EDUCATING THE NEW-CENTURY ENGINEER: UNDERSTANDING THE ROLE OF EXTRACURRICULAR PROJECT-BASED EXPERIENTIAL LEARNING IN ENGINEERING EDUCATION

A DISSERTATION

SUBMITTED TO THE FACULTY OF THE GRADUATE SCHOOL

OF THE UNIVERSITY OF MINNESOTA

BY

Kyle Dukart

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS

FOR THE DEGREE OF DOCTOR OF EDUCATION

Dr. David Weerts, Advisor

June 2016

Abstract

The purpose of this study is to understand the role that extracurricular project-based experiential learning plays in educating undergraduate students studying engineering. Informed by the literature in the fields of student engagement and experiential learning, the study examines perceptions and experiences of nascent engineers to understand how these specific extracurricular activities contribute to their collegiate experience. Extracurricular projects refer to non-credit and non-paid design-and-build activities where the majority of the activity takes place in a campus context and is student driven.

Students who were taking part in extracurricular engineering projects while completing their four-year engineering degree at the University of Minnesota were included in this qualitative case study. Ten interviews were conducted to collect the majority of the data, which was supplemented with three observations and the collection and inspection of artifacts.

The study results are organized into findings on student perceptions and the experiential learning process. Key findings include extracurricular projects as an especially impactful engagement activity for engineering students. Such projects also are effective tools for increasing self-efficacy and motivation and serve as a particularly valuable career preparation experience. Additionally, the organic design-build process students engage in outside the structure of a classroom parallels with Kolb's model of experiential learning, suggesting a particularly suitable method for educating "new-century" engineers.

Table of Contents

List of Figures

List of Tables

CHAPTER ONE: STUDY BACKGROUND

Spurred by the demise of the industrial revolution and the race for technological superiority during the Cold War, the mid-20th century United States economy started transitioning to a workforce trained in science, mathematics, engineering, and technology (STEM). That transition largely continues today as science and engineering (S&E) occupations have grown at an annualized 5.9% from 1950 to 2009, nearly five times the rate of the overall workforce (National Science Board, 2012). Many warn of trends in higher education that threaten the viability of this nation as the world's technological and innovation leader due to a shortage of a citizenry properly trained in science and engineering (National Science Board, 2003; Institute of Medicine, National Academy of Sciences, and National Academy of Engineering, 2007; National Research Council, 2010). Relatedly, experts and educators wonder whether scientists and engineers are properly prepared to solve increasingly complex problems ethically, and with a sense of the larger public welfare (Sheppard, Macatangay, Colby, & Sullivan, 2009; Cech, 2014). It is in this context that President Barack Obama stated his goal of increasing engineering graduates by 10,000 per year and ensuring that the United States is competitive in the development of new technology and a continued leader in science innovation (Cooper, 2011).

Yet, predicting workforce trends is challenging due to a confluence of factors that shape the economic landscape. For example, researchers and journalists have challenged the notion that a shortage of STEM graduates is on the horizon. They point to stagnant wages in S&E jobs, a large percentages of STEM graduates working outside of STEM, recent lay-offs in technology-heavy fields, and STEM PhDs struggling to find work (Charette, 2013; Salzman, Kuehn, & Lowell, 2013; Butz et al., 2004). Others look at the numbers and see at least the potential for a shortage, citing the continued higher growth rate for science and engineering jobs as compared to all jobs, wage growth better than average, unemployment rates well below the overall rate, and the fact that the data do not account for all the STEM related jobs that actually exist (Institute of Medicine, National Academy of Sciences, and National Academy of Engineering, 2007; National Research Council, 2010; Carnevale, Smith, & Strohl, 2013; Langdon, McKittrick, Beede, Khan, & Doms, 2011). What accounts for the discrepancies and the debate? Likely, the data are constrained by variables that do not paint a full picture of the supply and demand of STEM graduates and jobs. An NSF report recently noted that the data collected through the Departments of Labor and Commerce "suggests that the application of S&E knowledge and skills is widespread across the U.S. economy and not just limited to S&E occupations" (National Science Board, 2014 p. 3-11). In other words, capturing the full scope of the need for those trained in science and engineering is not present in the data, as it extends across occupations and careers not traditionally associated with STEM, such as finance, health-care delivery, and even fashion. Science and engineering no longer solely occupy distinct, easily identifiable fields or industries. Instead, as the developed world continues its transition from the industrial age to the information age, the amount and breadth of STEM training needed increases along with it.

This transition to a knowledge-driven economy has the parallel effect of not only requiring STEM knowledge across more of the workforce, but requiring a broader understanding of the social, economic, and environmental effect that a traditional STEM graduate can have on the larger society. For instance, in *Educating Engineers*, Sheppard, Macatangay, Colby, and Sullivan (2009) describe the new-century engineer emerging from the profound changes in technology. Engineers can no longer expect a linear environment, but rather a "network, web, or system" (p. 4). No longer are the "number of variables … severely constrained, and … problems reduced to quantitative dimensions," but systems are complex and "so heterogeneous that interdisciplinary interactive groups sharing perspectives and information are needed to create and control them" (as cited in Sheppard et al, 2009, p. 4). In other words, the professional engineer cannot continue to be a "disengaged problem solver" (p. 4) and, likewise, the methods used to educate new engineers cannot consist of disengaged students working through linear, constrained, quantitative problems with single answers. For the larger society, this means that fast-changing, globally-connected organizations can no longer simply make technical requests of siloed engineering departments and be effective, nor can an engineer toil away unnoticed, solving problems within a straightforward context and continue to advance and innovate. A more complex, inter-connected world is emerging and S&E jobs are adapting along with the change, putting pressure on our educational systems to not only produce more students capable in science, technology, engineering, and math, but students who understand how their role impacts a knowledge-driven, global economy. STEM graduates undoubtedly need to continue to be technical and scientific experts, but an expanded toolbox that includes the ability to identify and problem-solve for factors outside the confines of traditional engineering models, innovate socially, and apply principles of entrepreneurship are increasingly required in the age of information.

To take the intersection of STEM and the broader society even further, there is perhaps a growing need for citizen scientists and engineers. Positive social change needs citizens willing to apply their knowledge of STEM to solve difficult problems. Understanding, effectively communicating, and harnessing the science relevant to social problems can be a powerful tool for engaged citizens in debates over efficient use of limited resources, environmental impacts, and other information-intensive issues. The importance of citizen scientists and engineers may be best exemplified in the Civic Science movement captured in the work of Harry Boyte and the American Commonwealth Partnership. Boyte and Spencer (2012) write about science as a resource for action and a tool for human empowerment, emphasizing the importance for scientists and engineers to be more than experts offering information but active, engaged citizens solving problems in their own communities.

The makerspace movement is a recent phenomenon that exemplifies engaged citizen problem-solvers coming together to solve real and relevant problems. “A makerspace is a physical location where people gather to share resources and knowledge, work on projects, network, and build. Makerspaces provide tools and space in a community environment—a library, community center, private organization, or campus” (Educase Learning Initiative, 2013). Makerspaces are physical manifestations of the intersection of a knowledge-driven economy and a different, more connected scientist and engineer. This new wave of inventors and problem-solvers relies much less on large organizations and infrastructures, instead gaining knowledge and facility from each other and their community. Freed from reliance on organizations with large capital investment and structured networks, broad-thinking scientists and engineers are capable of being technical and social entrepreneurs—citizen scientists and engineers utilizing homegrown makerspaces to innovate and solve problems. How venerable institutions and organizations react to this new reality will likely play a large role in determining how much of society's technological potential is reached.

