# LIVING-LEARNING COMMUNITIES AS AN INTERVENTION TO IMPROVE DISCIPLINARY RETENTION AND LEARNING OUTCOMES IN ENGINEERING EDUCATION

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ABSTRACT

LIVING-LEARNING COMMUNITIES AS AN INTERVENTION
TO IMPROVE DISCIPLINARY RETENTION AND
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The challenge and impetus to increase both the quantity and quality of engineers in the United States is well-documented (Committee on Prospering in the Global Economy of the 21st Century, 2007; National Academy of Engineering, 2004; NSB, 2008). There have been considerable efforts to recruit students to engineering, yielding modest results (Seymour, 2002; NSB, 2008). However, the increase in enrollment has not coincided with a parallel increase in engineering graduates, indicating that retention is the core issue.

At the same time, the field of engineering has been responding to calls for educational reform from within the discipline and industry (Prados et al., 2005). An increasingly complex economy demands a broadening of the intended learning outcomes and a move toward outcomes-based assessment of engineering programs (ABET, 1995; 1997; Kastenberg, et al., 2006; National Academy of Engineering, 2004). As a result, the accrediting body ABET issued a new set of learning outcomes and assessment criteria that subsequently spurred innovation in engineering education.

The influential work of Seymour and Hewitt (1997) on students who switch out of STEM fields identified classroom experiences as the primary cause of disciplinary departure. As a result, reform efforts focused primarily on classroom interventions (e.g., Coward, Ailes & Bardon, 2000; Sheppard et al., 2009) because addressing deficiencies in pedagogy and curriculum could yield improvement not only in student learning but also in disciplinary

retention. Despite research confirming the link between certain types of classroom innovations (e.g., active learning) and improved retention and learning gains (Felder, 1995; Felder, Felder & Dietz, 1998; Smith et al., 2004), inertia and the culture of faculty work has prevented widespread adoption of these practices. Accordingly, non-classroom interventions such as living-learning communities (LLCs) should be considered as part of the solution.

The purpose of the study was to examine the effect of LLCs on disciplinary retention and learning outcomes in engineering. I identified the differences between LLC participants and non-participants in terms of (a) pre-college characteristics, (b) indirect measures of persistence, (c) direct measures of persistence, and (d) learning outcomes. I compared these groups using chi-square analyses, t-tests, and regression modeling, including measures of change over time.

The results of this study identified some differences between the two groups on pre-college characteristics in terms of demographic representation, the process of choosing engineering as a major, and expectations for college. On indirect persistence measures, LLC participants reported stronger connections to other undergraduate engineers and greater commitment to engineering. Moreover LLC participants experienced more significant gains over time on three measures: (a) Commitment to Engineering, (b) Connection to Engineering College and (c) Connection to Engineering Peers. These results suggest that the LLC may have a differential impact on participants in these domains. On direct persistence measures, LLC participants differed from non-participants on only one measure: choice of major in sophomore year. The retention rate for LLC participants was 85.1% compared to 76.1% for non-participants. Finally LLC participants and non-participants did not differ on learning outcomes measures for the most part, although LLC participants reported more significant gains over time on the Leadership construct.

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# CHAPTER ONE

# INTRODUCTION

In the United States, there is a growing concern among leaders in government, education, and industry about the production of scientists and engineers. Leaders at all levels acknowledge the importance of innovation driven by scientific and technological discovery to the nation's economic prosperity. Moreover many of the most vexing national security issues require technical solutions emerging from scientific expertise (Committee on Prospering in the Global Economy of the 21st Century, 2007). Therefore scientists and engineers are critical to maintaining the U.S.'s standing as a secure and prosperous nation.

The concern centers on two related trends in the preparation of an educated, scientific workforce. First, the growth in demand for skilled workers in science, technology, engineering, and mathematics (STEM) fields will soon outpace the projected supply in the U.S. The second trend is the widening gap between the U.S. and other developed countries in the production of scientists and engineers (Committee on Prospering in the Global Economy of the 21st Century; National Science Board (NSB), 2008). Together these changes represent major challenges for the country and higher education.

In the past few decades, enrollment and retention in STEM fields declined. Studies identified science, engineering, and mathematics as some of the few fields that have a net attrition of students as a student cohort moves through college (Astin & Astin, 1993; NSB, 2006; Seymour & Hewitt, 1997). The highest attrition rates are in the fields of physical sciences, computer sciences, and engineering where approximately 30% of the entering cohort from 1995 departed from these fields (NSB). Several prominent national organizations are calling for increased attention on the production of college graduates in STEM fields to address the projected shortages (Committee on Prospering in the Global Economy of the 21st Century, 2007; NSB, 2008).

The concern about the production of scientists and engineers extends to issues of quality. Although the data are clear about the urgency of addressing the quantity of graduates produced in the U.S., reviews of undergraduate science education raise concerns about the quality of learning as well. Leaders from government, industry and academe worry that the traditional method of educating undergraduate scientists and engineers is inadequate for the realities of an evolving, complex world (Committee on Prospering in the Global Economy of the 21st Century, 2007; Continental AG, 2006; Kastenberg, Hauser-Kastenberg & Norris, 2006; National Academy of Engineering, 2004; Sheppard, Macatangay, Colby & Sullivan, 2009). These groups articulate concerns about the ability of U.S. higher education to prepare STEM graduates in competencies such as critical thinking, working in diverse groups, and communication skills.

The dual issues of quantity and quality in the production of scientists and engineers are viewed as linked. Research on undergraduates who leave STEM fields identified the curricular experience as the primary cause for their departure, including disengaging pedagogical practices and disconnection from the field of study (Seymour & Hewitt, 1997). Thus efforts to promote engineering learning outcomes are related to efforts to increase the number of science and engineering graduates.

## Undergraduate Engineering as a Focal Point

Although the production and quality of graduates is an issue across the sciences, the field of engineering is an area of particular concern. First, engineering represents a critical field for the modern world. Given the complex and predominantly scientific problems facing the world, engineers will be at the forefront of solving some of the most pressing problems at the intersection of science and technology (Continental AG, 2006; Sheppard et al., 2009). These challenges relate to economic development through technological innovation and represent some of civilization's most significant challenges (e.g., alternative energy, climate change, and water management).

Second, the projected deficiencies in the number of graduates produced by engineering fields are stark. Indicators suggest that the U.S.'s production of engineers lag both the expected demand and the performance of other nations. With the economy increasingly science and technology-based, the National Science Board (NSB) projects a domestic need for an additional 109,000 engineers by 2012 above reported production levels (2006). At this time of high demand for engineers, the U.S. endures declines in the production of engineers. Meanwhile other countries continue to drastically increase their output of engineers. These trends threaten to place the U.S. at a competitive disadvantage globally in bids to attract and retain employers and drivers of innovation who require skilled workers in engineering fields (NSB, 2008).

Third, both industry leaders and engineering educators have called for fundamental reform in the preparation of engineers (Prados, Peterson, & Lattuca, 2005). In response, leaders in engineering education in conjunction with ABET, the discipline's accrediting body, initiated a fundamental transformation of the goals for engineering education and a subsequent movement towards outcomes-based assessment (ABET, 1995; 1997; 2008; National Academy of Engineering, 2004). The principal aim of these efforts is to equip future engineers to face the complex nature of a $21^{st}$ century global economy where creativity and analytical ability are more important than retention and memorization of facts. As a result, the field of engineering is more focused on teaching applied engineering skills and liberal learning skills such as lifelong learning, leadership and communication skills deemed necessary for success (ABET, 2008; Continental AG, 2006; National Academy of Engineering).

Finally, engineering education is an expensive and resource-intensive discipline that makes large-scale reform challenging. Most engineering programs are housed at large research universities (Gibbons, 2009) that are largely and increasingly dependent on research funds (Rugarcia, Felder, Woods, & Stice, 2000). These extramural funds not only extend research capacity, but are necessary to support core educational and administrative functions (Rugarcia et al.,). In addition to the integral function of research dollars, the problem is exacerbated in colleges of engineering where instructional costs tend to be higher (2-4 times as expensive) than most other disciplines even when controlling for other factors like institutional type (Middaugh, 2005; NCES, 2003; Smith, 1992). The magnitude of instructional costs associated with educating undergraduate engineers can hamstring a department’s ability to shift priorities away from revenue generating activities such as research and toward teaching and learning.

In step with the need for additional funds, faculty incentive structures encourage faculty to prioritize research as the most important component of their job. Faculty are rewarded for excellence in research in part because the procurement of grants financially supports the college’s operations (Duderstadt, 2008; Fairweather, 2005; Leslie, 2002; Rugarcia et al., 2000). Struggling with expanding workloads, faculty often cannot afford to divert large amounts of time from their research endeavors to pursue curricular or pedagogical innovations that may bolster disciplinary retention and learning (Gappa, Austin, & Trice, 2007; Rugarcia et al.). Although these obstacles are not unique to engineering faculty, they present a unique problem in engineering education where curricular and pedagogical reform represent the conventional hope for addressing disciplinary retention and learning outcomes. However, neither the incentives nor the resources exist in engineering to support large-scale dissemination and penetration of classroom interventions.

In summary, the field of engineering faces significant challenges to produce enough quality engineers to meet societal demand (NSB, 2008). Based on current trends, the challenge of increasing the number of qualified engineers produced in the U.S. remains at the forefront of issues facing the field. Concurrently, leaders in the field have begun addressing criticism of the educational process by moving towards more robust curricula and improved pedagogical techniques to satisfy raised expectations for student learning outcomes (ABET, 2008; Prados, et al., 2005). Despite these advances, the issues with the quantity and quality of engineers persist. In part, the culture of engineering with regards to money and faculty time are not conducive to resource-intensive reforms such as major curricular or pedagogical changes (Duderstadt, 2008; Fairweather, 2005; Middaugh, 2005; Rugarcia et al., 2000) which have previously been linked to improved disciplinary retention (e.g., Lichtenstein, Loshbaugh, Bailey, & Sheppard, 2007; Seymour & Hewitt, 1997; Smith, Dougals, & Cox, 2009)

Thus the field of engineering is a fertile environment for this study given the discipline's challenge to produce more and better prepared engineers and the state of research into these efforts. This study examines an effort to enhance the educational experience of undergraduate engineers that pertains both to disciplinary retention and learning outcomes.

## Living-Learning Communities as an Intervention

One understudied way to address retention and quality in engineering education simultaneously is the living-learning community (LLC). Most undergraduate engineers are trained at large research universities characterized by their impersonal nature and large class sizes. In 2007, 45 of the top 50 producers of baccalaureate engineering degrees were universities with more than 10,000 undergraduate students; only two of the top 50 producers were institutions with less than 5000 undergraduate students (Gibbons, 2009). Characterized by student anonymity and disengagement, many larger institutions use LLCs as an intervention to combat the negative effects on student outcomes such as persistence, academic achievement and intellectual engagement (Astin, 1993). LLCs enable institutions to embed a smaller, more intimate student learning environment within their larger enterprise (Astin, 1993; Gaff, 1970; Gamson, 2000; Inkelas, Zeller, Murphy & Humell, 2006). As many engineering departments struggle with retaining students and promoting the desired learning outcomes, LLCs are a potential solution for enhancing the undergraduate experience.

Previous research points to the effectiveness of LLCs at promoting similar outcomes in other contexts. LLCs counter the impersonal culture of large institutions by promoting higher levels of student engagement and more frequent and meaningful connections with faculty (Astin, 1993; Gaff, 1970; Gamson, 2000; Inkelas et al., 2006). Further LLCs also promote student learning through an emphasis on collaborative learning that can more naturally extend beyond the classroom into student residences in comparison to traditional housing arrangements (Pascarella & Terenzini, 2005; Pasque & Murphy, 2005; Pike, 1999). In many ways, LLCs seemed poised to help address the pressing concerns in engineering education at large research universities regarding retention within the discipline and promotion of learning outcomes. Although LLCs have been used in engineering for smaller scale residential programs often targeting specific populations (e.g., women and underrepresented minorities), the broad use of LLCs in engineering education is rare.

## Purpose and Research Questions

The purpose of the study was to investigate the use of LLCs as an intervention in engineering education. Because there is little research on LLCs in engineering targeting all students, I analyzed the characteristics of the students who choose to participate in the LLC in comparison to non-participants. The primary focus of the study was to determine the differences between LLC participants and non-participants on measures related to the retention of first-year students within the discipline. To do so, I examined (a) indirect persistence measures (i.e., series of outcomes measuring students' sense of belonging), and (b) direct persistence measures (e.g., choice of major in the sophomore year). Finally the study also examined the potential effect of LLCs to promote engineering learning outcomes within the first year. Thus I identified the differences between LLC participants and non-participants on a set of engineering learning outcomes.

The study addressed the following research questions**:**

1. How do students who choose to participate in an engineering LLC differ from other engineering students?

   (a) How do they differ by demographic characteristics?

   (b) How do they differ by their expectations for the college experience?

2. How do LLC participants and non-participants differ on indirect and direct measures of disciplinary persistence?

   a. How do they differ on Sense of Belonging measures?

   b. How do they differ on measures of disciplinary retention?

3. How do LLC participants and non-participants differ on attainment of engineering learning outcomes?

# CHAPTER TWO

# LITERATURE REVIEW

This study focuses on the relationship between participation in a living-learning community (LLC) and the production of engineers in terms of quantity and quality measures. In this chapter, I detail the extent of the decline in the production of engineers. I focus on retention as the critical issue in the number of engineers produced and describe what is known about disciplinary leavers. Then, I outline the concerns regarding the quality of engineers produced. After describing these issues of quantity and quality in engineering education, I review previous interventions in the field, which are largely classroom interventions. Due to the persistent issues in the production of engineers, I make the case for considering non-classroom interventions such as living-learning communities (LLCs). Then I review the existing literature on LLCs including its effects on student outcomes. At the end of the chapter, I introduce a conceptual framework for understanding disciplinary departure in engineering and discuss its relevance to the present study, including the choice of outcomes to compare LLC participants and non-participants.

## Quantity of Engineers

A fundamental issue facing engineering educators and industry leaders in the U.S. is the insufficient number of engineering graduates produced. Despite the projected need for additional engineers, the U.S. significantly trails its economic competitors in the production of STEM graduates, especially engineers. In comparison to its international peers, the U.S. experienced a large, relative decline in the production of engineers. While graduates from baccalaureate engineering programs decreased in the U.S. over the past two decades, Japan increased the number of engineering graduates by almost 50%; at the same time, South Korea tripled and China quadrupled their number of engineering graduates (NSB, 2008). As a percentage of total undergraduate degrees awarded, engineering degrees account for approximately 20% in Asian countries and more than 10% in most others. In the U.S., only five percent of American students graduate with a bachelor's degree in engineering (NSB).

Percentages only tell part of the story. These trends have resulted in a dramatic shift in proportional production of engineers across the globe. The U.S., once a leader in producing engineers, now trails those nations in absolute terms (NSB, 2010). China now is the leading producer with over 575,000 engineering baccalaureate degree recipients per year. In comparison, the U.S. produces approximately 68,000 engineering baccalaureate degree recipients per year, lagging Japan's production (40% higher), and remaining on par with South Korea (NSB). In comparison both to historical trends and global competitors, the U.S. has fallen behind in the production of engineers.

Efforts to address declining enrollment in undergraduate engineering have yielded positive results. National organizations in partnership with colleges and universities have been tackling the issue of recruitment over the past decade in response to the sharp decline in undergraduate engineering majors in the U.S. Enrollment trends indicate that the number of engineering majors decreased from a peak of 441,000 in 1983 to a low of 361,000 in 1999 (NSB, 2008). This drop is even more significant given the simultaneous increase (~28%) in the undergraduate population across the U.S. (NSB).

It is estimated that more than two billion dollars in federal funding was used to improve the recruitment of students to STEM fields (Seymour, 2002). Because of these significant efforts to attract more students, undergraduate enrollment in engineering has since rebounded to over 400,000, but is only nearing the level of the early 1980s (NSB). Nonetheless efforts to recruit students to the discipline have been at least modestly successful, as evidenced by the rebound in undergraduate enrollment.

However, the increase in enrollment has not coincided with a corresponding increase in engineering graduates. Since the early 1980s, the number of baccalaureate engineering degrees awarded by U.S. colleges and universities dropped from close to 73,000 to a little more than 62,000 in the early 1990s (NSB, 2008). This change represented almost a 16% decline in the absolute number of engineering graduates. Since that time, the number of engineering graduates produced has fluctuated from as low as 59,000 to as high as 66,000 (NSB). Despite the U-shaped trend in the recruitment of engineering students, the trend for the production of baccalaureate engineering degrees has flattened, well short of previous production levels (NSB).

An additional factor to consider is another form of recruitment: migration. Previous research identified engineering as the field with the lowest inward migration of undergraduates once in college (Ohland, et al., 2008). In other words, students who switch majors in college are least likely to switch into engineering. Only 7% of engineering graduates switch into the major while in college; for other majors the figure ranges from 30-65% (Ohland et al., 2008). This lack of migration has affected traditional calculations of retention, keeping them artificially low (Ohland et al.). Obstacles such as intense course loads and numerous prerequisites make transferring into engineering later in college more difficult than other majors. Regardless of how retention is calculated, improving retention efforts is even more important for engineering than other fields due to the lack of inward migration from other disciplines.

These trends suggest that interventions to increase the number of engineering graduates cannot focus solely on recruiting more students to the discipline. The issue is two-pronged. In addition to attracting more students to the field of engineering, colleges and universities also must retain these students in the discipline. The recent success in recruiting more students in the field will not succeed in producing more engineers if disciplinary retention remains an issue. Promoting disciplinary retention within engineering is the primary focus of this study.

## Quality of Engineers

Over the last three decades, efforts to reconceptualize the training of engineers gained prominence. As early as the 1980s, both employers and educational leaders in engineering perceived a need to revamp the education of undergraduates to better respond to the needs in the field (Prados et al., 2005). Around this time came calls to supplement technical instruction with other professional skills such as project management, teamwork and communication. In essence, engineering education needed to move beyond its traditional model in order to equip undergraduate engineers adequately (National Research Council, 1985).

Despite calls for reform, the field struggled to make substantial progress for another decade. In the mid-1990s, ABET, the discipline's accrediting body, assumed a leadership role in this change movement. ABET acknowledged the need to redefine the purpose and methods of educating future engineers and released a series of position papers arguing for substantial reform (ABET, 1995; 1997). The papers called for a new set of criteria for engineering programs that focus on the achievement of student learning outcomes instead of the use of a prescribed curriculum.

In 1997, ABET published *Engineering Criteria 2000* detailing the proposed shift in accreditation requirements. These new principles marked a dramatic change in engineering standards. The new standards simultaneously responded to employer needs for a broader skill set from engineering graduates, and to faculty frustration with the curricular constraints of the previous guidelines (Prados et al., 2005). ABET selected 11 wide-ranging learning outcomes to be achieved by undergraduates studying at participating institutions, commonly referred to as Criterion 3(a-k). Slightly amended since, the 11 program outcomes are summarized in the following table:

Table 1: ABET Criterion 3 Learning Outcomes

| Learning Outcome | Description |
|---|---|
| A | Ability to apply knowledge of mathematics, science, and engineering |
| B | Ability to design and conduct experiments, as well as to analyze and interpret data |
| C | Ability to design a system, component, or process to meet desired needs within realistic constraints |
| D | Ability to function on multidisciplinary teams |
| E | Ability to identify, formulate, and solve engineering problems |
| F | Understanding of professional and ethical responsibility |
| G | Ability to communicate effectively |
| H | Understanding of the impact of engineering solutions in a global, economic, environmental, and societal context |
| I | Recognition of the need for, and ability to engage in life-long learning |
| J | Knowledge of contemporary issues |
| K | Ability to use the techniques, skills, and modern engineering tools necessary for engineering practice |

These new accreditation criteria led to significant change and innovation in undergraduate engineering education, especially to address the broader liberal learning goals (Prados et al, 2005). At the same time, institutions are grappling with less prescriptive curricular expectations from ABET. These changes spurred reform within engineering departments. In a recent national survey, 3/4 of department chairs reported a moderate or significant increase in emphasis on communication, teamwork, use of modern engineering tools, technical writing, lifelong learning and engineering design since the introduction of the new ABET Criteria. In addition, 2/3 of faculty reported using more active learning methods (e.g., use of group work, design projects, and practical applications) during the same timeframe (Lattuca, Terenzini, & Volkwein, 2006). Therefore institutions are exploring new ways to address the Criterion 3 learning outcomes while maintaining or increasing standards of traditional engineering preparation; however these efforts have centered on classroom-based interventions.

In the wake of ABET's new standards, calls for reform persist. Many see U.S. engineering education at a critical juncture. The Committee on Prospering in the Global Economy of the 21st Century (2007) argued that one necessary change is a revision of the first-year experience away from focusing on technical aspects of the sciences and engineering that often discourage disciplinary persistence. Instead they call for a broader, more integrated approach that also includes broader learning outcomes as key goals:

> Therefore, introductory science and mathematics courses must find ways to provide students both with a broad education in these fields and with the specific skills they need to continue studying these subjects, as is the case with most other introductory courses in colleges. (p. 347)

This breadth should continue throughout the undergraduate engineering curriculum to prepare students for the realities of 21st century engineering practice and expose students to the opportunities in the profession. Sheppard et al. (2009) weigh the stakes and conclude that "with all that is at stake for engineering in the United States, a failure to press forward… would not only be disappointing; it would be self-defeating" (p. 212). These public statements reinforce the need to reform engineering education so it effectively promotes the broader ABET criteria such as critical thinking, creativity and problem-solving, professional awareness, and cultural competence (Committee on Prospering in the Global Economy of the 21st Century, 2007; Continental AG, 2006; Sheppard et al., 2009). In response, academic institutions increasingly are searching for ways to reform their practice to meet these challenges.

## Understanding Leavers: Linking Quantity to Quality

The previous research on leavers focused on either the effect of pre-college characteristics or the college experience. There is a considerable amount of research on the relationship between pre-college characteristics and persistence in engineering. The literature suggests that students who are more likely to persist in engineering: (a) are more committed to engineering at the outset (Atman et al., 2008), (b) perform better in terms of high school academic achievement (French, Imekus & Oakes, 2005; Mendez, Buskirk, Lohr &. Haag, 2008; Zhang, Anderson, Ohland & Thorndike, 2004), and (c) have stronger quantitative skills when matriculating (Astin & Astin, 1993; Moller-Wong & Edie, 1997; Zhang, et al.). These studies attempted to identify the factors that predict successful retention in the major to either enhance retention through targeted recruitment practices, or to identify groups that may struggle and benefit from early support.

Given the rigor of the engineering discipline, it is reasonable to assume that academic performance (e.g., GPA) plays a significant role in determining whether a student will persist in engineering. However, the data relating academic performance to departure from STEM fields are mixed. Some studies identified a link between lower college GPA and departure (French et al., 2005; Mendez et al., 2008). Although Veenstra, Dey, and Herrin (2009) highlight its effect on the decision to leave in a model of disciplinary departure, their own data confirm previous research demonstrating no significant differences in aptitude or achievement between students who persist in engineering and students who drop out (Green, 1989; Seymour & Hewitt, 1997). Seymour and Hewitt found that leavers and stayers did not differ significantly on measures of academic performance as well as motivation, and study-related behavior. Surprisingly, leavers disproportionately come from a pool of students who achieve academically in terms of pre-college and college performance indicators (i.e., GPA, standardized test scores) (Green).

In terms of college experiences, there are a few studies that have examined characteristics of the college experience that may explain disciplinary persistence in engineering. For example, more frequent student-faculty interactions are correlated positively with retention in engineering (Vogt, 2008). In addition, Besterfield-Sacre, Atman, & Shuman (1997) identified a number of attitudinal measures typical of students who leave the discipline when compared to students who persist: (a) lower general impression of engineering in terms of quality of work and careers; (b) less enjoyment of math and sciences; and (c) less confidence in engineering skills.

The most influential work studying disciplinary departure focused attention on the classroom. In the seminal study by Seymour and Hewitt (1997), students identified classroom experience as the foremost reason for switching out of science and engineering. The bulk of students' criticism centers on the quality of teaching, advising, and curriculum design (Seymour & Hewitt). Students expressed frustration with uninteresting and content-laden courses that led to an increasingly negative perception of STEM careers and an overall disinterest in the subject matter. Moreover, all science and engineering students (both stayers and leavers) reported that the quality of instruction is worse for their science professors than their high school teachers or instructors from other college departments. The study concluded that addressing pedagogical and curricular concerns represent the key leverage points for addressing retention issues in STEM education (Seymour & Hewitt). The results of the Seymour and Hewitt study significantly influenced the trajectory of reform efforts in engineering as well as other science disciplines, focusing efforts primarily on classroom interventions to improve retention rates.

## Focus on Classroom Interventions

Although pedagogical and curricular innovations have been used to target student learning, these interventions are now seen as a means to retain students in light of Seymour and Hewitt's work (1997). Thus many researchers view their work studying classroom interventions as serving a dual purpose: increasing retention and increasing learning (e.g., Coward et al., 2000;

Sheppard et al., 2009). In other words, interventions focused on addressing the learning outcomes of undergraduate engineering programs can simultaneously address the challenge of increasing the number of engineering graduates. The potential to impact both retention and learning has made research and programmatic development on curriculum and pedagogy in engineering widespread. In this section of the paper, I detail some of the research on curricular and pedagogical changes that aim to improve disciplinary retention.

Concurrent with the changes in ABET standards in the 1990s, the National Science Foundation launched a large-scale programmatic and research effort: Engineering Education Coalitions (EEC). The EECs worked across institutions to generate and share pedagogical resources and curricula to enhance the teaching and learning of undergraduate engineers at participating institutions. Explicitly stated, the goals of these multi-institutional collaborations included both increased retention and improved learning outcomes (Coward et al., 2000).

Subsequent research into the effectiveness of reformed pedagogy and curriculum followed. The use of supportive teaching and learning strategies is championed as a way to increase disciplinary retention within STEM fields (Smith et al., 2009). Engaged pedagogical strategies increased the rates of retention and graduation in a study comparing students instructed by traditional methods compared with students instructed by active learning practices (Felder et al., 1998). Moreover first-year courses designed to connect conceptual knowledge with professional practice (e.g. engineering design, prototype development) in team settings increased students' disciplinary retention (Fortenberry, Sullivan, Jordan & Knight, 2007).

