), 129-148.

Bean, J.P. (1983). The Application of a Model of Turnover in Work Organizations to the Student Attrition Process. *The Review of Higher Education*, 2, 129-148.

Bean, J. P., (1985). Interaction effects based on class level in an explanatory model college student dropout syndrome. *American Educational Research Journal*, 22(1), 35-64.

Bean, J. P., & Eaton, S. B. (2000). A psychological model of college student retention. In J. M. Braxton (Ed.), *Reworking the student departure puzzle*. Nashville, TN: Vanderbilt University Press.

Beal, P.E., & Noel, L. (1980). *What works in student retention?* Iowa City, IA: National Center for Higher Education Management Systems.

Bean, J. P., & Bradley, R. K. (1986). Untangling the satisfaction--performance relationship for college students. *Journal of Higher Education,* 57(4), 393--412.

Bean, J. P., & Vesper, N. (1994). *Gender differences in college student satisfaction. Paper presented at the annual meeting of the Association for the Study of Higher Education*, Tucson, AZ.

Beaver, W. (1994). Is TQM appropriate for the classroom? *College Teaching,* 42(3), 111-114.

Berger, J. B., & Lyon, S. C. (2005). Past and present: A historical view of retention. In A. Seidman (Ed.), *College student retention: Formula for student success*. Westport, CT: Praeger.

Berger, J. B., & Milem, J. F. (1999). The role of student involvement and perceptions of integration in a causal model of student persistence. *Research in Higher Education*, 40 (6), 641-664.

Berry, L.L., Zeithaml, V.A., & Parasuraman, A. (1990). Five imperatives for improving service quality. *Sloan Management Review*, 31(4), 29–38.

Betz, E.L., Klngensmith, J.E., & Menne, J.W. (1970). The measurement and analysis of college student satisfaction. *Measurement and Evaluation in Guidance,* 3(2), 110-118.

Beyer, H., & Holtzblatt, K. (1998). *Contextual design: defining customer-centered systems*. San Francisco, CA: Morgan Kaufmann.

Beynon-Davies, Carne, Mackay, and Tudhope (1999). Rapid application development (RAD): an empirical review. *European Journal of Information Systems*, 8(3):211–223.

Billups, F.D. (2008). *Measuring College Student Satisfaction: A Multi-Year Study of the Factors Leading to Persistence. Paper presented at the Northeastern Educational Research Association (NERA) Annual Conference NERA Conference*, Rocky Hill, CT.

Birnbaum, R. (2000). The life cycle of academic management fads. *Journal of Higher Education*, 71(1), 1-17.

Bititci, U., Carrie, A., and McDevitt, L., (1997) Integrated performance measurement systems: a development guide. *International Journal of Operations and Production Management*, 17(5/6), 522–534.

Bititci, U. S., Mendibil, K., Nudurupati, S., Turner, T., & Garengo, P. (2004). The interplay between performance measurement, organizational culture and management styles. *Measuring Business Excellence, 8*(3), 28.

Bititci, U. S., Turner, U. T., & Begemann, C. (2000). Dynamics of performance measurement systems. *International Journal of Operations & Production Management, 20*(6), 692 - 704.

Blanchard, B. S. (2008). *System Engineering Management*. New York, NY: John Wiley & Sons.

Blanchard, B.S. & Fabryky, W.J. (2006). *Systems Engineering and Analysis.* Upper Saddle River, NJ: Prentice Hall.

Bohoris, G.A. (1995). A comparative assessment of some major quality awards. *International Journal of Quality and Reliability Management*, 12(9), 30-43.

Bolton, A. (1995). A rose by any other name: TQM in higher education. *Quality Assurance in Education,* 3(2), 13-18.

Bourne, M., Kennerley, M., & Franco-Santos, M. (2005). Managing through measures: a study of impact on performance. *Journal of Manufacturing Technology Management,* 16(4), 373.

Bourne, M., Mills, J., Wilcox, M., Neely, A., & Platts, K. (2000). Designing, implementing and updating performance measurement systems. *International Journal of Operations & Production Management*, 20(7), 754-771.

Bourne, M., Neely, A., Platts, K., & Mills, J. (2002). The success and failure of performance measurement initiatives: Perceptions of participating managers. *International Journal of Operations & Production Management*, 22(11), 1288.

Bourne, M., Neely,A., Mills, J. and Platts K. (2003a). Implementing performance measurement systems: a literature review. *International Journal of Business Performance Management*, 5(1), 1-19.

Brainard S, Carlin L (1998). A six-year longitudinal study of undergraduate women in engineering and science. *Journal of Engineering Education*, 87, 369–375

Braxton, J. M. (2003). Student success. In S. R. Komives, D. B. Woodard, & associates (Eds.), *Student services: A handbook for the profession* (pp. 317-335). San Francisco, CA: Jossey-Bass Publishers.

Braxton, J.M. (2006). *Faculty Professional Choices in Teaching that Foster Student Success*. Washington, DC: National Postsecondary Education Cooperative.

Braxton, J. M., & Hirschy, A. S. (2005). Theoretical developments in the study of college student departure. In A. Seidman (Ed.), *College student retention: Formula for student success* (pp. 61-87). Westport, CT: Praeger.

Braxton, J. M., Hirschy, A. S., & McClendon, S. A. (2004). Understanding and reducing college student departure. ASHE-ERIC Higher Education Report, 30(3).

Braxton, J. M., & McClendon, S. A. (2002). The fostering of student integration and retention through institutional practice. *Journal of College Student Retention: Research, Theory & Practice*, 3(1), 57-71.

Braxton, J., McKinney, J., & Reynolds, P. (2006). Cataloging institutional efforts to understand and reduce college student departure, In E. St. John (Ed.), *Improving academic success: Using persistence research to address critical challenges*, New directions for institutional research. San Francisco: Jossey-Bass.

Braxton, J. M., Sullivan, A. S., & Johnson, R. M. (1997). Appraising Tinto's theory of college student departure. In J.C. Smart (Ed.), *Higher education: A handbook of theory and research (*pp. 107-164). New York, NY: Agathon Press.

Brower, A. M. (1992). The "second half" of student integration: The efforts of life tasks predominance on student persistence. *Journal of Higher Education*, 22, 35-64.

Brown J (1997) HCI and requirements engineering: exploring human computer interaction and software engineering methodologies for the creation of interactive software. *ACM SIGHCI Bulletin*, 29(1), 32–35.

Bryant, L. J. (2006). Assessing expectations and perceptions of the campus experience: The Noel-Levitz Student Satisfaction Inventory. *New Directions for Community College*, 134, 25-35.

Bryson, J.M. (2004). *Strategic Planning for Public and Nonprofit Organizations*. San Francisco, CA: Jossey-Bass.

Buede, D.M. (2009). *The Engineering Design of Systems: Models and Methods.* Hoboken, NJ: John Wiley & Sons.

Burchill, G. & Brodie, C.P. (2005). *Voices into Choices, Acting on the Voice of the Customer*. Madison, WI: Oriel.

Burtner, J. (2004). The Adaptation of Six Sigma Methodology to the Engineering Education Enterprise." Proceedings of the American Society for Engineering Education Southeast Section Conference. Auburn, AL, April 4-6, 2000.

Cabrera, A. F. & Castaneda, M. B. (1992). The role of finances in the persistence process: A structural model. *Research in Higher Education*, 33(5), 571-593.

Cabrera, A. F. & Castaneda, M. B., & Hengstler, D. (1992). The convergence between two theories of college persistence. *Journal of Higher Education*, 63(2), 123-137.

Cabrera, A. F. & Nora, A. (1994). College student's perceptions of prejudice and discrimination and their feeling of alienation. *Review of Education, Pedagogy, and Cultural Studies*, 16, 387-409.

Cabrera, A. F., Nora, A., & Castaneda, M. B. (1993). College persistence: Structural equations modeling test of an integrated model of student retention. *Journal of Higher Education*, 64(2), 123-139.

California Postsecondary Education Commission (1985). Retention of Students in Engineering-A Report to the Legislature in Response to Senate Concurrent Resolution 16, Sacramento, CA.

Carey, K. (2004). A matter of degrees: Improving graduation rates in four-year colleges and universities. In J.C. Smart (Ed.), *Higher education: A handbook of theory and research* (pp.107-164). New York: Agathon Press.

Carmel, R., Whitaker, R.D., & George, J.F. (1993). PD and Joint Application Design: A Transatlantic Comparison. *Communications of the ACM*, 40-48.

Carnevalli , J.A., & Miguel, P.C. (2008). Review, analysis and classification of the literature on QFD—Types of research, difficulties and benefits. *International Journal of Production Economics*, 114, 737– 754.

Chan,L.K., & Wu, M.L. (2002). Quality function deployment: A literature review. *European Journal of Operational Research*. 143(3), 463–497.

Chapman, W.L. Bahill, A.T. & Wymore, W.A. (1992). *Engineering modeling and design.* Boca Raton, FL: CRC Press.

Checkland, P. (1993). *Systems thinking, systems practice.* West Sussex, England: John Wiley & Sons.

Chen, S., Yang, C. Shiau, J. (2006). The application of balanced scorecard in the performance evaluation of higher education. *The TQM Magazine,* 18 (2), 190 - 205

Chenhall, R., (2003) Management control systems design within its organizational context: findings from contingency based research and directions for the future. *Accounting Organization and Society*, 28, 127-168

Chow, C., Granulin, D., Haddad, K., & Williamson, J., (Man/Jun 1998). The balanced scorecard: a potent tool for energizing and focusing healthcare organization management, *Journal of Healthcare Management*, 43(3), 263.

Chubin, D. E., G. S. May, and E. L. Babco (2005). Diversifying the engineering workforce. *Journal of Engineering Education*, 94, 73–86.

Chubin, D., K. Donaldson, B. Olds, and Fleming, L. (2008). Educating Generation Net-Can U.S. engineering woo and win the competition for talent? *Journal of Engineering Education*, 97(3), 245–57.

Churchill.G. A. (1979). A Paradigm for Developing Better Measures of Marketing Constructs. *Journal of Marketing Research*, 16, 64-73.

Churchill, G.A. & Surprenant, C. (1982). An Investigation Into the Determinants of Customer Satisfaction. *Journal of Marketing Research*, 19, 491–504

Clark D.N. (1997). Strategic management tools usage: a comparative study. *Strategic Change,* 6, 417–427.

Clark, L. A., & Watson, D. (1995). Constructing validity: Basic issues in objective scale development. *Psychological Assessment*, 7(3), 309-319.

Clewell, B., & Anderson, B. (1991). *Women of Color in Mathematics, Science, and Engineering: A Review of the Literature.* Washington, DC: Center for Women Policy Studies.

Clewell, B. & Campbell, P. (2002). Taking stock: Where we've been, where we are, where we're going. *Journal of Women and Minorities in Science and Engineering*, 8, 255-284.

Cohen, J.A. (1960). A Coefficient of Agreement for Nominal Scales. *Educational and Psychological Measurement*, 20, 37-46.

Cohen, J., & Cohen, P. (1983). *Applied multiple regression/correlation analysis for the behavioral sciences* (3rd ed.). Hillsdale, N J: Erlbaum.

Comrey A.L., & Lee H.B. (1992). A first course in factor analysis. Hillsdale, New Jersey: Erlbaum.

Cooper, C., & Bradshaw, R.A. (1984). How green is your academic climate. Check it out with moss: A monitor of student satisfaction. *College and University*, 62, 251-260.

Costello, A.B., Osborne, J. (2005). Best practices in exploratory factor analysis: four recommendations for getting the most from your analysis. *Practical Assessment Research & Evaluation*, 10, 1-9.

Crawley, E., Malmqvist, J., Ostlund, S., and Brodeur, D. (2007). *Rethinking Engineering Education: The CDIO Approach*. New York, NY, Springer.

Crosby, P.B. (1979). *Quality is free: The art of making quality certain*. New York, NY: New American Library.

Cross, N. (2000). *Engineering Design Methods: Strategies for Product Design.* New York, NY: John Wiley & Sons.

Cullen, J., Joyce, J., Hassall, T., Broadbent, M. (2003). Quality in higher education: from monitoring to management, Quality Assurance in Education, 11(1), 5-14.

Cummings, O. W. (1985). Comparison of three algorithms for analyzing questionnaire-type needs assessment data to establish need priorities. *Journal of Instructional Development*, 8(2), 11–16.

Curkovic, S., Melnyk, S., Calantone, R. (2000). Validating the Malcolm Baldrige National Quality Award framework through structural equation modelling. *International Journal of Production Research*, 38 (4), 765–791.

Daempfle, P. A. (2003/2004). An analysis of the high attrition rates among first year college science, math, and engineering, majors. *Journal of College Student Retention*, 5(1), 37-52.

Dahlgaard, J.J, Kristensen, K., Khanji, G.K. (2005). *Fundamentals of Total Quality Management.* Florence, Kentucky: Routledge.

Dahlgaard, J.J., Kristensen, K., Kanji, G.K. (1995). TQM and education. *Total Quality Management*, 6 (5/6), 445–455.

Daniels, J. (1988). Women in Engineering: A Program Administrator's Perspective. *Engineering Education*, 78(8), 766–768.

Daniels, S.E. (2002). First to the top. *Quality Progress*, 35(5), 41-53.

Danielson, C. (1998). Is satisfying college students the same as decreasing their dissatisfaction? Proceedings of the 38th Association for Institutional Research, Minneapolis, MN, May 17-20, 1998).

Davidson, E.J. (1999). Joint application design (JAD) in practice. *The Journal of Systems and Software*, 45, 215–223.

Davidson, W.B., Beck, H.P, & Milligan, M. (2009). The College Persistence Questionnaire: Development and Validation of an Instrument That Predicts Student Attrition. *Journal of College Student Development*. 50(4), 373-390.

Davis, A., Dieste, O., Hickey, A., Juristo, N. & Moreno, A. M. (2006). *Effectiveness of requirements elicitation techniques: Empirical results derived from a systematic review*. *Paper presented at the Fourteenth IEEE International Requirements Engineering Conference*. Minneapolis/St. Paul, MN: IEEE Computer Society Press.

Davis, A., Hickey, A., & Zweig, A. (2003). Requirements management in a project management context. In Morris, P. & Pinto, J. (Eds.). *The Wiley Managing Projects Resource Book*. New York, NY: John Wiley & Sons.

Davis, F. (1989). Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology. *MIS Quarterly*, 13(3), 319-339.

Dean, A.M. (1998). Defining and Achieving University Student Success: Faculty and Student Perceptions (Master's thesis). Virginia Polytechnic Institute and State University, Blacksburg, VA.

Dean, J.W., & D.E. Bowen (1994). Management theory and total quality: Improving research and practice through theory development. *Academy of Management Review*, 19(3), 392-418.

Delbecq, A.L., Van de Ven, A. H., & Gustafson, D. H. (1986). *Group techniques for program planning: A guide to nominal group and Delphi processes.* Middleton, WI: Greenbriar.

Delmar, F., & Shane, S. (2003). Does business planning facilitate the development of new ventures? *Strategic Management Journal*, 24(12), 1165-1185.

Deming, W.E. (1986). *Out of crisis*. Cambridge, MA: MIT Press.

DeVillis, R. F. (2003). *Scale development: Theory and applications*. Thousand Oaks, CA: Sage.

Dieter, G.E. & Schmidt, L.C. (2009), *Engineering Design*. New York, NY: McGraw-Hill.

Downey, C.J., Frase, L.E., & Peters, J.J. (1994). *The Quality Education Challenge*. Thousand Oaks, CA: Sage Publications.

Duggan, E. W. (2003). Generating systems requirements with facilitated group techniques. *Human-Computer Interaction,* 18, 373–394.

Duggan, E.W., & Thachenkary, C.S. (2004). Integrating nominal group technique and joint application development for improved systems requirements determination. *Information and Management*, 41(4) 399-411.

Eagle, L., Brenna, R. (2007). Are students customers? TQM and marketing perspectives. *Quality Assurance in Education*, 15 (1), 44-60.

Eaton, S. B., & Bean, J. P. (1995). An approach/avoidance behavioral model of college student attrition. *Research in Higher Education*, 36(6), 617–645.

El-Haik, B. S. (2005).*Axiomatic Quality – Integrating Axiomatic Design with Six-Sigma, Reliability, and Quality Engineering.* Hoboken, NJ: John Wiley & Sons.

Elliott, K. M., & Shin, D. (2002). Student satisfaction: An alternative approach to assessing this important concept. *Journal of Higher Education Policy and Management*, 24(2), 197-209.

Ermer, D. (1995). Using QFD Becomes an Educational Experience for Students & Faculty. *Quality Progress*, 28(5), 131-136

Evans, J.R. & Lindsay, W.H. (2008). *Managing for Quality and Performance Excellence*. Mason, OH: Thompson South-Western.

Everett (2002). Penn State's commitment to quality improvement. *Quality Progress*, 35(1), 44-48.

Falshaw, J.R., Glaister, K.W. & Ekrem, T. (2006). Evidence on formal strategic planning and company performance. *Management Decision*, 44 (1), 9-30.

Felder, G.N., Mauney, M., Hamrin, C.E., & Dietz, E.J.(1995). A longitudinal study of engineering student performance and retention. III. Gender differences in student performance and attitudes. *Journal of Engineering Education*, 84(2), 151-174.

Felder, R. M., and Brent, R. (2005). Understanding student differences. *Journal of Engineering Education* 94(1): 57–72.

Felder, R.M., Felder, G.N., & E.J. Dietz (1998). A Longitudinal Study of Engineering Student Performance and Retention. V. Comparisons with Traditionally Taught Students. *Journal of Engineering Education*, 87(4), 469-480.

Florman, S.C. (1996). *The existential pleasures of engineering*. New York, NY: St. Martins Press.

Flynn, B. B., Schroeder, R. G., & Sakakibara, S. (1994). A framework for quality management research and an associated measurement instrument. *Journal of Operations Management*, 11(4), 339-366.

Flynn, B.B., & Saladin, B. (2001). Further evidence on the validity of the theoretical models underlying the Baldrige criteria. *Journal of Operations Management*, 19, 617–652.

Folan, P., & Browne, J. (2005). A review of performance measurement: Towards performance management. *Computers in Industry*, *56*(7), 663-680.

Fornell, C., Mithas,S., Morgeson, F. & Krishnan, M. S. (2006). Customer Satisfaction and Stock

Prices: High Returns, Low Risk. *Journal of Marketing*, 70(1), 3–14.

Fortuin, L. (1988). Performance indicators – why, where and how?, *European Journal of Operational Research*, 34(1), 1-9.

Forza, C. (2002). Survey research in operations management: A process-based perspective. *International Journal of Operations & Production Management*, 22(2), 152-194.

Fox, M.F., Sonnert, G., Nikiforova, I. (2009). Successful Programs for Undergraduate Women in Science and Engineering: Adapting versus Adopting the Institutional Environment. *Research in Higher Education*, 50, 333–353.

Franco, M., & Bourne, M. (2003). Factors that play a role in "managing through measures". *Management Decision, 41*(8), 698-710.

Franco-Santos, M., & Bourne, M. (2005). An examination of the literature relating to issues affecting how companies manage through measures. *Production Planning & Control, 16*(2), 114.

Franco-Santos, M., Kennerley, M., Micheli, P., Martinez, V., Mason, S., Marr, B., et al. (2007). Towards a definition of a business performance measurement system. *International Journal of Operations & Production Management, 27*(8), 784 - 801.

French, M.J. (1998). *Conceptual Design for Engineers*. London, UK: The Design Council.

French, S. (2009). Critiquing the language of strategic management. *Journal of Management Development*, 28(1), 6-17.