Barriers to Increasing STEM Graduates

It is within this context that STEM education looks to evolve, producing more STEM-capable students who can interact in complex people-driven environments addressing problems within industry, education, and communities. How does one begin to address this two-fold problem of quality and quantity of STEM graduates? As articulated in the sections that follow, research suggests that the problem can be divided into five distinct obstacles. In order to produce more and better STEM graduates capable of leading a knowledge-driven economy, the following issues need to be addressed: a) changing the perception of science and math as boring or difficult; b) responding to changing demographics; c) reducing barriers to access; d) managing resistance to organizational change; and e) reviving disengaged curriculum and students.

Challenges of the Pathway

The first three on this list—perceptions, demographics, and access barriers—are closely related and can be thought of as challenges of the pathway, affecting the number of young people able and willing to be trained in STEM. First, related to the perception of science and math as boring or difficult, many contend that not enough college students are graduating with science and engineering degrees due to high school graduates that enter higher education lacking interest in science, math, and engineering (MyCollegeOptions & Stemconnector, 2013). Those with interest are often unprepared for the rigors of introductory courses in math, physics, and chemistry, resulting in higher attrition rates compared to other majors (Stine & Matthews, 2009; Daempfle, 2003).

Second, these trends are also exacerbated by changing demographics that reveal a future of declining white male college graduates, who have long been more likely to matriculate into engineering majors and more likely to complete majors in science and engineering than women and minorities (Lord et al, 2009; Hurtado, Eagan, & Chang, 2010). Students of color also increasingly represent the typical new college student as U.S. demographics change. As of 2011, less than half of those born in the U.S. are non-Hispanic whites (U.S. Census Bureau, 2011). Additionally, it is well-documented that women enroll in and graduate from college at a significantly higher rate.

Third, barriers to access to higher education due to cost and preparedness may leave many students on the sideline, unable to persist at or even enter institutions of higher education. From 1991 to 2012, cost of attendance at all degree-granting institutions has increased 66% in inflation adjusted dollars (U.S. Department of Education, 2013). The full implications of costs is not known but evidence suggests that those with a lower socio-economic status are more susceptible to holding the view that college is not worth the cost (Beal & Crockett, 2013).

Problems of the Organization

The final two obstacles—managing institutional change and disengaged curriculum—are not challenges of the pathway of students, but of the organization and culture in which future STEM students attain their education and start their careers. Higher education institutions are hard-to-change organizations, often with long histories, that are subject to complex and intractable governance (Birnbaum, 1988). Institutional theory posits that organizations with long histories tend to mimic each other and settle into a steady, agreed-upon state, which is difficult to alter, ultimately reflecting the myths of their environments, rather than the emerging demands of the larger society they serve (Meyer & Rowan, 1977; DiMaggio & Powell, 1983). In other words, campus resistance to change is the fourth key barrier to producing more and better STEM graduates.

Finally, STEM education has been critiqued as providing a disengaged curriculum that produces disengaged students (Cech, 2014; Sheppard, Macatangay, Colby & Sullivan, 2009). This phenomenon is only exacerbated by a greater lack of engaged and interested women and underrepresented minorities (Su, Round & Armstrong, 2009; Hurtado, Newman, Tran & Chang, 2010). The challenge for STEM educators in higher education is to recognize the demand from their students, the economy, and the public for a different kind of education. Once recognized, these organizations can take creative steps to reform curricula and create new opportunities for student involvement that engages students—including women and minorities—pushing them to think of themselves as active citizens in an interconnected, technical, and knowledge-driven society.

To make progress in this area, a key question for faculty, administrators, and scholars to ask is, "What curricular reforms, co-curricular and extracurricular activities, and resources are necessary and effective for a 21st century scientist and engineer?" Colleges and universities continue to experiment with how best to educate their students, but there is much to be learned. Laudable and successful forays have occurred in service-learning, living-learning communities, integrated core curricula, writing across the curricula, capstone projects, and transitional programming, to name just a few. Also on this list is experiential learning, which may be especially suitable for young scientists and engineers needing a space to practice the expectations that will soon be thrust upon them. A positive experiential learning environment may allow them to discover how their technical or "hard" skills are enhanced by a full set of professional or "soft" skills and experience the full breadth of what a STEM education can be (Atman et al., 2010; Knight, Carlson, & Sullivan, 2007; Sheppard et al., 2010). Shuman, Besterfield-Sacre, and McGourty (2005) thoroughly discuss the nature and development of professional skills for engineering students, concluding that such skills can be "mastered as part of a modern engineering education format that utilizes active and cooperative learning, recognizes differences in learning styles, and is cognizant of teaching engineering in its appropriate context" (p. 51).

The New-Century Engineer

As described, the challenge of producing enough highly capable science and engineering graduates is a broad one. Engineers are tasked with solving important problems like making energy consumption more efficient, improving the capabilities of medical imaging devices, and shrinking our technological components to unimaginably small sizes. The challenge is not just making technology better and more useful, but doing it within numerous constraints including time, money, environmental impact, profitability, security, and caution. These constraints are often in opposition and changing, requiring a new type of engineer to ensure success.

Traditionally, higher education has provided solid lessons in the discovery aspect of engineering, especially for those who receive quality secondary education in mathematics, but has lacked the wherewithal to provide an education in dealing with real-world constraints, which are only growing more complex in an increasingly interconnected world (Sheppard, Macatangay, Colby, & Sullivan, 2009). Sheppard, Macatangay, Colby, and Sullivan (2009) report that engineers achieve more on GRE exams and increase their analytic and problem-solving skills more than all other major fields; yet express the lowest satisfaction with their college experience, have the lowest belief in their ability to change society, and see the least importance in developing a meaningful philosophy of life (p. 161). These results are not a recipe for producing engineers that will be—as stated earlier—ethically responsible, environmentally aware, people-savvy innovators.

The challenge for institutions of higher education is how to implement change that will produce engineers that meet what the Accreditation Board for Engineering and Technology (ABET) prescribes for its student outcomes (see Appendix A). In 2000, ABET implemented major changes to these requirements for student outcomes for their accredited institutions (Besterfield-Sacre, et al., 2000). ABET recognized that current education requirements and practices did not meet the demands of industry and society (Lattuca, Terenzini, & Volkwein, 2006). In response, they added eight student outcomes across programs including team-building, communication, life-long learning, knowledge of contemporary issues, design, and a broad education for understanding global and societal context (see Appendix A). Soon after, ABET commissioned a study on the changes and found progress in the preparation of engineers for a changing world (Lattuca, Terenzini, & Volkwein, 2006). This kind of new-century engineer stands to emerge from their training more fully engaged and ready to make instant contributions to their field and their community. In addition, not only are these attributes necessary for new century engineers, but they may open up the possibility of attracting a broader, more diverse set of students to the field. However, despite these laudable changes, advocates for change still describe engineering curriculum as an “obstacle course” that lacks “the integration of knowledge, synthesis, design, and innovation” (Duderstadt, 2008, p. 32-33). As of June 2016, ABET is in the process of altering the student outcomes for clarity and moving two of them to the curriculum section, but the tenor of the outcomes remains the same: emphasizing communication, ethical and professional responsibility, life-long learning, and teamwork, alongside the traditional outcomes of problem-solving, analysis, and experimentation. There is broad agreement that these outcomes are essential for the new-century engineer.

The literature suggests that addressing the three barriers related to problems with the STEM pathway—perceptions, demographics, and access barriers—are not the sole responsibility of colleges and universities. However, higher education institutions have a direct role in addressing organizational challenges—managing institutional change and a disengaged curriculum. Addressing these problems of the organization can potentially have an impact on the aforementioned challenges of the pathway. Regardless, institutions of higher education run the risk of stagnating within the safety of their history and organizational clout, but are in a position to produce the new-century engineers capable of succeeding in a knowledge-driven economy.