A recent large-scale review sponsored by the Carnegie Foundation for the Advancement of Teaching used a case-studies approach to identify best practices in effective undergraduate engineering programs across the U.S. The initiative studied curriculum design and pedagogy by trying to identify strengths or weaknesses in engineering education in the United States resulting in a broader survey of classroom interventions (Sheppard et al., 2009). Sheppard et al. argue that the prevailing mode of teaching undergraduate engineers does not adequately prepare students for the world of engineering that awaits them. They outline three trends that prevent deep learning: (a) teaching theory before practice in a linear, step-wise fashion; (b) using labs for application or models of theory instead of opportunities to synthesize or integrate knowledge; and (c) neglecting the socialization of students to ethics and professional expectations of the field. In response, the authors advance a new interconnected model of learning emphasizing both technique and context that lead to higher levels of sophistication and understanding.

In contrast, bad experiences in the classroom tend to negatively affect disciplinary retention. Environmental factors such as classroom instruction, departmental culture and institutional structure have been identified as affecting disciplinary retention rates (Lichtenstein et al., 2007). In Lichtenstein et al.'s study, students most often switched out of engineering prior to enrolling in engineering courses. The classroom experiences in prerequisites in the sciences and mathematics, but non-major courses tended to increase the likelihood of disciplinary departure among undergraduate engineers (Lichtenstien et al.).

Therefore there is a significant amount of research tying more effective classroom instructional practices to higher disciplinary retention rates in engineering. Furthermore, the early part of students' undergraduate career as an engineer are critical in terms of making disciplinary retention decisions, and the effect of poor classroom experiences is strong. However reforming classroom experiences has not been successful in solving the retention problem.

## Case for Non-Classroom Interventions

These initiatives in pedagogy and curriculum are a key part of efforts to reform the quality of undergraduate engineering education. The identification of better instructional practices and the transformation of curricula to align with desired learning outcomes are two key ways to address the quality issue. However, these studies also intended to serve an additional purpose: to improve the classroom experience of undergraduate engineers in an effort to encourage persistence within the discipline. In light of the research on attrition, especially the work of Seymour and Hewitt (1997), the focus on teaching and curriculum development was expected to yield more engineering graduates as well as learning gains.

Despite these efforts to revamp curricular and pedagogical practices in undergraduate engineering, the production of engineers remains an issue. Previous research on engineering education identifies classroom experiences as the key leverage point for affecting the dual issues of the quantity and quality of engineering graduates. As indicated in the previous section, much is now known about how to improve the classroom experiences for undergraduate engineers. However, the field of engineering continues to attract and retain too few students.

Because classroom interventions have been shown to be effective, the persistent production issue must be at least in part related to a lack of adoption of these practices. The resistance to broader adoption of effective pedagogy and curriculum is well-documented (Duderstadt, 2008; Fairweather, 2008). This resistance is often a function of faculty culture, especially expanded and increased workloads with an emphasis on research over teaching (Duderstadt, 2000; Gappa, Austin & Trice, 2009; Schuster & Finkelstein, 2006). The incentive structure currently in place for faculty at most institutions seems inadequate for encouraging these types of changes (Fairweather, 2005; Leslie, 2002). Therefore, persistent shortfalls in the production of engineers suggest that non-classroom interventions might be useful. Without additional changes, the U.S. will continue to trail other countries in the production of engineers, threatening both the economic prosperity and security of the nation (Committee on Prospering in the Global Economy of the 21st Century, 2007).

In general, there is substantial evidence for the impact of non-classroom experiences on learning as well as retention and other persistence-related measures (Pascarella & Terenzini, 2005). Given the dual concerns in engineering education of producing more and better trained engineers, it seems reasonable to explore the potential impact of non-classroom experiences on undergraduate engineers, including the focus of this study: living-learning communities (LLCs)

## Living-Learning Communities

In this section, I describe the role of LLCs in U.S. higher education. First, I discuss the evolution of residential programs at colleges and universities. Then, I review the current state of literature describing the implementation of LLCs, the different types of LLCs present in the U.S. landscape, and the impact on student outcomes.

### History of LLCs as Educational Interventions

Living-learning communities (LLCs) have a long history in U.S. higher education. The roots of the present day concept of melding curricular experiences with residence halls date back to the early models of residential colleges adopted from the British higher education system (Ryan, 1992; Thelin, 2004). These residential structures allowed institutions to adopt a holistic approach to students' education that extended beyond the classroom walls through intensive, on-going mentoring by tutors (Ryan).

As U.S. higher education shifted toward the German model of research and disciplinary expertise at the end of the 19$^{th}$ Century, institutions increasingly moved away from this holistic, residential model (Ryan, 1992; Thelin, 2004). This change coupled with the significant increase in enrollment at U.S. colleges and universities over the coming decades led to the creation of larger flagship institutions across the country where these smaller learning communities became less feasible (Ryan; Thelin). As a result, LLCs became less prevalent in U.S. higher education during that time period.

Despite these trends, LLCs in various forms remained a part of higher education institutions across the country. Some institutions relied on the model exclusively (e.g., Harvard, Yale starting in the 1920s); others experimented with LLCs as a means to address concerns about the quality of undergraduate education. LLCs were seen as a way to counteract some of the negative trade-offs emerging at larger institutions such as student anonymity and disengagement (Gaff, 1970).

During the 1960s and 1970s, LLCs experienced resurgence. A number of institutions instituted LLCs during the 1960s, somewhat in response to the sizeable expansion of undergraduate enrollment due to the G.I. Bill (Gaff, 1970). Around this time, different versions of LLCs emerged ranging from a small number of students grouped by shared interests (e.g., global perspectives, eco-friendly) to a larger operation linked to an academic discipline or college (Shaprio & Levine, 1999; Smith, MacGregor, Matthews, & Gabelnick, 2004). Some pioneering institutions, such as UC Santa Cruz, instituted broad programs, dividing up their entire campuses into a series of semi-autonomous units to form formal residential colleges with independent academic governance for undergraduate programs (Brower & Inkelas, 2010; Gaff). Currently most large universities use LLCs in some form.

Typically the role of LLCs was to address shortcomings in undergraduate education resulting from the size of research institutions. LLCs were seen as an intervention to address a variety of challenges including academic performance, retention and engagement (Ryan, 1992; Shapiro & Levine, 1999). Using LLCs as an educational intervention relates directly to the present study's focus of assessing the impact of LLCs on the dual concerns of retention and learning in engineering education. LLCs are considered a way to improve students' educational experiences through increased collaboration with peers and faculty that spur deeper, more purposeful learning (Gamson, 2000; Guskin, 1994). Preliminary positive research results and positive feedback from participants have increased the use of LLCs to attract and retain students in colleges and universities across the U.S. As a result, LLCs are promising for engineering education because of the focus on fostering a sense of belonging and fit, integrating students' in and out of classroom experiences, and developing a community among the student members (Kuh, 1996).

## Types of LLCs

There is an array of LLCs in U.S. higher education. Typically LLCs have been categorized as a type of learning community with a residential component (Lenning & Ebbers, 1999; Shapiro & Levine, 1999). Inkelas et al. (2006) define LLC participants as students: (a) living together on campus; (b) participating in academic-related activities, or using resources in their residence environment to which other students do not have access; and (c) structuring social activities in the residence hall.

Recently there has been an attempt to distinguish between the variety of LLCs. Inkelas, Soldner, Longerbeam, and Leonard (2008) used an empirical approach to develop a typology of LLCs. Using a data cluster analysis of institutional programs, they identified a typology of three groups. The first group ("Small") includes those with a primarily residential life emphasis, approximately 50 students and limited resources. The second group ("Medium") includes those with approximately 100 students and involvement from both student affairs and academic affairs but with low levels of collaboration. The final group ("Large") includes those with approximately 350 students and is well-resourced with high levels of collaboration between student affairs and academic affairs.

The different types of LLCs make it difficult to discuss their impact as a monolithic group. Pascarella and Terenzini (2005) noted that since the 1990s the evidence for the effectiveness of LLCs has become muddled by an infusion of different types of LLCs that lack the cohesion seen in previous research in this area. The variety and range of LLCs resulted in more mixed findings of impact on students in generic LLCs when controlled for entering characteristics (Kanoy & Bruhn, 1996; Stassen, 2003). In response, researchers have begun examining the effects of LLCs using more sophisticated models to separate out effects by type of LLC (Wawrzynski & Jessup-Anger, 2010).

For example, residential colleges with intense faculty involvement, structured student experiences and tight-coupling to academic affairs demonstrate the most compelling and consistent impact on student learning and development (Pascarella, Terenzini & Bliming, 1994). Residential colleges are self-contained enterprises within an institution where students and faculty form a community within a space designated for both living and learning activities (Ryan, 1992). Students experience frequent contact with members of the community in and out of the classroom while sharing a common curricular experience. Therefore it is important to consider the type of LLC when either developing programs or assessing impact.

This range of LLC programs impacts the extent to which certain outcomes should be expected. Those LLCs that most closely resemble residential colleges seem to be most likely to have a significant impact on outcome measures. The LLC in this study is not a residential college, however, it shares many of the key characteristics that make residential colleges successful: (a) the link between the residential experience and curricular offerings; (b) the focus on increasing student retention and improving student learning; and (c) the involvement of older engineering undergraduates in the community as peer mentors. Although faculty involvement is more modest than is typical for a residential college, professional staff and a few faculty are involved significantly in the LLC in this study. Thus, it is reasonable to expect a positive impact on the student experience for LLC participants in this study.

## Contemporary Understanding of LLCs

In this section, I explore the current literature on LLCs in three sub-sections: (a) guidelines for developing LLCs; (b) outcomes associated with LLCs; and (c) LLCs used in engineering contexts.

### *Guidelines for Developing LLCs*

There is a significant body of literature that describes the characteristics of LLCs or provides suggestions for LLCs based on anecdotal experience. For example, there are a series of recommendations in the literature for how an institution should support the endeavor: (a) provide strong academic support (Rowe, 1981), (b) commit to fostering diversity, (c) promote social responsibility, and (d) foster a sense of belonging (Brazzell & Reisser, 1999). In addition, it is recommended that universities allocate adequate facility space and restrict the size of the population involved to allow for collaborative and cooperative learning opportunities (Lenning & Ebbers, 1999; Rowe). Finally, the literature encourages institutions to emphasize the recognition of the accomplishments by community members (Brazzell & Reisser).

Other recommendations have centered on the characteristics that the institution should promote among student participants. It is recommended that institutions encourage student involvement in terms of academic and extracurricular activities (Rowe, 1981; Schroder, 1994). Also successful LLCs are able to foster a sense of identification with the community among its student participants (Schroder). In addition, students should develop an interest in maximizing peer group influences by developing multiple and diverse opportunities to interact with other members of the LLC (Rowe).

Finally, there is a body of literature that describes common problems faced when implementing a LLC. These challenges include: (a) developing effective partnerships between academic and student affairs (Gabelnick, MacGregor, Matthews, & Smith, 1990; Lenning & Ebbers, 1999; O'Hara, 2001); (b) identifying the appropriate administrative oversight (Gabelnick, et al.); (c) investing adequately in the development and maintenance of facilities that foster the goals of LLCs (O'Hara); and (d) recruiting sufficient faculty (Lenning & Ebbers).

*Outcomes Associated with LLC Participants*

More recently, research has focused on measuring the impact of LLCs in various contexts. Much of the literature on LLCs compared students who participate in LLCs with non-participants on assessments of student outcomes. One common output measured students' satisfaction on constructs related to the LLC experience. In general, participants in LLCs tended to report higher levels of satisfaction with the college experience than non-participants. The higher levels of satisfaction pertained to all aspects of the experience from the quality of facilities to educational experiences (Armino, 1994; Pike, Schroder & Berry, 1997). These high levels of satisfaction may be linked to the higher reported levels of involvement, incorporation and engagement in the community among LLC participants (Inkelas et al., 2004; Inkelas & Weisman, 2003; Pike, 1999; Pike et al.). Furthermore LLC participants tended to perceive their residential communities as more supportive than non-participants (Inkelas; Inkelas & Weisman).

The impact of LLCs on academic achievement is mixed. Some studies have found that participants in LLCs performed better academically than non-participants (Pascarella & Terenzini, 1981; Pasque & Murphy, 2005; Rice & Lightsey, 2001); others found no significant gains for LLC participants in comparison to non-participants (Pike, et al., 1997). LLC participants experienced more significant gains in intellectual development and engagement compared to students in traditional residence hall settings (Inkelas et al., 2004; Pascarella & Terenzini, 2005; Pasque & Murphy; Pike, 1999). However, research suggests that LLCs do not have a statistically significant impact on the growth of cognitive complexity (Inkelas, Vogt, Longerbeam, Owen, & Johnson, 2006).

In contrast, LLCs had a positive effect on several involvement and engagement measures that are linked to student success and retention. For example, students who participated in LLCs were more likely to be involved in campus activities that non-participants (Inkelas et al., 2004; Pike, 1999). In addition, LLC participants tended to interact more with instructors and peers than non-participants (Inkelas; Inkelas & Weisman, 2003; Pike). LLC participants reported being more connected than non-participants to members of their community.

In general, participation in LLCs had positive effects on students. On a range of measures from intellectual development to social integration, LLC participants scored higher than students in traditional residence hall settings. Many of these outcomes previously studied such as sense of belonging, engagement, connection to community, and intellectual development relate to this study's focus on retention and learning in engineering education. Thus the findings in the general literature on LLCs provide support for the hypothesis that LLCs may be an effective intervention in engineering education.

*LLCs in Engineering Education*

There are few studies of LLCs in engineering education. Until recently, the majority of LLCs for undergraduate engineers were general STEM-based theme housing. Furthermore these LLCs are normally small and often target specific populations of underrepresented students. For example, there have been efforts to create Women in Science and Engineering (WISE) LLCs at institutions across the country. WISE programs are often based in a residence hall for women majoring in STEM fields These programs usually include various programmatic components such as (a) student-faculty mentoring programs, (b) programs to expose and encourage women toward STEM careers, and (c) disciplinary support in the form of advising or tutoring (Hathaway, Sharp & Davis, 2001; Pace, Witucki, & Blumerich, 2008).

There is not a significant amount of research on the impact of LLCs in engineering education; much of the literature focuses on descriptions of programs and implementation efforts. Data from WISE programs indicated that LLC participants had a higher GPA at the end of the academic year and were more likely to remain enrolled in college (Pace et al., 2008). The study reported general college retention figures as opposed to discipline-specific retention measures gauging students' likelihood to remain in STEM fields. One study of an engineering-specific LLC found that LLC participants reported (a) a stronger connection to the engineering college, (b) a stronger connection to engineering peers, and (c) increased awareness of tutoring and other academic services. However LLC participants did not differ from non-participants in terms of college GPA (McKelfresh, 1980).

These data echoed some of the findings from the larger body of literature on the impact of LLCs and lend credence to the use of LLCs to address issues in engineering education. However the data available has some limitations. First, there is very little research available on the use of LLCs for engineers, especially studies that do not include all STEM disciplines. Second, the engineering-specific research was completed over three decades ago. This lack of literature strongly suggested the need for additional research.

In summary, LLCs may impact the quality of the engineering experience by fostering deeper faculty and peer interactions and creating a more seamless learning environment. The outcomes of students participating in LLCs suggested that these communities could potentially impact the rate of retention within engineering by fostering a greater sense of belonging to the engineering community and the discipline. Examining the relationship between participating in a LLC and undergraduate disciplinary persistence for undergraduate engineers is the primary focus of this study.

Because participation in LLCs has been linked to higher levels of intellectual development and engagement (Inkelas et al., 2004; Pascarella & Terenzini, 2005; Pasque & Murphy; Pike, 1999), it is also reasonable to hypothesize that LLCs may have a positive impact on the new engineering learning outcomes identified by ABET as Criterion 3(a-k). Although I do not expect one year of participation in a LLC to strongly predict gains in learning outcomes and engineering skills, it is worthwhile to study for indications of a relationship. If a relationship exists between LLC participation and learning, then it would further the argument for the use of LLCs in undergraduate engineering programs. In addition, the LLC's focus on facilitating student integration into the engineering college through co-curricular programs and living arrangements intuitively relates to some of the ABET Criterion 3 (a-k) (e.g., Engineering Contexts, Communication, Leadership and Teamwork). Therefore the secondary focus of this study was to examine the extent to which LLC participants differ from non-participants on the achievement of student learning outcomes in engineering.

## Conceptual Framework for Retaining Engineers

One way to conceptualize the engineering student experience is through a recently proposed Model of Engineering Student Retention (Veenstra, Dey, & Herrin, 2009) and a subsequent revision (Micomonaco & Sticklen, 2010). This model extends the work of Tinto's (1993) Interactionalist Theory of student departure to better describe the experience of engineering students. Tinto's model suggests that pre-college characteristics (e.g., family support, pre-college academic achievement, etc.) significantly influence students' decisions to persist and graduate from college. The Revised Model of Engineering Student Retention is more detailed about the nature of the student experience and identifies unique intermediate factors that impact disciplinary persistence (Micomonaco & Sticklen; Veenstra et al.).

Veenstra et al. (2009) proposed a few minor revisions to Tinto's (1993) model to develop a theory that explains the departure of students from the engineering discipline (See Figure 1). First, they added the following pre-college characteristics to the model based on empirical findings from studies of entering engineering students: (a) quantitative skills and confidence with quantitative skills; (b) attitude and commitment toward engineering and the university; and (c) study habits.

More salient to the present study, Veenstra et al. (2009) proposed three factors that impact a student's retention decision. The first factor is academic success. Most undergraduate engineering programs require a minimum grade point average (GPA) beyond the first year of college for entrance into the discipline, including adequate success in basic mathematics and science courses. Furthermore, a student's GPA provides immediate feedback regarding their ability to succeed as an engineer. The other two factors are a student's commitment to the engineering college and commitment to learning engineering. All three factors are a function of

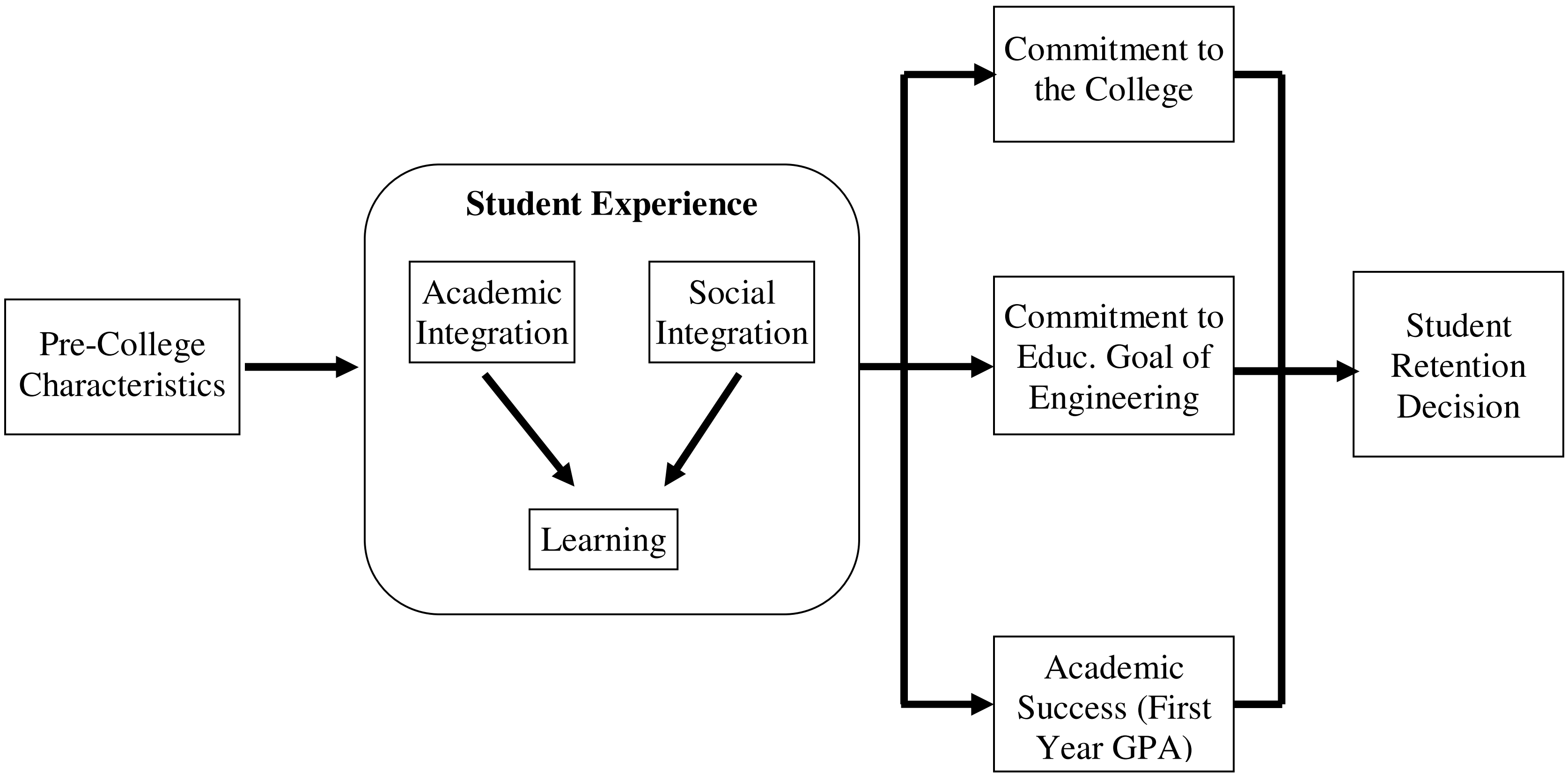


Figure 1: Model of Engineering Student Retention (Veenstra et al., 2009)

the student experience which involves learning as a consequence of academic and social integration.

As understanding the college experience was not a focus of Veenstra et al.'s work, they relied on Tinto's (1993) initial explanation of the student experience being an aggregation of academic and social integration. Academic integration results from experiences both in and out of the classroom that relate to a student's academic life. These interactions affect the strength of a student's association with an academic community. Experiences such as interactions with faculty, success in the classroom, and participation in disciplinary research outside of class contribute to a stronger sense of academic integration. Similarly, social integration represents the extent of a student's association to a social community. Social integration results from participation in activities that foster connections within the community such as co-curricular activities, informal conversations in the residence hall and social events (Tinto). In essence, integration is a measure of one's belonging to a community.

In Tinto's (1993) and Veenstra et al's (2009) models, academic and social integration relate positively to student learning. Moreover, the degree of integration in the community impacts the student's commitment to related goals and persistence in that domain (Tinto). For example, students who participate in engineering-related events outside of the classroom are more likely to feel connected to the community of engineers and see more value in persisting to degree completion.

However, at times it is difficult to distinguish between academic and social integration. In the present study, this is especially true because the LLC is associated with an academic department. Unlike Tinto's (1993) work on college departure, I studied disciplinary retention where the academic and social realms overlap considerably. As a result, a clear delineation between the concepts of academic and social integration was not possible in this study. A different conceptualization of the student experience was necessary in the context of the present study.

My recent qualitative work in this area suggested that a revised understanding of the specific elements of academic and social integration for engineering students may be appropriate (Micomonaco & Sticklen, 2010). Through interviews with students, it became apparent that in the context of disciplinary retention, academic and social integration are often indistinct because of the population and experiences studied. For example, when measuring the strength of peer relationships as a predictor of disciplinary retention, it was difficult to ask a participant to distinguish between a social event in the residence hall and an academic event because for many students in the LLC these lines were blurred. Therefore, Tinto's and Veenstra's concept of "student experience" composed of academic and social integration can be conceptualized more generally as a "Sense of Belonging" for engineers (see Figure 2).

In this new model, we identified three components of students' Sense of Belonging: (a) Connection to Engineering; (b) Commitment to Engineering; (c) Socialization to the Engineering Profession (Micomonaco & Sticklen, 2010). The Commitment to Engineering construct approximates students' satisfaction with and perception of their choice of engineering as a major. (Micomonaco & Sticklen). Students who view engineering as a good fit for their interests and abilities are more likely to view the discipline positively and report higher levels of satisfaction with their choice of engineering. This positive affect toward engineering would make them more likely to persist within the discipline.