Friedrich, K. A., Sellers, S. L., & Burstyn, J. N. (2007). Thawing the chilly climate: Inclusive teaching resources for science, technology, engineering and math. In Robertson, D. R. & Nilson, L. B. (Eds.) *To improve the academy*. Bolton, MA: Anker Publishing.

Füller, J. and Matzler, K. (2007). Virtual product experience and customer participation a chance for customer-centred, really new products. *Technovation*, 27, 378.

Gandara, P., & Maxwell-Jolly, J. (1999). *Priming the pump: Strategies for increasing the achievement of underrepresented minority undergraduates*. New York, NY: College Board Publications.

Ghamdi S. M A. (2005). The use of strategic planning tools and techniques in Saudi Arabia: an empirical study. *International Journal of Management*, 22(3), 376-396.

Ghosh, S., Handfield, R.B., Kannan, V.R., Tan, K.C. (2003). A structural model analysis of the Malcolm Baldrige National Quality Award framework. *International Journal of Management and Decision Making*, 4(4), 289–311.

Gielow, C. R., & Lee, V. E. (1988). The effect of institutional characteristics on student satisfaction with college. Paper presented at the American Educational Research Association annual meeting, New Orleans, LA.

Globerson, S. (1985). Issues in developing a performance criteria system for an organization, *International Journal of Production Research*, 23(4), 639-46.

Goguen, J. A. and Linde, C. (1993). *Techniques for Requirements Elicitation, Proceedings of the IEEE International Symposium on Requirements Engineering*, San Diego, CA: IEEE Computer Society.

Good, J., Halpin, G., & Halpin, G. (2002). Retaining black students in engineering: Do minority programs have a longitudinal impact? *Journal of College Student Retention: Research, Theory & Practice*, 3(4), 351-364.

Grady, J.O. (2007). *System verification: proving the design solution satisfies the requirements*. Burlington, MA: Elsevier/Academic Press.

Grady, J.O. (2006). *System requirements analysis.* Orlando, Fl: Academic Press.

Graf, L.A., Hemmasi, M., & Nielsen, W. (1992). Importance-Satisfaction Analysis: A Diagnostic Tool for Organizational Change. *Leadership and Organization Development Journal*, 13(6), 8–12.

Greenbaum, J. (1993). A design of one's own: towards participatory design in the United States. In D. Schuler and A. Namioka (Ed.) *Participatory design: principles and practices* (pp. 27–37), Hillsdale, NJ: Lawrence Erlbaum Associates.

Greenley, G. E. (1986). Does strategic planning improve company performance? *Long Range Planning*, 19(2), 101-109.

Greenley, G. E. (1994). Strategic Planning and Company Performance: An Appraisal of the Empirical Evidence. *Scandinavian Journal of Management,* 10(4), 383–396.

Griffin, A. (1996). Obtaining Customer Needs for Product Development. In M. Rosenau, et al. (Eds.), The *PDMA Handbook of New Product Development* (pp. 153-166). New York, NY: John Wiley & Sons.

Griffin, A. & J. Hauser (1993). The Voice of the Customer. *Marketing Science*, 12(1), 1-27.

Griffiths, J., (2003) Balanced Scorecard use in New Zealand government departments and crown entities. *Australian Journal of Public Administration*, 62(4), 70 -79.

Guiffrida, D.A. (2006). Toward a cultural advancement of Tinto's theory. *The Review of Higher Education*, 29(4), 451-472.

Gunn, R., & Williams, W. (2007). Strategic tools: an empirical investigation into strategy in practice in the UK. *Strategic Change*, 16, 201–216.

Habley, W.R., & McClanahan, R. (2004). *What Works in Student Retention? Four- Year Public Colleges*. Iowa City, IA: ACT.

Hackett, G., Betz, N. E., Casas, J. M., & Rocha-Singh, I. A. (1992).Gender, ethnicity, and social cognitive factors predicting the academic achievement of students in engineering. *Journal of Counseling Psychology*, 39(4), 527-538.

Hackman, JR, & Wagemen, R. (1995). Total Quality Management: Empirical, Conceptual, and Practical Issues. *Administrative Science Quarterly*, 40 (2), 309–342.

Hair, J.F., Anderson, R.E., Tatham, R.L., & Black, W.C. (1998). *Multivariate Data Analysis.* Upper Saddle River, NJ: Prentice Hall.

Hansen C. T. (1995). An approach to simultaneous synthesis and optimization of composite mechanical systems. *Journal of Engineering Design*, 6(3), 249–266.

Hargrove, S.K. (1998). *Using QFD to Improve Retention Efforts in Engineering. First Annual Regional HBCU Summit on Retention*, Ocean City, MD.

Hargrove, S.K. and Burge, L. (2002). Developing a Six Sigma Methodology for Improving Retention in Engineering Education," *Proceedings: Frontiers in Education*, 32nd Annual Conference, Boston, Massachusetts, November 2002.

Hari, A., Kasser, J. E., & M. P. Weiss (2007). How Lessons Learned from Using QFD Led to the Evolution of a Process for Creating Quality Requirements for Complex Systems. *Systems Engineering*, 10(1), 45-63.

Harnesk, R. & Abrahamsson, L (2007). TQM: an act of balance between contradictions. *The TQM Magazine*, 19 (6), 531 - 540

Hatcher L., K Kryter, J.S. Prus & V. Fitzgerald (1992). Predicting College Student Satisfaction, Commitment, and Attrition from Investment Model Constructs. *Journal of Applied Social Psychology*, 22(16), 1273-1296.

Hauser, J. R. & Clausing, D. (1988). The House of Quality. *Harvard Business Review*, 66(3), 63-73.

Heverly, M. (1999). Predicting retention from students' experiences with college processes. *Journal of College Student Retention*, 1 (1), 3-11.

Hickey, A., & Davis, A. (2003). *Elicitation technique selection: How do experts do it? Paper presented at the Eleventh IEEE International Requirements Engineering Conference*. Los Alamitos, CA: IEEE Computer Society Press.

Ho, S., & Goh, T. (2006). Adopting Six Sigma in higher education: some issues and challenges. *International Journal of Six Sigma and Competitive Advantage*, 2(4), 335-352.

Ho, S.K., & Wearn, K. (1995). A TQM model for higher education and training, *Training for*

Quality, 3(2), 25-33.

Holzblatt, K. & Jones, S. (1993). Contextual Inquiry: a participatory Technique for System Design. In Schuler, D. & Namioka, A. (Eds.), *Participatory design: Principles and practices* (177-210). New York, NY: Lawrence Erlbaum.

Hoque, Z., James, W., (2000) Linking Balanced Scorecard measures to size and market factors: impact on organizational performance, *Journal of Management Accounting Research*, 12, 1-17.

Hotlzblatt, K., Wendell, J.B. & Wood, S. (2005). *Rapid Contextual Design: A How-to-Guide to Key Techniques for User-Centered Design*. San Francisco, CA: Morgan Kauffman.

Houston, D. (2007). TQM and higher education: A critical systems perspective on fitness for purpose. *Quality in Higher Education*, 13(1), 1-17.

Hudson, M., Smart, A. and Bourne, M. (2001). Theory and practice in SME performance measurement systems, International Journal of Operations & Production Management, 21(8), 1096–1115.

Humphrey, A.S. (2004). "The origins of the SWOT analysis model." As reprinted at http://www.businessballs.com/swotanalysisfreetemplate.htm

Hurtado, S., & Carter, D. F. (1997). Effects of college transition and perceptions of the campus racial climate on Latino college students' sense of belonging. *Sociology of Education*, 70(4), 324–345.

Hwarng H.B. & Teo C., (2001). Translating Customers' Voices into Operations Requirements – A QFD Application in Higher Education. *International Journal of Quality & Reliability Management*, 18(2), 195-226.

INCOSE (1993). An Identification of Pragmatic Principles – Final Report. Systems Engineering Principles Working Group. Seattle, WA: J.C. Defoe.

ISO 13407. (1999). Human-centered design processes for interactive systems. International Organization for Standardization.

ISO 9241-11 (1998). Ergonomic requirements for office work with visual display terminals (VDTs) -- Part 11: Guidance on usability: International Organization for Standardization.

ISO 9241-11. (1998). Ergonomic requirements for office work with visual display terminals (vdts) - part 11: Guidance on usability. International Organization for Standardization.

Ittner, C., and Larcker, D. (1998). Are Nonfinancial Measures Leading Indicators of Financial Performance? An Analysis of Customer Satisfaction. *Journal of Accounting Research*, 36(1), 1-35.

Ittner, C., Larcker, D., and Randall, T. (2003). Performance implications of strategic performance measurement in financial services firms. *Accounting, Organizations and Society, 28*(7-8), 715-741.

Jaraiedi, M. & Ritz, D. (1994). Total Quality Management Applied in Engineering Education. *Quality Assurance in Education,* 2(1), 32-40.

Jenicke, L., Kumar, A., & Holmes, M. (2008). A framework for applying Six Sigma improvement methodology in an academic environment. *The TQM Journal*, 20 (5), 453-62.Jennrich R.I. (2002). A simple general method for oblique rotation. *Psychometrika*, 67(1), 7–19.

Johnson, C.F. & Golomski, W. A. J. (1999). Quality concepts in education. *The TQM Magazine*, 11(6), 467-473.

Johnson, M. D., Gustafsson, A., Andreassen, T. W., Lervik, L., & Cha, J. (2001). The evolution and future of national customer satisfaction index models. *Journal of Economic Psychology*, 22(2), 217–245.

Jones, J. C. (1992). *Design Methods*. New York, NY: Van Nostrand.

Juillerat, S. (1995). Investigating a two-dimensional approach to the assessment of student satisfaction: validation of the student satisfaction inventory (Doctoral Dissertation). Temple University, Philadelphia, PA.

Juran, J.M., & Godfrey, A.B. (1999). *Juran's Quality Handbook*. New York, NY: McGraw-Hill.

Kaiser, H. F. (1970). A second generation little jiffy. *Psychometrika, 35,* 401-415.

Kanji, G.K., Malek A., & Tambi, A.M. (1999). Total quality management in UK higher education institutions. *Total Quality Management,* 10(1), 129-53.

Kanji, G., Moura e Sá, P. (2002). Kanji's Business Scorecard. *Total Quality Management*, 13(1), 13–27.

Kano, N., Seraku, N., Takahashi, F., & Tsuji, S. (1984). Attractive quality and must be quality. Hinshitsu (Quality), 14(2), 147– 156 (in Japanese).

Kaplan, R.S., & Norton, D.P. (1992). The Balanced Scorecard - Measures That Drive Performance. *Harvard Business Review,* 70(1), 71.

Kaplan, R.S. and Norton, D.P. (1996). The Balanced Scorecard: Translating Strategy into Action, Harvard Business School Press, Boston, MA.

Kaplan, R. S., & Norton, D. P. (2001). *The strategy-focused organization: how balanced scorecard companies thrive in the new business environment*. Boston, MA: Harvard Business School Press.

Kaplan, R. S., & Norton, D. P. (2004). *Strategy Maps: converting intangible assets into tangible* *outcomes*. Boston, MA: Harvard Business School Publishing Corporation.

Karat, J. (1997). Evolving the scope of user-centered design. *Communications of the ACM*, 40(7), 33-38.

Karathanos, D., & Karathanos, P. (2005). Applying the Balanced Scorecard to education, *Journal of Education for Business*, March/April, 222-230.

Karkkainen, H., K. Elfvengren, and M. Tuominen (2003). A Tool for Systematic Assessment of Customer Needs in Industrial Markets. *International Journal of Technology Management*, 25(6/7), 588-604.

Kasser, J.E. (1995). *Applying Total Quality Management to Systems Engineering.* Boston, MA: Artech House.

Kaufman, R. A., & English, F. W. (1976). Needs assessment: A guide to improve school district management. Arlington, VA: American Association of School Administrators.

Kaufman, R.A., & English, F. W. (1979). Needs assessment: Concepts and applications. Englewood Cliffs, N.J: Educational Technology Publications, Inc.

Keegan, D.P., Eiler, R.G. & Jones, C.R. (1989). Are your performance measures obsolete? *Management Accounting,* June, 45-50.

Kennerley, M., & Neely, A. (2002). A framework of the factors affecting the evolution of performance measurement systems. *International Journal of Operations & Production Management*, 22(11), 1222-1245.

Kennerley, M., and Neely, A. (2003). Measuring performance in a changing business environment. *International Journal of Operations & Production Management*, 23(2), 213-229.

Kettunen, J. (2006). Strategies for the cooperation of educational institutions and companies in mechanical engineering, *International Journal of Educational Management*, 20(1), 19-28.

Kim, J., & Mueller, C. W. (1978). Factor analysis: Statistical methods and practical issues. Beverly Hills, CA: Sage.

Kirkpatrick, D. L. (1994). *Education training programs: The four levels.* San Francisco, CA: Berrett Kohler.

Kloot, L,. Martin, J., (2000) Strategic performance management: A balanced approach to performance management issues in local government. *Management Accounting Research*, 11, 231-251.

Koch, J. (2003). QM: why is its impact on higher education so small? *The TQM Magazine*, 15(5), 325-33.

Koch, J.V. and Fisher, J.L. (1998). Higher education and total quality management. *Total Quality Management*, 9(8), 659-68.

Koksal, G., & Egitman, A. (1998). Planning and design on industrial engineering education quality. *Computers and Industrial Engineering*, 35(3-4), 639–642.

Krippendorff, K. (2004). *Content analysis: An introduction to its methodology*. Thousand Oaks, CA: Sage Publications.

Krueger, R.A., & Casey, M. (2008). *Focus Groups: A Practical Guide for Applied Research*. Thousand Oaks, CA: Sage Publications.

Kuh G.D. (2001). Assessing What Really Matters to Student Learning: Inside the National Survey of Student Engagement. *Change*, 33(3), 10-17.

Kuh, G.D. (2009). The national survey of student engagement: conceptual and empirical foundations. *New Directions for Institutional Research*, 141, 1-20.

Kuh, G. D., Kinzie, J., & Schuh, J.H. (2005). Student Success in College. San Francisco, CA: Jossey-Bass.

Kuh, G.D., Kinzie, J., Buckley, J., Bridges, B., & Hayek, J. (2006). *What matters to student success: A review of the literature?* Bloomington, IN: National Postsecondary Education Cooperative.

Landis, R. (1985). A Model Retention Program, In R. Landis (Ed.), *Improving the Retention and Graduation of Minorities in Engineering* (7-11). New York, NY: NACME.

Landis, R. (1988). The Case for Minority Engineering Programs. *Engineering Education*, 78, 756–761.

Landis, R.B. (2005). *Retention By Design: Achieving Excellence in URM Engineering Education.* Long Beach, CA: The California State University, Office of the Chancellor.

Landry, C. C. (2002/2003). Retention of women and people of color: Unique challenges and institutional responses. *Journal of College Student Retention: Research, Theory, and Practice*, 4(1), 1-14.

Langford, J. & McDonaugh, D. (2003). *Focus Groups: Supporting Effective Product Development*. New York, NY: Taylor and Francis.

Lawrence, S. & Sharma, U. (2002), Commodification of Education and Academic Labour –Using the Balanced Scorecard in a University Setting. *Critical Perspectives on Accounting*, 13, 661–77.

Lebas, M. and Euske, K. (2002), "A conceptual and operational delineation of performance", in Neely, A. (Ed.), *Business Performance Measurement: Theory and Practice*, Cambridge University Press, Cambridge, pp. 65-79.

Lea, R. and Parker, B. (1989).The JIT spiral of continuous improvement, *IMDS*, 4, 10-13.

Lee, S. F., Lo, K. K., Leung, R. F. & Ko, A. S. O. (2000). Strategy formulation framework for vocational education: integrating SWOT analysis, balanced scorecard, QFD methodology and MBNQA education criteria. *Managerial Auditing Journal*, 15(8), 407-414.

Lent, R.W., H. Sheu, J. Schmidt, B. R. Brenner, G. Wilkins, S. D. Brown, C. S. Gloster, L. C. Schmidt, H Lyons, & Treisteman, D. (2005). Social Cognitive Predictors of Academic Interests and Goals in Engineering: Utility for Women and Students at Historically Black Universities. *Journal of Counseling Psychology*, 52 (1), 84-92.

Levitz, R. S., Noel, L., & Richter, B. J. (1999). Strategic moves for retention success. In G.H. Gaither (Ed.), *Promising practices in recruitment, remediation, and retention*. San Francisco: Jossey-Bass.

Lipe, M., Salterio, S., (July 2000) The Balanced Scorecard: judgmental effects of common and unique performance measures. *Accounting Review*, 75(3), 283-303.

Lockamy, A. & Khurana A. (1995). Quality function deployment: total quality management for new product design. *International Journal of Quality & Reliability Management*, 12(6), 73-84.

Lotkowski, V.A., Robbing, S.B., & Noeth, R.J. (2004). The role of academic and non-academic factors in improving college retention. ACT Policy Report. Iowa City, IA: American College Testing.

Lozier, G.G, & Teeter, D.J. (1996). Quality improvement pursuits in American Higher Education. *Total Quality Management*, 7(4), 189-201.

Lynch, R., and Cross, K. (1991). *Measure Up–The Essential Guide to Measuring Business Performance*, Mandarin, London.

Malhotra, M.K. & Grover, V. (1998) An assessment of survey research in POM: from constructs to theory, *Journal of Operations Management*, 16(4), 407-425

Malina, M., Selto, F., (2001) Communicating and controlling strategy: an empirical study of the effectiveness of the Balanced Scorecard. *Journal of Management Accounting Research*, 13(1): 47–90.

Marhevko, J.D. (2007). Kick Starting a Successful Lean Six Sigma System. The Quality Management Forum, American Society for Quality (ASQ), 14-17.

Marhevko,J.D. (2008). *Strategic Planning and Execution using Lean Tools*. *Presented at the 2008 ASQ World Conference on Quality and Improvement*, ASQ.

Marshall, V., & Schriver, R. (1994). Using evaluation to improve performance. *Technical and Skills Training*, January, 6-9.

Martilla, J.A., & James, J.C (1977). Importance-Performance Analysis. *Journal of Marketing*, 41(1), 77–79.

Maskell, B. (1989). Performance measurement for world class manufacturing, *Management Accounting*, 67(5), 32-33.

Medori, D. and Steeple, D. (2000). A framework for auditing and enhancing performance measurement systems. *International Journal of Operations & Production Management*, 20(5), 520-33.

Metz, G. W. (2004/2005). Challenge and changes to Tinto's persistence theory: A historical review. *Journal of College Student Retention: Research, Theory & Practice,* 6(2), 191–207.

Miberg-Skjerve A.B., Skraaning G. (2003). *A classification of validation criteria for new operational design concepts in nuclear process control. Presented at NEA/CSNI Workshop on Modification at Nuclear Power Plants*, Paris, France.

Miller W.J. (1996). A working definition for total quality management (TQM) researchers. *Journal of Quality Management.* I(2), 149–159.

Mintzberg, H. (1994). *The Rise and Fall of Strategic Planning*. New York, NY: Free Press.

Montano, C.B. & Utter, G.H. (1999). *Total quality management in higher education*. *Quality Progress*, 32(8), 52-59.

Montgomery, D., Burdick, R., Lawson, C., Molnau, W., Zenzen, F., Jennings, C., Shah, H., Sebert, D., Bowser, M., Holcomb, D. (2005). A university-based Six Sigma program. *Quality and Reliability Engineering International*, 21(3), 243-248.

Moore, G. C., & Benbasat, I. (1991). Development of an instrument to measure the perceptions of adopting an information technology innovation. *Information Systems Research*, 2(3), 192–222.