The Exceed Lab

Recently, the Department of Electrical and Computer Engineering (ECE), for which I am employed, partnering with the College of Science and Engineering's office of Collegiate Life and Student Engagement, built an experiential learning lab modeled after the idea of makerspaces, but serving the undergraduate student community on the University of Minnesota campus. *Signals* (2014), ECE's quarterly newsletter described the Exceed Lab as follows:

> A lab designed to accommodate student teams working on extra-curricular science and engineering projects through affiliated student groups or through the industry- and alumni-supported Envision Fund. Outfitted with necessary machining tools, electrical components, work benches, a room-length dry erase board and a touch-screen display and computer, the Exceed Lab is a young engineer's dream space for innovating, designing, and building.

The space now consists of three rooms totaling about 1,700 square feet of space, is mostly managed by students from affiliated student groups, and subsists on donations from alumni and industry who are interested in providing a space for students to design and build their own projects. Although most users are students in the College of Science and Engineering, it attracts students from other colleges as well who are in its many affiliated project-oriented student groups, especially the College of Design and the Carlson School of Management. In the fall of 2016, the College of Science and Engineering plans to open up two additional and larger spaces that will function as the Exceed Lab does, providing makerspace for University of Minnesota students to work on engineering-related design projects.

The Exceed Lab provides the backdrop for this study. Its genesis derived from a strong push from students for CSE to provide build space for the multiple projects they were already engaging in as well as from faculty and administrative leaders who saw the crucial need for a place for freshmen to engage with engineering projects as they arrived on campus. At the time of this writing, the lab had over 150 active users, most using the space to participate in extracurricular activities that consisted of building some kind of device or machine. Having witnessed firsthand the energy and passion that students put into their projects, I was compelled to take a closer look at this growing facet of an engineering students' experience at the University of Minnesota.

Purpose of the Study

The issue of increasing the quality and quantity of STEM graduates is complex and multi-faceted. Recognizing the breadth of factors that contribute to the STEM pathway, the purpose of this study is to examine the role that extracurricular project-based experiential learning (EPBEL) plays on student attitudes and experiences regarding the field of engineering. EPBEL refers to student designed projects that mimic the work of the student's chosen discipline and take considerable unsupervised and unstructured out-of-classroom time to complete. The projects are generally team projects that produce prototypes. As described above, research suggests that innovative curricular offerings, such as project-based learning, have a positive effect on a student engineer’s experience. More in-depth exploration of the role that project experiences play for engineers is a potentially fruitful area of study, in particular, extracurricular project-based experiential learning. My own experiences as an advisor in an academic engineering department suggest that many engineering students are shifting their limited time to out-of-classroom activities that involve the design and creation of engineering projects. This study examines the perceptions and experiences of nascent engineers to understand how these specific extracurricular experiences might contribute to their student experience.

The broad objectives of the study are to: 1) examine the role that extracurricular project-based experiential learning plays in the overall student experience for engineering students; 2) understand the conditions and resources that contribute to successful experiences for engineering students; and 3) explore promising practices for colleges of engineering in promoting high-quality student experiences. These objectives are situated in the larger context that began this chapter, as well as the challenges of the STEM pathway to college and the problems inherent in higher education organizations.

Research Question and Definitions

The research question guiding this study is, “How does extracurricular project-based experiential learning contribute to engineering students’ experiences?” To answer this overarching question, these following four exploratory queries help examine the underlying issues:

1. Why do students choose to participate in extracurricular project-based learning?
2. What do students perceive that they gain from participating in extracurricular project-based experiential learning?
3. What do students perceive as the necessary conditions to create a successful experience?
4. How do experiences with extracurricular project-based experiential learning differ among men and women?

The term *extracurricular* is defined as a non-credit and non-paid activity where the majority or all of the activity takes place in a campus context and is student-driven. This differs from curricular or co-curricular experiences, which suggest direction or structure from the student's chosen academic department. *Project-based experiential learning* is discussed extensively in chapter two and refers to the educational value of collaborative projects related to a student's field of study.

This chapter placed the study contextually within a major issue for higher education and our larger society, namely the importance of producing sufficient numbers of highly capable science and engineering graduates. The next chapter is a literature review that examines contemporary literature on student engagement and project-based experiential learning. The review of literature informed the development of a conceptual framework to guide my study, as introduced at the end of chapter two. Developing a thorough understanding of the context and literature allows for a critical exploration of how extracurricular project-based experiential learning contributes to the development of engineering students, a concept that is explored in the remainder of this study.

CHAPTER TWO: LITERATURE REVIEW

According to Kuh (2009), "student engagement represents the time and effort students devote to activities that are empirically linked to desired outcomes of college and what institutions do to induce students to participate in these activities" (p. 683). In particular, there is reason to believe that engagement activities related to experiential learning particularly resonate and positively impact engineering students (Atman et al., 2010; Knight, Carlson, & Sullivan, 2007; Sheppard et al., 2010). Exploring both of these connected areas thoroughly will lay a foundation upon which to explore the research question laid out above.

Student Engagement

Integration and Interaction

Perhaps one can trace the beginning of the conversation on student engagement to Tinto's (1975) seminal work on student retention. According to Tinto (1975), "other things being equal, the higher the degree of integration of the individual into the college systems, the greater will be his commitment to the specific institution and to the goal of college completion" (p. 96). This original literature examining college departure spawned a rich and immersive area of study that supports his integration hypothesis. Tinto (1987) expanded on his initial framework, instructing institutions of higher education to rethink traditional structure and concentrate on getting students actively involved on campus. Tinto identified two major sources that led to poor outcomes including (a) the absence of integration, namely incongruence or lack of fit; and (b) isolation, or lack of suitable interaction to foster integration. Tinto's (2012) most recent addition to his legacy advises clear and sustained institutional alignment to student needs across all elements of the institution, including high and clear expectations, academic and social support, assessment and feedback, and high social and academic involvement. Tinto's body of work argues that this type of systematic action and commitment is the path to meaningful outcomes for students.

Inputs, Environments, and Outcomes

Another pioneer in student engagement theory is Astin (1975, 1984, 1985, 1993) who used longitudinal data in developing his theory of student involvement. He hypothesized that the more involved a student is socially and academically in college, the more he or she will learn due to increases in motivation and interaction with faculty, fellow students, and other campus activities. Astin's (1984) contribution also speaks to the quality of involvement and thus engagement, emphasizing the importance of the "amount of physical and psychological energy that the student devotes to the academic experience" (p. 518).

Astin developed a model that had three elements, Inputs, Environments, and Outcomes (I-E-O). Inputs, such as gender, age, and socio-economic status, act as critical information used to construct the element that institutions can control: the environment. Environments are the attributes and characteristics of the institution that effect change. Outcomes refer to the psychological, behavioral, affective and cognitive growth in students. Astin recognized that higher education institutions could do "well" by simply picking those students already inclined for success but argued that the role of colleges and universities is talent development, not talent exploitation.

Particular to engineering, Astin's (1993) research discovered that choosing an engineering major had "negative effects on a variety of satisfaction outcomes: faculty, quality of instruction, Student Life, opportunities to take interdisciplinary courses, … the overall college experience, … writing skills, listening skills, [and] Cultural Awareness" (p. 371). He did find that engineering majors reported the highest growth in analytical and problem-solving skills. These outcomes may satisfactorily serve the isolated problem-solving engineer of the past century, but do not sufficiently prepare engineers entering the more complex knowledge-driven environment of today's economy.