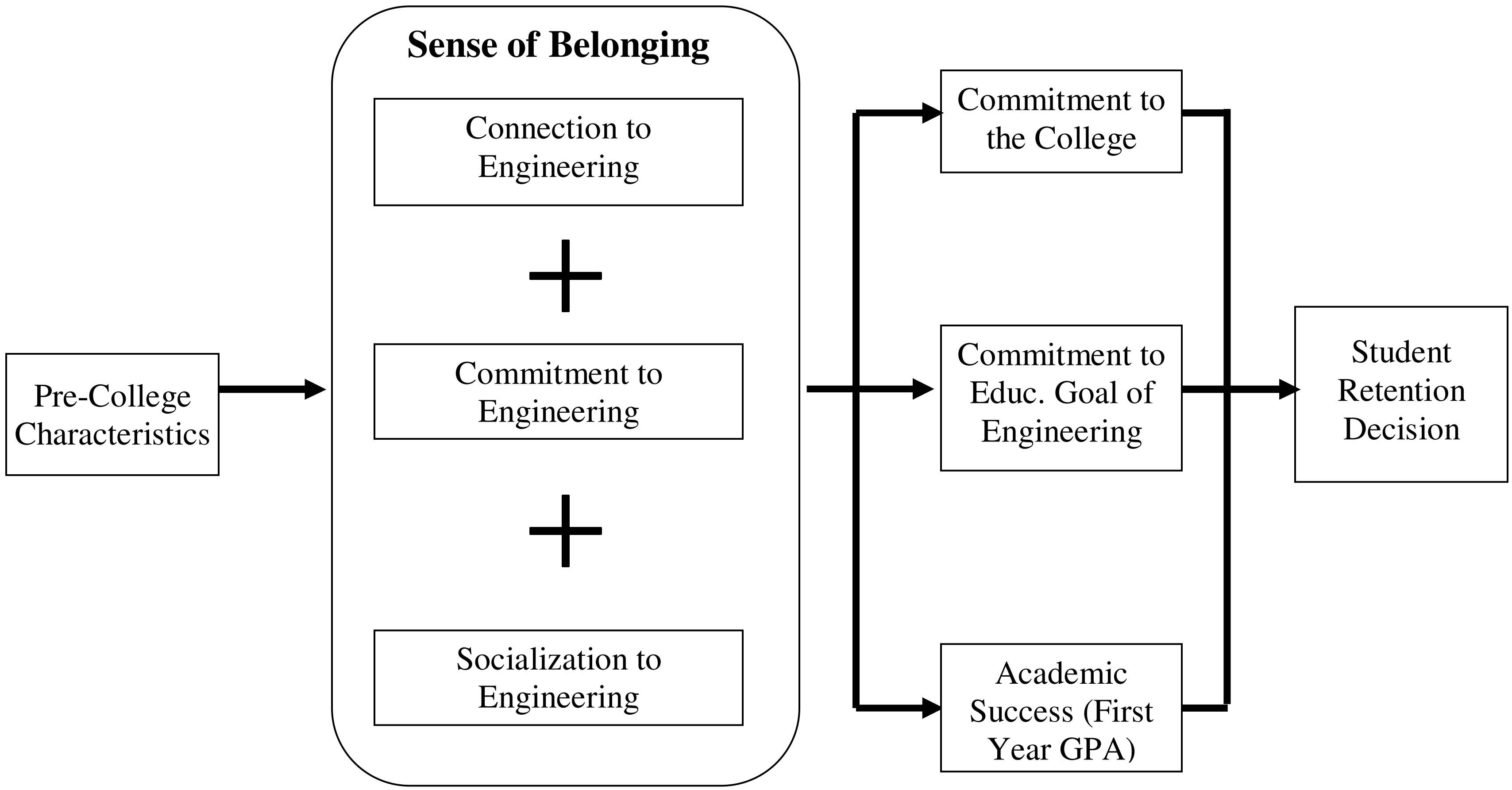


Figure 2: Revised Model of Engineering Student Retention (Micomonaco & Sticklen, 2010)

The Connection to Engineering construct relates directly to interactions described by Tinto (1993) as promoting integration. There are three key components of the Connection to Engineering in this model: (a) Connection to Engineering College; (b) Connection to Engineering Faculty; and (c) Connection to Engineering Peers (Micomonaco & Sticklen, 2010). These three elements of connection reflect the degree to which a student has developed a network of relationships and associations with the engineering community to foster a strong association to the discipline. By developing these functional relationships with their peers, the faculty and their College, students are likely to develop a stronger connection to the discipline of engineering (Braxton & Lien, 2000; Micomonaco & Sticklen; Tinto, 2000; Veenstra et al., 2009).

Finally, engineering is a professional discipline to which newcomers must be socialized. Participants expected to be engaged intensely in elements of the engineering profession as part of their training, yet many expressed frustration with a lack of connection between their undergraduate training and the engineering profession (Micomonaco & Sticklen, 2010). The findings underscored prior calls for inculcating students to the engineering profession as part of their educational experience (Sheppard et al., 2009). Experiences that norm students to the engineering profession help them identify with the profession and help them make more informed decisions. Further, the exposure to professional life helps initiate students into a community of practice, thus strengthening their association with the discipline and improving retention (Wegner & Snyder, 2000).

To frame this study, I chose the Revised Model of Engineering Student Retention for several reasons (Micomonaco & Stickeln, 2010). First, the model maintained a connection to Tinto's seminal work on student departure highlighting the roles of pre-college characteristics and the student experience in students' decision to persist. Second, the model incorporated recent work that identified the important engineering-related intermediate outcomes: (a) commitment to college of engineering community, (b) commitment to studying and becoming an engineer, and (c) college academic achievement. Finally the most recent revision clearly defined the student experience in the engineering context (Micomonaco & Sticklen). In the model, the student experience was reframed as a holistic sense of belonging measure encompassing (a) commitment to the discipline, (b) connection to the discipline including the college, faculty and peers, and (c) the socialization process of becoming an engineer. As a result, the model provided clear guidelines for constructing an instrument to measure these outcomes.

## Defining Outcomes for the Present Study

The Revised Model of Engineering Student Retention provided a useful framework for the current study (Micomonaco & Sticklen, 2010). Using the model in conjunction with the literature reviewed in this chapter, the current study examined three categories of outcomes: (a) indirect measures of persistence; (b) direct measures of persistence; and (c) engineering learning outcomes.

### Indirect Measures of Persistence

The first set of outcomes emerged from the identified subconstructs of Sense of Belonging in the Revised Model of Engineering Student Retention (Micomonaco & Sticklen, 2010). The Sense of Belonging subconstructs (Commitment to Engineering, Connection to Engineering, and Socialization to Engineering) were indirect measures of the student experience that influence students' retention decisions.

The first subconstruct, Commitment to Engineering, was included in each stage of the model. In addition to serving as a component of the Sense of Belonging construct, Commitment to Engineering was a part of the students' pre-college characteristics and was reflected as an intermediary outcome: Commitment to Educational Goal of Engineering. Commitment to Engineering measures the extent to which participants are confident in their choice of engineering and how that changes over time. It is appropriate to include Commitment to Engineering in this study because previous research identified LLC participants as associated with increased levels of satisfaction and engagement (Inkelas & Weisman, 2003; Pike, 1999; Pike, Schroeder & Berry, 1997; Stassen 2003).

The second subconstruct, Connection to Engineering, was comprised of three components: (a) Connection to Engineering College; (b) Connection to Engineering Faculty; and (c) Connection to Engineering Peers. Factors that contribute to the Connection to Engineering construct included students' participation in engineering activities and their connection to the engineering community. Participation in activities increases a student's level of integration in the community. In addition, interpersonal connections deepen the association to the engineering community causing students to feel more connected and less likely to depart from the discipline. These factors have been studied previously. LLC participants tend to view their community as more supportive than non-participants (Inkelas et al., 2004; Inkelas & Weisman, 2003); tend to report higher levels of involvement than non-participants (Inkelas; Pike, 1999); and tend to interact more often with instructors and peers than non-participants (Inkelas; Inkelas & Weisman). Based on these findings and the relation of the outcomes to persistence, these constructs are worth studying.

The final component of the Sense of Belonging construct is Socialization to Engineering. Although there are some opportunities in the first year to expose students to the engineering profession, the LLC in this study is not designed with this goal in mind. Furthermore, the socialization process is likely one that would be difficult to measure over a year's time. Thus measuring the impact of the LLC on first-year engineering students' socialization to the profession is not a focus of this study.

### Direct Measures of Persistence

In this study, I also analyzed direct measures of disciplinary persistence. These measures attempted to capture the impact of the student experience on their decision to stay and their ability to thrive in engineering. College academic performance is included in this category because minimum GPA requirements serve as a gateway to the major at most colleges and universities. Previous findings were mixed in terms of impact of LLCs on academic performance (Pascarella & Terenzini, 1981; Pasque & Murphy, 2005; Pike et al., 1997; Rice & Lightsey, 2001) and retention (Pace et al., 2008). Direct measures of persistence (e.g., student's choice of major) are the most robust outcome measures studied to determine the influence of the LLC.

### Engineering Learning Outcomes

Finally I explored the potential link between participation in the LLC and gains in learning outcomes. The literature supports the potential for LLCs to impact learning and intellectual development (Inkelas et al., 2004; Pascarella & Terenzini, 2005; Pasque & Murphy, 2005; Pike, 1999). These measures are different than the ABET Criterion 3 learning outcomes, but a link between LLCs and engineering learning outcomes is worth examining. Undoubtedly, engineering colleges which implement LLCs to improve disciplinary retention rates would be enthused by the intervention if they also promoted engineering learning outcomes. Therefore in addition to the primary focus of researching the differences between LLC participants and non-participants on persistence-related measures, I also examined the differences between the two groups on engineering learning outcomes.

# CHAPTER THREE

## STUDY DESIGN

In this chapter I describe the design of the study. I revisit the research questions, describe the LLC studied, and discuss my research design, including sampling and instrumentation. Finally I discuss the analytical strategies used in this study.

The purpose of the study was to examine the impact of living-learning communities (LLCs) on the engineering experience of first-year students. The study focused on the use of LLCs to promote disciplinary retention and learning outcomes. I organized the research project around the following research questions:

1. How do students who choose to participate in an engineering LLC differ from other engineering students?

   (a) How do they differ by demographic characteristics?

   (b) How do they differ by their expectations for the college experience?

2. How do LLC participants and non-participants differ on indirect and direct measures of disciplinary persistence?

   a. How do they differ on Sense of Belonging measures?

   b. How do they differ on measures of disciplinary retention?

3. How do LLC participants and non-participants differ on attainment of engineering learning outcomes?

### Description of the LLC

This study examined an LLC in its first year of operation at a large research university. The launch of the LLC occurred at a time when the institution was developing multiple interventions to improve student performance and retention in engineering. The LLC was created by an engineering college to serve three interrelated goals: (a) connect students to the engineering college; (b) increase retention of undergraduate engineers within the discipline; and (c) increase students' enjoyment of their undergraduate experience by reducing anxiety about studying engineering and providing a community of like-minded peers. In addition, administrators stated that they view the LLC as a potential enhancement of efforts targeting the retention of women in the discipline.

At the institution I studied, engineering students at this institution declared engineering as a major, completed the necessary prerequisite courses including an introductory design sequence, and then waited for a decision letter from the college officially granting them admission sometime during their sophomore or junior year. During this time, students enrolled in few disciplinary courses during the first two years and had few experiences based in the College of Engineering. Because the introductory engineering courses met in a different building, it was possible for a first-year engineering student to never enter the campuses' engineering building. The LLC was meant to combat this lack of formal connection between students and the engineering college.

The LLC in this study was located in a residence hall with students from other disciplines. A section of the building was reserved for engineering students and the College of Engineering's LLC program. For the year of this study, nearly half of the students in this residence hall were affiliated with the engineering college. Engineering students enrolled in the LLC lived on the same floors with peer mentors who were upperclass engineers. These peer mentors served in the traditional residential assistant role in the residence hall as well as provided support related to the engineering experience.

Students who chose to participate in the LLC had access to various programs and resources to support their development as undergraduate engineering students and introduce them to people associated with the engineering college. The group associated with the LLC included faculty members, professional staff, upperclassmen engineers, and other first-year engineering students. The involvement of faculty in the LLC was minimal other than a single faculty program director. Connecting students with faculty was not a goal of the LLC. Instead the primary resources for students living in the LLC were the RAs and professional administrative staff.

There were a number of formal programs, curricular and co-curricular, associated with the engineering LLC. First, the required first-year introductory courses for all first-year engineers met in the residence hall. In addition, the laboratory supporting these courses was located in this building. Second, the College of Engineering established a satellite advising center in the building to increase their formal presence in the residence hall. Third, drop-in peer tutoring in support of the first-year engineering requirements was available in large student lounges of the building five nights per week. These tutoring sessions normally drew between 25-50 students per night. Finally there were approximately four LLC community events per semester meant to further introduce students to the engineering profession and expose them to engineering-related concepts in practice. Events including dinners with faculty, guest speakers from industry, and presentations on cutting-edge research attracted audiences ranging from approximately 25 to nearly 200 faculty, staff and students.

## Instrumentation

For the study, I developed a survey to assess sense of belonging, plans to persist in the major, and learning outcomes.  With the exception of the engineering learning outcome items, which were developed by another research team (Center for the Study of Higher Education, 2006), I developed the individual survey items. I crafted these items based on the emergent themes from my qualitative research, which led to the revision of the Model for Engineering Student Retention (Micomonaco & Sticklen, 2010). The qualitative work on the first-year engineering experience resulted in detailed student accounts of attitudes, beliefs, and behaviors that informed student disciplinary retention decisions. The data from that study defined the student experience component of the retention model with greater specificity to include three Sense of Belonging components: (a) Commitment to Engineering; (b) Connection to Engineering (College, Faculty, and Peers) and (c) Socialization to Engineering (Micomonaco & Sticklen). For the current study, I devised survey items that corresponded to the emergent themes from the first two components.

The survey items for the current study are categorized into six sections, four of which map directly to the Sense of Belonging components of the Revised Model of Engineering Student Retention and discussed separately below (Micomonaco & Sticklen, 2010): (a) pre-college characteristics; (b) Commitment to Engineering; (c) Connection to Engineering College; (d) Connection to Engineering Faculty; (e) Connection to Engineering Peers; and (f) engineering learning outcomes. (See Appendix A for the entire instrument)

## Pre-College Characteristics

One of the outcomes of this study was to better understand the type of student who enrolls in the LLC and how they compared with non-participants. This section consisted of measures that required participants to reflect on their pre-college decisions and expectations related to engineering. Previous research on disciplinary retention in engineering identified links between motivation for choosing engineering and persistence within the major (Besterfield et al., 1997).

The survey items included: (a) “When did you first become interested in engineering?”; (b) “When did you first decide to major in engineering?”; (c) “Why did you choose engineering?” ; and (d) “How many hours per week do you expect to spend on homework?” In addition, one item asked respondents to indicate their reason for participating or not participating in the LLC. The responses on these items provided additional information regarding differences between LLC participants and non-participants beyond the student demographic data available from the institution.

Commitment to Engineering

I designed the Commitment to Engineering section of the instrument to assess students’ commitment to the field of engineering.  I asked participants to respond to a series of measures on a four-point Likert scale rating the extent to which they agree with a series of statements. The response options were (a) strongly agree, (b) somewhat agree, (c) somewhat disagree, and (d) strongly disagree. Participants rated their level of agreement with statements such as (a) “I am excited about studying engineering”, and (b) “I may switch to a non-engineering major”; the latter statement being reverse-scored. These items were administered at all three administrations to gauge students’ commitment to engineering and how it changed over time. Previous research using similar items identified confidence in one’s ability to be an engineer as predictive of disciplinary retention (Besterfield et al., 1997). One item was added to the Time 2 administration on a scale of “very unlikely” to “very likely”: “Please rate your likelihood to continue in an engineering major”. This item served as a direct measure of intent to persist in the major and was analyzed as part of the direct disciplinary retention measures.

## Connection to Engineering College

The next set of items related to the students' sense of belonging to the engineering college. Again, participants used a four-point Likert scale to rate their agreement with statements ranging from "strongly agree" to "strongly disagree". These items were designed in light of previous findings regarding students persistence being a function of their involvement in college (Tinto, 1993) and perceptions of the sense to which they are a member in a community affiliated with the institution (Tinto), or in this case, affiliated with the discipline (Micomonaco & Sticklen, 2010).

The statements in this subsection included self-perceptions of students' connection to the engineering college (e.g., "I consider myself a member of the College of Engineering") as well as behavioral statements (e.g., "I plan to use the resources available to me through the College of Engineering"). Data from these items were collected at all three administrations. I altered the verb tense of statements between Time 0 and Time 1 (e.g., "I plan to use…" at Time 0 became "I use…" at Time 1 and Time 2) to shift from examining expectations to actual attitudes and behaviors.

## Connection to Engineering Faculty

The second Sense of Belonging measure, Connection to Engineering Faculty, assessed participants' perception of their interactions with faculty. I used the same Likert scale ranging from "strongly disagree" to "strongly agree" for the items in this subsection. Similar to the Connection to Engineering College section, I turned to previous retention-related findings pointing to interactions with faculty in and out of the classroom as predictive of persistence within the major (Pascarella & Terenzini, 2005; Tinto, 1993) as well as the qualitative work specifically studying engineering students (Micomonaco & Sticklen, 2010).

To measure students' connection to the engineering faculty, participants responded to statements about (a) their perception of faculty (e.g., "Professors will be available to discuss non-class issues"), (b) their interactions with faculty (e.g., "I plan to interact with professors outside of classroom time"), and (c) the value they place on these interactions (e.g., "Developing relationships with faculty is important to me"). Similar to the Connection to Engineering College measures, these items were included in the survey at all three administrations with a change in verb tense to change measures of expectations to measures of current attitudes and behaviors where appropriate.

### Connection to Engineering Peers

The items measuring the Connection to Engineering Peers construct were designed in the same way as the previous two Sense of Belonging constructs building off the work of general student retention (Tinto, 1993) and engineering-specific retention studies (Micomonaco & Sticklen, 2010). Both the Likert scale measuring level of agreement and the change in verb tense between Time 0 and Time 1 were employed for these items. The Connection to Engineering Peers construct included items measuring participants' (a) peer relationships (e.g., "Most of my closest friends are engineering peers"), (b) connection to upperclass engineers (e.g., "I feel comfortable seeking help with my classes from upperclass students"), and (c) study habits with other engineers (e.g., "I plan to seek help from my classmates with homework and studying"). These items assessed both informal social connections and informal study groups that formed among first-year engineering students.

### Engineering Learning Outcomes

This part of the instrument consisted of items designed for the *Educating the Engineer of 2020 (E2020) Student Survey* used here with permission from the research team at the Center for the Study of Higher Education at Penn State University (2006). The survey examined the undergraduate experience of engineers as part of a larger study of graduating seniors and post-graduates assessing the state of engineering education in the United States (Center for the Study of Higher Education, 2006).

The *E2020 Student Survey* is one of six instruments created to assess the degree of alignment between engineering programs and the achievement of the required ABET outcomes (Center for the Study of Higher Education, 2006). The survey instrument was reviewed extensively by experts in the field including industry representatives as well as educational and engineering researchers. The team at Penn State then piloted the instrument, soliciting feedback from engineering students or recent graduates (Center for the Study of Higher Education).

I used the sections of the instrument that addressed the liberal learning outcomes required for engineering programs known as ABET Criterion 3 (a-k) (see Appendix A). There are nine sub-sections of statements on the original survey to address Criterion 3 outcomes. Participants are asked to rate themselves on a five-point, Likert scale of ability ranging from “weak/none” to “excellent”.

For this study, I chose to examine the four sub-sections most likely to manifest differences between LLC participants and non-participants. To select the sub-sections of the instrument to use, I considered two factors. First, I selected the constructs that were less connected to the classroom experience. For example, I did not compare the groups on measure related to the application of mathematics and science to engineering. Second, I chose learning outcomes that one could expect a first-year student to develop over a short time period because the study was limited to first-year students and confined to less than an academic year. For example, I deemed it unreasonable to expect a relationship between LLC participation and managing design projects to emerge in the first year.

The four sub-sections of the instrument included in this study were: (a) Engineering Contexts (e.g., “Please rate your ability to recognize how different contexts can change a solution”); (b) Communication (e.g., “Please rate your ability to write a well-organized, coherent report”); (c) Teamwork (e.g. “Please rate your ability to work with others to accomplish group goals”); and (d) Leadership (e.g., “Please rate your ability to develop a plan to accomplish a group or organization’s performance”). These learning outcomes most closely aligned with the aims of the LLC in this study and the previous research on the impact of LLCs. I excluded the measures for (a) applying math and science, (b) defining problems and generating design solutions, (c) managing a design project, (d) interdisciplinary knowledge and skills, and (e) recognizing perspectives when solving design problems because the content of the questions were likely beyond the experience of this sample of first-year students.

Validity

All parts of the survey except for the learning outcomes items were reviewed by experts to enhance validity. Three content experts who conduct research in engineering education reviewed the questions independently of one another, providing feedback on individual items and the overall structure of the instrument. Examples were added to some of the statements to clarify their meaning, such as “There are many resources (e.g., advising, career services, tutoring, etc.) available to me through the College of Engineering”. Another revision was to include a measure targeting students’ participation in engineering extracurricular activities, not just extracurricular activities in general. In addition, two researchers with experience in instrument design reviewed the draft version of the survey to provide structural feedback to improve flow.

I also piloted the survey using a group of students. Six engineering students completed the survey via pencil and paper and provided feedback regarding the clarity of survey items. In addition, students were asked to reflect on their understanding of certain items to ensure clarity where concerns were previously raised. The feedback from the pilot resulted in the rewording of some questions to clarify the meaning of statements. For example, I changed the term “study group” to “a group of classmates to study with” to avoid confusion with assigned groups for class projects. Also the students participating in the pilot brainstormed additional options for the “multiple select” questions: “Why did you choose engineering?”; “Please indicate your primary reason for selecting the residential experience in ‘Hall A’”; and “Please indicate your primary reason for not selecting the residential experience in ‘Hall A”.

## Data Collection

I collected the data three times during the 2009-10 academic year using the laboratory meetings of the first year introductory design sequence. The first course in the sequence provided students with an overview of topics common across engineering disciplines and included group projects involving elementary design experiences. For the second course in the sequence, most students enrolled in an introductory course on mathematical modeling; computer science and computer engineering students enrolled in an introductory course on computer programming.

The first administration occurred during the second full week of classes in the fall semester (Time 0). I used the Time 0 administration as an opportunity to collect pre-intervention data to ascertain differences between LLC participants and non-participants related to pre-college characteristics and expectations for the college experience. There were two additional data collections to assess student attitudes and behaviors during and near the end of the first-year engineering experience. These data provided early indications of whether the decision to participate in the LLC affected students on the range of measures. I collected most of the Time 1 data during the second full week of classes in the second semester. Because there are two tracks for first-year engineers in the second semester, a small group of students (approximately 13% of the target population) were not surveyed until the fourth week of classes. All of Time 2 data targeting the end of the academic year attitudes and behaviors were collected during the last two weeks of classes.

I administered the survey at the beginning of the scheduled laboratory meetings. The first 15 minutes of the class meeting were devoted to completing the survey. Participants completed the survey via the web needing approximately 7 minutes to complete the survey at Time 0, and 10-12 minutes to complete the survey at Time 1 and Time 2. The participants did not receive an incentive to participate in the survey.

I used an online classroom platform to administer the survey that requires participants to log in using their personal identification number (PIN). The PIN enabled me to track responses across the three administrations of the survey and to link responses to demographic data including pre-college characteristics and college academic performance. I only used the PINs to match these data to participants. Therefore the identity of participants including their names and other information remained confidential. I reported all data in aggregate form to preserve anonymity.

## Sample

The participants in this study were first-year students who declared engineering as their major at a large, research university. At this institution, students who have stated a preference to major in an engineering discipline must apply for acceptance into the major after completing a series of required courses. Normally students apply to the College of Engineering near the end of their sophomore year.

First-year engineering students at the institution enroll in a required introductory design sequence of two engineering courses. Most often, students begin the sequence in the fall semester and complete the second course in the spring semester of their first year; there is a choice of two course options in the spring depending on the students' planned major. Beyond the two introductory engineering courses, entering students enroll primarily in required courses in the other sciences (e.g., chemistry, physics) and mathematics.

The institution requires first-year students to live on campus unless they live with a parent or legal guardian within 50 miles of campus. Ninety-one percent of new first-year students lived on campus as of 2007. All entering engineering students had the option of participating in the institution's LLC for engineers. In the year of this study, approximately 30% of first-year engineers chose to live in the College of Engineering's LLC.

I identified the participants for this study from the cohort of new first time students for whom the 2009-10 academic year was their first full year in college. I targeted all of these students who enrolled in one of the introductory engineering courses during the 2009-10 academic year and were 18 years or older at the time of administration (N =499). The group of students was predominantly White (82.0%) and male (86.2%). All 499 students were included in the analysis of demographic and other pre-college characteristics derived from the institution's student records.

For the survey items, each administration yielded a slightly different sample of students. Therefore I compared the group who completed the survey (takers) with those who did not complete it (non-takers) in terms of their gender, ethnicity, decision to participate in the LLC, and pre-college academic achievement. Identifying these differences is important for interpreting the results reported in Chapter 4.

For the first administration (Time 0) at the beginning of the academic year, 76.2% of the total sample (N = 499) responded to the survey. Because only 87% of first-year engineering students were enrolled in the targeted course, the response rate of students asked to complete the survey was 87.6%. The takers differed slightly from the group of non-takers at Time 0 in three ways: (a) LLC participants were overrepresented among the takers, $\chi^2$ (1, n = 499) = 6.16, p = .013, phi. = .116; (b) international students were overrepresented among non-takers, $\chi^2$ (4, n = 493) = 62.11, p < .001, phi. = .355; and (c) takers (M = 28.32; SD = 3.37) and non-takers (M = 29.45, SD = 3.16) were different by a statistically significant margin, t (406) = 2.21, p = .03, but the effect size was low (eta squared = .01). However the two groups were similar in terms of gender, ACT Composite and high school GPA.

At Time 1 (the middle of the academic year), the percentage of the targeted sample enrolled in the introductory courses dropped to 72.6%. Thus, despite an 89.2% response rate from students enrolled in the courses, the response rate for the overall sample of 499 dropped to 64.7%. The two groups were similar on all measures except for the representation of LLC participants. There was a statistically significant relationship between LLC participation and taking the survey, $\chi^2$ (1, n = 499) = 6.787, p = .009, phi. = .121. LLC participants were overrepresented among the takers.

For the final administration (Time 2), the response rate among students enrolled in the second semester of the introductory course dropped to 84.0%, representing 60.9% of the original targeted group of 499 first-year engineering students. Once again, LLC participants were overrepresented in the sample of takers, $\chi^2$ (1, n = 499) = 10.77, p = .001, phi. = .151. In addition, there was one statistically significant difference between takers and non-takers on pre-college academic measures. The two groups were similar on mean scores for ACT Composite and ACT Math, but the two groups differed in terms of high school GPA. Takers had a statistically significant higher GPA in high school (M = 3.75, SD = .32) than non-takers (M = 3.55, SD = .35), t (300) = -3.96, p < .001. The effect size for the difference in high school GPA was low (eta squared = 0.03).

Overall, the takers and non-takers for each administration were quite similar. The initial underrepresentation of international students among takers at Time 0 is puzzling and may inform the interpretation of the results. The only persistent difference between takers and non-takers is the overrepresentation of LLC participants among the takers. Because the focus of the study is to compare LLC participants and non-participants, the prevalence of LLC participants in the sample is unlikely to bias the results; instead it may facilitate the analysis by making the two groups more comparable in terms of group size.

## Scale Construction: Principal Components Analysis

As described above, I developed a series of statements to assess students' sense of belonging as a indirect measure of disciplinary persistence. Unlike the learning outcomes measures previously studied (Center for the Study of Higher Education, 2006), these Sense of Belonging items and scales constructed from them were created for this study and warranted additional scrutiny prior to the analysis. I started by grouping the items into the four theoretical components derived from the literature: (a) Commitment to Engineering; (b) Connection to Engineering College; (c) Connection to Engineering Faculty; and (d) Connection to Engineering Peers. I used principal components analysis (PCA) with an oblique rotation to verify empirically the purported coherence of these items in their theoretical clusters and to form scales to reduce the total number of variables included in regression analyses. This type of scale construction also reduced the likelihood of multicollinearity in regression analyses.