Morgan, D.L. (1997). *Successful focus groups*. New York, NY: Sage Publications.

Morrison, C., & Williams, L. (1993). Minority Engineering Programs: a Case for Institutional Support, *NACME Research Letter,* 4(1), 1-11.

Muller, M.J., Hallewell, Haslwanter, J.D., and Dayton, T. (1997). Participatory practices in the software lifecycle. In M. Helander, T. Landauer, and Prabhu, (Eds.), *Handbook of human-computer interaction*. Amsterdam: Elsevier.

Mullur, A. A., Mattson, C. A.., & Messac, A. (2003). *Pitfalls of the typical construction of decision matrices for concept selection. Proceedings from the 41st AIAA Aerospace Science Meeting and Exhibit.* Reno, NV.

Muller, M.J., White, E.A., and Wildman, D.M. (1993). Taxonomy of PD practices: A brief practitioner's guide. *Communications of the ACM*, 36(6), 26-28.

Nagamachi, M. (2002). Kansei Engineering as a Powerful Consumer-Oriented Technology for Product Development. *Applied Ergonomics*, 33, 289-294.

National Center for Education Statistics. (2005). College persistence on the rise?: Changes in 5-year degree completion and postsecondary persistence rates between 1994 and 2000. (NCES Statistical Analysis Report 2005-156). Washington, DC: U.S. Department of Education, Office of Educational Research and Improvement.

National Science Board (2007). Moving forward to improve engineering education (NSB Publication No. 07-122).

National Science Foundation (2009). NSB science and engineering indicators report. Available at http://www.nsf.gov/nsb/.

Neale, H. & Nichols, S. (2001). Theme-based content analysis: a flexible method for virtual environment evaluation. *International Journal of Human-Computer Studies*, 55, 167-189.

Neely, A. (2004). *Measuring Operations Performance: Past, Present and Future*. Cranfield, United Kingdom: Centre for Business Performance, Cranfield University.

Neely, A. (2005). The evolution of performance measurement research: Developments in the last decade and a research agenda for the next. *International Journal of Operations & Production Management, 25*(12), 1264 - 1277.

Neely, A., Adams, C., & Crowe, P. (2001). The performance prism in practice. *Measuring Business Excellence, 5*(2), 6-13.

Neely, A., Adams, C., and Kennerley, M. (2002). The Performance Prism: The Scorecard for Measuring and Managing Business Success, Financial Times Prentice Hall, 2002.

Neely, A., Gregory, M., & Platts, K. (1995). Performance measurement system design: A literature review and research agenda. *International Journal of Operations & Production Management, 15*(4), 80-116.

Neely, A., Micheli, P., & Martinez, V. (2006). *Action on information: Performance management for the public sector*. London: The Advanced Institute of Management Research.

Neely, A., Mills, J., Platts, K., Richards, H. and Bourne, M. (2000). Performance measurement system design: developing and testing a process-based approach. *International Journal of Operations & Production Management*, 20(10), 1119-1145.

Norreklit, H. (2000). The balance on the balanced scorecard a critical analysis of some of its assumptions. *Management Accounting Research, 11*(1), 65-88.

Netemeyer, R. G., Bearden, W. O., & Sharma, S. (2003). *Scaling procedures: Issues and applications*. Thousand Oaks, CA: Sage Publications.

Nielsen J. (1993). *Usability engineering*. Boston, MA: Academic Press.

Noel, L., & Levitz, R. (2009). *Student Satisfaction Inventory: The 12 scales*. Iowa City, IA: USA Group

Nora, A. (2003). Access to higher education for Hispanic students: Real or illusory? In J. Castellanos & L. Jones (Eds.), *The majority in the minority: Expanding representation of Latino/a faculty, administration and students in higher education* (pp. 47–67). Sterling, VA: Stylus Publishing.

Nora, A., & Cabrera, A. F. (1996). The role of perceptions of prejudice and discrimination on the adjustment of minority students to college. *Journal of Higher Education*, 67(2), 119-148.

Norman, D. & Draper, S. (1986). *User-Centered System Design: New Perspectives on Human-Computer Interaction*, Hillsdale, NJ: Lawrence Earlbaum Associates.

Norros, L. & Savioja, P. (2004). *Usability evaluation of complex systems. A literature review*. (Report STUK-YTO-TR 204). Helsinki, Finland: Radiation and Nuclear Safety Authority.

Norros, L., & Nuutinen, M. (2005). Performance-based usability evaluation of a safety information and alarm system. *International Journal of Human–Computer Studies* 63(3), 328–361.

Nunnally, J.C., (1978). *Psychometric Theory*. New York, NY: McGraw-Hill.

Okun, M.A., Kardash, C.A., Stock, W.A., Sandler, I.N., & Baumann, D.J. (1986). Measuring perception of the quality of academic life among college students. *Journal of College Student Personnel*, 27, 447-451.

Oliver, R.L. (1997). *Satisfaction: A Behavioral Perspective on the Consumer*. New York: McGraw-Hill.

Oseguera, L., & Vogelgesang, L. (2003). Statistical alternatives for studying college student retention: Logistic versus linear regression—An update. Unpublished manuscript, UCLA.

Otto, K. & Wood, K. (2001). Product Design: Techniques in Reverse Engineering and New Product Development, Upper Saddle River, NJ: Prentice-Hall.

Owlia, M.S. & Aspinwall, E.M. (1998). A framework for measuring quality in engineering education. *Total Quality Management*, 9(6), 501–518.

Owlia, M.S., & Aspinwall, E.M. (1997). “TQM in higher A103education – a review.” *International Journal of Quality & Reliability Management*, 14(5), 527-543.

Padilla, R. V., Trevino, J., Gonzalez, K. & Trevino, J. (1997). Developing local models of minority student success in college. *Journal of College Student Development*, 38(2), 124-135.

Pahl, G. and Beitz, W., Feldhusen, J., & Grote, K. (2007). *Engineering Design: A Systematic Approach.* London. UK: The Design Council.

Papenhausen, C., & Einstein, W. (2006). Implementing the Balanced Scorecard at a college of business. *Measuring Business Excellence*, 10(3), 15-22.

Pascarella, E. T., and Terenzini, P. T. (1980). Predicting freshman persistence and voluntary dropout decisions from a theoretical model. *Journal of Higher Education*, 51, 60-75.

Pascarella, E. T., & Terenzini, P. T. (1991). *How college affects students.* San Francisco: Jossey-Bass.

Pascarella, E. T., & Terenzini, P. T. (2005). *How college affects students: A third decade of research.* San Francisco, CA: Jossey-Bass.

Patton, M. Q. (2002). *Qualitative research & evaluation methods*. Thousand Oaks, CA: Sage Publications.

Perna, L. W., & Thomas, S. L. (2006). *A framework for reducing the college success gap and promoting success for all.* Washington, DC: National Postsecondary Education Cooperative.

Person, D., & Christensen, M.C. (1996). Understanding Black student culture and Black student retention. *NASPA Journal*, 34, 47-56.

Peter, P. J., and Churchill, G. A. (1986). Relationships among research designs choices and psychometric properties of rating scales: a meta-analysis. *Journal of Marketing Research*, 23, 1-10.

Peterson, S.L. (1993). Career decision-making self-efficacy and institutional integration of underprepared college students. *Research in Higher Education*, 34(6), 659-685.

Pope, R. L., Miklitsch, T. A., & Weigand, M. J. (2005). *First-year students: embracing their diversity, enhancing our practice*. In Feldman, R. S. (Ed.), Improving the first year of college research and practice (pp. 51-71). Mahwah, NJ: Lawrence Erlbaum Associates.

Price, J. (1977). *The study of turnover*. Ames, IA: Iowa State University Press.

Pugh, S. (1991). *Total Design: Integrated Methods of Successful Product Engineering.* Reading, MA: Addison- Wesley Publishing Company.

Pun, K.F. & White, A.S. (2005). A performance measurement paradigm for integrating strategy formulation: a review of systems and frameworks. *International Journal of Management Reviews*, 7(1), 49-71.

Quinn, A., Lemay, G., Larsen, P. & Johnson, D.M. (2009). Service quality in higher education. *Total Quality Management & Business Excellence*, 48 (2), 139-152.

Quinlivan, D., (December 2000) Rescaling the balanced scorecard for local government, *Australian Journal of Public Administration*, 59 (4), 36-41.

Rinn, M. (1995). Surviving the first year of college. *Hispanic Outlook in Higher Education*, 6(1), 11-13.

Robotham, A. J. (2002). The use of function/means trees for modelling technical, semantic and business functions. *Journal of Engineering Design*, 13(3), 243–251.

Roozenburg, N.F.M., & Eekels, J. (1995). *Product Design: Fundamentals and Method.* New York, NY: John Wiley & Sons.

Rosnay, J. (1979). The Macroscope: a New World Scientific System. Harper & Row.

Rossi, P.H., Lipsey, M.W., & Freeman, H.E. (2004). *Evaluation: a systematic approach.* Thousand Oaks, CA: Sage Publications.

Royse, D., Thyer, B. A., & Padgett, D.K. (2009). *Program evaluation: An introduction*. Belmont, CA: Wadsworth Cengage Learning.

Rudd, J. M., Greenley, G. E., Beatson, A. T., & Lings, I. N. (2008). Strategic planning and performance: Extending the debate. *Journal of Business Research*, 61, 99-108.

Ruekert, R. (1992). Developing a market orientation: an organizational strategy perspective, *International Journal of Marketing*, 9, 225-45.

Sage, A.P. and Rouse, W.B. (2009). *Handbook of Systems Engineering and Management.* New York, NY: John Wiley & Sons.

Sahney, S., Banwet, D.K. & Karunes, S. (2004). Conceptualizing total quality management in higher education. *The TQM Magazine*, 16,145–159.

Sakthivel, P.B. & Raju, R., (2006). Conceptualizing Total Quality Management in Engineering Education and Developing a TQM Educational Excellence Model. *Total Quality Management*, 17(7), 913-934.

Sallis, E. (1993). *TQM in Education*. London, UK: Kogan Page.

Sanders, E. (1992). Converging Perspectives: Product Development Research for the 1990's, *Design Management Journal*, 3(4), 48-54.

Sanders, L.,& Burton, J. D. (1996). From retention to satisfaction: New outcomes for assessing the freshman experience. *Research in Higher Education.* 37(5), 555–567.

Schreiner, L.A., & Juillerat, S.L. (2010). *Sample student satisfaction inventory: 4- year college or university version*. Iowa City, IA: Noel Levitt.

Schuler, D. & Namioka, A. (1993). *Participatory design: Principles and practices.* Hillsdale, NJ: Lawrence Erlbaum.

Schwab, D. P. (2005). *Research methods for organizational studies*. Mahwah, NJ: Erlbaum.

Seibold, D.R. & Krikorian, D. H. (1997). Planning and facilitating group meetings. In L.R. Frey & J.K. Barge (Eds.), *Managing group life: Communicating in decision-making groups.* Houghton Mifflin.

Seidman, A. (2005). *College student retention: Formula for student success*. Westport, CT: Praeger.

Seymour, E. (1995). The loss of women from science, mathematics, and engineering undergraduate majors: An explanatory account. *Science Education*, 79(4), 437–73.

Seymour, E., & Hewitt, N.M (1997). *Talking about leaving: Why undergraduates leave the sciences*. Boulder, CO: Westview Press.

Shewart, W. (1939). *Statistical method from the viewpoint of quality control.* Washington, DC: US Department of Agriculture.

Shin, J. & Kim, K. (2000). Effect And Choice of the Weighting Scale In QFD. *Quality Engineering*, *12*(3), 347-356.

Silverman, S.N., & Silverman, L.L. (1994). Using total quality tools for marketing research: A qualitative approach for collecting, organizing, and analyzing verbal response data. In *Advanced Research Techniques Forum*, Chicago, IL: American Marketing Association.

Sink, D. S., Tuttle, T. C. (1989). *Planning and Measurement in Your Organization of the Future.* Norcross, GA: Industrial Engineering and Management Press.

Sirvanci (2004). TQM implementation: Critical Issues for TQM implementation in higher education. *The TQM Magazine,* 16(6), 382-386.

Solano-Flores, G. & Nelson-Barber, S. (2001). On the cultural validity of science assessments. *Journal of Research in Science Teaching, 38(5),* 553-573.

Sousa, R., & Voss, C. (2002).Quality management re-visited: a reflective review an agenda for future research. *Journal of Operations Management*, 20(1), 91-109.

Spady, W.(1970). Dropouts from higher education: An interdisciplinary review and synthesis. *Interchange*, 1, 64-65.

Spady, W. (1971). Dropouts from higher education: Towards an empirical model. *Interchange*, 2, 38-62.

Spanbauer, S.J. (1995). Reactivating higher education with total quality management: using quality and productivity concepts, techniques and tools to improve higher education. *Total Quality Management*, 6 (5/6), 519-537.

Spencer, B. (1994). Models of Organizational and Total Quality Management: A Comparison and Critical Evaluation. *Academy of Management Review*, 19(3): 446-471.

St. John, E. P., Hu, S., & Weber, J. (2000). Keeping public college affordable: A study of persistence in Indiana's public colleges and universities. *Journal of Student Financial Aid*, 29(2), 21–32.

St. John, E. P., Paulsen, M. B., & Carter, D. F. (2005). Diversity, college costs, and postsecondary opportunity: An examination of the financial nexus between college choice and persistence for African Americans and whites. *The Journal of Higher Education,* 76(5), 545–569.

St. John, E. P., Paulsen, M. B., & Starkey, J. B. (1996). The nexus between college choice and persistence. *Research in Higher Education*, 37(2), 175-220.

Stage, F. K., (1989). University attrition: LISREL with logistic regression in the persistence criterion. *Research in Higher Education*, 29(4), 343-357.

Steiner, G. (1979). *Strategic planning: What every manager must know*. New York: Free Press.

Stewart, D.W., Shamdasani, P.N., & Rook, D.W. (2007). *Focus groups: theory and practice*. Thousand Oaks, CA: Sage Publications.

Straub, D. W.(1989). Validating instruments in MIS research. *MIS Quarterly*. 13(2) 147–165.

Streett, W.B., Hale, R., Thomas, R.J., Fish, M.D., Price, D. (1993). The Military Influence on American Engineering Education. *Cornell Engineering Quarterly*, 27(2), 3-10.

Suh, N.P. (1998). Axiomatic design theory for system. *Research in Engineering Design*, 10, 189–209.

Suh,N.P.(2001). *Axiomatic design: advances and applications.* New York, NY: Oxford University Press.

Swail, S., Redd, K., Perna, L. (2003). *Retaining minority students in higher education: A framework for success.* San Francisco, CA: Jossey-Bass.

Tabachnik B.G., & Fidell L.S. (2007). *Using multivariate statistics*. Boston, MA: Pearson Education, Inc

Temponi, C. (2005). Continuous Improvement Framework – Implications for Academia. *Quality Assurance in Education*, 13(1), 17-36.

Tennant G. (2002). *Design for Six Sigma: Launching New Products and Services Without Failure.* Hampshire, England: Gower.

Tierney, W. G. (1992). An anthropological analysis of student participation in college. *Journal of Higher Education*, 63(6), 603-618.

Tinto, V. (1975). Dropouts from higher education: A theoretical synthesis of the recent literature. *A Review of Educational Research,* 45, 89-125.

Tinto, V. (1987). *Leaving college: Rethinking the causes and cures of student attrition*. Chicago, IL: The University of Chicago Press.

Tinto, V. (1993). *Leaving college: Rethinking the causes and cures of student attrition.* Chicago, IL: The University of Chicago Press.

Tinto, V. (2003). *Learning Better Together: The Impact of Learning Communities on Student Success.* Syracuse University Higher Education Monograph Series, 2003-1. Syracuse, NY: Syracuse University.

Tinto, V. & Pusser, B. (2006). *Moving from theory to action: Building a model of institutional action for student success.* Commissioned paper presented at the 2006 Symposium of the National Postsecondary Education Cooperative (NPEC).

Tinto, V. (2005). Epilogue: Moving from theory to action. In A. Seidman (Ed.), *College student retention: Formula for student success*. Westport, CT: ACE/Praeger.

Titus, M.A. (2004). An examination of the influence of institutional context on student persistence at 4-year colleges and universities: A multilevel approach. *Research in Higher Education*, 45(7), 673-699.

Ullman, D. (2003). *The Mechanical Design Process*. Boston, MA: McGraw-Hill.

Ulrich, K.T. & Eppinger, S.D. (2008). *Product Design and Development*. Boston, MA: McGraw-Hill.

Umashankar, V., Dutta, K. (2007). Balanced scorecards in managing higher education institutions: an Indian perspective. *International Journal of Educational Management*, 21(1), 54-67.

Van Gennep, A. (1960*).* *The Rites of Passage*. Chicago, IL: University of Chicago Press.

Van Slyke, C., Kittner, M., & Belanger, F. (1998). *Identifying Candidates for Distance Education: A Telecommuting Perspective. In Proceedings of the America's Conference on Information Systems.*

Veenstra, C.P., Dey, E.L., & Herrin, G.D. (2008). Is the Modeling of Freshman Engineering Success Different from Modeling of Non-Engineering Success. *Journal of Engineering Education* 97(4), 467–79.

Veenstra, C.P., Dey, E.L., & Herrin, G.D. (2009). A Model for Freshman Engineering Retention. *Advances in Engineering Education*, 1(3), 1-31.

Venkatraman, S. (2007). A framework for implementing TQM in higher education programs. *Quality Assurance in Education*, 15(1), 92-112.

Verma, D., Smith, C., & Fabrycky, W. (1999). Fuzzy set based multi-attribute conceptual design evaluation. *Systems Engineering*, 2(4), 187-197.

Vogt, C., D. Hocevar, & L. Hagedorn (2007). A social cognitive construct validation: Determining women and men's success in engineering programs. *Journal of Higher Education*, 78 (3), 336–64.

Wang, H., & Grimes, J.W. (2000/2001). A systematic approach to assessing retention programs: identifying critical points for meaningful interventions and validating outcomes assessment. *Journal of College Student Retention Research, Theory, and Practice*, 2(1), 59-68.

Watford, B. (2007). Undergraduate Student Support Programs. In Burke, R., Jr. & Mattis, M. (Eds.), *Women and minorities in science, technology, engineering and mathematics: Upping the numbers*. Northhampton, MA: Edward Elgar Publishing.

Webster, J.L., Reif, W.E., & Bracker, J.S. (1989). The manager's guide to strategic planning tools and techniques. *Planning Review*, 17, 4–13.

West-Burnham, J. (1992). *Managing Quality in Schools*. London, UK: Longman Publishers.

Winstanley, G. (1991). Artificial Intelligence in Engineering. New York, NY: John Wiley & Sons.

Yang, C.C. (2003). Improvement actions based on the customers' satisfaction survey. *TQM & Business Excellence*, 14(8), 919–930.

Yang, C.C., Yang, K., Yeh, T., & Pai, F. (2009). Methods for determining areas for improvement based on the design of customer surveys. *The Service Industries Journal*. 29(2), 143-154.

APPENDIX A: DEFINE STUDENT NEEDS MEETING PROTOCOL

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY
Informed Consent for Participants
in Research Projects Involving Human Subjects

Title of Project: Student Success-Oriented System Design Methodology: "Define Student Needs (DSN)" Meeting

Investigator(s): Tracee Gilbert (Advisor: Janis Terpenny)

I. Purpose of this Research/Project

You are invited to participate in a research study to determine the needs of engineering students that facilitate student success. The purpose of this meeting is to have students share their knowledge and experiences, which will ultimately assist in the development of an Engineering Student Needs Questionnaire (ESNQ). The questionnaire will be administered to engineering students at the applied research site. By eliciting information directly from the students, this ensures that relevant information is captured, and informed decisions can be made to improve the engineering experience.