Astin and Tinto were the central pioneers in the field of student engagement in the 1990s and beyond. They differ mainly in their approach to outcomes, with Tinto concerned with retention and persistence and Astin concerned with cognitive and affective growth. Both theorists ushered in a generation of researchers and educators who understood that creating the types of environments that foster the most student success and growth, no matter the inputs, should be every institution's goal, and that working to engage, involve, and energize students is the best pathway to such outcomes. Extracurricular activities related to students' majors are one such way to extract additional energy and effort from students and further their development. Specific to engineering students, institutions can provide environments that encourage and support experiential learning both inside and outside the classroom.

Motivation and Self-Efficacy

Before exploring the connections between engagement and extracurricular experiential learning, it is important to mention another research lineage that is seeing a convergence with the traditional student engagement literature. Student engagement literature has traditionally relied on behavioral measures of involvement with Astin (1984) writing that "it is not so much what the individual thinks or feels, but what the individual does, how he or she behaves, that defines and identifies involvement" (p. 519). However, issues of intrinsic motivation and self-efficacy can also play important roles in understanding student engagement. Bandura (1977) describes self-efficacy as the measure of "conviction that one can successfully execute the behavior required to produce the outcomes [desired]" (p. 193). There is a wealth of scholarship examining motivation and persistence; resiliency; identification with academics; and perceived ability and goal setting to name some of the strands of research (Walker, Greene, & Mansell, 2005). In addition, researchers are starting to explicitly explore the importance of psychological factors in measuring and understanding student involvement (Schreiner & Louis, 2011; Schreiner, 2013). For example, Baxter Magolda (1999, 2001) writes about the importance of self-authorship in student development, emphasizing the importance that lived experience, internal motivation, and contextualized co-curricular experiences play in truly meaningful student engagement. This vein of student engagement research all points to the importance of institutions molding environments that encourage students not just to persist to graduation, but to develop the motivation and self-efficacy to sustain meaningful connections to science and engineering.

Toward the goal of understanding, and thus improving, how engineering students specifically engage with their environments in higher education, the National Science Foundation commissioned the Center for the Advancement of Engineering Education

(CAEE) in 2003. The purpose of the Center was to conduct "research in engineering learning and teaching to support the education of a diverse community of engineers better able to meet the challenges of tomorrow in a world that continues to move faster and face more significant decisions than ever before" (Center for the Advancement of Engineering Education, 2011). The large majority of effort in CAEE focused on the Academic Pathways Study (APS) series. Sheppard, et al. (2010), as part of the APS, conducted the Academic Pathways of People Learning Engineering Survey (APPLES) to "characterize the engineering undergraduate experience and factors that influence undergraduate persistence in the engineering major and subsequently, the engineering profession" (p. 2). In 2008, over 4,500 undergraduate students at 21 universities who intended to be, previously were, or still were engineering majors took a 10-minute online survey. The survey focused on four broad areas: skills, identity, education and workplace, and produced five key findings related to an undergraduate engineer's experience. Of these findings, two are particularly relevant to understanding the environment best suited to producing successful engineers. First, "engineering students are principally studying engineering because they are psychologically and behaviorally motivated by the subject, and because they see that engineers can affect social good," suggesting the importance of enhancing students' motivation to study engineering through reinforcing college experiences, including extracurricular engineering activities, especially those that have a connection to improving society (p. 136). Second, high levels of motivation and confidence are important indicators for success in engineering, and students who participate in extracurricular activities are more likely to have high levels of motivation and confidence (p. 138).

Specifically for project-based learning, APPLES provides some data on participation rates and some interesting correlated data. Sheppard et al. (2010) report that in a sample of 869 first-year students, 61% indicate participation in individual project-based learning and 54% in team project-based learning (p. 36). There is a significant positive correlation between first-year students involved in team-based projects and their self-reported gain in engineering knowledge (p. 55). This self-reported knowledge increase may reflect how students engaged in the practice of engineering early, and develop the important elements of confidence and connection to engineering. Furthermore, these data suggest that courses or experiences that contain project-based experiential learning are key components for creating the type of environment that produces engaged and successful students.

From Theory to Practice

A central challenge for practitioners is to convert scholarly knowledge of engagement theory to effective practice. Chickering and Gamson (1987) translated developing engagement theory into practice with their "Seven Principles for Good Practice in Undergraduate Education." Chickering's (1969) previous work on identity development certainly influenced his influential list of principles that includes:

1. Encouraging contact between students and faculty.
2. Developing reciprocity and cooperation among students.
3. Encouraging active learning.

4. Giving prompt feedback.
5. Emphasizing time on task.
6. Communicating high expectations.
7. Respecting diverse talents and ways of learning (Chickering & Gamson, 1987, p. 3).

All seven of these principles are compatible and perhaps preferable in a well-designed project-based experiential learning experience.

Also influential in turning engagement theory into practice is Kuh (2001, 2003, 2009), who is responsible for the common definition of student engagement found at the beginning of this chapter. He is also largely responsible for the National Survey of Student Engagement (NSSE). First administered in 1999, the NSEE is a college-student survey that brings an essential measurement instrument to the understanding of student engagement. Kuh's work evolved from Pace's (1984) College Student Experience Questionnaire (CSEQ), the first major comparative survey to capture elements of the student experience.

Kuh was among the many researchers using NSEE and CSEQ data to dig deeper into engagement. For example, Carini, Kuh, and Klein (2004) tested the relationship between engagement and academic performance while controlling for inputs, finding that engagement is positively correlated to learning outcomes like grades and critical thinking. Pike and Kuh (2005) studied the specific effect engagement had for first and second generation students' intellectual development, finding that first-generation students were less engaged, and living on campus and having educational aspirations were crucial in increasing engagement.

Learning Communities

More relatable to project-based experiential learning is Zhao and Kuh's (2004) examination of the effect of learning communities on engagement, concluding that "participating in learning communities is uniformly and positive linked with student academic performance, engagement in educationally fruitful activities, … gains associated with college attendance, and overall satisfaction with the college experience" (p. 124). Specific to learning communities in the field of engineering, Olds and Miller (2004) found significantly higher graduation rates for students involved in a first-year learning community for first-year engineering students at the Colorado School of Mines. Learning communities and extracurricular experiential learning share structural similarities such as students interested in the same or similar academic fields, taking the same or similar courses, and participating in collaborative experiences. The body of literature connecting theory to practice is quite large, perhaps best exemplified by *Student Success in College* (Kuh, et al., 2010), a comprehensive examination of recent engagement research and how it is successfully applied in practice at a myriad of institutions. Among the suggestions for ensuring student success, Kuh, et al. (2010) found that quality institutions utilize active and collaborative learning as an effective strategy for student engagement and growth. Training the new-century engineer likely demands a particular set of learning and collaboration strategies built around such active and collaborative learning.

Extracurricular Activities

To that end, the scholarship in the field of student engagement is at a stage where a better understanding of how high-impact engagement within disciplines, distinct institutional types, organizational structures, and faculty culture is needed to improve student outcomes. Of special interest to this study is the role that extracurricular activities, especially as related to a student's chosen field of study, play in student development in their first and second year in college. Leading scholars agree that the first-year is critical to long-term success (Kuh, et al., 2008; Tinto, 2010, 2012). Cognizant of the importance of the First-Year Experience (FYE), institutions have assigned resources to learning communities, FYE courses, residential programming, and other programs geared at the first-year student. According to a survey by the National Resource Center for the First-Year Experience and Students in Transition, 87 percent of institutions offer a first-year seminar. However, little is known about how best to encourage social integration and engagement, especially when students leave the classroom and as they mature in their chosen disciplines.