For each theoretical component, I started with all items in the construct. I reduced the number of items one by one, checking the component weights and pattern structure matrix, eigenvalues, component correlation matrix, and interpretability of the results. Overall the PCA results were satisfactory producing interpretable scales. The total number of individual items was reduced from 26 to 8 factor components or scales.  I summarize the results for each theoretical construct below in separate sections: (a) Commitment to Engineering; (b) Connection to Engineering College; (c) Connection to Engineering Faculty; and (d) Connection to Engineering Peers.

## Commitment to Engineering

The four items measuring Commitment to Engineering ("I am excited about studying engineering"; "I am confident that engineering is the correct major for me"; "I may switch to a non-engineering major" (reverse-scored); and "I have considered switching to a non-engineering major" (reverse-scored) loaded meaningfully into a single component or scale. The data were suitable for the PCA because the Kaiser-Meyer-Oklin (KMO) value was 0.71, exceeding the recommended value of 0.6 (Cohen, 1988), and the Bartlett's Test of Sphericity was statistically significant ($p < .001$). The single component for Commitment to Engineering had an eigenvalue of 2.50 and explained 62.5% of the variance. Table 2 summarizes the pattern matrix from the factor loading.

Table 2: PCA Result for Commitment to Engineering

| Commitment to Engineering | Pattern Matrix<br>1 |
|---|---|
| Excited to study engineering | .862 |
| Confident engineering is the correct major | .852 |
| May switch to non-engineering major* | .750 |
| Considered switching to non-engineering major* | .684 |

* These items were reverse-scored.

## Connection to Engineering College

The best solution for the five items measuring Connection to Engineering College consisted of two components or scales. The two components were (a) College Member ("I consider myself a member of the College of Engineering"; and "I am involved in extracurricular activities associated with the College of Engineering"), and (b) College Support ("I feel supported by the College of Engineering"; "There are many resources (e.g., advising, career services, tutoring, etc.) available to me through the College of Engineering"; and "I (plan to) use the resources available to me through the College of Engineering"). Once again, the KMO value was above 0.6 (0.65) and the Bartlett's Test of Sphericity was statistically significant ($p < .001$). The two components explained 58.9% of the variance. Choosing the two component solution required including a component with an eigenvalue less than one (0.95), but increased the explained variance by 19.1%. The correlation coefficient for the two components was 0.29 supporting the use of two variables in this case. Table 3 details the loadings from the PCA for Connection to Engineering College.

Table 3: PCA Results for Connection to Engineering College

| | Pattern Matrix | |
|---|---|---|
| Connection to Engineering College | 1 | 2 |
| *Member of College* | | |
| Consider myself a member of the College of Eng. | .797 | |
| Involved in extracurriculars associated with College of Eng. | .687 | |
| *Supported by College* | | |
| Perceive many resources available through the College of Eng. | -.222 | .900 |
| Feel supported by College of Eng. | .194 | .708 |
| Use resources available through College of Eng. | .131 | .628 |

## Connection to Engineering Faculty

For the six items measuring Connection to Engineering Faculty, the PCA results indicated a two component solution using five of the items. The two components were (a) Student Perceptions of Faculty (“Professors will be/are available to provide guidance to me”; and “Professors will be/are available to help me with learning/understanding course material outside of class”); and (b) Student Interactions with Faculty (“Developing relationships with faculty is important to me”; “I (plan to) interact with professors outside of classroom time”; and “I (plan to) interact with professors about non-class issues (e.g., socially, career advice, etc.)”). The items satisfied both the KMO test (0.71) and the Bartlett’s Test of Sphericity ($p < .001$). The initial two factor solution using all six items explained 66.6%, but the loadings were difficult to interpret because individual items loaded onto multiple components in the pattern matrix. By discarding one item (“Professors will be/are available to discuss non-class issues”), the amount of explained variance increased to 71.8% and the pattern of the loadings was more inetrpretable (see Table 4). The correlation coefficient for the two components was low (0.29); often a coefficient of at least 0.6 is required to assert a relationship between the components (Ott & Longnecker, 2010). Therefore the low correlation coefficient suggests between the two components suggests that they were likely separate measures.

Table 4: PCA Results for Connection to Engineering Faculty

| | Pattern Matrix | |
|---|---|---|
| Connection to Engineering Faculty | 1 | 2 |
| *Student Perceptions of Faculty* | | |
| Available to provide guidance to me | .911 | |
| Available to help with learning/course material outside of class | .897 | |
| *Student Interactions with Faculty* | | |
| Developing relationships with faculty is important | | .826 |
| Interact with faculty outside of class | | .805 |
| Interact with faculty about non-class issues | | .769 |

## Connection to Engineering Peers

The reduction process for the Connection to Engineering Peers items was the most complicated. The 11 items met both the KMO value requirement (0.80) and the Bartlett's test significant at the $p < .001$ level. The best solution identified by the PCA was a three factor solution with the following factor components: (a) Comfortable Seeking Help from Engineering Peers ("I feel comfortable seeking help with my classes from classmates"; and "I feel comfortable seeking help with my classes from upperclass students"); (b) Relationships with Engineering Peers ("I am friends with other engineering students"; "Most of my closest friends are engineering students"; and "I know upperclass students (sophomores, juniors, or seniors) in the College of Engineering"); and (c) Study Habits with Engineering Peers ("I plan to seek a group of classmates to study with"; "Finding a group of classmates to study with is important to me"; "I plan to seek help from my classmates with homework and studying"). An initial three factor solution explained 63.6% of the variance, but the pattern matrix loading was difficult to interpret when examining the components resulting from the pattern and structural matrices. Based on pattern matrices and communalities scores, I dropped three of the Connection to Engineer Peers items ("I plan to get/sought help from upperclass engineers"; "I feel comfortable identifying a group of classmates to study with"; "I plan to seek/sought advice from upperclass students on course selection”). The new three component solution explained more of the variance (71.4%), resulted in eigenvalues greater than one for all three factor components, and resulted in a cleaner pattern matrix. The correlation coefficients for the three components were (a) 0.23 for Component 1 and 2; (b) -0.31 for Component 1 and 3; and (c) -0.25 for Component 2 and 3. These values were quite low supporting their treatment as separate variables. Table 5 reports the pattern matrix from the PCA.

Table 5: PCA Results for Connection to Engineering Peers

| | Pattern Matrix | | |
|---|---|---|---|
| Connection to Engineering Peers | 1 | 2 | 3 |
| *Comfortable Seeking Help from Engineering Peers* | | | |
| Comfortable seeking help from upperclass students | -.913 | | |
| Comfortable seeking help from classmates | -.847 | | |
| *Relationships with Engineering Peers* | | | |
| Closest friends are engineering students | | .805 | |
| Friends with other engineering students | | .782 | |
| Know upperclass engineering students | | .655 | |
| *Study Habits with Engineering Peers* | | | |
| Seek a group of classmates with whom to study | | | .903 |
| Finding a group of classmates is important | | | .896 |
| Seek help from classmates with homework and studying | | | .779 |

The PCA resulted in a total of eight factor components emerging from the Sense of Belonging items. The eight component factors were:

(a) Commitment to Engineering: measuring participants’ confidence in engineering as the correct major for them;

(b) Member of College: measuring participants’ involvement and engagement in the College of Engineering;

(c) Supported by College: measuring participants’ perception of support provided by the College of Engineering;

(d) Student Perceptions of Faculty: measuring participants' perceptions of faculty availability and support,

(e) Student Interactions with Faculty: measuring student interactions with faculty beyond instruction time,

(f) Comfortable Seeking Help from Engineering Peers: measuring participants' comfort level seeking help from other engineering undergraduates;

(g) Relationships with Engineering Peers: measuring participants' social connections with other engineering undergraduates; and

(h) Study Habits with Engineering Peers: measuring participants' tendency to study with other classmates in engineering.

Although the PCA resulted in eight factor components, I elected to reduce the number further. Due to the number of comparisons in this study, continuing the analysis with all eight factor components increased the likelihood for introducing Type I error and decreased statistical power. Moreover, an examination of the items in each factor component indicated that two components (Student Perceptions of Faculty, and Comfortable Seeking Help from Peers) measured perceptions of participants for which there are already measures of behaviors (Student Interactions with Faculty, and Study Habits with Engineering Peers). Therefore, to minimize the potential error, I elected to exclude these two components measuring perceptions from the analysis and included the more reliable measures of attitudes and behaviors.

The items for each factor component were combined to create scales for analysis. For each administration, I calculated the mean score for the scale by averaging the raw scores from each individual item included in the factor component. Therefore the subscale scores ranged from -2 (corresponding to "strongly disagree") to 2 (corresponding to "strongly agree").

## Data Analysis

*Research Question 1: How do students who choose to participate in an engineering LLC differ from other engineering students?*

*(a) How do they differ by demographic characteristics?*

*(b) How do they differ by their expectations for the college experience*?

To better understand the population studied, I compared the demographic characteristics for the two groups. These data included pre-college student records data procured from the institution such as high school GPA, ACT scores, ethnicity and gender. I also analyzed data describing students' decision to major in engineering (e.g., when and why students chose engineering). Finally, I examined data collected at Time 0 to describe the characteristics of the population studied from the Sense of Belonging constructs: (a) Commitment to Engineering; (b) Connection to Engineering College; (c) Connection to Engineering Faculty; and (d) Connection to Engineering Peers.

For this study, I treated these data as descriptive statistics of the participants in the study. The data collected at Time 0 are pre-intervention; in other words, the responses represented pre-college attitudes and expectations of the engineering and college experience. Students participating in the LLC have not experienced the intervention yet. Therefore there was no attribution of effect to be made at this point. Instead the data served to characterize LLC participants upon matriculation and compare them to non-participants.

The data in this section consisted of multiple types. For categorical data such as reason for choosing engineering and ethnicity, I examined the data via frequency distributions to describe the group. To compare LLC participants to non-participants, I used chi-square analyses when assumptions of the technique were not violated. For some items, I collapsed categories to ensure that the minimum expected cell frequency assumption was met. For example on the measure of ethnicity, I collapsed underrepresented designations (Hispanic, American Indian, Asian/Pacific Islander, Multiple Race/Ethnicity) with less than two percent of the sample in each individual category into a single category, "Other". Although collapsing the categories ignores differences between these groups, it was necessary to conduct the statistical tests and allow for comparisons where the frequencies were sufficient. These chi-square analyses revealed whether there was an association between participating in the LLC and the categorical variable (e.g., ethnicity). To analyze continuous data, I calculated mean scores for each measure including the Sense of Belonging constructs. Then the two groups, LLC participants and non-participants were compared using independent samples t-tests at Time 0.

*Research Question* 2: *How do LLC participants and non-participants differ on indirect and direct measures of disciplinary persistence?*

*a. How do they differ on Sense of Belonging measures?*

To analyze the impact of LLCs on the theoretical construct of Sense of Belonging, I calculated mean scores for each of the four component measures at Time 1 and Time 2: (a) Commitment to Engineering; (b) Connection to Engineer Faculty; (c) Connection to Engineering College and (d) Connection to Engineering Peers. First, I examined the mean scores on each scale at each administration. Because these scores are continuous, I compared LLC participants to non-participants via independent samples t-tests on each component measure for both Time 1 and Time 2. To control for the potential effect of other independent variables, I also used multiple regression modeling to examine the relationship of each Sense of Belonging component measure to participation in the LLC at Time 2. In addition to participation in the LLC, I included gender, ethnicity, and ACT Composite score as a measure of pre-college academic achievement.

Because there are two administrations (Time 1 and Time 2) measuring student attitudes and behaviors, I looked for change over time. First, I examined the trend line of means over time by comparing means at Time 1 and Time 2 for LLC participants and non-participants. In addition, I compared within group changes over time by performing paired samples t-tests relying on significance and calculated eta values to identify differences between the two groups. Finally I regressed the Time 2 Sense of Belonging factor components including the Time 1 measure of that component as an independent variable as well as LLC participation, gender, ethnicity, and ACT Composite.

*b. How do they differ on measures of disciplinary retention?*

In this section, I examined the data from persistence-related measures collected at Time 2. There are three items reported in this section: (a) choice of major at the start of sophomore year; (b) reported likelihood to persist at Time 2; and (c) GPA at end of the first academic year. I included college GPA in this section as a persistence-related measure because GPA acts as a gateway or minimum requirement for engineering students to persist within the major.

The choice of major consisted of categorical data taken from student records for which there are two options: engineering major; and non-engineering major. I examined the prevalence of engineering majors at the beginning of sophomore year in the two groups and compared LLC participants to non-participants via a chi-square analysis. To control for the potential impact of other factors such as gender, ethnicity, pre-college academic achievement and the Sense of Belonging component factors, I modeled the relationship via a logistics regression analysis.

I treated both the likelihood to persist and college GPA as continuous data. First, I calculated the means for both LLC participants and non-participants comparing them via independent samples t-tests. I also modeled the relationship between these two measures and

LLC participation along with the additional independent variables of gender, ethnicity, ACT Composite, and Sense of Belonging component factors via multiple regression analyses.

*Research Question 3: How do LLC participants and non-participants differ on attainment of engineering learning outcomes?*

To study the effect of LLCs on engineering learning outcomes, I conducted similar analyses to the Sense of Belonging component measures. First, I calculated mean scores for each construct at both Time 1 and Time 2. Then I compared LLC participants to non-participants on these mean scores via independent samples t-tests. To control for other independent variables, I modeled the relationships between participation in the LLC and each of the learning outcomes while including gender, ethnicity and pre-college academic achievement at Time 2.

I also compared the changes in engineering learning outcomes between Time 1 and Time 2 by examining the trajectory of mean scores for LLC participants and non-participants between the two data collection administrations. Then I compared these trends with the changes between Time 1 and Time 2 for non-participants. I also computed dependent samples t-tests for LLC participants and non-participants comparing effect sizes via eta values to compare the magnitude of change over time. Finally I modeled the relationship between LLC participation and Time 2 data using Time 1 data as an independent variable in addition to gender, ethnicity, and pre-college academic achievement.

# CHAPTER FOUR

# RESULTS

In this chapter, I report the results of the data analysis performed to answer the three research questions. I have organized the chapter into major sections corresponding to the research questions: (a) differences between LLC participants and non-participants; (b) impact of LLC on disciplinary retention; and (c) impact of LLC on engineering learning outcomes.

## Differences Between LLC Participants and Non-Participants

The first section of this chapter describes LLC participants including a comparison with non-participants. The results in this section answer the first research question:

*How do students who choose to participate in an engineering LLC differ from other engineering students?*

*(a) How do they differ by demographic characteristics?*

*(b) How do they differ by their expectations for the college experience*?

To answer these research questions, I examined the pre-college characteristics of the first-year engineering cohort. The data consisted of pre-college student records data for all targeted students and survey data of participant expectations collected at Time 0 (beginning of fall semester). I organized the data into the following sub-sections: (a) reasons for participating in the LLC; (b) demographic characteristics; (c) interest in engineering; and (d) expectations for college.

### Reasons for Participating in LLC

In this study, all first-year engineering students had the option to participate in the LLC. The LLC was designed to accommodate all of the students who demonstrated interest by a by the standard housing application deadline for first-year students at the institution studied. During the academic year of the present study, nearly 30% of students chose to participate in the LLC. As part of the survey administered at Time 0, participants were asked to indicate why they opted in or out of the LLC (see Table 6).

I asked LLC participants to indicate a reason for not choosing the LLC. The most commonly cited reasons were: (a) participants thought that living in the LLC would help them academically (45.7%); (b) participants wanted to live with other engineering students (29.3%); and (c) participants wanted to live in the specific residence hall that housed the LLC (17.2%). The most frequently cited reasons for choosing not to live in the LLC were (a) participants were unaware of the opportunity (28.4%); (b) participants wanted to live with friends in a different residence hall (18.2%); (c) participants wanted to live in a different location on campus (11.6%); and (d) participants did not want to live with other engineering students (11.6%).

Table 6: Frequency Distribution of Reasons for Participating in LLC

| Top Reasons for Participating in LLC | % | Top Reasons for Not Participating in LLC | % |
|---|---|---|---|
| 1. Thought that living in LLC would help academically | 45.7 | 1. Unaware of the LLC opportunity | 28.4 |
| 2. Wanted to live with other engineering students | 29.3 | 2. Wanted to live with friends in a different residence hall | 18.2 |
| 3. Wanted to live in the residence hall associated with the LLC | 17.2 | 3. Wanted to live in a different location on campus | 11.6 |
| 4. Thought living in LLC would help socially | 3.4 | 4. Did not want to live with other engineers | 11.6 |
| 5. Did not choose it; placed there based on housing preferences | 2.0 | 5. Wanted to live off campus | 8.9 |
| | | 6. Did not think the LLC would be worthwhile | 6.7 |
| | | 7. Unsure if s/he wants to be an engineering major | 5.3 |

## Demographic Characteristics

In this sub-section, I report data on the following demographic characteristics: (a) gender; (b) ethnicity; and (c) pre-college academic achievement. Nearly 20% of the LLC participants in this study were female; 80% were male (see Table 7). A chi-square analysis found a significant association between gender and participation in the LLC, $\chi^2$ (1, n = 430) = 5.205, p = .023, phi. = .108. Female first-year engineering students chose to participate in the LLC at a higher rate than expected.

Table 7: Frequency Distribution by Gender

| | Male | Female | Total |
|---|---|---|---|
| LLC | 119 (80.4%) | 29 (19.6%) | 148 (29.7%) |
| Non-LLC | 311 (88.6%) | 40 (11.4%) | 351 (70.3%) |
| Total | 430 (86.2%) | 69 (13.8%) | 499 (100%) |

I conducted the same analysis to compare the ethnic representation in the two groups. Both LLC participants and non-participants were predominantly White (greater than 80%). A chi-square analysis showed a significant association between ethnicity and participation in the LLC, $\chi^2$ (4, n = 409) = 10.692, p = .030, phi. = .147. As shown in Table 8, Asian and African-American students were overrepresented in the LLC; international students were underrepresented in the LLC.

Table 8: Frequency Distribution by Ethnicity

| | White | Asian | International | African-American | Other | Missing | Total |
|---|---|---|---|---|---|---|---|
| LLC | 124 (83.8%) | 13 (8.8%) | 3 (2.0%) | 6 (4.1%) | 1 (0.7%) | 1 (0.7%) | 148 (29.7%) |
| Non-LLC | 285 (81.2%) | 17 (4.8%) | 21 (6.0%) | 9 (2.6%) | 14 (4.0%) | 5 (1.4%) | 351 (70.3%) |
| Total | 409 (82.0%) | 30 (6.0%) | 24 (4.8%) | 15 (3.0%) | 15 (3.0%) | 6 (1.2%) | 499 (100%) |

I also examined pre-college academic achievement using ACT Composite and ACT Math scores, as well as high school grade point average. Independent samples t-tests showed no significant differences between LLC participants and non-participants in terms of pre-college academic performance measures (see Table 9).

Table 9: Comparison of Pre-College Academic Performance

| | N | Mean | Std. Dev. | S.E. Mean | F | Sig. | T | df | Sig. (2-tailed) | Std. Error Diff. |
|---|---|---|---|---|---|---|---|---|---|---|
| ACT Composite | | | | | | | | | | |
| LLC | 145 | 27.10 | 3.01 | .250 | 4.55 | .033 | .204 | 324 | .838 | .329 |
| Non-LLC | 308 | 27.16 | 3.49 | .199 | | | | | | |
| ACT Math | | | | | | | | | | |
| LLC | 145 | 28.37 | 3.09 | .257 | 9.83 | .002 | -.164 | 323 | .870 | .319 |
| Non-LLC | 308 | 28.31 | 3.60 | .205 | | | | | | |
| High School GPA | | | | | | | | | | |
| LLC | 145 | 3.72 | .303 | .025 | 4.14 | .043 | .497 | 361 | .620 | .035 |
| Non-LLC | 264 | 3.70 | .388 | .024 | | | | | | |

In terms of demographic characteristics, LLC participants were quite similar to non-participants except for their representation by gender (a higher proportion of women) and ethnicity (more underrepresented minorities, fewer international students).

## Interest in Engineering

Early interest in engineering may contribute to the likelihood of students choosing to participate in the LLC. Accordingly I compared LLC participants with non-participants on their pre-college interest in engineering as a college major. The participants responded to survey items asking (a) why they chose engineering, (b) when they became interested in engineering, and (c) when they decided to major in engineering.

Participants in the LLC most frequently chose types of learning experiences, such as hands-on experiences, problem-solving skills, and working in groups as their primary reason for choosing engineering as a major. The other popular response was "good at math and sciences". These two responses accounted for the majority of responses (~70%). The distribution of reasons selected by LLC participants did not differ markedly from non-participants (see Table 10). A chi-square analysis confirmed that there was no significant association between participating in the LLC and reason for choosing engineering as a major, $\chi^2$ (5, n = 304) = 3.137, p = .679) Participants from both groups in this sample tended to choose engineering primarily because of the types of learning experiences they expected and their aptitude in math and sciences.

Table 10: Frequency Distribution of Why Students Chose Engineering Major

| | LLC<br>N = 107 | Non-LLC<br>N = 197 | Entire Sample<br>N = 304 |
|---|---|---|---|
| Expectations for types of learning experiences (e.g., hands-on, practical) | 34<br>(31.8%) | 78<br>(39.6%) | 112<br>(36.8%) |
| Good at math and sciences | 41<br>(38.3%) | 64<br>(32.5%) | 105<br>(34.5%) |
| Encouraged by family, friends or high school teachers | 9<br>(8.4%) | 20<br>(10.2%) | 29<br>(9.5%) |
| Know an engineer; job seemed interesting | 8<br>(7.5%) | 14<br>(7.1%) | 22<br>(7.2%) |
| More likely to get a good job | 7<br>(6.5%) | 12<br>(6.1%) | 19<br>(6.3%) |

Table 10 cont'd.

| | | | |
|---|---|---|---|
| Other | 8 (7.5%) | 9 (4.6%) | 17 (5.6%) |

Participants also reported when they became interested in engineering and when they chose engineering as a major. A large majority of LLC participants (approximately 80%) became interested in engineering over a year before matriculating to college (see Table 11). Despite this early interest, the majority of LLC participants (approximately 55%) did not decide to major in engineering until the year prior to matriculation (see Table 10). These results are not surprising as most participants were traditional students and likely would not have thought seriously about a college major until the year prior to matriculation when completing college applications.

The comparison of LLC participants to non-participants on these measures showed few differences. The frequency distributions for when the two groups became interested in engineering are similar. The large majority of non-participants reported being interested in engineering over a year prior to matriculating (82.2%). A chi-square analysis indicated no statistically significant association between when students became interested in engineering and the choice to participate in the LLC, $\chi^2$ (6, n = 368) = 4.347, p = .630, phi. = .109. For the measure of when students chose engineering as a major, a chi-square analysis also indicated that there was no statistically significant association between when students chose engineering as a major and participation in the LLC, $\chi^2$ (6, n = 363) = 9.663, p = .140, phi. = .163.

Table 11: Frequency Distribution of When Students Become Interested and Chose Engineering

| | When Students Become Interested in Engineering | | | When Students Chose Engineering as a Major | | |
|---|---|---|---|---|---|---|
| | LLC N = 121 | Non-LLC N = 247 | Entire Sample N = 368 | LLC N = 121 | Non-LLC N = 242 | Entire Sample N = 363 |
| Over the Summer | 5 (4.1%) | 5 (2.0%) | 10 (2.7%) | 11 (9.1%) | 36 (14.9%) | 47 (12.9%) |
| Last Spring | 3 (2.5%) | 13 (5.3%) | 16 (4.3%) | 14 (11.6%) | 42 (17.4%) | 56 (15.4%) |
| Last Fall | 17 (14.0%) | 26 (10.5%) | 43 (11.7%) | 42 (34.7%) | 53 (21.9%) | 95 26.2% |
| 1-2 Years Ago | 37 (30.6%) | 84 (34.0%) | 121 (32.9%) | 34 (28.1%) | 66 (27.3%) | 100 (27.5%) |
| 2-4 Years Ago | 24 (19.8%) | 52 (21.1%) | 76 (20.7%) | 10 (8.3%) | 27 (11.2%) | 37 (10.2%) |
| 4-6 Years Ago | 17 (14.0%) | 29 (11.7%) | 46 (12.5%) | 7 (5.8%) | 13 (5.4%) | 20 (5.5%) |
| >6 Years Ago | 18 (14.9%) | 38 (15.4%) | 56 (15.2%) | 3 (2.5%) | 5 (2.1%) | 8 (2.2%) |

Chi-square analyses can mask differences among specific categories when the number of categories is large. That phenomenon appeared to be the case here because the overall lack of significant association masks an apparent difference between LLC participants and non-participants in the later stages of choosing engineering as a major (see Table 11). A chi-square analysis of only the final three options ("last fall", "last spring", and "over the summer") confirmed the association between participation in the LLC and when students choose engineering, $\chi^2$ (2, n = 198) = 8.805, p = .012, phi. = .211. The percentage of LLC participants that chose engineering in the fall of the year prior to college matriculation is much higher than non-participants (34.7% v. 21.9%). This trend is reversed in the following six month period when a much higher percentage of non-participants choose engineering in the spring and summer prior to matriculation than LLC participants (32% v. 20%). Therefore LLC participants chose engineering as their major earlier than non-participants in this study.

## Expectations for College

The final sub-group of pre-college factors is the Sense of Belonging measures at Time 0 that emerged from the Revised Model of Engineering Student Retention (Micomonaco & Sticklen, 2010). The four theoretical constructs examined were: (a) Commitment to Engineering, (b) Connection to Engineering College, (c) Connection to Engineering Faculty, and (d) Connection to Engineering Peers.

Time 0 data, collected at the beginning of the fall semester, represented students' expectations for college because the students had minimal exposure either to the first-year engineering experience or to the LLC at that point. With one exception, I examined Time 0 responses to assess differences in entering expectations between LLC participants and non-participants. The exception was the Commitment to Engineering component, which measures participants' commitment to engineering at Time 0 rather than an expectation.