II. Procedures

This study consists of five parts. **Part A** will inform you about my role as the facilitator of the meeting, the meeting's goals and objectives, what activities you will be expected to perform, and how this study fits into the larger context of this research study. **Part B** will require you to answer a series of planned questions that will be used to guide the discussion. The first set of questions is intended to allow the group to reflect on personal experiences. We will then engage in a group discussion to identify engineering student success needs. During **Part C**, we will use system design tools to organize and document the information provided by the group. **Part D** consists of a validation step to ensure that the key deliverables that we will design satisfy the goals and objectives of the meeting. Finally, **Part E** consists of a short evaluation questionnaire that will be used to get your feedback on improving the meeting's processes and output.

III. Risks

Participation in this project does not place you at more than minimal risk of harm.

IV. Benefits

The results of this study will be used to develop an Engineering Student Needs questionnaire. The questionnaire will assist institutional leaders in: (1) identifying the critical needs of engineering students that promote student success; (2) examining the extent to which student needs are being met; and (3) understanding how student needs are different among various student groups (e.g., minorities and women).

V. Extent of Anonymity and Confidentiality

Your anonymity will be preserved throughout this research effort. Information gained from this study will be used to develop a questionnaire for eventual use in a scientific publication. At no time will you be personally identified. No names will be associated with your input provided today or in future publications. In fact, the list of participants will be destroyed at the end of the research period.

VI. Compensation

You will be financially compensated individually for your participation. You will be paid $5/half an hour. This is a total of $20 for the full 2 hour participation.

VII. Freedom to Withdraw

Participants are free to withdraw without penalty and are free not to answer any questions that they choose. However, only those participants who participate for the entirety of the meeting will be able to enter the raffle.

VIII. Subject's Responsibilities

I voluntarily agree to participate in this study. I have the following responsibilities: to read and understand the procedures described in the consent form; to actively participate in the meeting by answering questions open and honestly; respect the confidentiality of the other meeting participants; and to participate in an evaluation of this meeting.

IX. Subject's Permission

I have read the Consent Form and conditions. I have had all my questions answered. I hereby acknowledge the above and give my voluntary consent:

Chair, Virginia Tech Institutional Review
Board for the Protection of Human Subjects
Office of Research Compliance
2000 Kraft Drive, Suite 2000 (0497)
Blacksburg, VA 24060

Should I have any pertinent questions about this research or its conduct, and research subjects' rights, and whom to contact in the event of a research-related injury to the subject, I may contact:

Tracee Gilbert_(703)725-5533/ trwalker@vt.edu________________________________
Investigator(s) Telephone/e-mail

Dr. Janis Terpenny (540)2319538/terpenny@vt.edu____________________________
Faculty Advisor Telephone/e-mail

David M. Moore (540)231-4991/moored@vt.edu________________________________
Departmental Reviewer/Department Head Telephone/e-mail

I have read and understand the Informed Consent and conditions of this study. I have had all my questions answered. I hereby acknowledge the above and give my voluntary consent to participate in this meeting, with the understanding that I may discontinue participation at any time.

____
Signature of Participant

DSN PART A: INFORM

The aim of my research is to develop a Student Success-Oriented Design Methodology (S^2OSD, pronounced "*SAWS-D*"), which is intended to help higher education administrators identify their students' needs, and translate those needs into a plan of action to facilitate engineering student success.

The first phase of this research is concerned with identifying and examining student needs in ways that will improve student success outcomes. The purpose of this meeting, therefore, is to identify engineering student needs. You will be asked to share your experiences in a group discussion with no more than 6 participants over the course of a 2-hour period.

The following goals have been established for this meeting. Additionally, objectives have also been established to ensure that this study is focused on identifying student needs in the context of student success research. These objectives will also provide you a reference point for determining whether your input falls within the scope of this research.

Table A-1: DSN Goals and Objectives

Goals	Objectives
1) Identify enablers and hinderers of engineering student success.	1) Define critical factors in the context of student success
2) Translate enablers/hinderers into student need statements.	2) Include only aspects the engineering college experience that the institution can directly impact.
3) Provide a comprehensive set of student needs.	3) Generate actionable need statements.

To achieve these goals and objectives, Figure A-1 summarizes the mapping process that will be used to carry out each part of this meeting, which describes the process to translate the voice of the 'student' into a comprehensive set of student needs that will facilitate student success. A color coding scheme will be used in the remaining steps to track key aspects of this process as follows:

- Blue – Enablers
- Pink – Hinderers
- Yellow – Student Success Need Statements
- Green – Student Success Need Categories
- White –Student Success Factors (i.e., based on the typology)

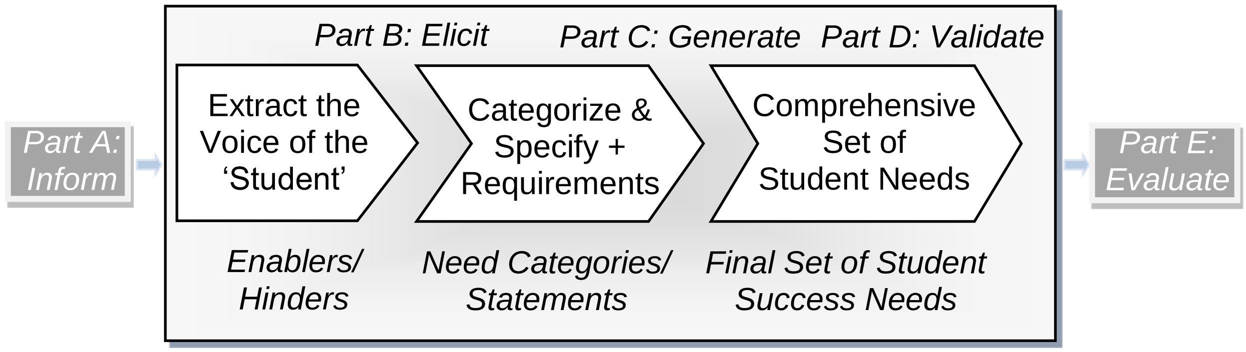


Figure A-1: Define Student Needs Meeting

DSN PART B: ELICIT

Once you have an understanding of the scope of the meeting, you will then be asked to participate in a brainstorming session. The first set of questions allows the group to reflect on their own experiences and provide their perception of those needs that facilitate engineering student success.

Discussion Question #1: What characteristics of your engineering experience have enabled and/or hindered your success? (Write each *enabler* on a blue Post-it note and each *hinderer* on a pink Post-it note)

Discussion Question #2: How would you group the enablers/hinderers into major categories? (Write each category on a separate green Post-it note).

Part B: Probing Questions:

- Tell me about a time when you had a good/bad experience with …..?
- What adjectives would you use to describe a good/mediocre/bad ….?
- What are the greatest challenges?
- What is needed to help you overcome these barriers/challenges?
- What is needed to facilitate your success?

DSN PART C: GENERATE

During the Generate step, actionable need statements will be developed. Need statements should be written as short phrases that describe the actions that institutional practices must deliver in order to enable student success. Whenever possible, need statements should be written such that an action verb is followed by a noun. Finally, the output should be structured using the affinity method; such that student success factors are connected in a hierarchy to the categories of student success needs, which are then connected to the need statements.

Discussion Question #3: What needs must be fulfilled in order to facilitate the success of engineering students. (Write each need on a separate yellow Post-It note)

DSN PART D: VALIDATE

During the Validate step, the participants will determine whether the output satisfies the meeting's goals and objectives. To do so, use the Define Student Needs Analysis Tool (Figure A-2) to help the team verify for each student success factor whether all of the need statements are critical to student success, and if additional categories or need statements need to be added in order to comprehensively address the needs of students. Furthermore, this tool will also help to identify needs that do not belong in the category.

Discussion Question #4: Are all of the need statements critical to student success?

Discussion Question #5: Do you have additional input that is needed to make the Needs Analysis Tree complete?

Part D: Probing Questions

- Should there be additional categories or needs added?
- Should the categories/needs be rearranged in a different way?
- Should the categories have different heading names?

Figure A- 2: Define Student Needs Analysis Tool

Student Success Factor				
Student Success Need Category				
Enablers				
Hinderers				
Student Success Need Statements				

Student Success Factor				
Student Success Need Category				
Enablers				
Hinderers				
Student Success Need Statements				

DSN PART E: FORMATIVE EVALUATION

Thank you for your participation! Your input is invaluable and will be used to develop an Engineering Student Needs Questionnaire. Please take a moment to fill out this questionnaire to help me identify areas that need to be improved. Please refer back to the procedures, if necessary, and provide comments or recommendations that will help me refine and improve this meeting.

	Please answer the following questions.	1 = Strongly Disagree	2	3	4	5 = Strongly Agree
Design Goals	This meeting was able to draw out needs that I may not have considered at the start of the meeting.	❍	❍	❍	❍	❍
	This meeting was able to transform my needs from my initial broad ideas into functionally precise statements.	❍	❍	❍	❍	❍
	This meeting was able to comprehensively define the needs of engineering students that facilitate their success.	❍	❍	❍	❍	❍
Ease of Learning	I did not encounter problems in learning this process.	❍	❍	❍	❍	❍
	My peers could learn how to use this process.	❍	❍	❍	❍	❍
	My role in this in this process was clear and understandable.	❍	❍	❍	❍	❍
Ease of Participation	My participation in this process was straightforward.	❍	❍	❍	❍	❍
	My peers could participate in this process with ease.	❍	❍	❍	❍	❍
	I did not encounter problems participating in the process.	❍	❍	❍	❍	❍
Usability of Tools	The participatory group meeting format was effective.	❍	❍	❍	❍	❍
	The process of organizing the ideas into the hierarchy was effective in identifying a comprehensive set of student needs.	❍	❍	❍	❍	❍
Usability Overall	I would recommend this approach to faculty and program administrators.	❍	❍	❍	❍	❍
	The information produced from this meeting can be used to understand the needs of engineering students.	❍	❍	❍	❍	❍

1. What aspects of the meeting were effective?

2. If you encountered any problems, please explain?

3. What needs to be improved?

APPENDIX B: ESNQ REFINEMENT

The ESNQ was developed and described in Chapter 4. As a result of the four DSN meetings, an initial questionnaire was developed for the student Expert Review #1. Then, the questionnaire was refined to develop the practitioner Expert Review #2, the pilot study, and the main study. Additionally, the dimensions of student success needs were modified during this process as well. These dimensions for the main study are bolded and italicized below.

Table B-1: ESNQ Refinement Stages

Dimension	#	(a) Expert Review #1	(b) Expert Review #2	(c) Pilot Study	(d) Main Study
01a_ Teaching and Learning (TL)	01_1	Being challenged and intellectually stimulated in class	To be challenged and intellectually stimulated in class	To have classes that stimulate interest in my field of study	To have classes that stimulate interest in my field of study
01b_Classroom Teaching and Learning (CTL)	01_2	Providing links between what I have learned and how it all fits together	~~Providing links To understand the link between what I have learned and how it all fits together~~		
01c_Classroom Learning	01_3	Being adequately prepared for future courses	~~Being adequately prepared for future courses~~		
	01_4	To understand what I am learning and how to apply (e.g., HW, exams, labs)	To have opportunities to practice what I have learned	To have relevant assignments (e.g., HW, labs, exams) that reinforce what I am learning in class	To have relevant assignments (e.g., HW, labs, exams, etc.) that reinforce what I am learning in class
	01_5	To connect what I am learning to the real world	To connect what I am learning to the real world	To connect what I am learning in class to the engineering profession	To connect what I am learning in class to the engineering profession
	01_6		To understand course material	To comprehend class material	To comprehend class material

Dimension	#	(a) Expert Review #1	(b) Expert Review #2	(c) Pilot Study	(d) Main Study
	01_7 ~~02_2~~		To have course concepts communicated in a manner that I can comprehend	To have class concepts communicated in a manner that I understand	To have class concepts communicated in a manner that I understand
01a_Faculty Contact (FC)	02_1	Accessible and Approachable Faculty	To have accessible and approachable teaching staff	To have approachable faculty members that I can discuss issues of interest and importance to me	To have approachable faculty members that I can discuss issues of interest and importance to me
01b_Student – Teaching Staff Interactions (STFI)	02_2	Faculty that can effectively communicate and convey their knowledge	~~Faculty that can effectively communicate and convey their knowledge~~		
01c_Faculty Interactions	02_3	Opportunities outside of class to cultivate relationships with faculty	~~Opportunities outside of class to cultivate relationships with faculty~~		
	02_4	Empathetic Faculty that demonstrates flexibility and responsiveness	To have an empathetic teaching staff that demonstrate flexibility and responsiveness to my needs	To have faculty members who demonstrate flexibility and responsiveness to my needs	To have faculty members who demonstrate flexibility and responsiveness to my needs
	02_5	Faculty genuinely interested in teaching and engaging students	To have a teaching staff genuinely interested in engaging me in their field	To have faculty members who are interested in engaging me in their fields	To have faculty members who are interested in engaging me in their fields
	02_6	Receiving timely feedback from faculty (e.g., grades,	To receive timely feedback from teaching staff (e.g., grades, hw, exams)	To receive timely feedback from faculty members (e.g., grades, homework, exams)	To receive timely feedback from faculty members (e.g., grades, homework, exams)

Dimension	#	(a) Expert Review #1	(b) Expert Review #2	(c) Pilot Study	(d) Main Study
	02_7		To understand what the teaching staff expects of me.	~~To understand what the teaching staff expects of me.~~	
03a_Advisor/Mentor (A/M)	03_1	Receiving advice on dealing with academic demands	~~Receiving advice on dealing with academic demands~~		
~~Advisor/Mentor (A/M)~~ ***03b_04b Resources***	03_2	Receiving advice on educational aspirations and post-graduation options	To receive guidance on educational aspirations and post-graduation options	To receive guidance on post-graduation options	To get help with post-graduation planning (e.g., graduate school, career opportunities, etc.)
	03_3	Planning undergraduate education (e.g., course scheduling, meeting institutional requirements)	To receive guidance on planning my undergraduate education (e.g., course scheduling, meeting institutional requirements)	To receive guidance on planning my undergraduate education (e.g., course scheduling, meeting institutional requirements)	To get help with academic planning (e.g., degree requirements, course scheduling, etc.)
	03_4	Receiving advice on identifying interests, setting goals, and achieving goals	To receive guidance on identifying my interests and setting goals to achieve them	To receive guidance on identifying my interests and setting goals to achieve them	~~To receive guidance on identifying my interests and setting goals to achieve them~~
	03_5	Cultivating close personal relationships that motivate and encourage you to succeed	~~To cultivate close personal relationships that motivate and encourage me to succeed~~		
04a_Help/Resources (H/R)	04_1			To receive guidance on post-graduation options	To get help with post-graduation planning (e.g., graduate school, career opportunities, etc.)

Dimension	#	(a) Expert Review #1	(b) Expert Review #2	(c) Pilot Study	(d) Main Study
04b_Resources	04_2			To receive guidance on planning my undergraduate education (e.g., course scheduling, meeting institutional requirements)	To get help with academic planning (e.g., degree requirements, course scheduling, etc.)
	04_3			To receive guidance on identifying my interests and setting goals to achieve them	To get help with personal development (e.g., personal concerns, social issues, etc.)
	04_4	Providing assistance to gain mastery of course materials (e.g., exam prep, HW assistance)	To receive extra help in gaining mastery of course materials (e.g., exam prep, HW assistance)	To get help in mastering course materials	To get help with mastering course concepts (e.g., exam preparation, homework assistance)
	04_5	Accessible resources available to help me	To have resources available to help me. (e.g., reference material, equipment, software)	To have resources available to help me (e.g., reference materials, equipment, software)	To have resources available to help me (e.g., reference materials, equipment, software)
	04_6	Providing mental health resources	~~To have mental health resources~~		
05a_Workload (W)	05_1	Time to understand what I have learned and complete my coursework	To keep up with the fast pace	To keep up with the pace of my courses	To keep up with the pace of my courses
05b_Workload Management (WM)	05_2	To manage the volume of work	To manage the volume of work	To have a manageable workload	To have a manageable workload
	05_3	To cope with the educational demands	To manage the stress	To cope with stress	To cope with stress

Dimension	#	(a) Expert Review #1	(b) Expert Review #2	(c) Pilot Study	(d) Main Study
	05_4	To balance the academic workload with social and personal life	To balance my academic, social, and personal responsibilities	To have a balanced social, personal, and academic experience	To have a balanced social, personal, and academic experience
	05_5		To cope with the difficult courses	~~To cope with the difficult courses~~	
06a_Financial(F)	06_1	To ease the financial burden	To ease my financial burden	To ease my financial burden	To ease my financial burden
	06_2	To have opportunities to earn money	To have opportunities to earn money	To have opportunities to earn money in order to offset my expenses (e.g., jobs, work study, etc.)	To have opportunities to earn money in order to offset my expenses (e.g., jobs, work study, etc.)
	06_3	To be aware of financial resources/ opportunities	To be aware and educated about financial assistance/ opportunities	To be informed about financial assistance opportunities	To be informed about financial assistance opportunities
	06_4		To have financial assistance/opportunities available to me	To have financial assistance available to me (e.g., scholarships, grants, etc.)	To have financial assistance available to me (e.g., scholarships, grants, etc.)
07a_Peer Contact (PC)	07_1	Opportunities to develop close personal relationships with other students	To have opportunities to cultivate close personal relationships with students that share my interests	To have opportunities to cultivate close personal relationships with students who share my interests	To have opportunities to cultivate close personal relationships with students who share my interests

Dimension	#	(a) Expert Review #1	(b) Expert Review #2	(c) Pilot Study	(d) Main Study
07b_Student -Student Relationships (SSR)	07_2	Opportunities to learn from other students.	To have opportunities to exchange ideas and gain knowledge from other students	To have opportunities to exchange ideas and gain knowledge from other students	To have opportunities to exchange ideas and gain knowledge from other students
07c_ Student Interaction (SI)	07_3	Opportunities to socialize and explore interests with other students	~~To have opportunities to socialize and explore interests with other students~~	To have opportunities to socialize with students from diverse backgrounds	To have opportunities to socialize with students from diverse backgrounds
	07_4	Opportunities to socialize and create connections with students from different economic, social, and racial or ethnic backgrounds	To have opportunities to socialize and create connections with students from different economic, social, and racial or ethnic backgrounds	To have opportunities to participate in extracurricular activities with other students	To have opportunities to participate in extracurricular activities with other students
08a_Sense of Community (SC)	08_1	An environment where students feel a sense of belonging	To have an environment where I feel a sense of belonging	To have a welcoming environment where I feel a sense of belonging	To have a welcoming environment where I feel a sense of belonging
	08_2	A cooperative environment among teachers and students	To have a cooperative environment among teachers and students	~~To have a cooperative environment among teachers and students~~	
	08_3	To have a supportive community that provides help and encouragement	To have a supportive community of people that provide help and encouragement	To have a supportive group of people who provide help and encouragement	To have a supportive group of people who provide help and encouragement
	08_4	Fair and unbiased treatment for all students	To receive fair and unbiased treatment	To have an environment where I receive fair and unbiased treatment	To have an environment where I receive fair and unbiased treatment

Dimension	#	(a) Expert Review #1	(b) Expert Review #2	(c) Pilot Study	(d) Main Study
	~~02_3~~ 08_5		To have opportunities outside of class to cultivate personal relationships with faculty	To have opportunities outside of class to cultivate relationships with the engineering community on campus	To have opportunities outside of class to cultivate relationships with the engineering community on campus
09a_Skills (S)	09_1	Providing research and industry -related skills, knowledge, and experiences	To have research and industry-related skills, knowledge and experiences	To develop research skills, knowledge, and, experiences in my field	To develop research skills and experiences
09b_Skill (S)	09_2	Developing basic academic skills (e.g., study, time management)	To develop basic academic skills (e.g., study skills, time management)	To develop basic academic skills (e.g., study skills, time management, etc.)	To develop basic academic skills (e.g., study skills, time management, etc.)
	09_3	Developing my ability to work as a team member	To develop my ability to work as a team member	To develop my ability to work as a team member	To develop teamwork skills
	09_4	Developing my communication (written & verbal) skills	To develop my communication (e.g., verbal and written) skills	To develop my communication skills (e.g., verbal and written)	To develop communication skills (e.g., verbal and written)
	09_5	Developing my critical thinking and problem-solving skills	To develop my scientific knowledge and reasoning skills	To develop my problem solving skills	To develop problem solving skills
	09_6	Developing my Computer Skills	To develop my technical skills (e.g., programming languages, software applications)	To develop my technical skills (e.g., programming languages, software applications)	To develop technical skills (e.g., programming languages, software applications, etc.)
	09_7	Developing my Math Ability	To develop my math ability	~~To develop my math ability~~	

Dimension	#	(a) Expert Review #1	(b) Expert Review #2	(c) Pilot Study	(d) Main Study
	09_8	Developing my ability in science	~~Developing my ability in science~~		
	09_9			To have job or work-related skills, knowledge and experiences in my field	To develop job or work-related skills and experiences
Overall Satisfaction	Overall, I am satisfied with my engineering college experience.				