Such outside-the-classroom interactions are extremely valuable to students. Kuh (1995) studied the effect that extracurricular activities had on a myriad of valued outcomes, finding that students reported the development of more complicated views, the synthesis and integration of academic program concepts, opportunities for leadership, planning and decision-making, and interaction with a diverse set of people. Gerber, Olson, and Komarek (2012) found that extracurricular design-based learning positively influenced students' skills and their confidence in participating in engineering related tasks. In addition, Gallup and Purdue University (2014) released an inaugural report on engagement in the work place and found that employees were twice as likely to be engaged at work if their college experience included opportunities for major related internships and projects and active involvement in extracurricular organizations. Not only is out-of-classroom involvement important while at school, but it has a sustaining impact on outcomes after graduation. Extracurricular activities that involve engineering related tasks have the potential to be an especially impactful engagement activity for new-century engineering students.

Service-Learning

Although generally offered as part of academic curriculum, service-learning is a good example of active experiential learning that often takes place in the context of a student’s major field and, like learning communities, shares structural similarities to extracurricular project-based experiential learning. Astin, Vogelgesang, Ikeda, and Yee (2000) found that participating in service-learning led to positive growth in 11 outcome measures, including academic performance and self-efficacy. Eyler, Giles, and Gray (1999) reviewed the literature and concluded that service-learning had positive effects on a myriad of student outcomes including personal, social, learning, career, and connection to the university. Ropers-Huilman, Carwile, and Lima (2005) studied a biological engineering service-learning course and found that service-learning provides value for reaching engineering specific learning outcomes.

Engineering projects in an extracurricular context share key attributes with service-learning, such as team-based approaches, outside-the-classroom experiences, and “real-world” problem solving. This likeness suggests that similar positive engagement outcomes are also possible for those who participate in extra-curricular engineering projects and there is some literature to support such a conjecture. For instance, Atman et al. (2010) suggested that entering engineering students often have little idea about what engineers do and that exposure to engineering experiences or projects may increase persistence. Knight, Carlson, and Sullivan (2007) found increased retention for students who participated in a first-year engineering projects course at the University of Colorado at Boulder, with an increase of 19% for the seventh semester for all students and 27% for women. Sheppard et al. (2010) also found a correlation between exposure to team-based projects and perceived importance of interpersonal skills. Extracurricular project-based experiential learning does not equate to the immersive, mentored experience of service-learning, but the parallels are instructive.

Higher education institutions have invested, for good reasons, in providing student access to engagement building through learning communities, extracurricular activities, and service-learning. Based on some of the structural similarities to these effective engagement experiences, extracurricular project-based experiential learning (EPBEL) represents a practice that may offer key engagement benefits to science and engineering students.

Project-Based Experiential Learning (PBEL)

Kuh et al. (2006), examined an expansive set of data from NSEE and found that “student engagement in educationally purposeful activities is positively related to academic outcomes as represented by first-year and senior student grades and to persistence between the first and second year of college" (p. 70). Relatedly, Baxter Magolda (1992, 2001) writes about the importance of interactions where students start to assign validity to their own thoughts and begin constructing their own knowledge. For young engineers this is especially important as their curricular demands include large amounts of abstract basic science and mathematics that affords little opportunity for personal knowledge construction. Thus, this body of research would suggest that project-based experiential learning is potentially an effective strategy to engage students through knowledge building opportunities early in an engineering curriculum that cements their interest in engineering and integrates them into the institution and the discipline.

Some scholars have found clear links between offering hands-on project learning and higher retention in the first year (Knight, Carlson, & Sullivan, 2007). Froyd, Wankat, and Smith (2012) argue that engineering education is in the midst of a shift toward a "renewed emphasis on design" and the application of "education, learning, and social-behavioral sciences research," which includes first-year project design courses and the application of project-based and cooperative learning in and outside-the-classroom. If such a shift is happening, it is crucial to better understand the role of extracurricular project-based experiential learning in the emerging engineering education environment. Leaving aside the extracurricular aspect momentarily, this section traces back the origins of experiential learning, defines experiential learning and project-based learning, reviews related learning models and activities, and explores the impact on motivation and self-efficacy.

The Origins of Project-Based Experiential Learning

At a basic level, project-based experiential learning refers to John Dewey's longtime association with "learn by doing," which succinctly (albeit poorly) summarizes Dewey's canon of work on education. Dewey's (1959) philosophy on education is best captured in his work, *Experience and Education* in which he declares "the only freedom that is of enduring importance is freedom of intelligence, that is to say, freedom of observation and of judgment exercised in behalf of purposes that are intrinsically worthwhile" (p. 69). Project-based experiential learning aims to be intrinsically worthwhile by freeing the student through a process of creativity, curiosity, observation, and open decision-making that results in something tangible and relatable. In the literature, scholars also refer to project-centered learning, active learning, problem-based learning, team model-eliciting activities, and experiential and project-based learning separately (Sheppard, Macatangay, Colby, & Sullivan, 2009; Johnson, Johnson, & Smith, 2006; Barrows & Tamblyn, 1980; Zawojewski, Diefes-Duz, & Bowman, (2008); Kolb, 1984; Jones, Rasmussen, & Moffitt, 1997). Although certainly important, if subtle, differences distinguish the terms, project-based experiential learning is the most appropriate term for this study, as it succinctly connotes "hands-on" through project and "practice" through experiential. The term allows for a broad understanding of the activity while still emphasizing the importance of learning by doing. The extracurricular element will be revisited again later leaving the importance of the setting out of the discussion momentarily.

Experiential Learning Model

Maria Montessori (1967/1995), famed educator of young children, said "the environment must be rich in motives which lend interest to activity and invite the child to conduct his own experience" (p. 92). Although speaking of the development of pre-school aged children, the quote encapsulates the connection of interest leading to experience. Expanding on that idea, Kolb (1984) writes, "this perspective on learning is called 'experiential' for two reasons. The first is to tie it clearly to its intellectual origins in the work of Dewey, Lewin, and Piaget. The second reason is to emphasize the central role that experience plays in the learning process" (p. 20). Kolb aligns Lewin's model of action research, Dewey's model of learning, and Piaget's model of cognitive development into his own model of experiential learning that he described as "the process whereby knowledge is created through the transformation of experience" (p. 38). Figure 1, utilizing a recast and critiqued version of Kolb's experiential learning model from Bergsteiner, Avery, & Neumann (2010), illustrates four ways of experiencing: *Concrete Experience, Reflective Observation, Abstract Conceptualization,* and *Active Experimentation.* These four ways of experiencing iteratively interact with four distinct learning styles, *Diverging, Assimilating, Converging,* and *Accommodating.* Project-based experiential learning ideally harnesses a student's natural interest and motivation to navigate an iterative path of evolving experiences, each of which enhance learning in different ways.

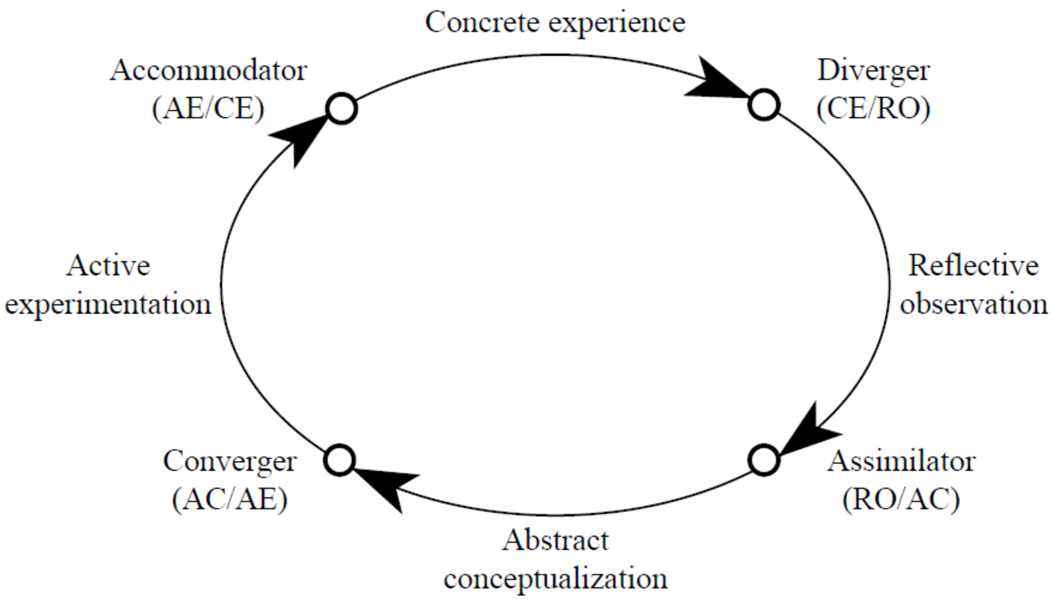

Figure 1: Kolb's Experiential Learning Conceptual Model

Project-Based Learning

Implementation of the experiential learning model is commonly done through project-based learning. Blumenfeld et al. (1991) defined project-based learning as:

> A comprehensive perspective focused on teaching by engaging students in investigation. Within this framework, students pursue solutions to nontrivial problems by asking and refining questions, debating ideas, making predictions, designing plans and/or experiments, collecting and analyzing data, drawing conclusions, communicating their ideas and findings to others, asking new questions, and creating artifacts. (p. 371)

Dutson, Todd, Magleby, and Sorensen (1997) described the relatively recent changes in engineering curricula that have brought back elements of engineering practice. After World War II, reacting to an increasingly complex technological environment, educators removed many of the traditional practical skills such as drawing and shop in favor of analytical training heavy in math and science. This newfound return to the basics was mainly achieved through senior capstone courses that implemented project-based learning as defined above. Dym, Agogino, Eris, Frey, and Leifer (2005) discuss the role of project-based learning in design pedagogy for engineers discussing how it is the ideal outlet for the application of convergent-divergent thinking and exemplifies Kolb's model of experiential learning.

Kolb's experiential learning model is a natural fit as a conceptual model for understanding the impact of project-based experiential learning in engineering education, because it is similar to design thinking and the design process of the field of engineering. Harrisberger (1976) identified experiential learning as crucial to quality engineering education because "engineering was perceived as being responsible for the creation and application of more sophisticated devices utilizing the newest scientific discoveries" (p. 2). The act of converting discovery into device is similar to the process of students taking the abstract concepts in their coursework and through evolving experiences in the lab or field, creating a project artifact. ABET (2013) suggests that "engineering design is the process of devising a system, component, or process to meet desired needs. It is a decision-making process (often iterative), in which the basic sciences, mathematics, and the engineering sciences are applied to convert resources optimally to meet these stated needs" (p. 4). Sheppard writes that engineers "scope, generate, evaluate, and realize ideas," (as cited in Dym et al., 2005, p. 104) providing similar language to Kolb. As mentioned above, Dym et al. (2005) describe design-thinking as iterations of divergent-convergent questioning and see divergent inquiry as lacking in engineering curricula. They then suggest a systems design approach to engineering problem solving that includes four aspects parallel to Kolb's model of experiential learning:

- Thinking About System Dynamics (Kolb's Concrete Experience)
- Reasoning About Uncertainty (Kolb's Reflective Observation)
- Making Estimates (Kolb's Abstract Conceptualization)
- Conducting Experiments (Kolb's Active Experimentation)

Dym, et al. (2005) go on to recommend project-based learning at the first-year level and making design pedagogy the top priority for educators.

Finally, outside the academy, there is a popular, business-oriented call for team-oriented project-based experiential learning. Tony Wagner's (2012) book *Creating Innovators* is a recent example that makes the case for the values of collaboration; multidisciplinary learning; thoughtful risk-taking; trial and error; creating; and intrinsic motivation through play, passion, and purpose. These innovation values are an additional way to understand the goals of project-based experiential learning manifested from Kolb's model of experiential learning.

Beyond Kolb, there are other useful ways of understanding the value and potential of project-based learning. A relatively recent entry into the conversation is model-eliciting activities (MEA), defined as "open-ended, realistic, client-driven problems that require the creation or adaptation of a mathematical model for a given situation" (Diefes-Dux, Hjalmarson, Miller, & Lesh, 2008, p. 17). In MEAs, generally a team of students design a mathematical model to solve a real world problem using materials and artifacts related to the problem. This type of activity reverses the typical project-based activity where students produce an artifact or product of their own. Nothing precludes the construction of an artifact, but the emphasis is on creating a mathematical model, with the process becoming the product. This type of experiential learning has the advantage of grounding the project in mathematics, allowing students to draw direct connections between the math they are required to learn and the real world project they are actively doing.

Yildirim, Shuman, and Besterfield-Sacre (2010) found that properly designed, MEAs lead to improved conceptual understanding and problem-solving processes. Diefes-Dux et al. (2010) make an argument that the proper use of MEAs will lead to increased motivation and persistence for women. The impact of MEAs requires more investigation, but holds promise in the fields of science and engineering education. Carefully designed MEAs have the potential to provide a concrete link between basic science and mathematics on the one hand, and engineering and science application on the other. This connection is an important goal for consequential project-based experiential learning aiming to increase student confidence and motivation to persist as engineers.

Active Learning

Active learning provides another way to think about project-based experiential learning. Johnson, Johnson, and Smith (1991) introduce active learning as a paradigm shift from pouring wisdom into an empty vessel to the active construction of knowledge by students. The authors identified six principles:

1. Knowledge is jointly constructed by faculty and students.
2. Students are active in knowledge construction.
3. Faculty effort is aimed at developing students’ competencies and talents.
4. Education is a personal transaction among students and between faculty.

5. Education can be cooperative rather than competitive.
6. Teaching requires reflection, training, and continuous refinement (Johnson, Johnson, & Smith, 1991).

Johnson, Johnson, and Smith (1991) discuss the long history and trail of research that demonstrates "higher achievement, more positive relationships among students, and healthier psychological adjustment" when compared to competitive and individualistic learning (p. 1:13). According to these scholars, active, constructivist learning is especially suited for an environment of interdependence, face-to-face interaction, accountability, small interpersonal groups, and clear process-oriented goals. Their review of the research demonstrates a connection between active learning and increased social support, better faculty and student relationships, and increased retention. Chi's (2009) taxonomy on learning activities describes active learning as physical activity that requires engagement and attending to a process. At its most basic level, project-based experiential learning requires students to be such active learners. Likely, more often students are constructive learners, or as Chi (2009) describes it, producing outputs through self-construction activities and the creation of their own process.

Group Learning

Further along on Chi's (2009) taxonomy is interactive learning, which usually takes place in the context of group learning. This type of group interaction adds substantive dialogue, co-construction, and the joint creation of process to constructive learning. Although not a requirement for successful project-based experiential learning, group learning and teambuilding is usually an important component of the experience for students. When project-based experiential learning becomes extracurricular in nature, the likelihood of the project involving a team increases even further. Springer, Stanne, and Donovan (1997) describe three useful perspectives, drawn from the literature, on how group learning functions. The first is motivational, where students shift from a competitive zero-sum mode of thinking with individual work to a cooperative mode with individual accountability and group goal-setting. Second is the affective perspective, which emphasizes more intrinsic motivation through nonthreatening and frequent interactions in small groups. This perspective contends that group-learning leads to a more natural and fruitful learning environment that is especially valuable to marginalized groups, who gain the opportunity to participate and have their voice heard. Third, the cognitive perspective posits that group learning facilitates more intense and critical interactions among its members, which leads to increased understanding and achievement. Regardless of which perspective best explains how group learning works, Springer, Stanne, and Donovan (1997) concluded that “students who learn in small groups generally demonstrate greater academic achievement, express more favorable attitudes toward learning, and persist through STEM courses or programs to a greater extent than their more traditionally taught counterparts” (p. 21-22).