I analyzed the four Sense of Belonging constructs by calculating the mean for each factor component identified through the PCA (see Tables 2-5 for results of PCA). On the Likert scale, a value of 1.0 corresponds to "somewhat agreeing" with the series of statements, and 2.0 represents "strongly agreeing" with the series of statements. Conversely, -1.0 corresponds to "somewhat disagreeing" with the series of statements; -2.0 corresponds to "strongly disagreeing." In sum, a positive mean value means the respondents agreed with the statements and a negative value indicates their disagreement with the statements.

At the beginning of the first-year engineering experience, the LLC participants reported positive expectations on all four of the Sense of Belonging constructs. LLC students tended to agree with statements for each factor component (means ranged from 0.72-1.47) with the exception of the Member of College component (M = 0.27, SD = 0.89). The Member of College component is one of the two factor components for the Connection to the Engineering College measure. The mean scores were graphed below in Figure 3.

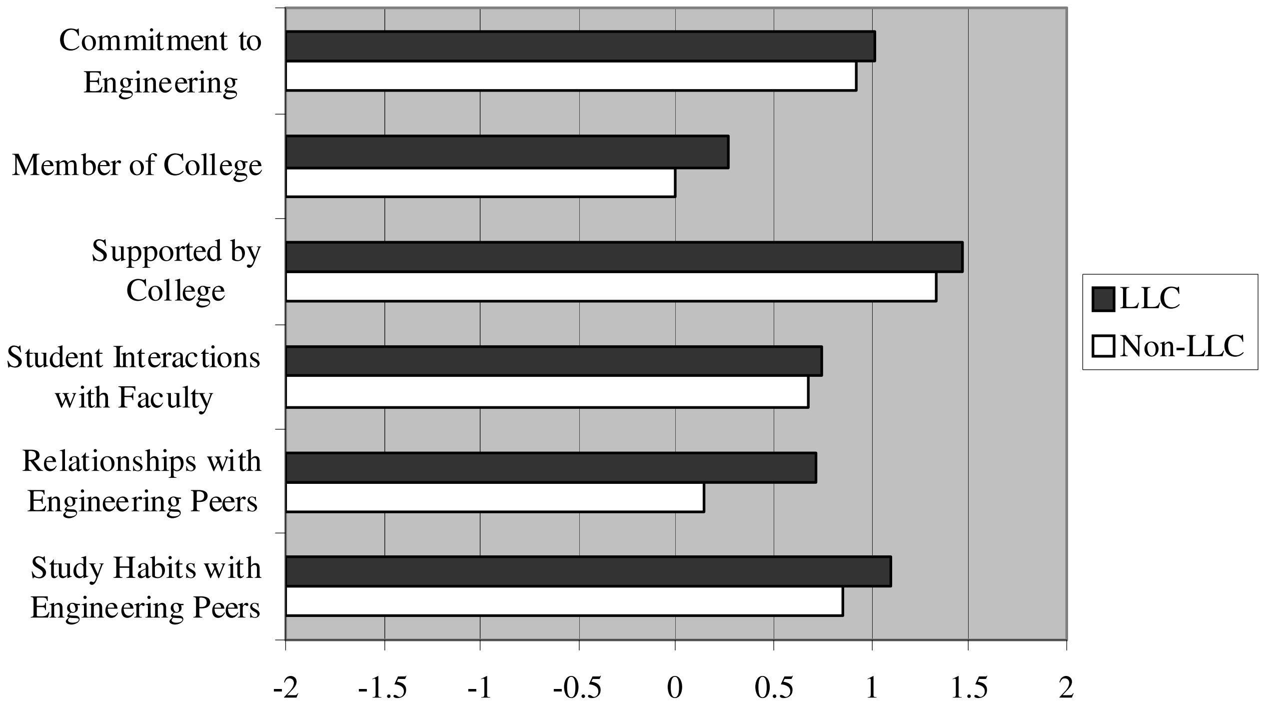


Figure 1: Mean Score Comparison for Sense of Belonging Components at Time 0

LLC participants and non-participants differed on some dimensions. First, non-participants scored lower, or with less agreement, than LLC participants on every theoretical construct: (a) Commitment to Engineering; (b) Connection to Engineering College; (c) Connection to Engineering Faculty; and (d) Connection to Engineering Peers; although not all results were statistically significant. The two groups did not differ significantly on Commitment to Engineering and Connection to Engineering Faculty components at Time 0. The two groups differed significantly on the Connection to the Engineering College and Connection to Engineering Peers constructs. Participants in the LLC reported significantly higher expectations on the following factor components: (a) Member of College; (b) Supported by College; (c) Study Habits with Engineering Peers; and (d) Relationships with Engineering Peers.

To determine the effect size, I calculated the eta squared value for each statistically significant test. According to Cohen (1988), eta squared values of 0.01 are considered a small effect; 0.06 are considered a moderate effect; and 0.14 are considered a large effect. Using eta values to calculate the magnitude of the effect size, the magnitude of these differences were small (eta squared = 0.01-0.02) with the exception of the Relationships with Engineering Peers components which had a moderate effects size difference (eta squared = 0.09). Complete results from the independent samples t-tests are reported in Table 12.

Table 12: Comparison of Expectations for College and Studying Engineering

| | N | Mean | Std. Dev. | S.E. Mean | F | Sig. | T | df | Sig. (2-tailed) | Std. Error Diff. |
|---|---|---|---|---|---|---|---|---|---|---|
| Commitment to Engineering | | | | | | | | | | |
| LLC | 122 | 1.02 | .861 | .078 | .003 | .955 | 1.05 | 369 | .294 | .094 |
| Non-LLC | 249 | .93 | .848 | .054 | | | | | | |
| Member of College | | | | | | | | | | |
| LLC | 123 | 0.27 | .890 | .080 | .206 | .650 | 2.73 | 372 | .007* | .100 |
| Non-LLC | 251 | 0.00 | .914 | .058 | | | | | | |
| Supported by College | | | | | | | | | | |
| LLC | 121 | 1.47 | .533 | .048 | .045 | .832 | 1.99 | 371 | .048* | .063 |
| Non-LLC | 252 | 1.34 | .580 | .037 | | | | | | |
| Student Interactions with Faculty | | | | | | | | | | |
| LLC | 122 | 0.74 | .836 | .076 | .214 | .644 | .569 | 373 | .570 | .090 |
| Non-LLC | 253 | 0.68 | .807 | .051 | | | | | | |
| Relationships with Engineering Peers | | | | | | | | | | |
| LLC | 123 | 0.72 | .801 | .072 | 11.7 | .001 | 5.95 | 296 | .000* | .096 |
| Non-LLC | 254 | 0.15 | 1.00 | .063 | | | | | | |
| Study Habits with Engineering Peers | | | | | | | | | | |
| LLC | 121 | 1.10 | .864 | .079 | 1.36 | .244 | 2.36 | 375 | .019* | .101 |
| Non-LLC | 256 | 0.86 | .934 | .058 | | | | | | |

*p < .05

The final comparison analyzed students' expectations for the amount of time necessary to spend on homework. Both LLC participants and non-LLC participants expected to spend approximately 13 hours per week on homework; the difference was not statistically significant, $t(371) = .381$, $p = .703$.

## Summary

LLC participants and non-participants were similar on most demographic characteristics including pre-college academic performance. The two groups differed in race/ethnicity and gender compositions. Women were overrepresented in the LLC. Similarly African-American and Asian students disproportionately participated in the LLC; international students were underrepresented in the LLC.

In terms of expectations for college, LLC participants agreed with statements indicating a commitment to engineering, and an expectation to be supported by the engineering college, connected to engineering faculty and connected to engineering peers. The only measure on which the LLC participants' responses were ambivalent (i.e., mean score near zero indicating neither agreement nor disagreement with related statements) was their expectation to be a member of the engineering college. In comparison to non-participants, LLC participants did not differ significantly on measures of their commitment to engineering, and expectations for their connection to faculty. However LLC participants agreed more strongly than non-participants with statements regarding their expectations to be connected with the college of engineering and to other engineering students.

## Impact on Disciplinary Retention

This section of the chapter focuses on answering the second research question:

*How do LLC participants and non-participants differ on indirect and direct measures of disciplinary persistence?*

In this study, there were two categories of measures related to disciplinary retention. The first set consisted of indirect measures of disciplinary retention. These measures emerged from the Sense of Belonging constructs in the Model of Engineering Student Retention. The second set consisted of direct measures of retention within the engineering major. This section is organized into two corresponding categories.

Indirect Measures of Disciplinary Retention

This section examines the first sub-question of disciplinary retention comparing LLC participants and non-participants on Sense of Belonging measures at Time 1 and Time 2:

*a. How do they differ on Sense of Belonging measures?*

Participants reported their current attitudes about engineering and reflected on their behaviors over the past semester or year. The Time 1 data represented the baseline for this longitudinal study of the impact of the LLC on first-year engineering undergraduates. In addition, these data demonstrated the initial impact of the LLC on students after a short exposure to the intervention (3-4 months).

Throughout the analysis and discussion, it is important to consider the short time frame of this study. The entire study occurred over a nine month period of time. Furthermore the period between Time 1 and Time 2 administrations was brief (approximately four months). Therefore even modest findings could be interpreted as indicative of differences between the groups and suggestive of potential greater differences that would arise over time.

There are three indicators of the differences between LLC participants and non-participants. First are the differences between the two groups on the Sense of Belonging measures at Time 1. This comparison indicates the extent to which the LLC participants differed from non-participants in the initial few months of the intervention. I investigated these comparisons by calculating mean scores, and comparing groups via independent samples t-tests. The second indicator is the difference between LLC participants and non-participants at Time 2. Although still early in participants' college career, differences between LLC participants and non-participants were more likely to appear in Time 2 data than Time 1 data. I replicated the statistical comparison used at Time 1 including mean comparisons and t-tests. In addition, I added regression analysis to model the relationship between participation in the LLC and the Sense of Belonging outcomes. The final indicator of the differences between the two groups on Sense of Belonging measures is the comparison of how the two subgroups changed over time. The analysis of change over time is also the best indicator of differences between the two groups because it best isolated the impact of LLC participation as the most likely variable responsible for demonstrated differences. Change over time comparisons keep other independent variables (e.g., gender, race, pre-college characteristics) constant and therefore controlled for in these analyses (Allison, 2005). I compared the two groups by examining the mean score differences on each scale and the magnitude of change via paired samples t-tests. In addition, I repeated the regression models of each Time 2 outcome measures, but added Time 1 values as an additional independent variable to further isolate the predictive influence of the LLC if it is a factor.

*Sense of Belonging Measures at Time 1*

At Time 1, LLC participants agreed with the statements on four of the six Sense of Belonging factor components (mean scores range from 0.86-1.07): (a) Commitment to Engineering; (b) Supported by College; (c) Relationships with Engineering Peers; and (d) Study Habits with Engineering Peers. For the other two component factors at Time 1 (Member of

College, and Student Interactions with Faculty), LLC students were ambivalent (mean scores of -0.02 and -0.26 respectively). I provide a graph of the mean scores for the Sense of Belonging measures below in Figure 4 comparing LLC students to non-participants.

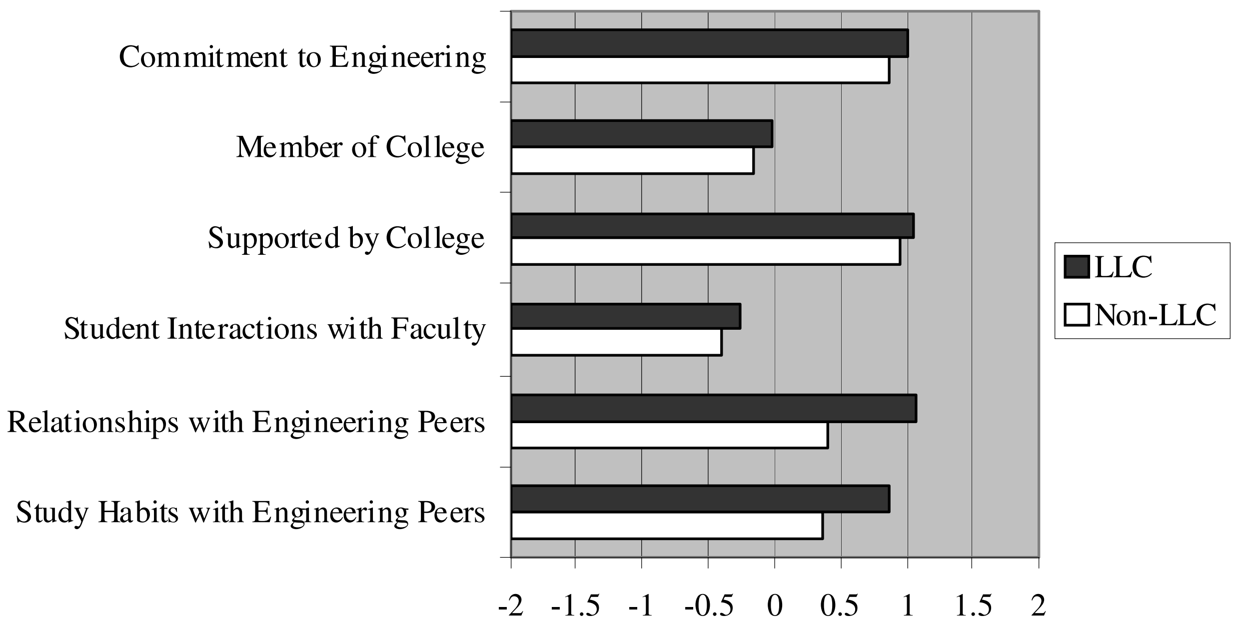


Figure 2: Mean Score Comparison for Sense of Belonging Components at Time 1

In addition, I compared LLC participants and non-participants on the mean scores of these scales. Non-participants scored lower on all factor components. The groups differed significantly ($p < .05$) on both factor components of Connection to Engineering Peers (Relationships with Engineering Peers; and Study Habits with Engineering Peers). The differences between LLC participants and non-participants was large for the Relationships with Engineering Peers component (eta squared = 0.13) and moderate for the Study Habits with Engineering Peers component (eta squared = 0.05). None of the other differences in mean scores was statistically significant. All of the t-test comparisons are included in Table 13.

Table 13: Comparison of Attitudes and Behaviors at Time 1

| | N | Mean | Std. Dev. | S.E. Mean | F | Sig. | T | df | Sig. (2-tailed) | Std. Error Diff. |
|---|---|---|---|---|---|---|---|---|---|---|
| Commitment to Engineering | | | | | | | | | | |
| LLC | 106 | 1.00 | .768 | .075 | 2.36 | .125 | 1.29 | 309 | .198 | .102 |
| Non-LLC | 205 | 0.87 | .893 | .062 | | | | | | |
| Member of College | | | | | | | | | | |
| LLC | 108 | -0.02 | 1.08 | .104 | 7.28 | .007 | 1.29 | 186 | .199 | .121 |
| Non-LLC | 209 | -0.17 | .902 | .062 | | | | | | |
| Supported by College | | | | | | | | | | |
| LLC | 107 | 1.05 | .694 | .067 | 0.43 | .512 | 1.33 | 309 | .185 | .081 |
| Non-LLC | 204 | 0.94 | .666 | .047 | | | | | | |
| Student Interactions with Faculty | | | | | | | | | | |
| LLC | 108 | -0.26 | .855 | .082 | 0.15 | .697 | 1.47 | 317 | .144 | .101 |
| Non-LLC | 211 | -0.41 | .856 | .059 | | | | | | |
| Relationships with Engineering Peers | | | | | | | | | | |
| LLC | 107 | 1.07 | .743 | .072 | 11.06 | .001 | 6.81 | 261 | .000* | .097 |
| Non-LLC | 210 | 0.41 | .941 | .065 | | | | | | |
| Study Habits with Engineering Peers | | | | | | | | | | |
| LLC | 105 | 0.86 | .989 | .097 | 2.15 | .144 | 3.90 | 310 | .000* | .128 |
| Non-LLC | 207 | 0.36 | 1.10 | .077 | | | | | | |

*p < .05

*Summary*

At Time 1, differences emerged between the two groups. LLC participants reported greater agreement on factor components associated with each theoretical construct. The most noteworthy difference was the stronger reported connection to other engineers by LLC participants in comparison to non-participants. The independent samples t-tests indicated a difference between LLC participants and non-participants on the Connection to Engineering Peers construct.

*Sense of Belonging Measures at Time 2*

In this section, I report the results from the Sense of Belonging data at the end of the academic year (Time 2). At Time 2, LLC participants continued to agree with the statements of most component factors (mean scores ranging from 0.75-1.11): (a) Commitment to Engineering; (b) Supported by College; (c) Relationships with Engineering Peers; and (d) Study Habits with Engineering Peers. LLC participants neither agreed nor disagreed with the Member of College component factor (mean = -0.03). At Time 2, LLC participants disagreed with the Student Interactions with Faculty component factor (mean = -0.41), indicating that participants neither interacted with faculty out of class or about non-class issues, nor valued developing a relationship with faculty members. Figure 5 provides a graphical summary of these results in comparing LLC participants to non-participants.

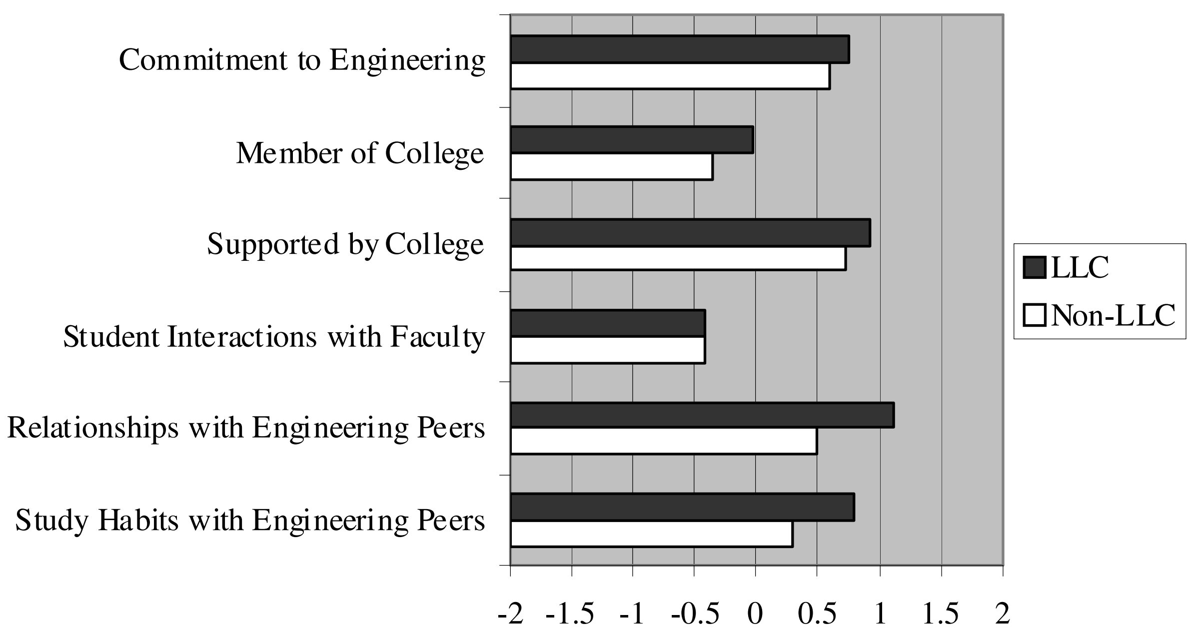


Figure 3: Mean Score Comparisons for Sense of Belonging Components at Time 2

I also statistically compared the responses from the LLC participants with the non-participants at Time 2. Once again, LLC participants reported higher scores (greater agreement) on every factor component. The two groups differed significantly ($p < .05$) on both of the component factors for the Connection to Engineering Peers construct (Relationships with Engineering Peers; and Study Habits with Engineering Peers). The differences between LLC participants and non-participants were large for the Relationships with Engineering Peers component (eta squared = 0.11) and moderate for the Study Habits with Engineering Peers component (eta squared = 0.05). LLC participants and non-participants were also significantly different on one of the two component factors of Connection to Engineering College construct (Member of College) at the $p < .05$ level. The t-test result for the other Connection to Engineering College scale, Support by College, was significant at the $p < 0.1$ level ($p = 0.57$). Both of these Connection to Engineering College constructs yielded low eta squared values (eta squared = .02 and .01 respectively) indicating a small effect size difference. All comparisons are reported below in Table 14.These statistically significant comparisons to non-participants suggest that participation in the LLC positively affected students' connection to the engineering college as well as students' connection to other engineering undergraduates.

Table 14: Comparison of Attitudes and Behaviors at Time 2

| | N | Mean | Std. Dev. | S.E. Mean | F | Sig. | T | df | Sig. (2-tailed) | Std. Error Diff. |
|---|---|---|---|---|---|---|---|---|---|---|
| Commitment to Engineering | | | | | | | | | | |
| LLC | 103 | 0.75 | 1.01 | .099 | .323 | .570 | 1.18 | 291 | .240 | .125 |
| Non-LLC | 190 | 0.61 | 1.03 | .074 | | | | | | |
| Member of College | | | | | | | | | | |
| LLC | 105 | -0.03 | 1.04 | .101 | .002 | .963 | 2.62 | 297 | .009* | .123 |
| Non-LLC | 194 | -0.35 | 1.00 | .072 | | | | | | |
| Supported by College | | | | | | | | | | |
| LLC | 105 | 0.92 | .871 | .085 | .867 | .353 | 1.91 | 295 | .057** | .190 |
| Non-LLC | 192 | 0.73 | .789 | .057 | | | | | | |
| Student Interactions with Faculty | | | | | | | | | | |
| LLC | 102 | -0.41 | .975 | .097 | .006 | .937 | .058 | 295 | .954 | .119 |
| Non-LLC | 195 | -0.42 | .967 | .069 | | | | | | |
| Relationships with Engineering Peers | | | | | | | | | | |
| LLC | 103 | 1.11 | .762 | .075 | 3.25 | .072 | 6.00 | 296 | .000* | .104 |
| Non-LLC | 195 | 0.49 | .902 | .065 | | | | | | |
| Study Habits with Engineering Peers | | | | | | | | | | |
| LLC | 104 | 0.79 | .943 | .092 | 2.72 | .100 | 3.98 | 298 | .000* | .125 |
| Non-LLC | 196 | 0.30 | 1.08 | .077 | | | | | | |

*$p < 0.05$; **$p < 0.1$

To further explore the relationship between participating in the LLC and the Sense of Belonging measures at Time 2, I modeled the relationship via multiple regression. To control for the potential effects of other factors, I included a measure of pre-college academic achievement (ACT Composite), gender, and ethnicity in the model as independent variables, as well as participation in the LLC. I regressed each Sense of Belonging component factor as the dependent variable on the set of independent variables. For each component factor, I ensured that there were no violations of regression modeling assumptions in terms of multicollinearity, normality, linearity, homoscedasticity, and independence of residuals.

On three component factors, participation in the LLC had a significant predictive effect: (a) Member of College; (b) Relationships with Engineering Peers; and (c) Study Habits with Engineering Peers. The magnitude of the predictive power was modest in each case, but significant. For the Member of College component factor, the model explained 5% of the variance, $F(4, 274) = 3.768$, $p = .006$ (see Table 15). The influence of participation in the LLC was statistically significant ($\beta = .147$, $p = .014$). Although only 5% of the variance is explained by the variables, 2% is explained by LLC participation.

Table 15: Multiple Regression Analysis Modeling Member of College

| | Coefficients | | |
|---|---|---|---|
| Variable | B | S.E. | β |
| LLC Participation | .331 | .133 | .147* |
| ACT Composite | .052 | .018 | .170* |
| Gender | -.052 | .176 | -.018 |
| Ethnicity | .072 | .060 | .071 |
| Constant | -1.784 | .548 | |
| $R^2$ | .051 | | |
| F | 3.768* | | |

*p < .05

Therefore participating in the LLC acted as a significant positive predictor of the Member of College component.

For the Relationships with Engineering Peers component factor, the model explained 11% of the variance, $F (4, 271) = 8.440$, $p < .001$ (see Table 16). The influence of participation in the LLC was statistically significant ($\beta = .325$, $p < .001$) accounting for 10% of the total variance explained by the model.

Table 16: Multiple Regression Analysis Modeling Relationships with Engineering Peers

| | Coefficients | | |
|---|---|---|---|
| Variable | B | S.E. | B |
| LLC Participation | .646 | .115 | .325* |
| ACT Composite | .010 | .016 | .035 |
| Gender | .012 | .152 | .005 |
| Ethnicity | .086 | .052 | .095 |
| Constant | .113 | .471 | |
| $R^2$ | .111 | | |
| F | 8.440* | | |

*p < .05

The regression model demonstrated that participation in the LLC was a positive predictor of student friendships with other engineering undergraduates.

Finally for the Study Habits with Engineering Peers component factor, the model explained 7% of the variance, $F (4, 273) = 5.049$, $p = .001$ (see Table 17) with the influence of participation in the LLC statistically significant ($\beta = .217$, $p < .001$). LLC participation accounted for 5% of the total variance explained by the variables in the model.

Table 17: Multiple Regression Analysis Modeling Study Habits with Engineering Peers

| Variable | Coefficients B | S.E. | β |
|---|---|---|---|
| LLC Participation | .502 | .136 | .217* |
| ACT Composite | -.034 | .019 | -.107 |
| Gender | .209 | .180 | .068 |
| Ethnicity | -.042 | .061 | -.040 |
| Constant | 1.064 | .559 | |
| $R^2$ | .069 | | |
| F | 5.049* | | |

*p < .05

Although the variance explained by these models modest, the results are noteworthy because of the limited duration of time in this study. Furthermore, in each case, LLC participation accounted for the majority of the explained variance when the models were predictive. In terms of the significant predictive power, participating in the LLC related to three factor components: (a) Member of College; (b) Relationships with Engineering Peers; and (c) Study Habits with Engineering Peers.

*Summary*

Time 2 data suggest that some differences between LLC participants and non-participants were evident. The results from the independent samples t-tests and the regression models suggest LLC participants tended to have a stronger connection to the engineering college and other engineering undergraduates than non-participants.