Table B-2: Final ESNQ as a Result of the Main Study

Indicate Your Level of Importance																	**Indicate Your Level of Satisfaction**
1 - *Not At All Important* 7 – *Very Important*								*4 – Neutral* N/A – *Not Applicable* *1 – Not At All Satisfied* *7 – Very Satisfied*									
How important is this need to you?								**#**	**Need**	***How satisfied are you with this need being met?***							
1	2	3	4	5	6	7	N/A			1	2	3	4	5	6	7	N/A
								01_1	To have classes that stimulate interest in my field of study								
								01_4	To have relevant assignments (e.g., HW, labs, exams, etc.) that reinforce what I am learning in class								
								01_6	To comprehend class material								
								01_7	To have class concepts communicated in a manner that I understand								
								02_1	To have approachable faculty members that I can discuss issues of interest and importance to me								
								02_4	To have faculty members who demonstrate flexibility and responsiveness to my needs								
								02_5	To have faculty members who are interested in engaging me in their fields								
								02_6	To receive timely feedback from faculty members (e.g., grades, homework, exams)								

								05_1	To keep up with the pace of my courses								
								05_2	To have a manageable workload								
								05_3	To cope with stress								
								05_4	To have a balanced social, personal, and academic experience								
								06_1	To ease my financial burden								
								06_2	To have opportunities to earn money in order to offset my expenses (e.g., jobs, work study, etc.)								
								06_3	To be informed about financial assistance opportunities								
								06_4	To have financial assistance available to me (e.g., scholarships, grants, etc.)								
								07_1	To have opportunities to exchange ideas and gain knowledge from other students								
								07_2	To have opportunities to socialize with students from diverse backgrounds								
								07_3	To have opportunities to socialize with students from diverse backgrounds								
								08_1	To have a welcoming environment where I feel a sense of belonging								

								08_3	To have a supportive group of people who provide help and encouragement								
								08_4	To have an environment where I receive fair and unbiased treatment								
								08_5	To have opportunities outside of class to cultivate relationships with the engineering community on campus								
								09_4	To develop communication skills (e.g., verbal and written)								
								09_5	To develop problem solving skills								
								09_6	To develop technical skills (e.g., programming languages, software applications, etc.)								
								09_9	To develop job or work-related skills and experiences								

Indicate Your Level of Agreement Indicate Your Level of Satisfaction

1 – *Strongly Disagree* 4 – *Neutral* 7 – *Strongly Agree* N/A – *Not Applicable*

Need	1	2	3	4	5	6	7	N/A
Overall, I am satisfied with my engineering college experience								

Please indicate your responses below:

What is your class? (Freshmen, Sophomore, Junior, Senior)

What is your major?

What is your sex? (Female, Male)

What is your racial and ethnic identity? (American Indian or Other Native American) (Asian, Asian American or Pacific Islander) (Black or African American) (White, non-Hispanic) (Hispanic or Latino) (Other)

Are you an international student? (Yes, No)

What have been most of your grades up until now? (A, B+, B, B-, C+, C, C- or lower)

Enter your email address if would like to be entered into a drawing ($25 gift card). ________________________________

APPENDIX C: STUDENT EXPERT PANEL REVIEW

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY
Informed Consent for Participants
in Research Projects Involving Human Subjects

Title of Project: Student Success Oriented System Design Methodology: "Student Expert Panel Review" Meeting

Investigator(s): Tracee Gilbert (Advisor: Janis Terpenny)

I. Purpose of this Research/Project
You are invited to participate in a focus group meeting that will help determine the needs of engineering students that facilitate student success. The purpose of this meeting is to assess the construct validity of the Engineering Student Needs Questionnaire. This will require you to judge if the items are reflective of the overall constructs, and that the items are representative of those needs that are critical to engineering student success.

II. Procedures
This study consists of three parts. **Part A** will require you to complete the questionnaire, comment on the clarity of items, and group items into similar categories. Based on your responses, **Part B** will require you to share your responses with the group so that we are collectively able to refine the questionnaire. Finally, **Part C** will require you to provide feedback in order to help me refine and improve this meeting.

III. Risks
Participation in this project does not place you at more than minimal risk of harm.

IV. Benefits
The results of this study will be used to refine an Engineering Student Needs questionnaire. The questionnaire will assist institutional leaders in: (1) identifying the critical needs of engineering students that promote student success; (2) examining the extent to which student needs are being met; and (3) understanding how student needs are different among various student groups (e.g., minorities and women).

This questionnaire is a critical part of a larger research effort that seeks to develop a Student Success - Oriented System Design Methodology. This methodology will be used to help institutional leaders translate student needs into improvement practices that will ultimately help to facilitate student success.

V. Extent of Anonymity and Confidentiality
Your anonymity will be preserved throughout this research effort. Information gained from this study will be used to develop a questionnaire for eventual use in a scientific publication. <u>At no time will you be personally identified</u>. No names will be associated with your input provided today or in future publications. In fact, the list of participants will be destroyed at the end of the research period.

VI. Compensation
You will be financially compensated individually for your participation. You will be paid $5/half an hour. This is a total of $20 for the full 2 hour participation.

VII. Freedom to Withdraw
Participants are free to withdraw from the focus group without penalty and are free not to answer any questions that they choose. However, only those participants who participate for the majority of the meeting will be compensated.

VIII. Subject's Responsibilities
I voluntarily agree to participate in this study. I have the following responsibilities: to read and understand the procedures described in the consent form; to actively participate in the meeting by answering questions open and honestly; respect the confidentiality of the other meeting participants; and to participate in an evaluation of this meeting.

IX. Subject's Permission
I have read the Consent Form and conditions of this project. I have had all my questions answered. I hereby acknowledge the above and give my voluntary consent:

Chair, Virginia Tech Institutional Review
Board for the Protection of Human Subjects
Office of Research Compliance
2000 Kraft Drive, Suite 2000 (0497)
Blacksburg, VA 24060

Should I have any pertinent questions about this research or its conduct, and research subjects' rights, and whom to contact in the event of a research-related injury to the subject, I may contact:

Tracee Gilbert_ (703)-725-5533/trwalker@vt.edu______________________
Investigator(s) Telephone/e-mail

Dr. Janis Terpenny (540) 231-9538/terpenny@vt.edu____________________
Faculty Advisor Telephone/e-mail

David M. Moore 540-231-4991/moored@vt.edu_________________________
Departmental Reviewer/Department Head Telephone/e-mail

I have read and understand the Informed Consent and conditions of this study. I have had all my questions answered. I hereby acknowledge the above and give my voluntary consent to participate in this meeting, with the understanding that I may discontinue participation at any time.

____
Signature of Participant

Part A: Complete the Questionnaire

Please read and answer each item as if you were taking the questionnaire. For each item, please do the following:

a) Edit the items to ensure appropriateness of language, clarity, and readability.

b) Rate each of the items from 1 (not clear) to 7 (very clear) in terms of clarity.

c) Items are ordered randomly. Please indicate which category (dimension) the item should be a part of.

- Advisor/Mentor (A/M)
- Faculty Contact (FC)
- Financial(F)
- Help/Resources (H/R)
- Peer Contact (PC)
- Sense of Community (SC)
- Skills (S)
- Teaching and Learning (TL)
- Workload (W)

Each item below describes needs that are deemed critical to your success as an engineering student.
On the *left,* indicate how <u>important</u> this need is to you.
On the *right,* indicate how <u>satisfied</u> you are with this need being met by the institution.

Importance to me **My Satisfaction**

1 - not at all important	5 - somewhat important	1 - not at all satisfied	5 - somewhat satisfied
2 - not very important	6 - important	2 - not very satisfied	6 - satisfied
3 - somewhat unimportant	7 - very important	3 - somewhat dissatisfied	7 - very satisfied
4 – neutral	N/A – not applicable	4 - neutral	N/A - not applicable

How important is this need to you?								**Need**	***How satisfied are you with this need being met?***								***Clarity***	***Category***
1	2	3	4	5	6	7	N/A		1	2	3	4	5	6	7	N/A		
								A.1: Being challenged and intellectually stimulated in class										
								E.3: To cope with the educational demands										
								I.7: Developing my Math Ability										
								B.3: Opportunities outside of class to cultivate relationships with faculty										
								F.3: To be aware of financial resources/ opportunities										
								I.1: Providing research and industry -related skills, knowledge, and experiences										
								I.8: Developing my ability in science										
								A.5: To connect what I am learning to the real world										
								H.4: Fair and unbiased treatment for all students										

How important is this need to you?								**Need**	*How satisfied are you with this need being met?*								*Clarity*	*Category*
1	2	3	4	5	6	7	N/A		1	2	3	4	5	6	7	N/A		
								A.2: Providing links between what I have learned and how it all fits together										
								E.4: To balance the academic workload with social and personal life										
								G.1: Opportunities to develop close personal relationships with other students										
								C.3: Planning undergraduate education (e.g., course scheduling, meeting institutional requirements)										
								A.3: Being adequately prepared for future courses										
								B.1: Accessible and Approachable Faculty										
								F.1: To ease the financial burden										
								C.5: Cultivating close personal relationships that motivate and encourage you to succeed										
								I.5: Developing my critical thinking and problem-solving skills										
								B.2: Faculty that can effectively communicate and convey their knowledge										
								C.4: Receiving advise on indentifying interests, setting goals, and achieving goals										
								F.2: To have opportunities to earn money										
								G.2: Opportunities to learn from other students.										
								B.4: Empathetic Faculty that demonstrates flexibility and responsiveness										

How important is this need to you?								**Need**	*How satisfied are you with this need being met?*								*Clarity*	*Category*
1	2	3	4	5	6	7	N/A		1	2	3	4	5	6	7	N/A		
								H.3: To have a supportive community that provides help and encouragement										
								I.2: Developing basic academic skills (e.g. study, time management)										
								I.6: Developing my Computer Skills										
								I.4: Developing my communication (written & verbal) skills										
								C.1: Receiving advise on dealing with academic demands										
								D.1: Providing assistance to gain mastery of course materials (e.g., exam prep, HW assistance)										
								G.3: Opportunities to socialize and explore interests with other students										
								D.2: Accessible resources available to help me										
								B.6: Receiving timely feedback from faculty										
								D.3: Providing mental health resources										
								C.2: Receiving advise on educational aspirations and post-graduation options										
								G.4: Opportunities to socialize and create connections with students from different economic, social, and racial or ethnic backgrounds										
								B.5: Faculty genuinely interested in teaching and engaging students										

How important is this need to you?								**Need**	*How satisfied are you with this need being met?*								*Clarity*	*Category*
1	2	3	4	5	6	7	N/A		1	2	3	4	5	6	7	N/A		
								H.2: A cooperative environment among teachers and students										
								E.1: Time to understand what I have learned and complete my coursework										
								H.1: An environment where students feel a sense of belonging										
								A.4: To understand what I am learning and how to apply (e.g., HW, exams, labs)										
								I.3: Developing my ability to work as a team member										
								E.2: To manage the volume of work										

Part B: Refine the Questionnaire

Below are the initial dimensions that were developed by the researcher. Please fill in your 'Assigned #' from part A. The following questions will be used to refine the questionnaire.

a) Should additional categories be added or renamed?

b) Should additional items be added to a particular category or modified?

c) Are there any improvements that should be made to the questionnaire?

Dimensions	Initial #	Item Description	Assigned #
A_Teaching and Learning (TL)	A.1	Being challenged and intellectually stimulated in class	
	A.2	Providing links between what I have learned and how it all fits together	
	A.3	Being adequately prepared for future courses	
	A.4	To understand what I am learning and how to apply (e.g., HW, exams, labs)	
	A.5	To connect what I am learning to the real world	
B_Faculty Contact (FC)	B.1	Accessible and Approachable Faculty	
	B.2	Faculty that can effectively communicate and convey their knowledge	
	B.3	Opportunities outside of class to cultivate relationships with faculty	
	B.4	Empathetic Faculty that demonstrates flexibility and responsiveness	
	B.5	Faculty genuinely interested in teaching and engaging students	
	B.6	Receiving timely feedback from faculty	

Dimensions	Initial #	Item Description	Assigned #
C_Advisor/Mentor (A/M)	C.1	Receiving advise on dealing with academic demands	
	C.2	Receiving advise on educational aspirations and post-graduation options	
	C.3	Planning undergraduate education (e.g., course scheduling, meeting institutional requirements)	
	C.4	Receiving advise on identifying interests, setting goals, and achieving goals	
	C.5	Cultivating close personal relationships that motivate and encourage you to succeed	
D_Help/Resources (H/R)	D.1	Providing assistance to gain mastery of course materials (e.g., exam prep, HW assistance)	
	D.2	Accessible resources available to help me	
	D.3	Providing mental health resources	
E_Workload (W)	E.1	Time to understand what I have learned and complete my coursework	
	E.2	To manage the volume of work	
	E.3	To cope with the educational demands	
	E.4	To balance the academic workload with social and personal life	
F_Financial(F)	F.1	To ease the financial burden	
	F.2	To have opportunities to earn money	
	F.3	To be aware of financial resources/ opportunities+I14	
G_Peer Contact (PC)	G.1	Opportunities to develop close personal relationships with other students	
	G.2	Opportunities to learn from other students.	
	G.3	Opportunities to socialize and explore interests with other students	
	G.4	Opportunities to socialize and create connections with students from different economic, social, and racial or ethnic backgrounds	

Dimensions	Initial #	Item Description	Assigned #
H_Sense of Community (SC)	H.1	An environment where students feel a sense of belonging	
	H.2	A cooperative environment among teachers and students	
	H.3	To have a supportive community that provides help and encouragement	
	H.4	Fair and unbiased treatment for all students	
I_Skills (S)	I.1	Providing research and industry -related skills, knowledge, and experiences	
	I.2	Developing basic academic skills (e.g., study, time management)	
	I.3	Developing my ability to work as a team member	
	I.4	Developing my communication (written & verbal) skills	
	I.5	Developing my critical thinking and problem-solving skills	
	I.6	Developing my Computer Skills	
	I.7	Developing my Math Ability	
	I.8	Developing my ability in science	

Part C: Feedback

1. What aspects of the meeting were effective?

2. If you encountered any problems, please explain?

3. What needs to be improved?

APPENDIX D: PRACTITIONER EXPERT PANEL REVIEW

Introduction

Thank you for agreeing to be an expert reviewer for the Engineering Student Needs Questionnaire (ESNQ). This questionnaire has been designed to capture the critical 'student success' needs of undergraduate engineering students. The ESNQ is a part of a larger research effort that shifts the focus from trying to understand why students leave or stay in college (which is largely the current trend in student success research), to placing the needs of students at the heart of designing engineering student success practices that satisfy their needs.

For example, African American engineering students left their engineering programs because of the psychological effects related to racial discrimination. While Asian engineering students do not typically experience being left out because they are perceived as inherently inferior, they do experience being left out because of their perceived academic superiority. So as a result, the ESNQ is intended to capture the generic need (i.e., *to have an environment where I feel welcome and belong*). By doing so, institutional decision makers can administer the ESNQ to all engineering students as a whole, as well as assess the unique needs of various student sub-groups.

Instructions

Please follow the instructions below to complete your expert review. For the purpose of this review, the questionnaire is formatted such that you are able to make suggestions to improve both the individual items and the overall questionnaire. However, an example below is used to illustrate how the actual questionnaire will be formatted when it is administered to students.

How important is this need to you?								**Need**	***How satisfied are you with this need being met by the institution?***							
1	2	3	4	5	6	7	N/A		1	2	3	4	5	6	7	N/A
								To ease the financial burden								

The item above illustrates a need that is critical to the success of engineering students. On the left side, students will be asked to rate their level of importance; and on the right side, students will be asked to indicate how satisfied they are with this need being met by the institution on a 7-point scale (1 - Not Important At All or Not Satisfied At All to 7 - Very Important or Very Satisfied). By assessing both, improvements can be focused on those important needs that are not being satisfactorily met.

- ***Part A: Expert Review*** **-** The ESNQ items are included on pages 2-5. For each 'student need' dimension, please:
  1) Edit the items to ensure appropriateness of language, clarity, and readability.
  2) Rate each of the items from 1 (not clear), 2 (somewhat clear), or 3 (very clear) in terms of clarity.
  3) Indicate whether each of the items is representative of the student need dimesion from 1 (not representative), 2 (somewhat representative), or 3 (very representative).
  4) Make suggestions to improve each item.
  5) Make suggestions to improve each dimension overall.

- ***Part B: Feedback*** **-** Answer two questions regarding your general impressions about the ESNQ.