Intrinsic Motivation

To understand why these early experiences in active cooperative learning provide positive benefits, it is important to examine student motivation. Sheppard et al. (2010) suggest that understanding intrinsic motivational factors may be key to understanding persistence and retention of young engineers. Similarly, understanding intrinsic motivation is key to understanding how project-based experiential learning relates to engaged, persisting, and retained students. Atman et al. (2010) contend that commitment to engineering depends on students identifying with engineering activities. Understanding an individual student's particular characteristics and experiences becomes important for devising effective strategies to increase motivation. For example, they contrast one student who "always liked building stuff" to another who announces "…what makes things work, taking things apart, and figuring all this stuff out, and all the intricacies, sometimes I just don't care about that" (p. 32). The former may be well suited to project experiences when he or she matriculates while the latter may need additional context before a team project effectively increases motivation.

To study motivation, Sheppard et al. (2010) used APPLES to assign values to students for six different motivational types as summarized below:

- Intrinsic Psychological Motivation: The student is motivated to study engineering for its own sake. He or she enjoys the inherent activity of engineering.
- Intrinsic Behavioral Motivation: The student is motivated by the practical and hands-on aspects of engineering, enjoying building and figuring out how things work.
- Financial Motivation: The student is motivated by the desire to secure a well-paying job.
- Parental Influence Motivation: The student is motivated by influence of parents, who may see engineering as a "smart" career choice or family tradition.

- Social Good Motivation: The student is motivated by the desire to make the world a better place.
- Mentor Influence Motivation: The student is motivated by personal relationships, not including parents, who are encouraging engineering as a field of study.

According to Sheppard et al. (2010), when students arrive at college, they are equally motivated by psychological/behavioral intrinsic motivations and social good motivation. Financial motivation is a close fourth, with the other two trailing by large margins. Although it was beyond the scope of APPLES to causally link intrinsic motivation to measured student retention, the authors correlated intrinsic motivation and the intention to complete an engineering degree (p. 48).

In the study, senior engineering students reported the following five items as their most significant learning experiences while in college:

- Encouraged or even required self-directed learning;
- Hands-on and/or clearly applicable to the real world;
- Enabled students to integrate a lot of diverse knowledge, to see the big picture;
- Provided intrinsic motivation by empowering students to own the experience;
- Challenged students (Atman et al., 2010, p. 45).

That list is remarkably similar to the basic definition of project-based experiential learning that emerged earlier in this section. Sheppard et al. (2010) further connect intrinsic motivation, project-based experiential learning, and persistence by showing a significant positive correlation between both (a) intrinsic-psychological motivation for men and (b) intrinsic-behavioral motivation for men and women with exposure to project-based learning (p. 47). Such exposure also positively correlates with social good motivation and mentor influence motivation. Altogether, project-based experiential learning has been shown to positively correlate with increases in four of the six motivational types listed above.

Yet, despite these robust findings, Eris et al. (2010) provide some data that complicates the link directly from PBEL to persistence in engineering. Their study indicated no difference or a negative correlation in the reporting of a project-based experience and persistence through two, three, four, and seven semesters, concluding that no trend exists. That study was confined to only four institutions, however, so the quality of the student experience may have played a role in the results.

Influencing Motivation

Overall, the majority of evidence suggests that there is much to be gained for colleges that utilize project-based experiential learning to facilitate student success, especially in engineering. Additional understandings about PBEL could lead to innovative methods of reaching targeted groups of students. For instance, under-represented minorities (URM) are both less likely to participate in extracurricular engineering activities and less psychologically motivated as seniors than non-URM, possibly suggesting an important role in developing strong internal motivation through team-based engineering projects (Sheppard et al., 2010). In the same vein, the realizations that—(a) social good motivation and participation in extracurricular engineering activities are highly correlated; and (b) women are more likely to be motivated by social good and mentors than men—indicate that project-based learning which emphasizes mentorship and community engagement could be especially powerful to support women in engineering. Prior studies within this domain are primarily quantitative and are limited in providing a full assessment of PBEL, with the extracurricular variety not assessed at all. Thus, an opportunity exists to create a richer understanding of how extracurricular project-based experiential learning contributes to internal psychological and behavioral motivations, as well as extrinsic motivators like social good and mentorship motivation. All four of these motivators can be influenced by institutional policy and curricula, as can, of course, the offering of PBEL. Such new knowledge, combined with proper institutional change, could prove critically important in attracting and retaining students in engineering.

Self-efficacy and Underrepresentation

PBEL also shows promise in understanding practices that support specific student populations. Additional research has been done on the retention of under-represented minorities (URM) and women in engineering, both of which have been shown to persist at a lower rate than white males (Atman et al., 2010, p. 27). Leslie, McClure, and Oaxaca (1998) examine the psychological phenomena of self-concept and self-efficacy, strongly suggesting that high levels of each lead to achievement in science and engineering for women, and possibly for URMs as well. According to the authors, development of self-concept comes first. If young engineers see themselves as having the ability and the desire to do mathematics and science, even if their experience is limited, they will develop self-concept as related to science, mathematics, and engineering. In other words, they will be able to conceptualize themselves as people who are able to do science, mathematics, and engineering. Self-concept evolves into self-efficacy, referring to the notion that behavior is derived from analysis of personal experiences, which in this case, is the personal experience of doing mathematics, science, and engineering. "Performance accomplishment" is the most important element of this experience, and if students view themselves as succeeding in their experiences, they are much more likely to cope with adversity and persist in tasks related to the experiences (Leslie, McClure, & Oaxaca, 1998, p. 252).

As for gender, Leslie, McClure, and Oaxaca (1998) point out that when entering college, men rate science and mathematics as more useful, are more confident about their mathematics and science ability, and have a greater interest. These gender differences result in higher levels of self-concept/self-efficacy for science and mathematics in men (p. 254). The authors suggest fostering commitment through peer reinforcement and academic challenges where women can build confidence through accomplishment. Project-based experiential learning fits into this mold and such experiences can be structured to offer the added dimension of mentorship.

Offering additional reasons for using PBEL to retain women engineering students, Kilgore, Yasuhara, Saleem, and Atman (2006) suggest using hands-on experiences for women to help them envision the active/experimental nature of engineering, as women make that association less often than men. Exposing women to active, hands-on aspects of engineering while also integrating the design and creative nature of the field would potentially increase self-efficacy and commitment to its study. Well-designed and supported PBEL activities can potentially fill this role starting in a student's first semester.

Extracurricular Project-Based Experiential Learning (EPBEL)

As previously stated, Sheppard, Macatangay, Colby, and Sullivan (2009) report that engineers achieve higher scores on GRE exams and increase their analytic and problem-solving skills more than all other major fields, yet express the lowest satisfaction with their college experience, have the lowest belief in their ability to change society, and see the least importance in developing a meaningful philosophy of life (p. 161). Meanwhile, ABET suggests that successful engineering students should be ethical, able to function on multidisciplinary teams, design systems within complex socio-economic constraints, communicate well to different audiences, all while understanding the potential impact they can bring to a global society. Closing the gap between graduates who are having less than meaningful experiences that do not inspire them to create change in their communities and the goals for the new century engineer is a critical challenge. This chapter has described the role that project-based experiential learning can and does play in closing this gap. Although PBEL has been shown to contribute positively to an engineer's student experience, if available only through the curriculum, it must be integrated into current coursework. Such a structure makes multidisciplinary work difficult, introduces the time constraint of semesters or quarters, and leaves in place a motivating structure tilted toward getting a good grade. To potentially address these challenges, this study explores the value of project-based experiential learning that is extracurricular in nature.