*Change in Attitudes and Behaviors from Time 1 to Time 2*

The longitudinal design of this study allows for a time-dependent examination of the LLC's impact. By focusing on change over time, this analysis limited the effect of conflating independent variables. The comparisons focused on intra-individual differences for each group thereby isolating the effect of the intervention (i.e., participation in the LLC) by using the individual participant as a control. In this section, I report the change over time for both groups based on the mean score difference on each Sense of Belonging component. I also examined the change over time via paired samples t-tests which indicated whether intra-group change over time is significant. Then I compared the magnitude of the effect sizes (eta squared values) between groups to infer the differential impact of participating in the LLC. Finally I again modeled the relationship between participating in the LLC and the Sense of Belonging measures via standard multiple regression analysis but included Time 1 scores as an additional independent variable to focus on the change over time.

In this study, LLC participants and non-participants reported decreases on all Sense of Belonging scales except for the Relationship with Engineering Peers factor components between Time 1 and Time 2. In other words, both groups decreased their level of agreement with statements corresponding to the following factor components: (a) Commitment to Engineering; (b) Member of College; (c) Supported by College; (d) Student Interactions with Faculty; (e) Study Habits with Engineering Peers.

LLC participants reported significant decreases over time ($p < 0.05$) on two Sense of Belonging components:

(a) Commitment to Engineering, $t(91) = 2.50$, $p = .014$;

(b) Supported by College, $t(94) = 2.32$, $p = .023$

Non-participants reported statistically significant decreases on the same two factor components as well as an additional one (Member of College):

(a) Commitment to Engineering, $t(162) = 5.22$, $p < .001$;

(b) Supported by College, $t(165) = 3.51$, $p = .001$;

(c) Member of College, $t(171) = 2.23$, $p = .027$.

For paired samples t-tests, eta squared values of 0.01 are considered a small effect; 0.06 are considered a moderate effect; and 0.14 are considered a large effect (Cohen, 1988). According to these values, non-participants experienced larger decreases on all three of the factor components: (a) Commitment to Engineering, (b) Member of College, and (c) Supported by College (see Table 18). For the Support by College component factor, the two groups experienced a similar decrease in agreement over time. Table 18 reports both the mean score differences as well as effect sizes for the significant changes within both groups.

Table 18: Change in Means (T1 v. T2) and Paired Samples t-Tests on Sense of Belonging Component Factors

| Factor Component | | T1 | T2 | ΔT1-T2 | Eta (if sig.) | Effect Size |
|---|---|---|---|---|---|---|
| Commitment to Engineering | LLC | 1.00 (.77) N=106 | .75 (1.01) N=103 | -6.3%* | .07 | Moderate |
| | Non-LLC | .87 (.89) N=205 | .61 (1.03) N=190 | -6.5%* | .14 | Large |
| Member of College | LLC | -.02 (1.08) N=108 | -.03 (1.04) N=105 | -0.3% | | |
| | Non-LLC | -.17 (.90) N=209 | -.35 (1.00) N=194 | -4.5%* | .03 | Small |
| Supported by College | LLC | 1.05 (.69) N=107 | .92 (.87) N=105 | -3.3%* | .05 | Moderate |
| | Non-LLC | .94 (.67) N=204 | .73 (.79) N=192 | -5.3%* | .07 | Moderate |
| Student Interactions with Faculty | LLC | -.26 (.86) N=108 | -.41 (.97) N=102 | -3.8% | | |
| | Non-LLC | -.41 (.86) N=211 | -.42 (.96) N=195 | -0.3% | | |

Table 18 cont'd.

| | | | | |
|---|---|---|---|---|
| Relationship with Engineering Peers | LLC | 1.07 (.74) N=107 | 1.11 (.76) N=103 | 1.0% |
| | Non-LLC | .41 (.94) N=210 | .49 (.90) N=195 | 2.0% |
| Study Habits with Engineering Peers | LLC | .86 (.99) N=105 | .79 (.94) N=104 | -1.8% |
| | Non-LLC | .36 (1.10) N=207 | .30 (1.08) N=196 | -1.5% |

* p < .05

To further explore the change over time for LLC participants and non-participants, I again explored the relationship between participating in the LLC and the Sense of Belonging measures via standard multiple regression analysis at Time 2. I included the same controls as independent variables: (a) ACT Composite; (b) gender; and (c) ethnicity; however to focus the analysis on the change over time, I included the corresponding Time 1 Sense of Belonging score for each dependent variable modeled. Once again, for each component factor, I ensured that there were no violations of regression modeling assumptions in terms of multicollinearity, normality, linearity, homoscedasticity, and independence of residuals. This analysis was the most rigorous because I included the Time 1 measures from four months prior to the Time 2 administration as a control. It was expected that the majority of the predictive power would be attributed to the Time 1 variable. Because this was an exploratory study during which there was little time for the LLC to impact participants, I used a less stringent standard for significance, $p < .1$, rather than the standard $p < .05$ used elsewhere in this study.

On three component factors, participation in the LLC had a significant predictive effect: (a) Member of College; (b) Relationships with Engineering Peers; and (c) Study Habits with

Engineering Peers. The magnitude of the predictive power for LLC participation was modest in each case, but significant. For the Member of College component factor, the model explained 32% of the variance, $F(5, 265) = 24.909$, $p < .001$ (see Table 19). The influence of participation in the LLC was statistically significant ($\beta = .106$, $p = .039$); LLC participation explained a meager 1% of the model's variance.

Table 19: Multiple Regression Analysis Modeling Member of College Change Over Time

| | Coefficients | | |
|---|---|---|---|
| Variable | B | S.E. | β |
| LLC Participation | .239 | .115 | .106* |
| ACT Composite | .042 | .016 | .138* |
| Gender | -.218 | .153 | -.073 |
| Ethnicity | -.002 | .052 | -.002 |
| Time 1 Member of College | .562 | .055 | .528* |
| Constant | -1.126 | .476 | |
| $R^2$ | .051 | | |
| F | 3.768* | | |

*p < .05

Therefore participating in the LLC is a significant positive predictor of the Member of College component even when controlling for the scores at Time 1.

For the Relationships with Engineering Peers component factor, the model explained 42% of the variance, $F(5, 264) = 38.926$, $p < .001$ (see Table 20). The influence of participation in the LLC was also statistically significant ($\beta = .117$, $p < .021$) explaining 1% of the variance explained by the variables in the model.

Table 20: Multiple Regression Analysis Modeling Relationships with Engineering Peers Over Time

| | Coefficients | | |
|---|---|---|---|
| Variable | B | S.E. | B |
| LLC Participation | .232 | .100 | .117* |
| ACT Composite | .013 | .013 | .047 |
| Gender | .035 | .124 | .013 |
| Ethnicity | .042 | .042 | .046 |
| Time 1 Relationship with Eng. Peers | .584 | .049 | .598* |
| Constant | -.186 | .385 | |
| $R^2$ | .424 | | |
| F | 38.926* | | |

*p < .05

The regression model demonstrated that participation in the LLC positively predicts the extent of student friendships with other engineering undergraduates.

Finally for the Study Habits with Engineering Peers component factor, the model explained 37% of the variance, $F (5, 265) = 30.703$, $p < .001$ (see Table 21) with influence of participation in the LLC statistically significant ($\beta = .094$, $p = .065$) and accounting for 1% of the model's variance.

Table 21: Multiple Regression Analysis Modeling Study Habits with Eng. Peers Over Time

| | Coefficients | | |
|---|---|---|---|
| Variable | B | S.E. | β |
| LLC Participation | .217 | .117 | .094** |
| ACT Composite | .006 | .016 | .020 |
| Gender | .150 | .151 | .049 |
| Ethnicity | -.077 | .051 | -.073 |
| Time 1 Study Habits with Eng. Peers | .563 | .050 | .576* |
| Constant | -.124 | .480 | |
| $R^2$ | .367 | | |
| F | 30.703* | | |

*p < .05; **p < .1

Participating in the LLC had predictive power in the models for three factor components: (a) Member of College; (b) Relationships with Engineering Peers; and (c) Study Habits with Engineering Peers. Although the variance explained by participation in the LLC is modest, the results are noteworthy given the stringent nature of the test, the limited time for change to occur and the exploratory nature of the current study.

*Summary*

The results indicated that both LLC participants and non-participants experienced decreases on Sense of Belonging measures over time. On two factor components (Commitment to Engineering, and Supported by College), the decreases were statistically significant over time for both groups. However, non-participants experienced a larger decrease than LLC participants on both measures as well as on the Member of College component.

The results suggested that the LLC had a positive effect on the Sense of Belonging measures in comparison to the reported scores of non-participants. Although LLC participants reported decreases on these measures, the magnitude of change for LLC participants was less than non-participants. Furthermore, the regression models confirm that living in the LLC has a significant predictive power in models of Member of College, and Connection to Engineering Peers factor components even when controlling for Time 1 scores.

Thus the LLC may serve as a protective factor for its participants by limiting the overall erosion of agreement on measures of commitment to engineering and connection to the engineering college. Similarly the LLC has a positive effect on participants in terms of the Connection to Engineering Peers construct. Because these constructs are indirect measures of disciplinary retention, these findings suggested a benefit to participation in the LLC for engineering majors

## Direct Measures of Persistence

In the following section, I present data to address the second sub-question regarding disciplinary retention:

*Does participating in the LLC increase engineering students' disciplinary retention?* Ultimately the focus of this study was to examine the differences in disciplinary retention within engineering between LLC participants and non-participants. This section reports on the comparison of these two groups on direct measures of persistence.

In this study, there were two direct measures of persistence. The first measure asked participants to rate their likelihood to persist in an engineering major at Time 2. LLC participants (M = 1.37, S.D = 1.17) and nonparticipants (M = 1.36, S.D. = 1.16) responded that they were likely to continue majoring in engineering. There was no significant difference between the two groups, t (299) = -.130, $p = 0.90$.

The second measure of persistence was the prevalence of disciplinary leavers in each group of participants: LLC participants and non-participants. Overall 21% of engineering students in the first-year introductory design sequence were not registered in an engineering college major at the start of their second year. A chi-square test for independence indicated a significant association between not participating in the LLC and departure from engineering $\chi^2$ (1, n = 499) = 5.115 p = .024, phi. = .101. In the sample, LLC students were retained within engineering disproportionately in comparison to non-participants. At the start of the students' sophomore year, 85.1% of LLC students were enrolled in an engineering major compared to 76.1% of non-participants.

Finally, I examined one indirect measure related to persistence: grade point average (GPA). Although the academic profile of students departing engineering does not differ significantly from students who persist (Seymour & Hewitt, 1997), most U.S. institutions, including the institution in this study, require students to maintain an adequate GPA to remain in the major (often between 2.7 and 3.0 on a 4-point scale). Therefore GPA serves as a gateway to disciplinary persistence. At the beginning of the participants' sophomore year, LLC participants earned a higher grade point average (M = 3.06, SD = 0.62) than non-participants (M = 2.99, SD = 0.72), but the difference was not statistically significant, $t(319) = 1.20$, $p = .259$.

In addition to these direct comparisons, I modeled the relationship between the Sense of Belonging component factors, participation in LLC and some pre-college characteristics (ACT Composite, gender, and ethnicity) with the persistence measures. For the rating of students' likelihood to persist, the multiple regression model explained 46% of the variance $F(10, 265) = 23.048$, $p < .001$, after ensuring the appropriate assumptions for regression were not violated (see Table 22). The only significantly predictive factor components were: (a) Commitment to Engineering ($\beta = .617$, $p < .001$); (b) Relationships with Engineering Peers ($\beta = .122$, $p = .024$); and (c) Study Habits with Engineering Peers ($\beta = -.102$, $p = .015$).

Table 22: Multiple Regression Analysis Modeling Likelihood to Persist with All Sense of Belonging Measures at Time 2

| | Coefficients | | |
|---|---|---|---|
| Variable | B | S.E. | β |
| LLC Participation | -.115 | .123 | -.045 |
| ACT Composite | .007 | .016 | .020 |
| Gender | .135 | .153 | .040 |
| Ethnicity | .084 | .053 | .073 |
| Commitment to Engineering | .703 | .060 | .617* |
| Member of College | .057 | .065 | .050 |
| Supported by College | .055 | .078 | .039 |
| Student Interactions with Faculty | -.021 | .060 | -.017 |
| Relationships with Engineering Peers | .156 | .068 | .122* |
| Study Habits with Engineering Peers | -.139 | .057 | -.126* |

Table 22 cont'd.

| | | |
|---|---|---|
| Constant | .376 | .493 |
| $R^2$ | .465 | |
| F | 23.048 | |

*p < .05

Participating in the LLC was not a statistically significant predictor of students' likelihood to persist. However, based on previous analyses, participation in the LLC was related to the Relationships with Engineering Peers and Study Habits with Engineering Peers components that had a significant predictive effect on this persistence measure.

I also modeled the choice of major at the start of the students' sophomore year via a logistics regression analysis using the same independent variables. The full model was statistically significant $\chi^2$ (10, n = 272) = 56.177, p < .001 (see Table 23) indicating that the model was able to distinguish between respondents who remained in the engineering college and those who did not. The model explained between 19-36% of the variance in choice of major at the start of sophomore year, correctly classifying 88.6% of cases. Only two of the variables made a unique statistically significant contribution: (a) pre-college academic achievement; and (b) Commitment to Engineering. As a result, there does not appear to be a direct relationship between participation in the LLC and choice of major at the beginning of the sophomore year. However, because the inclusion of the Commitment to Engineering component was significantly predictive, the model links LLC participation indirectly to disciplinary retention.

Table 23: Logistic Regression Predicting Likelihood of Majoring in Engineering at Start of Sophomore Year

| Variable | B | S.E. | Wald | df | p | Odds Ratio |
|---|---|---|---|---|---|---|
| LLC Participation | .820 | .541 | 2.30 | 1 | .129 | 2.27 |
| ACT Composite | .174 | .075 | 5.36 | 1 | .021* | 1.19 |
| Gender | -.289 | .627 | .212 | 1 | .645 | .749 |
| Ethnicity (Majority/Minority) | .578 | .747 | .597 | 1 | .440 | 1.78 |
| Commitment to Engineering | 1.12 | .263 | 17.96 | 1 | .000* | 3.05 |
| Member of College | -.008 | .303 | .001 | 1 | .979 | .992 |
| Supported by College | .320 | .299 | 1.15 | 1 | .285 | 1.38 |
| Student Interactions with Faculty | -.292 | .266 | 1.20 | 1 | .273 | .747 |
| Relationships with Engineering Peers | .363 | .308 | 1.39 | 1 | .239 | 1.44 |
| Study Habits with Engineering Peers | -.323 | .264 | 1.50 | 1 | .220 | .724 |
| Constant | -3.54 | 2.04 | 3.01 | 1 | .083 | .029 |

*p < .05

## Engineering Learning Outcomes

This section reports data collected to answer the third research question comparing LLC participants and non-participants on the engineering learning outcomes:

*Does participating in a LLC increase students' achievement of engineering learning outcomes?*

To address this question, I report survey data from four composite measures that address some of ABET's Criterion 3: (a) Engineering Contexts; (b) Communication; (c) Teamwork; and (d) Leadership. Participants rated their ability to perform tasks related to these learning outcomes on a five-point Likert scale with the following options: (a) 0 – "weak/none"; (b) 1 – "poor"; (c) 2 – "good"; (d) 3 – "very good"; and (e) 4 – "excellent". I analyzed these data in the same way as the Sense of Belonging measures from Time 1 and Time 2: (a) comparing LLC participants and non-participants at Time 1; (b) comparing LLC participants and non-participants at Time 2; and (c) comparing LLC participants and non-participants in terms of their change over time. The learning outcome measures were not included at Time 0 because they asked participants to reflect on how much they learned as a result of their study of engineering, none of which occurred by Time 0.

Because of anomalies in the data collection, I revised the scale construction tested previously (Center for the Study of Higher Education, 2006). On the original *E2020* instrument, the leadership construct consisted of four items. During the data collection for this study, a significant proportion of the sample did not respond to the final item of the leadership construct. At Time 1, 309 participants responded to the first three of the leadership items; only 233 participants responded to all four of the leadership items. Similarly, at Time 2, 283 participants responded to the first three leadership items; only 210 responded to all four. Given high inter-item correlations among the four items (ranging from .621-.771), I dropped the fourth item so I could include more participants in the sample (i.e., the participants who omitted only the fourth leadership item). By dropping the one item, the Cronbach's alpha decreased only slightly from .903 to .897.

### Learning Outcome Measures at Time 1

At Time 1, LLC participants rated themselves "good" to "very good" on all of the learning outcome measures. The highest rating (M = 2.72; S.D. = 0.87) was on Teamwork measure and the lowest rating (M = 1.97; S.D. = 0.83) was for the Engineering Contexts measure. Figure 6 charts the comparison of responses between LLC participants and non-participants.

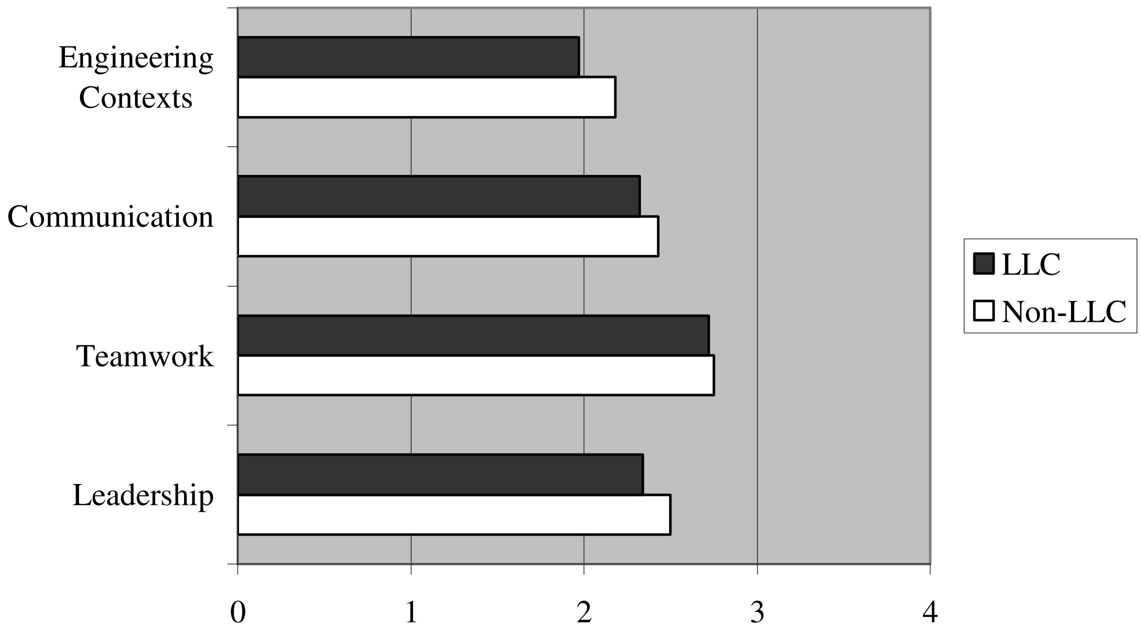


Figure 4: Mean Score Comparison for Engineering Learning Outcomes at Time 1

In comparison to LLC participants, non-participants rated themselves higher on all learning outcomes at Time 1. There were significant differences ($p < .05$) between the two groups on one of the learning outcome scales: (a) Engineering Contexts: $t(242) = 1.973$, $p = .050$. The effect size difference between the two groups was small (eta squared = 0.01). All of the mean scores and t-test comparisons are included in Table 24.

Table 24: Comparison of Engineering Learning Outcomes at Time 1

| | N | Mean | Std. Dev. | S.E. Mean | F | Sig. | T | df | Sig. (2-tailed) | Std. Error Diff. |
|---|---|---|---|---|---|---|---|---|---|---|
| Engineering Contexts | | | | | | | | | | |
| LLC | 107 | 1.97 | .832 | .080 | 3.91 | .049 | 1.97 | 242 | .050* | .104 |
| Non-LLC | 207 | 2.18 | .957 | .067 | | | | | | |
| Communication | | | | | | | | | | |
| LLC | 107 | 2.32 | .816 | .079 | .112 | .738 | 1.13 | 313 | .260 | .099 |
| Non-LLC | 208 | 2.43 | .844 | .059 | | | | | | |

Table 24 cont'd.

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Teamwork | | | | | | | | | | |
| LLC | 107 | 2.72 | .865 | .084 | .157 | .692 | .293 | 312 | .770 | .104 |
| Non-LLC | 207 | 2.75 | .872 | .061 | | | | | | |
| Leadership | | | | | | | | | | |
| LLC | 107 | 2.34 | .931 | .090 | .093 | .761 | 1.47 | 314 | .144 | .108 |
| Non-LLC | 209 | 2.50 | .901 | .062 | | | | | | |

*p < .05

*Summary*

The findings relating participation in the LLC on engineering learning outcomes at Time 1 yielded only one statistically significant result. Non-participants reported higher mean scores on every learning outcome construct at Time 1.

Learning Outcome Measures at Time 2

This section reports the engineering learning outcomes data collected at the end of the academic year. At Time 2, LLC participants again rate themselves between "good" and "very good" on all measures with means ranging from 2.20 to 2. 79 (see Figure 7).

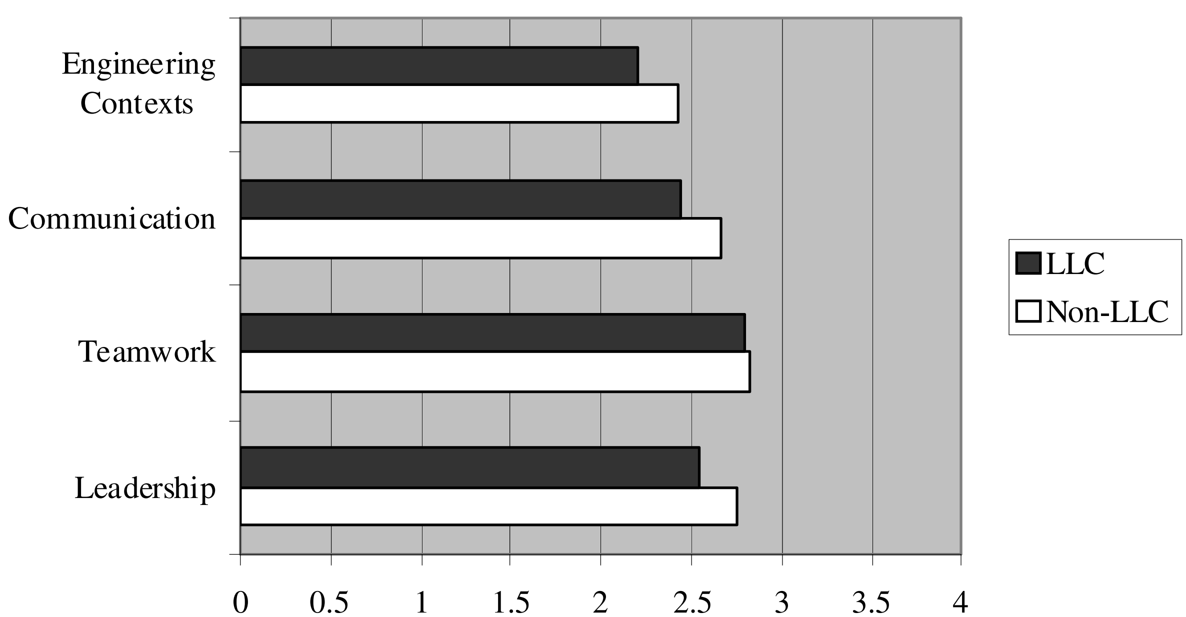


Figure 5: Mean Score Comparisons of Engineering Learning Outcomes at Time 2

As was the case at Time 1, non-participants rated themselves higher than LLC participants on all learning outcomes at Time 2. Among these comparisons, LLC participants and non-participants were statistically significant ($p < .05$) for three out of the four measures:

(a) Engineering Contexts: t (292) = 2.00, p = 0.047

(b) Communication: t (289) = 2.45, p = 0.015

(c) Leadership t (288) = 2.01, p  = 0.046

In each case, the effect size of the differences between the two groups was small (eta squared = 0.01-0.02). Table 25 provides a complete list of the mean scores and t-test comparisons.

Table 25: Comparison of Learning Outcomes at Time 2

| | N | Mean | Std. Dev. | S.E. Mean | F | Sig. | T | df | Sig. (2-tailed) | Std. Error Diff. |
|---|---|---|---|---|---|---|---|---|---|---|
| Engineering Contexts | | | | | | | | | | |
| LLC | 99 | 2.20 | .889 | .089 | .318 | .573 | 2.00 | 292 | .047* | .111 |
| Non-LLC | 195 | 2.42 | .900 | .064 | | | | | | |
| Communication | | | | | | | | | | |
| LLC | 98 | 2.44 | .719 | .073 | .953 | .330 | 2.45 | 289 | .015* | .094 |
| Non-LLC | 193 | 2.67 | .780 | .056 | | | | | | |
| Teamwork | | | | | | | | | | |
| LLC | 98 | 2.79 | .737 | .074 | 1.13 | .289 | .374 | 289 | .709 | .099 |
| Non-LLC | 193 | 2.83 | .825 | .059 | | | | | | |
| Leadership | | | | | | | | | | |
| LLC | 97 | 2.54 | .834 | .085 | .032 | .858 | 2.01 | 288 | .046* | .106 |
| Non-LLC | 193 | 2.75 | .860 | .062 | | | | | | |

*p < .05

Finally I explored the relationship between participating in the LLC and the engineering learning outcomes using standard multiple regression analysis. I included pre-college characteristics (ACT Composite, gender, and ethnicity) as independent variables to control for their effect on the learning outcomes. For each regression output, I ensured that there were no violations of regression modeling assumptions in terms of multicollinearity, normality, linearity, homoscedasticity, and independence of residuals. Participation in the LLC did not have a significant predictive effect on any of the composite learning outcomes measures. Given the short timeframe of this study, finding a significant predictive factor in the model was unlikely.

*Summary*

At Time 2, the differences between LLC participants and non-participants persisted. Non-participants continued to rate themselves higher than LLC participants on all engineering learning outcomes. Furthermore there were more statistically significant differences at Time 2 (three) than at Time 1 (one). These results suggested that participation in the LLC related to lower self-ratings on engineering learning outcomes.