Dimension	Item	Clear	Representative	Suggestions
		1 –Not; 2 – Somewhat; 3 – Very		
Classroom Teaching and Learning	To be challenged and intellectually stimulated in class			
	To have opportunities to practice what I have learned			
	To connect what I am learning to the real world			
	To understand course material			
	To have course concepts communicated in a manner that I comprehend			
Overall:				

Dimension	Item	Clear	Representative	Suggestions
		1 –Not; 2 – Somewhat; 3 – Very		
Student – Faculty (i.e., professors, instructors, teaching assistants, etc.) Interactions	To have accessible and approachable teachers			
	To have empathetic teachers that demonstrate flexibility and responsiveness to my needs			
	To have a teachers genuinely interested in engaging me in their field			
	To receive timely feedback from the teachers (e.g., grades, hw, exams)			
	To understand what my teachers expect of me			
Overall:				

Dimension	Item	Clear	Representative	Suggestions
		1 –Not; 2 – Somewhat; 3 – Very		
Resources	To receive guidance on educational aspirations and post-graduation options			
	To receive guidance on planning my undergraduate education (e.g., course scheduling, meeting institutional requirements)			
	To receive guidance on indentifying my interests and setting goals to achieve them			
	To receive extra help in gaining mastery of course materials (e.g., exam prep, HW assistance)			
	To have resources available to help me. (e.g., reference material, equipment, software)			
Overall:				

Dimension	Item	Clear	Representative	Suggestions
		1 –Not; 2 – Somewhat; 3 – Very		
Workload Management	To keep up with the fast pace			
	To manage the volume of work			
	To manage the stress			
	To balance my academic, social, and personal responsibilities			
	To cope with the difficult courses			
Overall:				

Dimension	Item	Clear	Representative	Suggestions
		1 –Not; 2 – Somewhat; 3 – Very		
Community Environment	To have an environment where I feel welcome and belong			
	To have a cooperative environment among teachers and students			
	To have a supportive community of people that provide help and encouragement			
	To have an environment where I receive fair and unbiased treatment			
	To have opportunities outside of class to cultivate personal relationships with faculty role models			
Overall:				

Dimension	Item	Clear	Representative	Suggestions
		1 –Not; 2 – Somewhat; 3 – Very		
Financial	To ease the financial burden associated with the cost of attendance			
	To have opportunities to earn money			
	To be educated and aware of financial opportunities			
	To have financial assistance available to me			
	To ease the financial burden associated with the cost of personal and living expenses			
Overall:				

Dimension	Item	Clear	Representative	Suggestions
		1 –Not; 2 – Somewhat; 3 – Very		
Student – Student	To have opportunities to cultivate close personal relationships with students that share my interests			
	To have opportunities to exchange ideas and gain knowledge from other students			
	To have opportunities to socialize with other students			
	To have opportunities to socialize and create connections with students from different economic, social, and racial/ethnic backgrounds			
Overall:				

Dimension	Item	Clear	Representative	Suggestions
		1 –Not; 2 – Somewhat; 3 – Very		
Skill	To have research and industry-related skills, knowledge and experiences			
	To develop basic academic skills (e.g., study skills, time management)			
	To develop my ability to work as a team member			
	To develop my communication (e.g., verbal and written) skills			
	To develop my scientific knowledge and reasoning skills			
	To develop my technical skills (e.g., programming languages, software applications)			
	To develop my math ability			
Overall:				

1) What is your general impression of the questionnaire?

2) Does the questionnaire comprehensively address the needs that are critical to engineering student success? If not, explain

APPENDIX E: PHASE I – DIAGNOSE THE BASELINE MEETING PROTOCOL

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY
Informed Consent for Participants
in Research Projects Involving Human Subjects

Title of Project: Student Success - Oriented System Design Methodology: "Diagnose the Baseline" Meeting

Investigator(s): Tracee Gilbert (Advisor: Janis Terpenny)

I. Purpose of this Research/Project
You are invited to participate in a research study to that seeks to examine how to serve the needs of engineering students that will facilitate their success. The purpose of this meeting is to document the current baseline of 'student success' practices for undergraduate female engineering students and to identify areas that will be improved for next year.

II. Procedures
This study consists of five parts. **Part A** will inform you about my role as the facilitator of the meeting, the meeting's goals, what activities you will be expected to perform, and how this study fits into the larger context of this research study. **Part B** will require you to answer a series of planned questions that will be used to guide the discussion. The first set of questions is intended to allow the group to reflect on personal experiences. We will then engage in a group discussion to identify engineering student needs. During **Part C**, we will use system design tools to organize and document the information provided by the group. **Part D** consists of a validation step to ensure that the key deliverables that we will design satisfy the goals of the meeting. Finally, **Part E** consists of a short evaluation questionnaire that will be used to get your feedback on improving the meeting's processes and output.

III. Risks
Participation in this project does not place you at more than minimal risk of harm.

IV. Benefits
This meeting is a part of a larger research effort to develop a Student Success-Oriented System Design Methodology (S^2OSD, pronounced "*SAWS-D*"), which is intended to help higher education administrators identify their students' needs, and translate those needs into a plan of action that facilitates student success. The methodology consists of four phases, in which this meeting is focused on Phase I.

- ➢ *<u>Phase I</u>*: Diagnose the Baseline – diagnoses the current state of affairs in order to develop areas that are in need of improvement.
- *<u>Phase II:</u>* Assess Needs – determines the needs of female engineering students.
- <u>Phase III:</u> Design Improvements – translates student needs into recommended improvement practices.
- <u>Phase IV:</u> Develop Plan of Action - develops a plan of action based off of the information generated from the previous Phases.

V. Extent of Anonymity and Confidentiality
Your anonymity will be preserved throughout this research effort. Information gained from this study will be used to develop a questionnaire for eventual use in a scientific publication.

VI. Compensation
There is no financial compensation for your participation.

VII. Freedom to Withdraw
Participants are free to withdraw without penalty and are free not to answer any questions that they choose. However, only those participants who participate for the entirety of the meeting will be able to enter the raffle.

VIII. Subject's Responsibilities
I voluntarily agree to participate in this study. I have the following responsibilities: to read and understand the procedures described in the consent form; to actively participate in the meeting by answering questions open and honestly; respect the confidentiality of the other meeting participants; and to participate in an evaluation of this meeting.

IX. Subject's Permission
I have read the Consent Form and conditions of this project. I have had all my questions answered. I hereby acknowledge the above and give my voluntary consent:

Chair, Virginia Tech Institutional Review
Board for the Protection of Human Subjects
Office of Research Compliance
2000 Kraft Drive, Suite 2000 (0497)
Blacksburg, VA 24060

Should I have any pertinent questions about this research or its conduct, and research subjects' rights, and whom to contact in the event of a research-related injury to the subject, I may contact:

Tracee Gilbert_ (703)-725-5533/trwalker@vt.edu______________________________________
Investigator(s) Telephone/e-mail

Dr. Janis Terpenny (540) 231-9538/terpenny@vt.edu____________________________________
Faculty Advisor Telephone/e-mail

David M. Moore 540-231-4991/moored@vt.edu____
Departmental Reviewer/Department Head Telephone/e-mail

I have read and understand the Informed Consent and conditions of this study. I have had all my questions answered. I hereby acknowledge the above and give my voluntary consent to participate in this meeting, with the understanding that I may discontinue participation at any time.

____
Signature of Participant

DB PART A: INFORM

The goal of this phase is to identify the baseline of current student success practices, and to identify areas that are in need of improvement. As a result of these goals, objectives have also been established to ensure that this study is focused on identifying student needs in the context of student success. These objectives will also provide you a reference point for determining whether your input falls within the scope of this research.

Goal #1: To baseline current undergraduate engineering practices	***Goal #2: To identify areas that are in need of improvement***
Objective #1: To define practices in the context of student success.	***Objective #2: To include only factors that the institution can directly impact.***

PART B: ELICIT

Once you have an understanding of the scope of the meeting, we will begin to document current practices and brainstorm ideas to identify areas that are in need of improvement. A series of planned questions will be used to guide the meeting to diagnose key performance areas: mission/goals, student needs, capacity, system design processes, and success measures.

I. Current State

Mission/Goals:
- Discussion Question 1a: What are the goals of the program?
- Discussion Question 1b: How does the program define success in achieving the goals?

Student Success Needs:
- Discussion Question 2a: What are the needs of undergraduate engineering students that should be met in order for them to succeed?
- Discussion Question 2b: How does the program meet the 'student success' needs of their undergraduate engineering students?
- Discussion Question 2c: How does the program define and measure success for meeting student needs?

Capacity:
- Discussion Question 3: What infrastructure is needed to meet the needs of the students?

Measurement:
- Discussion Question 4: How is success defined and measured?

Results:
- Discussion Question 5: What are the outcomes of the current practices (red- needs improvement, yellow – adequate, green – good, blue – excellent)?

II. Strengths and Weaknesses

- Discussion Question 6: What are the strengths of practice X?
- Discussion Question 7: What aspects of practice X need to be improved?

III. Desired State

- Discussion Question 8: Where are opportunities for desired improvements?
- Discussion Question 9: What barriers can impede progress toward improvements?

Part C: Generate

The output of the meeting is shown in Figure E-1. Each of the discussion questions are intended to guide the completion of the matrices identified in Figure E-1.

Part D: Validate

Once we have completed all of the matrices, we will review the goals and objective to ensure that they have been met. Where this is not the case, then we will iterate through the meeting process to elicit, generate, and validate the output as needed

Figure E-1: Baseline Diagnosis Matrix

Current State: Advising		**Current Goals: To help students navigate through their undergraduate engineering experience.** ①			
Dimensions of Student Success Needs ②	**Practices** ③	**Measures of Success** ④	**Results** ⑥	**Desired State (Opportunities)**	**Threats**
Classroom Learning					
Workload Management					
Skil					
Faculty Interaction					
Sense of Community /Student Interaction					
Financial					
Capacity ⑤					
Strengths					
Weaknesses					

DB Part E: Formative Evaluation

Thank you for your participation! Please take a moment to fill out this two-part questionnaire to help me identify areas in this meeting that need to be improved. Please refer back to the procedures, if necessary, and provide comments or recommendations that will help me refine and improve this meeting.

	Please answer the following questions.	1 = Strongly Disagree	2	3	4	5 = Strongly Agree
Design Goals	This meeting was able to draw out ideas that I may not have considered at the start of the meeting.	❍	❍	❍	❍	❍
	This meeting was able to comprehensively baseline current practices.	❍	❍	❍	❍	❍
	This meeting was able to comprehensively identify areas that are in need of improvement.	❍	❍	❍	❍	❍
Ease of Learning	I did not encounter problems in learning this process.	❍	❍	❍	❍	❍
	My peers could learn how to use this process.	❍	❍	❍	❍	❍
	My role in this in this process was clear and understandable.	❍	❍	❍	❍	❍
Ease of Participation	My participation in this process was straightforward.	❍	❍	❍	❍	❍
	My peers could participate in this process with ease.	❍	❍	❍	❍	❍
	I did not encounter problems participating in the process.	❍	❍	❍	❍	❍
	This meeting was able to draw out ideas that I may not have considered at the start of the meeting.	❍	❍	❍	❍	❍
Usability of Tools	The key performance areas comprehensively aligned key aspects of the program that are critical to managing student success practices.	❍	❍	❍	❍	❍
	This Baseline Diagnosis Matrix was effective.	❍	❍	❍	❍	❍
Usability of Overall	I would recommend this approach to faculty and program administrators.	❍	❍	❍	❍	❍
	The information produced from this meeting can be used to understand the needs of engineering students.	❍	❍	❍	❍	❍

1. What aspects of the meeting were effective?

2. If you encountered any problems, please explain?

3. What needs to be improved?

APPENDIX F: PHASE II – IDENTIFY NEEDS

APPENDIX F-1: Female Engineering Students Mean Importance, Mean Satisfaction, Mean Unmet Need Scores, and USN_i

Dimension	#	Questionnaire Items	Mean *Imp*	Mean *Sat*	Mean *UN*	USN_I
Classroom Learning	01_1	To have classes that stimulate interest in my field of study	6.53	4.81	1.72	24.83
	01_4	To have relevant assignments (e.g., HW, labs, exams, etc.) that reinforce what I am learning in class	6.45	5.20	1.25	16.54
	01_6	To comprehend class material	6.71	5.39	1.32	13.37
	01_7	To have class concepts communicated in a manner that I understand	6.66	5.17	1.49	18.76
Workload Management	05_1	To keep up with the pace of my courses	6.58	5.47	1.11	15.80
	05_2	To have a manageable workload	6.38	4.77	1.61	22.61
	05_3	To cope with stress	5.91	4.75	1.16	13.20
	05_4	To have a balanced social, personal, and academic experience	6.34	4.78	1.56	18.52
Financial	06_1	To ease my financial burden	5.64	4.93	0.69	-8.10
	06_2	To have opportunities to earn money in order to offset my expenses (e.g., jobs, work study, etc.)	5.53	5.24	0.30	-18.98
	06_3	To be informed about financial assistance opportunities	5.42	5.39	0.03	-22.76
	06_4	To have financial assistance available to me (e.g., scholarships, grants, etc.)	5.97	5.31	0.65	-2.50

Dimension	#	Questionnaire Items	Mean *Imp*	Mean *Sat*	Mean *UN*	USN_I
Faculty Interaction	02_1	To have approachable faculty members that I can discuss issues of interest and importance to me	6.01	5.46	0.55	3.01
	02_4	To have faculty members who demonstrate flexibility and responsiveness to my needs	5.91	5.45	0.47	-2.18
	02_5	To have faculty members who are interested in engaging me in their fields	5.86	5.41	0.45	0.76
	02_6	To receive timely feedback from faculty members (e.g., grades, homework, exams)	5.97	5.54	0.43	-3.61
Sense of Community	08_1	To have a welcoming environment where I feel a sense of belonging	5.86	5.63	0.23	-9.73
	08_3	To have a supportive group of people who provide help and encouragement	6.04	5.40	0.64	4.52
	08_4	To have an environment where I receive fair and unbiased treatment	6.29	5.78	0.55	4.26
	08_5	To have opportunities outside of class to cultivate relationships with the engineering community on campus	5.73	5.73	0.00	-9.94
Skill	09_4	To develop communication skills (e.g., verbal and written)	6.01	5.65	0.38	3.65
	09_5	To develop problem solving skills	6.27	6.00	0.27	2.56
	09_6	To develop technical skills (e.g., programming languages, software applications, etc.)	5.92	5.38	0.54	4.63
	09_9	To develop job or work-related skills and experiences	6.34	5.07	1.28	16.47
Student Interaction	07_1	To have opportunities to cultivate close personal relationships with students who share my interests	5.85	5.71	0.13	-6.15
	07_2	To have opportunities to exchange ideas and gain knowledge from other students	5.59	5.64	-0.05	-16.81
	07_3	To have opportunities to socialize with students from diverse backgrounds	5.37	5.90	-0.54	-33.52

Appendix F-2: Descriptive Statistics of Dependent Variables: WIE's SNID Method (Gender * Ethnicity/Race)

Female Engineering Students										
	Minority (N= 15)		Asian (N=26)		White (N= 61)		Other (N= 3)		All Females (N= 105)	
	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.
Classroom Learning	1.85	1.42	1.17	0.93	1.47	0.87	1.25	0.25	1.45	0.98
Workload Management	1.38	1.72	1.04	1.24	1.50	1.13	1.17	0.63	1.36	1.24
Skills	0.34	1.49	0.13	1.28	0.44	1.43	-0.53	0.81	0.52	1.08
Faculty Interaction	0.62	1.37	0.07	1.78	0.63	1.38	0.17	0.76	0.47	1.48
Financial	0.05	1.42	0.52	0.88	0.69	1.03	-0.25	2.14	0.42	1.98
Sense of Community	0.58	2.52	0.03	1.94	0.58	1.87	0.25	0.75	0.35	1.38
Student Interaction	-0.16	1.63	-0.37	1.48	-0.07	1.40	-0.22	0.69	-0.16	1.43
Male Engineering Students										
	Minority (N= 32)		Asian (N=11)		White (N=59)		Other (N=6)		All Males (N=108)	
	Mean	St. Dev	Mean	St. Dev	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.
Classroom Learning	1.35	0.84	1.02	0.85	1.42	0.86	1.92	1.54	1.36	0.85
Workload Management	1.34	1.35	1.41	1.85	0.75	1.30	1.50	3.09	1.00	1.40
Faculty Interaction	0.51	1.37	0.14	1.39	0.72	1.23	1.00	1.75	0.59	1.29
Skill	0.39	1.32	0.31	0.86	0.60	0.76	1.10	1.71	0.50	0.97
Financial	0.59	1.99	0.23	1.00	0.17	1.54	-0.71	2.35	0.31	1.64
Sense of Community	0.27	1.31	0.05	1.08	-0.02	0.87	0.17	2.15	0.08	1.04
Student Interaction	0.03	1.46	-0.27	1.61	-0.19	1.26	-0.28	2.08	-0.13	1.35

APPENDIX F-3: Two - Way ANOVA Results (Main Effect1: Gender, Main Effect2: Ethnicity/Race, Interaction Effect: Ethnicity/Race * Gender)

Dependent Variable: Classroom Learning Needs

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	7.968	7	1.138	1.302	.251	.043
Intercept	172.506	1	172.506	197.275	.000	.490
Gender	.002	1	.002	.002	.967	.000
Ethnicity/Race	4.818	3	1.606	1.837	.142	.026
Gender * Ethnicity/Race	2.842	3	.947	1.083	.357	.016
Error	179.261	205	.874			
Total	614.000	213				
Corrected Total	187.229	212				

Dependent Variable: Workload Management Needs

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	20.677	7	2.954	1.538	.156	.050
Intercept	133.878	1	133.878	69.726	.000	.254
Gender	.012	1	.012	.006	.938	.000
Ethnicity/Race	1.927	3	.642	.335	.800	.005
Gender * Ethnicity/Race	10.841	3	3.614	1.882	.134	.027
Error	393.612	205	1.920			
Total	718.375	213				
Corrected Total	414.289	212				

Dependent Variable: Financial Needs

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	18.010	7	2.573	.754	.626	.025
Intercept	1.924	1	1.924	.564	.454	.003
Gender	.560	1	.560	.164	.686	.001
Ethnicity/Race	9.262	3	3.087	.905	.440	.013
Gender * Ethnicity/Race	2.978	3	.993	.291	.832	.004
Error	695.830	204	3.411			
Total	737.229	212				
Corrected Total	713.840	211				

Dependent Variable: Faculty Interaction Needs

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	11.706	7	1.672	.852	.546	.028
Intercept	19.339	1	19.339	9.849	.002	.046
Gender	1.018	1	1.018	.518	.472	.003
Ethnicity/Race	7.987	3	2.662	1.356	.257	.019
Gender * Ethnicity/Race	1.511	3	.504	.257	.857	.004
Error	402.552	205	1.964			
Total	477.069	213				
Corrected Total	414.258	212				

Dependent Variable: Sense of Community Needs

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	7.352	7	1.050	.657	.708	.022
Intercept	3.525	1	3.525	2.206	.139	.011
Gender	.660	1	.660	.413	.521	.002
Ethnicity/Race	.844	3	.281	.176	.913	.003
Gender * Ethnicity/Race	1.785	3	.595	.372	.773	.005
Error	327.526	205	1.598			
Total	344.597	213				
Corrected Total	334.878	212				

Dependent Variable: Skill Needs

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	11.723	7	1.675	1.543	.154	.050
Intercept	12.812	1	12.812	11.806	.001	.054
Gender	3.728	1	3.728	3.435	.065	.016
Ethnicity/Race	6.232	3	2.077	1.914	.128	.027
Gender * Ethnicity/Race	6.965	3	2.322	2.139	.096	.030
Error	222.483	205	1.085			
Total	293.573	213				
Corrected Total	234.206	212				

Dependent Variable: Student Interaction Needs

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	3.074	7	.439	.216	.981	.007
Intercept	3.044	1	3.044	1.496	.223	.007
Gender	.017	1	.017	.008	.928	.000
Ethnicity/Race	1.374	3	.458	.225	.879	.003
Gender * Ethnicity/Race	.838	3	.279	.137	.938	.002
Error	415.052	204	2.035			
Total	422.806	212				
Corrected Total	418.125	211				

Appendix F-4: URM Engineering Students' Mean Importance Score, Satisfaction Score, Unmet Need Score, and USNi

Dimension	#	Questionnaire Items	Mean *Imp*	Mean *Sat*	Mean *UN*	USN_I
Classroom Learning	01_1	To have classes that stimulate interest in my field of study	6.60	4.89	1.70	23.30
	01_4	To have relevant assignments (e.g., HW, labs, exams, etc.) that reinforce what I am learning in class	6.55	5.21	1.34	17.46
	01_6	To comprehend class material	6.77	5.36	1.40	14.84
	01_7	To have class concepts communicated in a manner that I understand	6.70	5.11	1.60	21.18
Workload Management	05_1	To keep up with the pace of my courses	6.45	5.04	1.40	18.98
	05_2	To have a manageable workload	6.21	4.57	1.64	21.26
	05_3	To cope with stress	5.81	4.66	1.15	15.20
	05_4	To have a balanced social, personal, and academic experience	5.87	4.64	1.23	8.00
Financial	06_1	To ease my financial burden	5.74	4.87	0.84	-6.25
	06_2	To have opportunities to earn money in order to offset my expenses (e.g., jobs, work study, etc.)	5.65	5.36	0.27	-14.15
	06_3	To be informed about financial assistance opportunities	5.76	5.50	0.26	-6.96
	06_4	To have financial assistance available to me (e.g., scholarships, grants, etc.)	6.07	5.15	0.91	9.94

Dimension	#	Questionnaire Items	Mean *Imp*	Mean *Sat*	Mean *UN*	USN_I
Faculty Interaction	02_1	To have approachable faculty members that I can discuss issues of interest and importance to me	6.34	5.55	0.79	10.30
	02_4	To have faculty members who demonstrate flexibility and responsiveness to my needs	6.13	5.37	0.82	9.25
	02_5	To have faculty members who are interested in engaging me in their fields	5.66	5.49	0.17	-2.01
	02_6	To receive timely feedback from faculty members (e.g., grades, homework, exams)	5.89	5.43	0.47	-0.04
Sense of Community	08_1	To have a welcoming environment where I feel a sense of belonging	5.85	5.38	0.47	-0.68
	08_3	To have a supportive group of people who provide help and encouragement	6.24	5.52	0.72	8.15
	08_4	To have an environment where I receive fair and unbiased treatment	5.98	5.91	0.16	-3.84
	08_5	To have opportunities outside of class to cultivate relationships with the engineering community on campus	5.63	5.80	-0.17	-11.01
Skill	09_4	To develop communication skills (e.g., verbal and written)	5.91	5.89	0.04	-2.30
	09_5	To develop problem solving skills	6.19	6.13	0.06	-2.56
	09_6	To develop technical skills (e.g., programming languages, software applications, etc.)	6.13	5.77	0.36	1.60
	09_9	To develop job or work-related skills and experiences	5.85	5.19	0.66	5.28
Student Interaction	07_1	To have opportunities to cultivate close personal relationships with students who share my interests	5.96	5.61	0.35	-0.72
	07_2	To have opportunities to exchange ideas and gain knowledge from other students	5.74	5.76	-0.02	-10.76
	07_3	To have opportunities to socialize with students from diverse backgrounds	5.65	6.07	-0.41	-20.87

Appendix F-5: Descriptive Statistics of Dependent Variables: MEP SNID Method (Ethnicity/Race, Class Level)

Ethnicity/Race										
	Minority (N= 47)		Asian (N=37)		White (N= 120)		Other (N= 9)		All (N= 213)	
	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.
Classroom Learning	1.51	1.07	1.13	0.90	1.45	0.86	1.69	1.27	1.4155	.94
Workload Management	1.36	1.46	1.15	1.43	1.13	1.27	1.39	2.47	1.1948	1.40
Financial	0.58	2.15	0.09	1.70	0.38	1.72	-0.56	2.16	.3322	1.84
Faculty Interaction	0.54	1.36	0.09	1.66	0.67	1.31	0.72	1.50	.5430	1.40
Sense of Community	0.30	1.35	0.11	1.21	0.22	1.20	0.19	1.74	.2136	1.26
Skill	0.28	1.35	0.45	0.87	0.64	0.91	0.56	1.63	.5279	1.05
Student Interaction	-0.03	1.51	-0.34	1.50	-0.13	1.33	-0.26	1.68	-.1486	1.41
Class Level										
	Freshmen (N=10)		Sophomore (N=11)		Junior (N=14)		Senior (N=12)		All URMs (N=47)	
	Mean	St. Dev	Mean	St. Dev	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.
Classroom Learning	0.83	0.72	1.91	1.28	1.93	0.57	1.23	1.25	1.51	1.07
Workload Management	0.83	0.91	1.16	1.66	2.07	1.25	1.15	1.70	1.36	1.46
Financial	-0.78	0.67	0.30	2.49	2.17	1.79	0.26	2.13	0.58	2.15
Faculty Interaction	-0.26	0.87	0.68	1.68	1.25	1.24	0.25	1.17	0.54	1.36
Sense of Community	-0.80	0.87	0.11	1.54	1.30	0.97	0.20	1.17	0.30	1.35
Skill	-0.32	0.86	0.30	1.97	0.90	1.27	0.05	0.81	0.28	1.35
Student Interaction	-0.50	1.49	-0.85	1.90	0.85	1.11	0.17	1.00	-0.03	1.51

Appendix F-6: MEP SNID Method: One-way ANOVA Results (Minority/Non-Minority)

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Classroom Learning	Between Groups	.761	2	.380	.324	.725
	Within Groups	51.609	44	1.173		
	Total	52.370	46			
Workload Management	Between Groups	2.039	2	1.020	.468	.629
	Within Groups	95.804	44	2.177		
	Total	97.843	46			
Faculty Interaction	Between Groups	4.283	2	2.141	1.171	.320
	Within Groups	80.479	44	1.829		
	Total	84.762	46			
Sense of Community	Between Groups	6.631	2	3.315	1.877	.165
	Within Groups	77.714	44	1.766		
	Total	84.345	46			
Student Interaction	Between Groups	14.371	2	7.185	3.527	.038
	Within Groups	87.591	43	2.037		
	Total	101.961	45			
Financial	Between Groups	20.974	2	10.487	2.416	.101
	Within Groups	186.679	43	4.341		
	Total	207.653	45			
Skills	Between Groups	12.779	2	6.389	3.987	.026
	Within Groups	70.512	44	1.603		
	Total	83.291	46			

Appendix F-7: MEP SNID Method: One-way ANOVA Results (Class Level)

		Sum of Squares	df	Mean Square	F	Sig.
Classroom Learning	Between Groups	9.843	3	3.281	3.318	.029
	Within Groups	42.526	43	.989		
	Total	52.370	46			
Workload Management	Between Groups	10.942	3	3.647	1.805	.161
	Within Groups	86.901	43	2.021		
	Total	97.843	46			
Faculty Interaction	Between Groups	14.661	3	4.887	2.998	.041
	Within Groups	70.101	43	1.630		
	Total	84.762	46			
Sense of Community	Between Groups	26.698	3	8.899	6.638	.001
	Within Groups	57.646	43	1.341		
	Total	84.345	46			
Student Interaction	Between Groups	20.022	3	6.674	3.421	.026
	Within Groups	81.940	42	1.951		
	Total	101.961	45			
Financial	Between Groups	53.177	3	17.726	4.819	.006
	Within Groups	154.476	42	3.678		
	Total	207.653	45			
Skill	Between Groups	9.622	3	3.207	1.872	.149
	Within Groups	73.668	43	1.713		
	Total	83.291	46			

Tukey HSD Post Hoc Comparisons

Multiple Comparisons

Dependent Variable	(I) About You-What is your class?	(J) About You-What is your class?	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Classroom Learning	Freshman	Sophomore	-1.08409	.43452	.075	-2.2453	.0771
		Junior	-1.10357*	.41175	.049	-2.2039	-.0032
		Senior	-.40417	.42581	.779	-1.5421	.7338
	Sophomore	Freshman	1.08409	.43452	.075	-.0771	2.2453
		Junior	-.01948	.40069	1.000	-1.0903	1.0513
		Senior	.67992	.41512	.369	-.4294	1.7893
	Junior	Freshman	1.10357*	.41175	.049	.0032	2.2039
		Sophomore	.01948	.40069	1.000	-1.0513	1.0903
		Senior	.69940	.39122	.293	-.3461	1.7449
	Senior	Freshman	.40417	.42581	.779	-.7338	1.5421
		Sophomore	-.67992	.41512	.369	-1.7893	.4294
		Junior	-.69940	.39122	.293	-1.7449	.3461
Workload Management	Freshman	Sophomore	-.33409	.62114	.949	-1.9940	1.3259
		Junior	-1.24643	.58860	.164	-2.8194	.3266
		Senior	-.32083	.60869	.952	-1.9475	1.3059
	Sophomore	Freshman	.33409	.62114	.949	-1.3259	1.9940
		Junior	-.91234	.57278	.393	-2.4430	.6184
		Senior	.01326	.59341	1.000	-1.5726	1.5991
	Junior	Freshman	1.24643	.58860	.164	-.3266	2.8194
		Sophomore	.91234	.57278	.393	-.6184	2.4430
		Senior	.92560	.55926	.360	-.5690	2.4202
	Senior	Freshman	.32083	.60869	.952	-1.3059	1.9475
		Sophomore	-.01326	.59341	1.000	-1.5991	1.5726
		Junior	-.92560	.55926	.360	-2.4202	.5690
Faculty Interaction	Freshman	Sophomore	-.94015	.55788	.344	-2.4310	.5507
		Junior	-1.50833*	.52865	.032	-2.9211	-.0956
		Senior	-.50833	.54670	.789	-1.9693	.9527
	Sophomore	Freshman	.94015	.55788	.344	-.5507	2.4310
		Junior	-.56818	.51444	.689	-1.9430	.8066

		Senior	.43182	.53297	.849	-.9925	1.8561
	Junior	Freshman	1.50833*	.52865	.032	.0956	2.9211
		Sophomore	.56818	.51444	.689	-.8066	1.9430
		Senior	1.00000	.50230	.207	-.3423	2.3423
	Senior	Freshman	.50833	.54670	.789	-.9527	1.9693
		Sophomore	-.43182	.53297	.849	-1.8561	.9925
		Junior	-1.00000	.50230	.207	-2.3423	.3423
Sense of Community	Freshman	Sophomore	-.91364	.50590	.285	-2.2656	.4383
		Junior	-2.10357*	.47939	.000	-3.3847	-.8224
		Senior	-1.00139	.49576	.197	-2.3263	.3235
	Sophomore	Freshman	.91364	.50590	.285	-.4383	2.2656
		Junior	-1.18994	.46651	.066	-2.4366	.0568
		Senior	-.08775	.48331	.998	-1.3794	1.2039
	Junior	Freshman	2.10357*	.47939	.000	.8224	3.3847
		Sophomore	1.18994	.46651	.066	-.0568	2.4366
		Senior	1.10218	.45550	.088	-.1151	2.3195
	Senior	Freshman	1.00139	.49576	.197	-.3235	2.3263
		Sophomore	.08775	.48331	.998	-1.2039	1.3794
		Junior	-1.10218	.45550	.088	-2.3195	.1151
Student Interaction	Freshman	Sophomore	.34848	.61029	.940	-1.2840	1.9810
		Junior	-1.34615	.58751	.116	-2.9177	.2254
		Senior	-.66667	.59806	.683	-2.2664	.9331
	Sophomore	Freshman	-.34848	.61029	.940	-1.9810	1.2840
		Junior	-1.69464*	.57222	.025	-3.2253	-.1640
		Senior	-1.01515	.58304	.316	-2.5748	.5445
	Junior	Freshman	1.34615	.58751	.116	-.2254	2.9177
		Sophomore	1.69464*	.57222	.025	.1640	3.2253
		Senior	.67949	.55915	.621	-.8162	2.1752
	Senior	Freshman	.66667	.59806	.683	-.9331	2.2664
		Sophomore	1.01515	.58304	.316	-.5445	2.5748
		Junior	-.67949	.55915	.621	-2.1752	.8162
Financial	Freshman	Sophomore	-1.07045	.83795	.582	-3.3119	1.1710
		Junior	-2.94167*	.80667	.004	-5.0995	-.7839
		Senior	-1.03889	.82116	.590	-3.2354	1.1577
	Sophomore	Freshman	1.07045	.83795	.582	-1.1710	3.3119
		Junior	-1.87121	.78568	.096	-3.9729	.2304
		Senior	.03157	.80054	1.000	-2.1098	2.1730

	Junior	Freshman	2.94167*	.80667	.004	.7839	5.0995
		Sophomore	1.87121	.78568	.096	-.2304	3.9729
		Senior	1.90278	.76774	.078	-.1509	3.9564
	Senior	Freshman	1.03889	.82116	.590	-1.1577	3.2354
		Sophomore	-.03157	.80054	1.000	-2.1730	2.1098
		Junior	-1.90278	.76774	.078	-3.9564	.1509
Skill	Freshman	Sophomore	-.62455	.57190	.696	-2.1529	.9038
		Junior	-1.22000	.54194	.126	-2.6683	.2283
		Senior	-.37000	.56044	.911	-1.8677	1.1277
	Sophomore	Freshman	.62455	.57190	.696	-.9038	2.1529
		Junior	-.59545	.52737	.674	-2.0048	.8139
		Senior	.25455	.54637	.966	-1.2056	1.7147
	Junior	Freshman	1.22000	.54194	.126	-.2283	2.6683
		Sophomore	.59545	.52737	.674	-.8139	2.0048
		Senior	.85000	.51492	.362	-.5261	2.2261
	Senior	Freshman	.37000	.56044	.911	-1.1277	1.8677
		Sophomore	-.25455	.54637	.966	-1.7147	1.2056
		Junior	-.85000	.51492	.362	-2.2261	.5261

*. The mean difference is significant at the 0.05 level.

APPENDIX G: PHASE III – DESIGN IMPROVEMENTS

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY
Informed Consent for Participants
in Research Projects Involving Human Subjects

Title of Project: Student Success-Oriented System Design (S^2OSD) Methodology: "Design Improvements" Meeting

Investigator(s): Tracee Gilbert (Advisor: Janis Terpenny)

I. Purpose of this Research/Project
You are invited to participate in a research study that seeks to examine how to serve the needs of engineering students that facilitates student success. The purpose of this meeting is to design improvements of existing practices or to propose new practices in order to address student success needs that are currently not being met by the program.

II. Procedures
This study consists of five parts. **Part A** will inform you about my role as the facilitator of the meeting, the meeting's goals and objectives, what activities you will be expected to perform, and how this study fits into the larger context of this research study. **Part B** will require you to answer a series of pre-planned questions that will be used to guide the discussion. During **Part C**, we will use system design tools to organize and document the information provided by the group. **Part D** consists of a validation step to ensure that the key deliverables that we will design satisfies the goals and objectives of the meeting. Finally, **Part E** consists of a short evaluation questionnaire that will be used to get your feedback on improving the meeting's processes and output.

III. Risks
Participation in this research does not place you at more than minimal risk of harm.

IV. Benefits
This meeting is a part of a larger research effort to develop a Student Success-Oriented System Design Methodology (S^2OSD, pronounced "*SAWS-D*"), which is intended to help higher education administrators identify their students' needs, and translate those needs into a plan of action that facilitates student success. The methodology consists of four phases, in which this meeting is focused on Phase III.

- <u>Phase I</u>: Diagnose the Baseline – diagnoses the current state of affairs in order to develop areas that are in need of improvement.
- <u>Phase II:</u> Assess Needs – determines the needs of female engineering students.
- ➢ *<u>Phase III:</u> Design Improvements – translates student needs into recommended improvement practices.*
- <u>Phase IV:</u> Develop Plan of Action - develops a plan of action based off of the information generated from the previous Phases.

V. Extent of Anonymity and Confidentiality
Your anonymity will be preserved throughout this research effort. Information gained from this study will be used to develop a questionnaire for eventual use in a scientific publication.

VI. Compensation
You will be financially compensated individually for your participation. This is a total of $20 for the full 2 hour participation.

VII. Freedom to Withdraw
Participants are free to withdraw without penalty and are free not to answer any questions that they choose.

VIII. Subject's Responsibilities
I voluntarily agree to participate in this study. I have the following responsibilities: to read and understand the procedures; to actively participate in the meeting by answering questions open and honestly; respect the confidentiality of the other meeting participants; and to participate in an evaluation of this meeting.

IX. Subject's Permission
I have read the Consent Form and conditions of this project. I have had all my questions answered. I hereby acknowledge the above and give my voluntary consent:

Chair, Virginia Tech Institutional Review
Board for the Protection of Human Subjects
Office of Research Compliance
2000 Kraft Drive, Suite 2000 (0497)
Blacksburg, VA 24060

Should I have any pertinent questions about this research or its conduct, I may contact:

Tracee Gilbert_ trwalker@vt.edu
Investigator(s) Telephone/e-mail

Dr. Janis Terpenny (540)231-9538/ terpenny@vt.edu
Faculty Advisor Telephone/e-mail

David M. Moore (540)231-4991/moored@vt.edu
Departmental Reviewer/Department Head Telephone/e-mail

I have read and understand the Informed Consent and conditions of this study. I have had all my questions answered. I hereby acknowledge the above and give my voluntary consent to participate in this meeting, with the understanding that I may discontinue participation at any time.

____
Signature of Participant

Part A: Inform

The purpose of this meeting is to develop recommendations for program administrators to address the student success needs of engineering students. As a result, the following goals have been established for this meeting.

Table G-1: Meeting's Goals and Objectives

Goals	Objectives
1) To review the critical needs of engineering students	1) To use the results of Phase II to review the unmet needs of the students.
2) To define how institutional practices can address the needs of students.	2) To first describe desired characteristics of student success practices, and then to consider the strengths and weaknesses of current student success practices.
3) To recommend how the program can help support these needs.	3) To determine how the strengths and weaknesses of current practices can be used to develop improvement practices that address the desired characteristics of student success practices.

To achieve these goals, Figure G-1 summarizes the mapping process that will be used to carry out each part of this meeting, which describes the process to translate the critical student needs into improvement practices that will be recommended to program administrators.

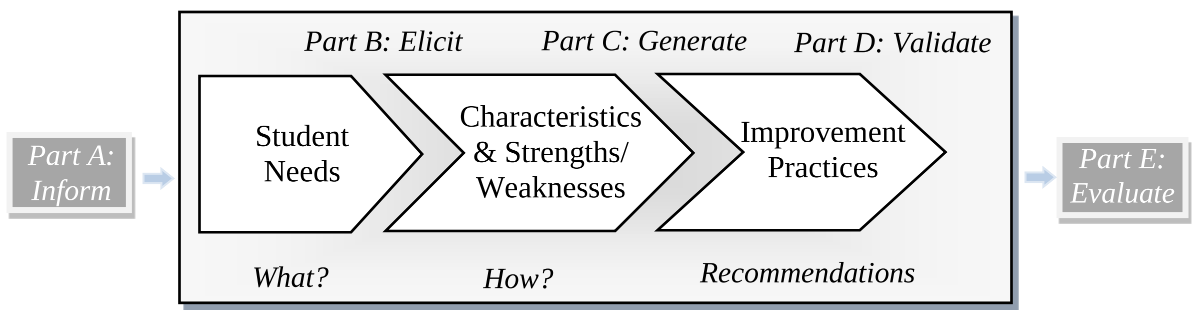


Figure G-1: Design Improvements Meeting

Part B: Elicit

Once you have an understanding of the scope of the meeting, you will then participate in a brainstorming session that is guided by a set of pre-determined questions. A color coding scheme will be used in the remaining steps to track key aspects of this process as follows:

- Green – Unmet Student Success Needs
- Blue – Characteristics
- Yellow – Current Practices
- Purple – Strengths
- Pink – Shortcomings
- White – Proposed Improvements

The elicit step is then used to functionally decompose the student needs into desired characteristics of institutional practices, which will then be used as the basis for critically examining how existing practices met the needs of students. The following discussion questions are used to execute the elicit step:

Discussion Question #1**:** What characteristics of student success practices are required to address the needs? (Write each characteristic on a blue Post-it note)

Discussion Question #2**:** What are the current practices that address these characteristics? Describe key aspects. (Write each practice on a yellow Post-it note).