## Change in Learning Outcomes from Time 1 to Time 2

Similar to the analysis of the Sense of Belonging component factors, I used the longitudinal data collected to examine the impact of the LLC by tracking changes within each group (LLC participants v. non-participants) over time. Between Time 1 and Time 2, LLC participants reported gains on all learning outcome measures (see Table 26). For LLC participants, the increase between Time 1 and Time 2 was statistically significant ($p < 0.05$) on three of the four measures:

(a) Engineering Contexts, $t(91) = 2.37$, $p = .020$; Mean increase = .219;

(b) Communication, $t(90) = 2.02$, $p = .047$, Mean increase = .159;

(c) Leadership, $t(89) = 2.49$, $p = .015$; Mean increase = .27.

Similar to LLC participants, non-participants experienced increases on all learning outcomes between Time 1 and Time 2. The results of the paired-samples t-tests indicated that the changes on the same three measures were statistically significant at the $p < 0.05$ level:

(a) Engineering Contexts, $t(172) = 3.05$, $p = .003$; Mean increase = .20;

(b) Communication, t (172) = 2.72, p = .007; Mean increase = .14;

(c) Leadership, t (171) = 2.47, p = .014; Mean increase = .17.

Table 26 summarizes the changes over time including effect size for statistically significant comparisons.

Table 26: Change in Means (T1 v. T2) on Engineer Learning Outcomes

| | | T1 | T2 | ΔT1-T2 | Eta (If sig.) | Effect Size |
|---|---|---|---|---|---|---|
| Engineering Contexts | LLC | 1.97<br>(0.83)<br>N=107 | 2.20<br>(0.89)<br>N=99 | 11.7%* | .06 | Moderate |
| | Non-LLC | 2.18<br>(0.96)<br>N=207 | 2.42<br>(0.90)<br>N=195 | 11.0%* | .05 | Moderate |
| Communication | LLC | 2.32<br>(0.82)<br>N=107 | 2.44<br>(0.72)<br>N=98 | 5.2%* | .04 | Small/<br>Moderate |
| | Non-LLC | 2.43<br>(0.84)<br>N=208 | 2.67<br>(0.78)<br>N=193 | 9.9%* | .04 | Small/<br>Moderate |
| Teamwork | LLC | 2.72<br>(0.87)<br>N=107 | 2.79<br>(0.74)<br>N=98 | 2.6% | | |
| | Non-LLC | 2.75<br>(0.87)<br>N=207 | 2.83<br>(0.83)<br>N=193 | 2.9% | | |
| Leadership | LLC | 2.34<br>(0.93)<br>N=107 | 2.54<br>(0.83)<br>N=97 | 8.5% | .06 | Moderate |
| | Non-LLC | 2.50<br>(0.90)<br>N=209 | 2.75<br>(0.86)<br>N=193 | 10% | .03 | Small |

*p < .05 for paired samples t-tests

On two of the learning outcomes, LLC participants and non-participants experienced similar changes between Time 1 and Time 2: (a) Engineering Contexts; and (b) Communication. For the Leadership construct, LLC participants reported larger gains than non-participants between Time 1 and Time 2. Based on the magnitude and direction of change over time, this result indicated that the LLC may have a differential positive impact on the Leadership learning outcome.

The final analysis of change over time involved modeling again the relationship between participating in the LLC and the learning outcomes via standard multiple regression analysis at Time 2. I included the same controls as independent variables: (a) ACT Composite; (b) gender; and (c) ethnicity; however to focus the analysis on the change over time, I included the corresponding Time 1 Learning Outcome score for each dependent variable modeled. Once again, for each learning outcome, I ensured that there were no violations of regression modeling assumptions in terms of multicollinearity, normality, linearity, homoscedasticity, and independence of residuals. This analysis was the most rigorous in terms of separating out the differences by participation in the LLC. Despite using a less stringent standard for significance, $p < .1$, participation in the LLC was not a significant predictor for any of the learning outcomes.

*Summary*

In general, participation in the LLC was associated with lower scores on all engineering learning outcomes. However these differences may be a result of how the two groups rate themselves. Therefore the comparison of change over time from Time 1 to Time 2 was important. The trend over time indicated that both LLC participants and non-participants were experiencing modest gains over time on all measures. However on constructs with statistically significant change, LLC participants experienced slightly greater gains over time than non-participants on the Leadership construct.

## Summary

The results of the present study indicated differences between LLC participants and non-participants. On pre-college characteristics, LLC participants did not differ from non-participants on most measures except for representation by gender and ethnicity. Women disproportionately chose to enroll in the LLC. Similarly African-American and Asian students were overrepresented in the LLC, while international students are underrepresented. LLC participants also had different expectations for their engineering experience than non-participants. LLC participants tended to have greater expectations for their level of connection to the engineering college and their level of connection to other engineering undergraduates.

The primary focus of this study was to examine the impact of LLCs on disciplinary persistence in engineering. To examine the effect of LLCs on retention within engineering, I analyzed both indirect factors related to persistence (i.e., Sense of Belonging measures) and direct measures of persistence (e.g., college major selection). I analyzed the Sense of Belonging constructs by comparing LLC participants and non-participants at Time 1, Time 2 and their change over time. To summarize these data, I developed Table 27 (see below). For each Sense of Belonging construct, I determined a relative value to the influence of the LLC on participants in comparison to the non-participants. A "+" in the cell indicates that the LLC participants reported a positive effect in comparison to non-participants on that measure; a "0" means no difference between the two groups; and a "-" would indicate that the LLC participants reported a negative effect compared to non-participants, but none were found. For each time period, I used a combination of the analyses to determine a rating, focusing on statistically significant effects.

Table 27: LLC's Impact on Sense of Belonging Constructs Compared to Non-Participants

| Sense of Belonging Constructs | Time 1 Comparison | Time 2 Comparison | Change over Time Comparison |
|---|---|---|---|
| Commitment to Engineering | 0 | 0 | + |
| Connection to Engineering College | 0 | + | + |
| Connection to Engineering Faculty | 0 | 0 | 0 |
| Connection to Engineering Peers | + | + | + |

Developing relationships with peers was an important element of disciplinary persistence as indicated by the theoretical model and confirmed by the regression model of likelihood to persist (Relationships with Engineering Peers: $\beta = .136$, $p = .013$). Overall, LLC participants exhibited a greater connection to engineering peers at both Time 1 and Time 2. Both the independent samples t-tests and the regression analysis confirmed this difference. Most significant for this study, LLC participation was a significant predictor for both factor components of Connection to Engineering Peers in regression models that included Time 1 data (Relationships with Engineering Peers: $\beta = .117$, $p = .021$; Study Habits with Engineering Peers: $\beta = .094$, $p = .065$). As mentioned previously, I classified the Time 2 regression models including Time 1 data as the most rigorous test of the LLC's impact in this study. These results strongly indicated a relationship between participation in the LLC and connection to others studying engineering.

The results also strongly imply that participation in the LLC was a factor in cultivating students' connection to the engineering college. Although the two groups were not different at Time 1, LLC participants reported higher scores than non-participants on both of the Connection to Engineering College factor components at Time 2. Examining the effects of the LLC over time, LLC participants experienced a less significant decrease than non-participants between Time 1 and Time 2. Moreover, participating in the LLC was a significant predictor of the Member of College factor component in the regression analysis at Time 2 when including Time 1 scores as an independent variable (Member of College: $\beta = .106$, $p = .039$). These results suggested that participating in the LLC may serve as a protective factor, diminishing the decrease in connection to the engineering college over time.

Finally the LLC seems to have an effect on students' commitment to engineering. Both LLC participants and non-participants experienced a significant decrease in their level of commitment to engineering over time. Although the two groups did not differ significantly on their Commitment to Engineering mean scores at Time 1 or Time 2, LLC participants experienced a less significant decrease over time than non-participants. This modest result provides an indication that the LLC may have some effect on students' commitment to continue studying engineering. Similar to connecting with engineering peers, participants' commitment to engineering significantly predicts their likelihood to persist based on the regression analysis ($\beta = .704$, $p < .001$) and was therefore an important indirect measure for this study.

In terms of direct persistence measures, there was not a direct relationship with participating in the LLC. However LLC participants disproportionately chose to remain as engineering majors at the start of their sophomore year in comparison to non-participants. This finding provided modest evidence for the impact of participation in the LLC on disciplinary retention. Once again, these early trends were encouraging given the nature of the phenomenon studied.

When interpreting the engineering learning outcomes, it is important to be cautious given students' limited exposure to the intervention and the curriculum. At this institution, the curriculum for most first-year engineering students consisted of non-engineering courses with the exception of the year-long required introductory course. This caveat is particularly important for considering the change over time data as collections were only 4-5 months apart. These findings are based initial and exploratory research. They provide an indication of differences emerging between LLC participants and non-participants on these measures, but longer term follow-up is necessary to draw more definitive conclusions.

On all learning outcome measures, non-participants self-reported scores were higher than LLC participants throughout the study. Furthermore, the number of statistically significant differences increased from one measure at Time 1 to three measures by Time 2. Despite these differences, the two groups (LLC participants and non-participants) experienced similar changes over time in these outcomes. The only differences on changes over time favored the impact of the LLC. LLC participants experienced a more significant increase over time than non-participants on one measure: Leadership. With the only statistically significant positive changes over time attributed to the LLC, these initial findings suggested that the LLC may have a differential impact on learning in this domain; however additional research is necessary to confirm this initial and modest trend.

Having responded to the research questions, I turn now to a discussion of the findings. In the final chapter, I relate the results to previous research and outline implications for practice, policy and future research. As part of the discussion, I also outline the limitations of the present study.

# CHAPTER FIVE

## DISCUSSION AND IMPLICATIONS

In this final chapter, I relate the findings from the study to the extant research in the field of engineering education and disciplinary retention including the context and rationale for this study. Next, I outline the limitations of this study. Finally, I recommend implications for theory, research, policy and practice, including potential avenues for additional research.

The scope of this study was to identify the difference between LLC participants and non-participants in terms of disciplinary retention of engineering undergraduates and the attainment of engineering learning outcomes. LLCs represent a potential non-classroom intervention to address the quantity and quality issues in engineering education. There are many concerns about the lack of engineers produced in the U.S. (Committee on Prospering in the Global Economy of the 21st Century, 2007; NSB, 2010). Furthermore, there have been significant efforts within the engineering community to revamp the focus of undergraduate education to promote learning outcomes that include both greater practical applications and broader liberal learning objectives (ABET, 2008; National Academy of Engineering, 2004).

The LLC in this study was designed primarily to connect students to the institution's college of engineering with the ultimate aim of increasing retention within the discipline. The faculty and administrators overseeing the initiative hoped to develop a community where first-year engineers could connect to other undergraduate engineering majors in the residence hall, as well as to the college of engineering through various support services and programming. Through the supportive environment of like-minded peers, the LLC's goal was to increase student success in first-year courses and increase students' satisfaction with their first-year experience.

Given the challenges facing the engineering discipline and the climate in which change is necessary, the findings of this study are compelling. The discipline has been primarily focused on improving disciplinary retention rates through pedagogical and curricular innovations. Despite decades of advances in the body of knowledge regarding effective teaching practices in engineering, improving teaching practice has not achieved broad penetration nationally (Duderstadt, 2008; Fairweather, 2008). Additionally, although there is compelling evidence for the use of pedagogical and curricular interventions to improve retention rates, the production of engineers remains an issue (NSB, 2008).

One potential explanation is the challenges inherent in faculty culture. Because of ever-increasing workloads and pressures to pursue research dollars, the prioritization by faculty of their research agenda above their teaching and service responsibilities is well-documented, especially at research-intensive institutions (Duderstadt, 2008; Gappa, Austin & Trice, 2009; Schuster & Finkelstein, 2006). The challenge is not unique to engineering, but certain characteristics of the discipline make the obstacles to changing teaching practice even more difficult to overcome.

Engineering is taught almost exclusively at large research universities where faculty research expectations are often greatest due to the necessity of garnering extramural funding (Gibbons, 2009; Rugarcia et al., 2000). In addition, engineering is the most expensive discipline to teach to undergraduate students on average. With the exception of just a few majors, its cost per student credit hour is twice that of most majors and four times the cost of others (Middaugh, 2005; NCES, 2003; Smith, 1992. In a normal economic climate, these types of changes would be difficult in most majors. Combine the unique elements of the current economic climate and the challenges inherent in the discipline of engineering, and the necessity to look beyond classroom interventions is apparent. Institutions cannot afford to divert faculty away from their revenue-generating research agendas and redirect them to teaching reform agendas which are most often either revenue neutral or revenue negative.

Institutions stretched thin and scrambling for additional outside funds require interventions with minimal impact on the bottom line, including faculty time. Reflecting on the current climate in engineering, the following three requirements for a viable programmatic intervention to emerge:

(1) It must be inexpensive to launch;

(2) It must be inexpensive to maintain.

(3) It must require minimal faculty time and resources.

The LLC in this study meets those standards for the most part. It did require some administrative and faculty time to launch and maintain, but the investment was minimal. The start-up and maintenance costs are relatively low. The institution used an existing residence hall with no significant alterations and used no additional resources to designate part of the building for engineering students. The only recurrent expenses beyond what the university normally provides are: (a) the monthly programs, which may be similar to other residence hall programming budgets; and (b) the in-house tutoring program, where paid upperclass engineers host tutoring sessions five nights per week, a program which might occur in some other form for students regardless.

By conducting research on participants of an engineering LLC, the current study addressed some of the shortcomings in the literature on the impact of LLCs on engineering retention and non-classroom interventions in general. Although not an expressed goal of the LLC in this study, I also studied the achievement of learning outcomes prompted by the evidence in the literature for LLC's impact on intellectual development and engagement outcomes (Inkelas et al., 2004; Pascarella & Terenzini, 2005; Pasque & Murphy; Pike, 1999). Any finding linking the use of LLCs to the advancement of learning outcomes would augment the argument for using LLCs as an intervention in engineering education.

To address these areas of inquiry, I investigated the following research questions. The next section relates the findings of this study to previous research organized by research question:

1. How do students who choose to participate in an engineering LLC differ from other engineering students?

    (a) How do they differ by demographic characteristics?

    (b) How do they differ by their expectations for the college experience?

2. How do LLC participants and non-participants differ on indirect and direct measures of disciplinary persistence?

    a. How do they differ on Sense of Belonging measures?

    b. How do they differ on measures of disciplinary retention?

3. How do LLC participants and non-participants differ on attainment of engineering learning outcomes?

## Key Findings and Relationship to Previous Research

I organize this section of the discussion around the three research questions: (a) differences between LLC participants and non-participants; (b) impact of the LLC on disciplinary retention; and (c) impact of the LLC on engineering learning outcomes.

### Differences between LLC Participants and Non-Participants

This section discusses the findings related to the first research questions:

*1. How do students who choose to participate in an engineering LLC differ from other engineering students?*

*(a) How do they differ by demographic characteristics?*

*(b) How do they differ by their expectations for the college experience?*

Some differences exist between LLC participants and non-participants, principally on gender and ethnicity. Chi-square analyses confirmed an association between LLC participation and these demographic characteristics. Women, African-Americans and Asians are overrepresented in the LLC. Two of these three groups (women and African-Americans) are underrepresented in the general population of undergraduate engineers nationally. In 2004, women comprised 62% of all undergraduates in the U.S., but only 18% of engineering undergraduates; African-Americans comprised 12% of all undergraduates, but only 6% of engineering undergraduates (NSF, 2007). Furthermore increasing the retention of women and underrepresented minorities is a goal of the LLC in this study. Thus these findings are encouraging in relation to the local and national priorities of better supporting women and other minorities.

An additional finding relates to when students choose engineering as a major. In this study participants who decided to major in engineering in the six months prior to matriculation were less likely to opt for the LLC. This finding is not entirely surprising for a few reasons: (a) students who choose the major later may decide after appropriate housing deadlines have passed and therefore not be eligible to select the LLC; (b) these students may be less committed to the major and therefore less interested in committing to an engineering-specific residential experience; and (c) students who choose the major later in the process may be less informed and receive fewer marketing and outreach materials about the LLC. Although the reason for this finding is unclear, the finding has implications for policy and practice that I enumerate below.

On the Sense of Belonging measures, both LLC participants and non-participants tended to agree with all statements regarding their expectations for college, with one exception. Neither LLC participants nor non-participants expected to be a member of the engineering college. The mean scores for the groups (M = 0.27; M = 0.00 respectively) were much lower than any of the other Sense of Belonging expectations. At the beginning of the semester, despite having declared engineering as their intended major, the participants did not expect to be treated or to act as members of the engineering college community. It seems that the prevailing sentiment among first-year students is that they do not belong yet to the community of engineers at their institution. With integration into the community identified as a key factor in disciplinary retention models (Micomonaco & Sticklen, 2010; Veenstra et al., 2009), this finding identifies a deficiency in the orientation of first-year students to the engineering college. One possible explanation for participants' sense of alienation is the application process to their major that occurs in either the sophomore or junior year.

## Impact of LLC on Disciplinary Retention

This study examined the impact of LLCs on a series of factors that are linked to disciplinary retention based on the following research question:

*2. How do LLC participants and non-participants differ on indirect and direct measures of disciplinary persistence?*

*a. How do they differ on Sense of Belonging measures?*

*b. How do they differ on measures of disciplinary retention?*

I discuss each sub-question separately below.

*Indirect Measures of Persistence*

Overall, the general trend for both LLC participants and non-participants was a decrease on Sense of Belonging constructs over time with the exception of Relationships with Engineering Peers component factor. These results indicate that first-year engineering students experience a notable decline in their connection to the discipline of engineering over time. Whether measured by their connection to faculty, peers or the engineering college itself, the first-year engineering experience fails to enhance students' allegiance to the discipline.

This finding is consistent with previous research on engagement whereby all students reported decreased engagement over time (Ohland et al., 2008). This tendency to experience an erosion of their sense of belonging may help explain the high attrition rates in the field of engineering (Astin & Astin, 1993; NSB, 2010; Seymour & Hewitt, 1997). Moreover, Ohland et al. (2008) found that in engineering, disciplinary leavers reported more rapid declines in engagement than students who persist. The results of this current study suggest that one significant factor in students' decision to persist is their ability to withstand the decrease in these Sense of Belonging measures over time.

Although the current study did not attempt to identify the specific causes for the decline in students' sense of belonging, one possible explanation is the nature of the engineering first-year experience at the institution in this study. The curriculum requires first-year engineering students to spend the majority of their time in prerequisite mathematics and science courses. The structure of these courses does not meet engineering students' expectations for learning through hands-on, real-world activities with practical applications (Micomonaco & Sticklen, 2010). Moreover these courses effectively distance first-year students from the college of engineering whether it be from support programs, the faculty, their engineering peers or the building itself.

Thus over the course of the year, it is unsurprising that students reported a decrease in their level of connection to engineering.

An important finding of this study is that LLC participants experienced less significant decreases on Sense of Belonging component factors between Time 1 and Time 2. In other words, they experienced a less pronounced deterioration of their commitment to engineering and their connection to the engineering college, faculty and peers. Therefore the LLC may act as a buffer against the typical declines on the Sense of Belonging constructs. The LLC may function to better preserve students' sense of belonging, and in turn, their willingness to persist in the discipline.

These findings echoed previous research about the impact of LLCs on undergraduates in general. Participation in LLCs is linked to higher levels of satisfaction with the undergraduate experience; satisfaction with the student experience is an indicator of likelihood to persist (Armino et al., 1994; Pike, et al., 1997). In other studies, LLC participants reported being more integrated into their college community (Pike, 1999) and experienced a smoother transition to college (Inkelas et al., 2004). These outcomes are also tied to college persistence. Thus it seems reasonable to conclude that participation in the LLC may serve as a protective factor against more rapid declines in students' sense of belonging to the discipline of engineering.

On specific Sense of Belonging component measures, there were a few noteworthy differences between LLC participants and non-participants. First, LLC participants reported a stronger connection to other undergraduate engineers. On the factor components of Connection to Engineering Peers, LLC participants rated themselves higher at both Time 1 and Time 2. Furthermore this difference was confirmed by both regression analyses at Time 2 using pre-college characteristics as independent variables to control for their impact and then adding Time 1 scores to examine change over time.

The differences between LLC participants and non-participants on the Connection to Engineering Peers constructs are consistent with previous research on LLCs. Earlier studies found that LLC participants were more engaged in their community (Pike, 1999) with a stronger connection to their engineering peers (McKelfresh, 1980). Also LLC participants tended to have more positive interactions with their peers (Inkelas et al., 2004). Therefore LLC participants in this study responded to statements as expected in terms of experiencing stronger connections with other engineering undergraduates both academically and socially.

The second significant component finding relates to LLC participants' sense of integration into the College of Engineering. On the Connection to Engineering College factor component, LLC participants scored significantly higher at Time 2; this finding was confirmed by a regression analysis controlling for pre-college characteristics. In terms of change over time, the LLC participants experienced a less significant decrease from Time 1 to Time 2 indicating a positive effect of LLC participation over time. Finally this difference between LLC participants and non-participants was confirmed when Time 1 data were added to the regression analysis and participation in the LLC maintained significant predictive power on the Connection to Engineering College component.

There is extensive research demonstrating a similarly positive impact of LLCs on students' connection to the college or level of engagement. For example, previous research links participation in an LLC with increased involvement and engagement in college including higher levels of participation in community activities (Inkelas et al., 2004; Inkelas & Weisman, 2003; Pike, 1999; Pike et al., 1997). In a similar vein, LLCs have been shown to increase participants' perception of available support (Inkelas; Inkelas & Weisman). Finally on general measures of students' connection to their college, LLC participants consistently scored higher (Pike et al.) including in a previous study targeting the LLC experience of undergraduate engineers (McKelfresh, 1980). Therefore participation in the LLC in this study produced expected results in terms of their connection to the college of engineering.

One surprising finding related to the Sense of Belonging constructs and the differences between LLC participants and non-participants on the Connection to Engineering Faculty factor component. In previous studies, LLC participants reported more frequent interactions with faculty (Inkelas, 1997; Pike et al., 1997). In this study, however, LLC participants reported similar scores on the Student Interactions with Faculty factor component. Furthermore LLC participants experienced a greater decrease (i.e., increased disagreement) on these items than non-participants. No significant differences between the two groups were found.

Based on previous research, I expected that LLC participants would score higher than non-participants on these measures (Inkelas & Weisman, 2003; Pike, 1999). The discrepancy between the results of this study and those of previous research may be attributed to the design of the LLC. The LLC in this study was not established with the explicit intention to increase student-faculty interactions. Although there are some programs associated with the LLC that provide opportunities to engage faculty, these offerings occur less than once per month and the promotion of student-faculty interaction is not a primary focus. In contrast, faculty engagement, including formal mentoring expectations, is an integral component of some LLCs.

A possible explanation for the greater decline for LLC participants involves differences in expectations for the college experience. Because many LLCs include faculty interaction as a key element of the program, students in the engineering LLC may have expected to interact more often with faculty. If LLC participants held higher expectations for substantial amounts of student-faculty interaction because of their LLC participation, then it is reasonable that over time, as these notions were dispelled, their reported values on measures assessing participants' connection to faculty would decrease at a higher rate than non-participants.

*Direct Measures of Persistence*

In this study, there were three direct measures of persistence; two of the measures dealt with students' choice of major beyond the first year. The first measure was a survey item asking participants to rate their likelihood to persist as a student in engineering. There were no significant difference between LLC participants and non-participants on the first measure. However, the analysis of the second measure yielded significant results. Comparing LLC participants and non-participants on their choice of major at the beginning of the sophomore year, LLC participants were more likely to have remained in engineering.

The dissonance between the two measures may have resulted from a response bias. At Time 2, the survey takers were disproportionately LLC students. It is possible that this difference in survey participants resulted in an enthusiasm gap between takers and non-takers that would impact the mean score value on a persistence survey item. Additionally, by Time 2, some non-participants may have already switched out of the discipline after enrolling in the first semester of the required introductory course sequence. These leavers would be captured in the second measure of persistence (i.e., choice of major at the start of sophomore year), but not on the Likert item administered at Time 2. If these leavers were disproportionately not members of the LLC, then an early departure would artificially inflate the mean score for likelihood to persist in engineering for non-participants.

Much of the previous research studying the impact of LLCs on retention focused generally on college retention. In these studies the results were mixed, with some indicating a positive effect (Inkelas et al., 2004) and others demonstrating no effect on college persistence (Pike et al., 1997). In terms of disciplinary retention, the results of the current study provided evidence of participation in LLCs positively predicting retention within engineering. This finding is noteworthy in relationship to the seminal work of Seymour and Hewitt (1997) that identified classroom interventions as key to improving persistence in STEM. The results of the current study suggest that LLCs, a non-classroom intervention, may be an effective intervention to promote disciplinary retention by curbing the impact of the students' experience on their sense of belonging and commitment to the discipline..

In this study, I also examined academic performance as an indirect measure of persistence because a minimum GPA is a requirement by most engineering colleges for engineers to persist. In this study, there was not a significant difference between LLC participants and non-participants on GPA at the start of their sophomore fall. This finding contradicts most studies that found LLC participants outperformed non-participants on academic achievement measures (Pace et al., 2008; Pascarella & Terenzini, 1981; Pasque & Murphy, 2005; Rice & Lightsey, 2001). On the other hand, consistent with the present study other studies also found no difference between the two groups (Pike et al., 1997).

## Impact on Engineering Learning Outcomes

In this final sub-section, I discuss the findings from the final research question:

*3. How do LLC participants and non-participants differ on attainment of engineering learning outcomes?*

The analysis of the engineering learning outcomes yielded some noteworthy results. Although non-participants rated themselves higher than LLC participants on all engineering learning outcomes, the more reliable finding for these self-assessments is the change over time. The results indicated minimal differences between LLC participants and non-participants in terms of learning outcomes gains. Using change over time as the indicator of learning, LLC participants reported greater learning gains than non-participants on the leadership learning outcome only. Therefore on one of the engineering learning outcomes, LLC participants experienced a greater, significant increase over time. There were no other significant changes over time. Because of the short timeframe of this study during participants' first-year, any significant result, as well non-statistically significant trends, is worth acknowledging

Previous research on the effect of LLC participation on learning outcomes is mixed. Furthermore the targeted learning outcomes in this study are different than measures used in prior studies. For example, participation in LLCs was associated with higher scores on measure of intellectual development (Pike, 1999); however LLC participants did not score higher than non-participants on measures of cognitive complexity in a different study (Inkelas, et al., 2006). Thus the current study's lack of a strong association between participation in the LLC and learning outcomes gains seems consistent with previous research. Both the current study and previous research failed to establish a compelling link between participating in a LLC and learning outcomes, but offered evidence for potential effects requiring further study.

## Limitations

Through external review and careful design, I ensured that the data collection and analysis were completed with the aim of accurately capturing the differences between LLC participants and non-participants. However, several limitations were inherent to the process. One limitation related to the use of self-report data. Concerns about the validity of self-report data have been raised previously in the literature (Anaya, 1999; Gonyea, 2005). To address these concerns, I sought to phrase questions clearly, ask questions that are relevant to the participants' recent experience, and ensure the questions were not emotionally unsettling. Furthermore, I piloted the instrument with students similar to the targeted population to increase the likelihood that the questions were both relevant and understandable.

A second limitation of the study was the use of a model that is not well-tested. To design the questions regarding indirect measures of persistence, I relied heavily on the Revised Model of Engineering Student Retention (Micomonaco & Sticklen, 2010). The model is based on previous work on college student retention (Tinto, 1993) and on disciplinary retention in engineering (Veenstra et al., 2009). The Sense of Belonging items used in this study emerged from previous qualitative work that aimed to better understand the influence of the student experience on disciplinary retention in engineering which forms the core of the college's effect in Veenstra et al.'s model (Micomonaco & Sticklen). Though a result of qualitative research, the Sense of Belonging constructs have not been rigorously tested.

A third limitation related to the potential for self-selection bias. By focusing the study on a single institution and collecting data from required course meetings, I hoped to include as many of the target population as possible to limit coverage error. Members of the target population could either choose not to participate, may not have attended the laboratory meeting on the day of the survey administration, or may not have enrolled in the targeted course. Although response rates were high (81-87% of the sample surveyed in these courses), decreasing the likelihood of error, the response rates for the targeted initial sample of 499 first-year students dropped to 61% by Time 2. Although the response rate is still high, the individuals who chose not to participate differed significantly from survey participants along some dimensions that may have skewed some of the results. For example, LLC participants were overrepresented at all three administrations; international students were underrepresented at the Time 0.

A fourth limitation relates to conducting a one year longitudinal study. With little time elapsing between Time 1 and Time 2 administrations, there was limited opportunity to allow the effect of the LLC to manifest itself in the differences between LLC participants and non-participants on attitudinal and behavioral measures. Moreover the study was situated in the students' first year during which course selection is very limited and primarily outside of the college of engineering. These factors combined may have muted differences between the two groups. It is possible that with more time between administrations, or by waiting until later in students' career to survey them again, greater differences between LLC participants and non-participants would emerge.

Finally this study was situated at a single institution. Although there were compelling reasons for choosing to situate the study at single campus (i.e., unique nature of LLC, opportunity to collect data through courses, longitudinal data collection requiring multiple administrations), the extent to which the findings are generalizable is limited. In this paper, I provided a rich description of the LLC studied so that readers can make better judgments about the suitability of these findings to their contexts.

## Implications of Findings

Building on the discussion of the results and their relationship to previous findings, I suggest implications of the present study. I have organized this section into the following sub-sections: (a) implications for theory; (b) implications for practice; (c) implications for policy; (d) implications for research; and (e) areas for future research.

## Implications for Theory

This focus of this study was to understand the impact of LLCs on both retention and learning within undergraduate engineering programs. I used theory to inform the study, but a revised theory or conceptual model was not a goal of this research. Thus the results of this study have limited application to theory. In this section, I outline a couple of theoretical considerations that emerge from the more practical results of this study.

In the design of this study, I relied on the Revised Model of Engineering Student Retention (Micomonaco & Sticklen, 2010) because the model probed, from an engineering student perspective, the concepts of academic and social integration that were initially proposed by Tinto in his general theory of student departure (Tinto, 1993). I used the revised model because it combats the lack of distinction between academic and social integration which served as the key factors in determining student persistence. As a result, the revised model described the factors affecting disciplinary retention in more specific terms for item construction.

The results of this study lend support to the model's conceptualization of the students' experience. Beginning with the factor analysis, the results of this study affirmed the theoretical constructs identified in the Revised Model of Engineering Student Retention as influencing retention: (a) Commitment to Engineering; (b) Connection to Engineering College; (c) Connection to Engineering Faculty; and (d) Connection to Engineering Peers. Although the study was not designed to validate the model, the ease with which the items organized statistically into these categories based on collected data lends support to the components of the model (see Tables 2, 3, 4 & 5). The factor analysis resulted in a total of eight factor components to explain the students' overall Sense of Belonging: (a) Commitment to Engineering; (b) Member of College; (c) Supported by College; (d) Student Perceptions of Faculty; (e) Student

Interactions with Faculty; (f) Comfortable Seeking Help from Engineering Peers; (g) Relationships with Engineering Peers; and (h) Study Habits with Engineering Peers. These eight factor components organized well into the four broader constructs of the model: (a) Commitment to Engineering; (b) Connection to Engineering College; (c) Connection to Engineering Faculty; and (d) Connection to Engineering Peers.

In addition, the results of the regression analysis modeling the relationship between the Sense of Belonging measures and the persistence measures suggested some elements of the model are observable. Reviewing both direct measures of persistence, the following factors had a significant predictive effect: (a) Commitment to Engineering; and (b) Relationships with Engineering Peers. At this early stage of measurement, these component factors related to persistence as predicted by the theoretical model and lend additional support for the use of the Revised Model of Engineering Student Retention.

## Implications for Practice

There are several ways that the findings from this study could inform practice. First, there are implications for colleges of engineering. The results of this study indicated that the LLC disproportionately attracts women and African-American students, although the difference between LLC participants and non-participants is modest in terms of enrollment of African-American students. Nonetheless, these results suggest that engineering faculty and administrators could leverage the LLC to recruit these historically underrepresented populations. Once enrolled in the discipline’s residential program, these students would be part of a community designed to increase their retention through increased support and services. Thus the LLC has the potential to be an effective promoter of female and African-American engineering graduates.

An additional implication for colleges is to actively market the LLC to entering students. The data indicated that students who participated in the LLC tend to choose engineering as a major earlier than non-participants. Also, non-participants cited not being aware of the LLC as the primary reason for not participating. The results of this study demonstrated that participating in the LLC improves retention-related outcomes and may have a differential impact on learning outcomes. Therefore colleges and universities should heavily market the LLC to incoming first-year engineers as a potential way to enhance their success. Furthermore institutions should target students who choose engineering closer to the date of matriculation so that they are aware of the LLC opportunity.

In this study, the relationship between student-faculty interactions and LLC participation was not positive. Contrary to prior research, LLC participants in the current study did not differ from non-participants on Connection to Faculty measures. LLC participants reported “somewhat disagreeing” with these measures by Time 2. LLC participants were interacting less with the faculty over the course of the academic year, despite entering college “somewhat agreeing” with statements regarding expectations to interact with faculty. This finding may be attributable to the stated goals of the LLC I examined, because the institution did not focus on fostering student-faculty interactions through the LLC, choosing instead to focus on peer and programmatic influences.

In terms of practice, one cannot assume that all types of LLCs will have the same outcomes, especially with regards to faculty. In this study, the administrators met their stated objectives of designing an LLC to promote peer interactions and affiliation with the college among undergraduate engineering majors. On the other hand, the LLC did not have a residual impact on promoting gains related to students’ connection to engineering faculty despite events that involved faculty. The data suggest that to be successful, practitioners who implement LLCs must intentionally pursue intended outcomes. If student-faculty interactions are a priority, then the institution must intentionally design opportunities and devote resource to facilitating these relationships. On the other hand, if the use of faculty time for this purpose and the resources are tight, then there are other gains (connection to college; connection to engineering peers) that can be achieved from a more minimalist approach with fewer resources.

The findings of this study also suggested an implication for entering first-year students. LLC participants reported increased connection to their engineering peers including studying with them more often. Furthermore, this study and previous research suggest that higher level of engagement with peers, especially in academic settings, links to better outcomes in terms of retention and some learning outcomes (Kuh, 1996; Micomonaco & Sticklen, 2010; Pascarella & Terenzini, 2005; Tinto, 1993; Veenstra et al., 2009). Because most engineering programs are at large research universities, entering students may not be prepared for the large classes and often impersonal nature of college classroom experiences. Students, especially those accustomed to working closely with their peers, would benefit from participating in a LLC. Therefore students should strongly consider residing in a LLC, viewing it as a potential source of support for their college experience.

## Implications for Policy

The data from this study demonstrated that LLCs have a positive impact on measures related to disciplinary persistence and may have an impact on engineering learning outcomes. Although the results are modest, non-participants experienced a larger deterioration of their commitment to engineering and sense of belonging in two out of three domains (connection to college and peers). Similarly, the change over time measures for engineering learning outcomes indicated that the LLC had a slightly more positive impact on engineering learning outcomes when comparing participants to non-participants. At a minimum, there is preliminary evidence for the effectiveness of LLCs to promote indirect measures of disciplinary persistence. On a national level where concerns about the quantity and quality of engineering persist, policy makers in government and national foundations should consider funding the broader implementation of LLC programs as a way to promote more and better educated engineers.

On the campus level, the findings of the study have implications for policy as well. Given the demonstrated benefits of LLCs in engineering education, college officials should consider establishing more engineering-specific LLCs to promote disciplinary retention. In addition, colleges and universities might encourage engineering students to participate in LLC programs, including lowering barriers to their participation. One factor contributing to whether students participated in the LLC was the timing of their choice to major in engineering. Students who choose engineering closer to the date of matriculation are less likely to choose the LLC. Faculty and administrative leadership might identify ways to market the LLC option, especially to these students who make decisions about college and major later in the process. Furthermore, administrators might establish housing policies that enable these students selecting engineering later in the process to still select the LLC as their residential home.

## Implications for Research

The current study represents a shift in various lines of inquiry. First, efforts to improve disciplinary retention in STEM fields including engineering have been strongly influenced by the work of Seymour and Hewitt (1997). Their research emphasized the role of pedagogy and curriculum in discouraging students from persisting within the discipline. Although I acknowledge the value of continuing to pursue classroom innovation to improve student outcomes, I conceptualized this study to examine the effects of a non-classroom intervention on retention. The results of this study suggested that there may be a positive relationship between LLC participation and retention-related outcomes worthy of further examination. Thus further study should continue my line of inquiry into the effectiveness of non-classroom interventions (e.g., mentoring programs, college-wide social/professional events, clubs and other activities) on engineering-related outcomes (i.e., persistence and learning outcomes).

An additional implication for research involves the focus on LLCs to promote specific disciplinary goals. Unlike previous studies of LLCs focusing on general student outcomes, this study is situated in engineering and, as a result, focused on disciplinary retention as well as the promotion of disciplinary learning outcomes. The results of this study demonstrated the potential for LLCs to address targeted goals within specific disciplines. An interesting future study would examine the effectiveness of LLCs in other disciplinary contexts and in relation to other disciplines' departmental goals.

Finally this study extended the research on retention within engineering. Previous research focused on either the effect of classroom interventions (Sheppard et al., 2009) or pre-college characteristics (Veenstra et al., 2009). The scope of this study examined the impact of LLCs, as a non-classroom intervention, on persistence and persistence-related measures. Through this study, I argued for shifting the focus of research from classroom interventions to non-classroom experiences as another avenue for reform in the discipline.

## Future Areas of Research

The results of this study suggest several additional research projects. First, this study could be extended by adding data collections later in the sample's college career. One of the limitations of this study is the short time frame for measuring the impact of the LLC on the Sense of Belonging and learning outcomes measures. Both measures are complicated and may require a longer duration for the effects to fully manifest. Further, even tracking the sample of students based on their choice of major would enhance the study of the LLC's impact. An ideal complement to the present study would be a senior year administration to analyze the longer term impact on students' ultimate choice of major, commitment to engineering, sense of belonging and learning outcomes.

Another possible study would attempt to attribute the effects of the LLC to particular elements of the experience. The scope of this study is to examine the impact of the LLC by comparing LLC participants to non-participants on a series of measures. In other words, the purpose was to determine if there was an effect. At this early stage in the students' college career, the present study indicated at least modest effects on disciplinary retention and attainment of learning outcomes. However I made no attempt to discern why the LLC had this impact. Therefore a future study could attempt to identify the types of experiences or services offered by the LLC that contributed to these outcomes.

There is also potential for more theoretical studies to emerge from this line of inquiry. For example, the Sense of Belonging constructs identified in the Revised Model of Engineering Student Retention (Micomonaco & Sticklen, 2010) were the result of an exploratory, qualitative study. The relationship of these constructs to students' retention decisions have not been confirmed by further empirical work. The results of the factor analysis in this study supported the theoretical constructs as distinct, measurable entities; however the nature of the relationship between these constructs and students' decision to persist remains unclear. Thus a future study could explore the proposed theoretical model in more depth to determine the accuracy of the current proposed relationship between the Sense of Belonging components and the disciplinary retention decision.

Finally, the use of self-report data to assess learning outcomes presents an additional area for further research. One challenge with using self-report data to assess student learning outcomes is the inconsistency with which participants rate their abilities (Anaya, 1999; Gonyea, 2005. For example, in this research, it is difficult to standardize responses at one level (e.g., “good” or “very good”) when making statistical comparisons. For the analysis in this study, I supplemented direct mean comparisons with comparisons of change over time which eliminated the bias in absolute terms and improved upon the measurement of an intervention (e.g., LLC) over time. However the study still relied on self-assessments of learning gains over time which may not necessarily be accurate in absolute terms (Anaya; Gonyea). Therefore a new study could attempt to replicate similar assessments using more direct, objective measures of student learning.

## Conclusion

The purpose of the present study was to study the impact of LLCs on its participants in relation to disciplinary retention and promotion engineering learning outcomes. The examination of both direct measures (e.g., choice of major) and indirect measures (e.g., Sense of Belonging measures) of persistence provided evidence for the positive influence of LLCs in these domains. In addition, although the findings were minimal, LLCs may potentially be linked to gains on engineering learning outcomes

The current state of global affairs suggests that the work of engineers will likely drive economic growth and national security for the foreseeable future. As a result, the production of sufficient quantity and quality of engineers is a national priority. At present, the U.S. is falling behind on both accounts and needs to identify innovative ways to retain more engineers and promote more robust learning outcomes. Concurrently colleges and universities face challenging fiscal times where internal funding for new local programs is scarce. The results of the present study are relevant to the national discourse on engineering education by identifying a potential efficient intervention to supplement efforts to produce greater numbers of high-quality engineers.

# APPENDIX A

# SURVEY INSTRUMENT

APPENDIX A: SURVEY INSTRUMENT

1. When did you first become interested in engineering?
2. When did you first decide to major in engineering?
   - ☐ Over the summer
   - ☐ Last Spring
   - ☐ Last Fall
   - ☐ 1-2 Years Ago
   - ☐ 2-4 Years Ago
   - ☐ 4-6 Years Ago
   - ☐ More than 6 years ago

3. Why did you choose engineering? Please select the statements that best reflect your reason for choosing engineering as your major.
   - ☐ I am good at math and science.
   - ☐ My parent is an engineer and wanted me to be one as well.
   - ☐ I know an engineer and thought their job seemed interesting.
   - ☐ I was encouraged to do so by high school teachers/counselors.
   - ☐ I was encouraged to do so by family and friends.
   - ☐ I enjoy learning through hands-on experiences.
   - ☐ I enjoy learning that has practical applications.
   - ☐ I enjoy problem-solving.
   - ☐ I enjoy working in groups.
   - ☐ I am more likely to get a good job when I graduate.
   - ☐ Other (please indicate below):

4a. <u>For LLC Participants</u>: Please indicate your primary reason for selecting the residential engineering experience:
   - ☐ I wanted to live with other engineers.
   - ☐ I thought living in [the LLC] would help me academically.
   - ☐ I thought living in [the LLC] would help me socially.
   - ☐ I have friends from high school who wanted to live in [Hall A].
   - ☐ I wanted to live in [Hall A].
   - ☐ Other (please indicate below):

4b. <u>For Non-participants</u>: Please indicate your primary reason for not selecting the residential engineering experience:
   - ☐ I was unaware that there was residential engineering experience in [Hall A].
   - ☐ I did not want to live with other engineers.
   - ☐ I am unsure if I want to be an engineering major.
   - ☐ I wanted to live with friends in a different residence hall.
   - ☐ I wanted to live in a different location on campus.
   - ☐ I did not think the residential experience would be worthwhile.
   - ☐ Other (please indicate below):

5. On average, how many hours per week do you expect to spend on homework outside of class for all of your courses combined?

6. Please rate your likelihood to continue in an engineering major.

- ☐ Very unlikely
- ☐ Somewhat unlikely
- ☐ Somewhat likely
- ☐ Very likely

7. Please rate the extent to which you agree or disagree with the following statements:

| Item | Strongly Agree | Somewhat Agree | Somewhat Disagree | Strongly Disagree |
|---|---|---|---|---|
| I am excited about studying engineering. | ❑ | ❑ | ❑ | ❑ |
| I am confident that engineering is the correct major for me. | ❑ | ❑ | ❑ | ❑ |
| I may switch to a non-engineering major. | ❑ | ❑ | ❑ | ❑ |
| I have considered switching to a non-engineering major. | ❑ | ❑ | ❑ | ❑ |
| I consider myself a member of the College of Engineering. | ❑ | ❑ | ❑ | ❑ |
| I feel supported by the College of Engineering. | ❑ | ❑ | ❑ | ❑ |

8. Please rate the extent to which you agree or disagree with the following statements:

| Item | Strongly Agree | Somewhat Agree | Somewhat Disagree | Strongly Disagree |
|---|---|---|---|---|
| Professors will be/are available to provide guidance to me. | ❑ | ❑ | ❑ | ❑ |
| Professors will be/are available to help me with learning/understanding course material outside of class. | ❑ | ❑ | ❑ | ❑ |
| Professors will be/are available to discuss non-class issues (e.g., socially, career advice, etc.). | ❑ | ❑ | ❑ | ❑ |
| I (plan to) interact with professors outside of classroom time. | ❑ | ❑ | ❑ | ❑ |
| I (plan to) interact with professors about non-class issues (e.g., socially, career advice). | ❑ | ❑ | ❑ | ❑ |

9. Please rate the extent to which you agree or disagree with the following statements:

| Item | Strongly Agree | Somewhat Agree | Somewhat Disagree | Strongly Disagree |
|---|---|---|---|---|
| Developing relationships with faculty is important to me. | ❑ | ❑ | ❑ | ❑ |
| I am friends with other engineering | ❑ | ❑ | ❑ | ❑ |

| | | | | |
|---|---|---|---|---|
| students. | | | | |
| Most of my closest friends are engineering students. | ❑ | ❑ | ❑ | ❑ |
| I know upperclass students (sophomores, juniors, or seniors) in the College of Engineering. | ❑ | ❑ | ❑ | ❑ |
| Finding a group of classmates to study with is important to me. | ❑ | ❑ | ❑ | ❑ |

10. Please rate the extent to which you agree or disagree with the following statements:

| Item | Strongly Agree | Somewhat Agree | Somewhat Disagree | Strongly Disagree |
|---|---|---|---|---|
| I feel comfortable identifying a group of classmates to study with. | ❑ | ❑ | ❑ | ❑ |
| I feel comfortable seeking help with my classes from classmates. | ❑ | ❑ | ❑ | ❑ |
| I feel comfortable seeking help with my classes from upperclass students. | ❑ | ❑ | ❑ | ❑ |
| I plan to seek/sought a group of classmates to study with. | ❑ | ❑ | ❑ | ❑ |
| I plan to seek/sought help from my classmates with homework and studying. | ❑ | ❑ | ❑ | ❑ |
| I plan to seek/sought help from upperclass students with homework and studying. | ❑ | ❑ | ❑ | ❑ |
| I plan to seek/sought advice from upperclass students on course selection. | ❑ | ❑ | ❑ | ❑ |

11. Please rate the extent to which you agree or disagree with the following statements:

| Item | Strongly Agree | Somewhat Agree | Somewhat Disagree | Strongly Disagree |
|---|---|---|---|---|
| There are many resources (e.g., advising, career services, tutoring, etc.) available to me through the College of Engineering. | ❑ | ❑ | ❑ | ❑ |
| I (plan to) use the resources available to me through the College of Engineering | ❑ | ❑ | ❑ | ❑ |
| I am involved in extracurricular activities.. | ❑ | ❑ | ❑ | ❑ |
| I am involved in extracurricular activities **associated with the College of Engineering.** | ❑ | ❑ | ❑ | ❑ |

*12. Applying Math & Science*

Please rate your ability to apply:

| Item | Weak/ None | Fair | Good | Very Good | Excellent |
|---|---|---|---|---|---|
| Math to engineering problems. | ❑ | ❑ | ❑ | ❑ | ❑ |
| The physical sciences to engineering problems. | ❑ | ❑ | ❑ | ❑ | ❑ |
| Computer tools and applications to engineering problems. | ❑ | ❑ | ❑ | ❑ | ❑ |
| Life sciences to engineering problems. | ❑ | ❑ | ❑ | ❑ | ❑ |

*13. Defining Problems and Generating Design Solutions*

Please rate your ability to:

| Item | Weak/ None | Fair | Good | Very Good | Excellent |
|---|---|---|---|---|---|
| Define design problems and objectives clearly and precisely. | ❑ | ❑ | ❑ | ❑ | ❑ |
| Ask questions to understand what a client/customer really wants in a "product". | ❑ | ❑ | ❑ | ❑ | ❑ |
| Computer tools and applications to engineering problems. | ❑ | ❑ | ❑ | ❑ | ❑ |
| Undertake a search (literature review, databases, benchmarking, reverse-engineering, etc.) before beginning team-based brain-storming. | ❑ | ❑ | ❑ | ❑ | ❑ |
| Take into account the design contexts and the constraints they may impose on each possible solution (social, cultural, economic, environmental, political, ethical, etc.). | ❑ | ❑ | ❑ | ❑ | ❑ |
| Generate and prioritize criteria for evaluating the quality of a solution. | ❑ | ❑ | ❑ | ❑ | ❑ |
| Brainstorm possible engineering solutions. | ❑ | ❑ | ❑ | ❑ | ❑ |
| Apply systems thinking in developing solutions to an engineering problem. | ❑ | ❑ | ❑ | ❑ | ❑ |
| Develop pictorial representations of possible designs (sketches, renderings, engineering drawings, etc.). | ❑ | ❑ | ❑ | ❑ | ❑ |
| Evaluate design solutions based on a specified set of criteria. | ❑ | ❑ | ❑ | ❑ | ❑ |
| Producing a product (prototype, program, simulation, etc.). | ❑ | ❑ | ❑ | ❑ | ❑ |

*14. Managing a Design Project*
Please rate your ability to apply:

| Item | Weak/ None | Fair | Good | Very Good | Excellent |
|---|---|---|---|---|---|
| Break down a design project into manageable components or tasks. | ❑ | ❑ | ❑ | ❑ | ❑ |
| Identify team members' strengths/weaknesses and distribute tasks and workload accordingly. | ❑ | ❑ | ❑ | ❑ | ❑ |
| Recognize when changes to the original understanding of the problem may be necessary. | ❑ | ❑ | ❑ | ❑ | ❑ |
| Monitor the design process to ensure goals are being met. | ❑ | ❑ | ❑ | ❑ | ❑ |
| Put aside differences with a design team to get the work done. | ❑ | ❑ | ❑ | ❑ | ❑ |

*15. Engineering Contexts*
Please rate your ability to apply:

| Item | Weak/ None | Fair | Good | Very Good | Excellent |
|---|---|---|---|---|---|
| Knowledge of contexts (social, political, economic, cultural, environmental, ethical, etc.) that might affect the solution to an engineering problem. | ❑ | ❑ | ❑ | ❑ | ❑ |
| Knowledge of the connections between technological solutions and their implications for the society or groups they are intended to benefit. | ❑ | ❑ | ❑ | ❑ | ❑ |
| Ability to use what you know about different cultures, social values, or political systems in developing engineering solutions. | ❑ | ❑ | ❑ | ❑ | ❑ |
| Ability to recognize how different contexts can change a solution. | ❑ | ❑ | ❑ | ❑ | ❑ |

*16. Communication*
Please rate your ability to:

| Item | Weak/ None | Fair | Good | Very Good | Excellent |
|---|---|---|---|---|---|
| Write a well-organized, coherent report. | ❑ | ❑ | ❑ | ❑ | ❑ |
| Make effective audiovisual presentations. | ❑ | ❑ | ❑ | ❑ | ❑ |
| Construct tables or graphs to communicate a solution. | ❑ | ❑ | ❑ | ❑ | ❑ |
| Communicate effectively with clients, | ❑ | ❑ | ❑ | ❑ | ❑ |

| | | | | | |
|---|---|---|---|---|---|
| teammates, and supervisors. | | | | | |
| Communicate effectively with *non-technical* audiences. | ❑ | ❑ | ❑ | ❑ | ❑ |
| Communicate effectively with people from different cultures or countries. | ❑ | ❑ | ❑ | ❑ | ❑ |

*17. Teamwork*

Please rate your ability to:

| Item | Weak/ None | Fair | Good | Very Good | Excellent |
|---|---|---|---|---|---|
| Work with others to accomplish group goals. | ❑ | ❑ | ❑ | ❑ | ❑ |
| Work in teams of people with a variety of skills and backgrounds. | ❑ | ❑ | ❑ | ❑ | ❑ |
| Work in teams where knowledge and ideas from multiple engineering fields must be applied. | ❑ | ❑ | ❑ | ❑ | ❑ |
| Work in teams that include people from fields *outside engineering*. | ❑ | ❑ | ❑ | ❑ | ❑ |

*18. Leadership*

Please rate your ability to:

| Item | Weak/ None | Fair | Good | Very Good | Excellent |
|---|---|---|---|---|---|
| Help your group or organization work through periods when ideas are too many or too few. | ❑ | ❑ | ❑ | ❑ | ❑ |
| Develop a plan to accomplish a group or organization's goals. | ❑ | ❑ | ❑ | ❑ | ❑ |
| Take responsibility for group's or organization's performance. | ❑ | ❑ | ❑ | ❑ | ❑ |
| Motivate people to do the work that needs to be done. | ❑ | ❑ | ❑ | ❑ | ❑ |

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