- ***Discussion Question #2a*****:** What are the strengths of the current practices? (Write each strength on a purple Post-it note).
- ***Discussion Question #2b*****:** What are the shortcomings of the current practices? (Write each shortcoming on a pink Post-it note).

<u>Part C: Generate</u>

Next, the generate step is used to synthesize the information from the previous questions to generate improvements. The output of the meeting is shown in Figure 2, which has been transcribed into a table format (Table 1). Each of the discussion questions from the Elicit and Generate steps are intended to guide the completion of the tree shown in Figure 2.

Discussion Question #3: What improvement practices can be created to incorporate the characteristics of institutional practices and address the shortcomings of current practices?

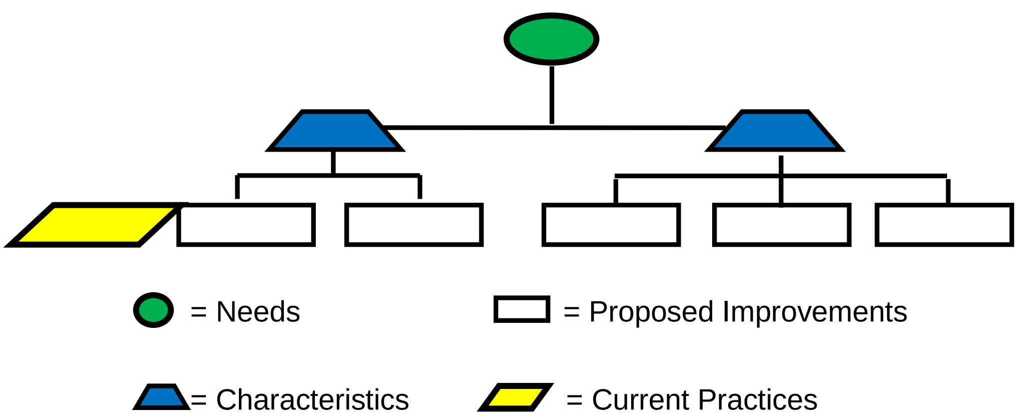


Figure G-2: Improvement Practice Synthesis Tree

○	Need	To connect what I am learning in class to the engineering profession	
⏢	Characteristics	To have real world examples	To have real world projects and work
▱	Current Practices	Curriculum	Research Scholars
	- Strengths	- Class Demonstrations - Class Projects - Example applications	- Paid Participants - Work on faculty research projects
	- Shortcomings	Not enough	Incorporate volunteers so more students can participate
▭	Improvements	Incorporate strengths into core courses	Develop a volunteer research program
		Develop course evaluation improvement process	“

Figure G-3: Improvement Practice Synthesis Matrix Example

Part D: Validate

Once we have completed the tree for the needs, we will use relationship matrices to ensure needs are systematically addressed by mapping and assessing the relationship between student needs and the proposed improvement practices.

Discussion Question #4: Does the proposed improvement practices address the needs of the students?

In Figure 4, the relationships between the student needs and the improvement practices are evaluated in the example. Strength symbols are then used to assess the relationship to determine whether the improvement practices address the needs using the following symbols:☺ (1) – strongly; 😐 (2) adequately; or ☹ (3) poorly.

Needs \ Proposed Improvements	Course Evaluations	Volunteer Research Program
To connect what I am learning in class to the engineering profession	😐	☺

Figure G-4: Validation of Proposed Improvements

Part E: Formative Evaluation

Thank you for your participation! Please take a moment to fill out this two-part questionnaire. Please refer back to the procedures, if necessary, and provide comments or recommendations that will help me refine and improve this meeting.

	Please answer the following questions.	1 = Strongly Disagree	2	3	4	5 = Strongly Agree
Design Goals	This meeting was able to systematically identify how engineering student success practices should address student needs.	❍	❍	❍	❍	❍
	This meeting was able to guide the process of determining how the women in engineering program can help to address student needs.	❍	❍	❍	❍	❍
Ease of Learning	I did not encounter problems in learning this process.	❍	❍	❍	❍	❍
	My peers could learn how to use this process.	❍	❍	❍	❍	❍
	My role in this in this process was clear and understandable.	❍	❍	❍	❍	❍
Ease of Participation	My participation in this process was straightforward.	❍	❍	❍	❍	❍
	My peers could participate in this process with ease.	❍	❍	❍	❍	❍
	I did not encounter problems participating in the process.	❍	❍	❍	❍	❍
Usability of Tools	This meeting was able to draw out ideas that I may not have considered at the start of the meeting.	❍	❍	❍	❍	❍
	The participatory team meeting format was effective.	❍	❍	❍	❍	❍
	The process of organizing the ideas was effective in meeting the goals of this meeting.	❍	❍	❍	❍	❍
Usability Overall	I would recommend this approach to faculty and program administrators.	❍	❍	❍	❍	❍
	The information produced from this meeting can be used to understand baseline a program’s current state.	❍	❍	❍	❍	❍

1. What aspects of the meeting were effective?

2. If you encountered any problems, please explain?

3. What needs to be improved?

APPENDIX H: PHASE IV – DEVELOP PLAN OF ACTION

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY
Informed Consent for Participants
in Research Projects Involving Human Subjects

Title of Project: Student Success Oriented System Design Methodology: "Develop a Plan of Action" Meeting

Investigator(s): Tracee Gilbert (Advisor: Janis Terpenny)

I. Purpose of this Research/Project

You are invited to participate in a research study that seeks to examine how to serve the needs of engineering students that will facilitate their success. The purpose of this meeting is to develop a plan of action to help students' succeed.

II. Procedures

This study consists of five parts. **Part A** will inform you about my role as the facilitator of the meeting, the meeting's goals, what activities you will be expected to perform, and how this study fits into the larger context of this research study. **Part B** will require you to answer a series of planned questions that will be used to guide the discussion. During **Part C**, we will use system design tools to organize and document the information provided by the group. **Part D** consists of a validation step to ensure that the key deliverables that we will design during the meeting satisfies the goals and objectives. Finally, **Part E** consists of a short evaluation questionnaire that will be used to get your feedback on improving the meeting's processes and output.

III. Risks

Participation in this research does not place you at more than minimal risk of harm.

IV. Benefits

This meeting is a part of a larger research effort to develop a Student Success-Oriented System Design Methodology (S^2OSD, pronounced "*SAWS-D*"), which is intended to help higher education administrators identify their students' needs, and translate those needs into a plan of action that facilitates student success. The methodology consists of four phases, in which this meeting is focused on Phase IV.

- <u>Phase I</u>: Diagnose the Baseline – diagnoses the current state of affairs in order to develop areas that are in need of improvement.
- <u>Phase II:</u> Assess Needs – determines the needs of female engineering students.
- <u>Phase III:</u> Design Improvements – translates student needs into recommended improvement practices.
- ➢ *<u>Phase IV:</u> Develop Plan of Action - develops a plan of action based off of the information generated from the previous Phases.*

V. Extent of Anonymity and Confidentiality
Your anonymity will be preserved throughout this research effort. Information gained from this study will be used to develop a questionnaire for eventual use in a scientific publication.

VI. Compensation
You will not be financially compensated for your participation.

VII. Freedom to Withdraw
Participants are free to withdraw without penalty and are free not to answer any questions that they choose.

VIII. Subject's Responsibilities
I voluntarily agree to participate in this study. I have the following responsibilities: to read and understand the procedures; to actively participate in the meeting by answering questions open and honestly; respect the confidentiality of the other meeting participants; and to participate in an evaluation of this meeting.

IX. Subject's Permission
I have read the Consent Form and conditions of this project. I have had all my questions answered. I hereby acknowledge the above and give my voluntary consent:

Chair, Virginia Tech Institutional Review
Board for the Protection of Human Subjects
Office of Research Compliance
2000 Kraft Drive, Suite 2000 (0497)
Blacksburg, VA 24060

Should I have any pertinent questions about this research or its conduct, I may contact:

Tracee Gilbert_ trwalker@vt.edu
Investigator(s) Telephone/e-mail

Dr. Janis Terpenny (540)231-9538/ terpenny@vt.edu
Faculty Advisor Telephone/e-mail

David M. Moore (540)231-4991/moored@vt.edu
Departmental Reviewer/Department Head Telephone/e-mail

I have read and understand the Informed Consent and conditions of this study. I have had all my questions answered. I hereby acknowledge the above and give my voluntary consent to participate in this meeting, with the understanding that I may discontinue participation at any time.

____
Signature of Participant

Part A: Inform

Based on the information presented from the previous phases, a plan of action will be developed. First, a concept evaluation tool will be used to ultimately facilitate the institutional decision makers' evaluation and selection of the best feasible improvement practices to meet the needs of students. A preferred course of action will then be documented using the Student Success Action Planning Tool. The S^2OPD method will be used to execute Phase IV. Specifically, this phase will accomplish the following goals and objectives:

Table H-1: Meeting's Goals and Objectives

Goals	Objectives
1) To determine the most promising improvement practices	1) To use performance criteria to analyze and select the most feasible improvement practices recommended from Phase III.
2) To translate recommended improvement practices into a plan of action that facilitates student success	2) To use the key performance areas to develop a plan of action.

Part B: Elicit

A number of performance criteria will be used to evaluate the recommended improvement practices from Phase III. Performance criteria essentially provide characteristics to judge the proposed improvement practices. The following performance criteria will provide the foundation for comparing and selecting the most promising improvement practices (Performance criteria can be added or deleted as necessary):

- ***Efficiency*** - The improvement practice can achieve a better result over current practices
- ***Productivity*** - The results generated from the improvement practice are worth the effort required to implement the improvement practice.
- ***Effectiveness*** - The Center has the capability/capacity to implement this practice successfully.
- ***Cost-effectiveness*** - The result of the improvement practice is worth the amount of money needed to implement the practice.
- ***Quality*** **-** The improvement practice meets the needs of the student.
- ***Innovation*** - The improvement practice introduces a new way of satisfying the needs of students

Discussion Question #1*: What criteria should be used to evaluate improvement practices?*

Discussion Question #2: *How should the performance criteria be weighted to capture the relative importance with respect to the other criteria?*

Discussion Question #3*: How do the proposed improvement practices satisfy each of the criteria?*

Discussion Question #4: *Which improvement practices should be considered for implementation?*

Based on the performance criteria for the four improvement practices, please fill out the matrix in Figure H-1. You will then provide a weighting system (if necessary), which captures the relative importance with respect to the other criteria. The equation below depicts the mathematical formulation to complete the decision matrix:

$$TS_j = \sum_{i=1}^{n} r_{ij}\, w_i$$

where TS_j = the total score for the improvement practice j

n = the number of design criteria

w_i= the weight of the ith criterion

r_{ij} = the rating of the improvement practice j for the ith criterion

Criteria	Weight	IP_1	IP_2	IP_3	IP_4
Quality					
Efficiency					
Total Score					
Rank					

1 – Strongly Disagree 3 – Somewhat Disagree 5 – Somewhat Agree 7 – Strongly Agree

2 – Disagree 4 – Neutral 6 – Agree

Figure H-1: Student Success Decision Matrix

Part C: Generate

Next, a Student Success Planning Matrix will be used to document a plan of action. The Student Success Action Planning Matrix maps the following elements of the S^2OSD methodology:

- ***Improvement Goals*** - The goals for the Program
- ***Student Needs*** - The "critical" student success needs identified from Phase II
- ***Student Success Practices*** - The practices that will meet the needs of the students
- ***Student Success Strategies*** - The student success improvement strategies that should be implemented
- ***Performance Measures*** - The key metrics that provide measurable goals, which quantify the effectiveness and the efficiency of the actions taken
- ***Capacity Owner*** - The responsible party (ies) for each line item
- ***Results*** - The expected outcomes

Discussion Question #5: *Based on the information gained from the previous phases, what is the plan of action that facilitates student success?*

Based on these areas, the worksheet in Figure H-2 will be used to develop a Student Success Action Planning Matrix.

Part D: Validate

Once we have completed the matrices, we will review the goals and objective to ensure that they have been met. Where this is not the case, then we will iterate through the meeting process to elicit, generate, and validate the output as needed.

Discussion Question #6*: Does the plan of action facilitate student success?*

STUDENT SUCCESS PLANNING MATRIX	
Goals	
Needs	
Practices	
Strategies	
Measures	
Capacity Owner	
Results	

Figure H-2: Student Success Action Planning Matrix

Part E: Formative Evaluation

Thank you for your participation! Please take a moment to fill out this two-part questionnaire. Please refer back to the procedures, if necessary, and provide comments or recommendations that will help me refine and improve this meeting.

	Please answer the following questions.	1 = Strongly Disagree	2	3	4	5 = Strongly Agree
Design Goals	This meeting was able to help me determine the most promising improvement practices.	❍	❍	❍	❍	❍
	This meeting allowed me to align student needs with a plan of action in order to facilitate effective decision making.	❍	❍	❍	❍	❍
	This meeting helped me translate recommended improvement practices into a plan of action that facilitates student success.					
Ease of Learning	I did not encounter problems in learning this process.	❍	❍	❍	❍	❍
	My peers could learn how to use this process.	❍	❍	❍	❍	❍
	My role in this in this process was clear and understandable.	❍	❍	❍	❍	❍
Ease of Participation	My participation in this process was straightforward.	❍	❍	❍	❍	❍
	My peers could participate in this process with ease.	❍	❍	❍	❍	❍
	I did not encounter problems participating in the process.	❍	❍	❍	❍	❍
Usability of Tools	This performance criteria was effective helping me to evaluate the improvement practices.	❍	❍	❍	❍	❍
	The matrix tool allowed me to think through key aspects of the program in order to develop a plan of action.	❍	❍	❍	❍	❍
	The output of this meeting could be used to create a framework for internal communication between program personnel.	❍	❍	❍	❍	❍
Usability Overall	I would recommend this approach to faculty and program administrators.	❍	❍	❍	❍	❍
	The information produced from this meeting can be used to effectively define a concrete course of action.	❍	❍	❍	❍	❍

1. What aspects of the meeting were effective?

2. If you encountered any problems, please explain?

3. What needs to be improved?

APPENDIX I: S^2OSD SUMMATIVE EVALUATION

Please answer the following questions.						
	1 = *Strongly Disagree* 3 = *Neutral* 4 = *Agree* 2 = *Disagree* 5 = *Strongly Agree*	1	2	3	4	5
Design Goals	***Phase I: Diagnose the Baseline*** – Documented the current baseline of practices (where we are) and identified areas that are in need of improvement (where we want to be).					
	1. Phase I helped our team to comprehensively baseline current practices.	❍	❍	❍	❍	❍
	2. Phase I helped our team to comprehensively identify areas that are in need of improvement.	❍	❍	❍	❍	❍
	3. The Baseline Diagnosis tool helped our team to systematically think through how to satisfy student needs within the context of our program's environment.	❍	❍	❍	❍	❍
	4. The six interrelated performance areas in the Baseline Diagnosis tool comprehensively identified key aspects of our program that are critical to facilitating student success.	❍	❍	❍	❍	❍
	Phase II: Assess Needs – Identified, assessed, and prioritized the needs of engineering students.					
	5. Phase II provided an understanding of the unique needs of our students.	❍	❍	❍	❍	❍
	6. Phase II facilitated the prioritization and identification of important needs.	❍	❍	❍	❍	❍
	7. The information from Phase II set the direction for identifying opportunities for improvement that are critical to helping students succeed.	❍	❍	❍	❍	❍
	8. The Engineering Student Needs Questionnaire (ESNQ) comprehensively defined the critical needs of undergraduate engineering students that help to facilitate their success.	❍	❍	❍	❍	❍
	9. The ESNQ was effective in assessing the extent to which student success needs are being met.	❍	❍	❍	❍	❍
	10. The Action Grid tool effectively portrayed the results of the ESNQ by highlighting the priority areas that required the greatest attention.	❍	❍	❍	❍	❍
	11. Phase II uncovered additional need areas requiring attention that were not initially considered in Phase I.	❍	❍	❍	❍	❍

Please answer the following questions.						
	1 = *Strongly Disagree* 2 = *Disagree* 3 = *Neutral* 4 = *Agree* 5 = *Strongly Agree*	1	2	3	4	5
Design Goals	***Phase III: Design Improvements*** – Students translated critical needs (identified in Phase II) into improvement practices to address their needs.					
	12. Phase III systematically identified how engineering student success practices should address student needs.	❍	❍	❍	❍	❍
	13. Involving students in the design process incorporated an important perspective that otherwise would not have been captured if left solely to the responsibility of the program administrators.	❍	❍	❍	❍	❍
	14. The Improvement Practice Synthesis tools were effective in helping students systematically think through how to design improvements to satisfy the needs of students.	❍	❍	❍	❍	❍
	Phase IV: Develop a Plan of Action – Developed a plan of action based on the information generated from the previous phases.					
	15. Phase IV helped our team to assess the most promising improvement practices.	❍	❍	❍	❍	❍
	16. Phase IV allowed our team to align student needs with a plan of action in order to facilitate effective decision making.	❍	❍	❍	❍	❍
	17. Phase IV helped our team to translate recommended improvement practices into a plan of action that facilitates student success.	❍	❍	❍	❍	❍
	18. The Improvement Practices Decision Matrix helped our team to evaluate and select the most feasible improvement strategies.	❍	❍	❍	❍	❍
	19. The performance criteria used in the Improvement Practice Decision Matrix facilitated the comprehensive evaluation and selection of the most feasible improvement strategies.	❍	❍	❍	❍	❍
	20. The Student Success Action Planning Matrix set the direction for implementing and monitoring progress towards meeting the needs of our students.	❍	❍	❍	❍	❍
Methods and Tools	***Student Success-Oriented Participatory Design (S^2OPD) Meeting Process***– Used a team-based meeting approach that provided the processes and tools to execute the S^2OSD methodology (i.e., to diagnose the baseline, identify and assess student needs, improvement strategies, and a plan of action that fosters student success).					
	21. The participatory team meeting format was effective.	❍	❍	❍	❍	❍
	22. The tools used to carry out the S^2OSD methodology created a record for decision-making process, which could be to facilitate internal communication between program personnel	❍	❍	❍	❍	❍
	23. The team-based approach engaged and mobilized students and decision makers in the process to design student success practices.	❍	❍	❍	❍	❍

Ease of Learning	24. I did not encounter problems learning the S^2OSD methodology.	❍	❍	❍	❍	❍
	25. My peers could learn how to use the S^2OSD methodology.	❍	❍	❍	❍	❍
	26. My role in using the S^2OSD methodology was clear and understandable.	❍	❍	❍	❍	❍
Ease of Participation	27. My participation in using the S^2OSD methodology was straightforward.	❍	❍	❍	❍	❍
	28. My peers could participate in using the S^2OSD methodology with ease.	❍	❍	❍	❍	❍
	29. I did not encounter problems participating in the phases of the S^2OSD methodology.	❍	❍	❍	❍	❍
Usability Overall	30. The S^2OSD methodology was effective in developing a plan of action to address the needs of our engineering students.	❍	❍	❍	❍	❍
	31. The S^2OSD methodology provided quality information needed for program administrators to make decisions and take action in order to facilitate student success.	❍	❍	❍	❍	❍
	32. I would recommend that decision makers at my institution use the S^2OSD methodology.	❍	❍	❍	❍	❍

1. What is your overall impression of the S^2OSD methodology?

2. What aspects of the S^2OSD methodology were effective?

3. What aspects of the S^2OSD methodology need to be improved?