Kuh (1995) found that out-of-classroom experiences are of considerable value for developing leadership, learning to work with diverse sets of people, and "synthesizing and integrating material presented in the formal academic program" (p. 146). Based on evidence like this, there may be value in providing an environment for engineering students that emphasizes and encourages EPBEL.

College Impact Model

In order to explore whether extracurricular project-based experiential learning can be a valuable part of the educationally purposeful, out-of-classroom experiences necessary for the new-century engineer, a return to an influential general theory of student engagement and success is in order. The college impact model developed by Terenzini and Reason (2005) offers a powerful framework for exploring the potential effectiveness of EPBEL. The authors build on Pascarella and Terenzini's (1991, 2005) work showing clear links between first-year academic performance and both persistence and degree-completion. The Terenzini and Reason framework expands the understanding of environmental impacts on student change in college by offering distinct environmental elements to consider individually or interactively, including faculty behavior, organizational structure, cultures, the peer environment, and attitudes. The authors term this framework as a "college impact model." The framework (see Figure 2) considers variables inside three input and environmental categories:

- Student Precollege Characteristics and Experiences
- Organizational Context
- Peer Environment

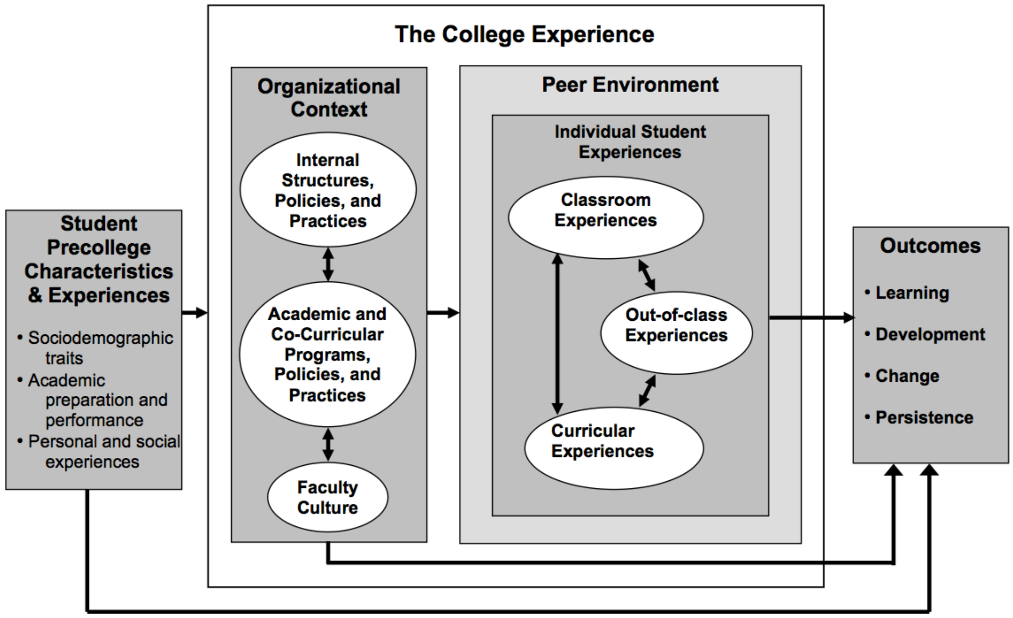

Figure 2: The Terenzini and Reason Framework

Although this study does not concentrate only on first-year students, the Terenzini and Reason framework adapts well to the full undergraduate experience. These three input and environmental categories all influence various measurable outcomes such as learning, development, change, and persistence. The framework is attractive in the context of this paper for two reasons. First, institutional effectiveness must be evaluated through the lens of *organizational context* to have true relevance to any particular institution. For example, the faculty culture can affect how extracurricular activities are offered and delivered. Is it best to provide close faculty interaction or best to encourage distance between faculty and students? Second, students must be understood as complex individuals with differing *characteristics and experiences* as they enter the institution in order to develop optimal strategies for engagement. An example of this is the student with little to no experience doing hands-on projects. Basic training and encouragement may be appropriate for this student while other more experienced students may be turned off by starting too slowly. These attributes impact the *peer environment* which is most germane to this study. Terenzini and Reason's framework serves as an effective aid to place the specific out-of-class experience of EPBEL within the larger context of the university toward the aim of better understanding how such out-of-class experiences affect the *outcomes* of learning, development, change, and persistence.

Considering the *organizational context* in regards to EPBEL, its success as a meaningful and resource efficient engagement experience is greatly impacted by the challenge of creating change within specific institutions and across the curricula of engineering education. Two levels of organizations are important in this context with the first being the individual college or university where students are majoring in engineering. Even if EPBEL were to be accepted by scholars as a crucial high-impact piece in engineering education, institutions may be constrained by resources, lack or inflexibility of facilities, fealty to tradition or the status quo, confusion of organizational level and hierarchy, and lack of effective leadership (Birnbaum, 1988).

Conversely, even if an institution is able to work through its constraints, the second type of organization, represented by the accreditors and driven by the culture of the academic engineering discipline, would need to approve. ABET's student outcomes have served as an important source for the arguments put forth in this paper, but those desired outcomes are not easily reconciled with the stringent curricular requirements of the ABET accreditation process and the typical discipline specific curriculum requirements at leading institutions. ABET requires 32 credits of basic mathematics and science and 48 credits of discipline specific engineering (ABET, 2013). These credit numbers are often exceeded by specific institution requirements, and my own experience at three public research universities tells me that workload for such courses is viewed by students as consistently higher than other courses on campus. Sheppard, Macatangay, Colby, and Sullivan (2009) report this as a consistent problem in engineering education dating back to the Mann report of 1918—widely seen as the first ever evaluation of engineering education—as the engineering curriculum is overcrowded, theoretically heavy, pedagogically stale, and highly structured (p. 22); or as Duderstadt (2008) put it, "an obstacle course" (p. 34). The curricular culture, embodied by ABET and magnified by common practice, is another potential challenge to advancing PBEL in an institutional context.

Student precollege characteristics and experiences, referring to the pathway mentioned in the introduction, provide an additional challenge for the implementation of successful extracurricular project-based experiential learning. First-year student exposure to and skill level in engineering, science, and mathematics can vary greatly and have a large effect on any institutions ability to develop the self-efficacy, confidence, interest, and intrinsic motivation so important to retaining and attracting young engineers. Institutions may have limited impact in this regard, especially if they commit to educating a diverse population of students.

An Engagement Framework for EPBEL

Despite concerns about the potential constraints that *organizational context* and *student precollege characteristics and experiences* can have on creating a positive EPBEL experience, there is—as documented in this chapter—many reasons to explore

EPBEL in the peer environment. Terenzini and Reason (2005) highlight Astin's (1993) conclusion that "*the student's peer group is the single most potent source of influence on growth and development during the undergraduate years*" (p. 398, emphasis in the original). Peer environment, in this context, encompasses more than a group of friends or fellow students but the "broader, more general, and subtle set of influences that are more easily sensed than measured" (Terenzini & Reason, 2005, p. 11). It is the individual student experience within the peer environment that is rich in information crucial to understanding the learning and development of said students.

Most germane to this study, Terenzini and Reason (2005) relate that "the possibilities for out-of-class impacts are substantial, and their impacts on academic, as well as psychosocial or attitudinal outcomes is only now coming to be adequately documented" (p. 12). Building on the Terenzini and Reason framework, Strauss and Terenzini (2007) studied 4,200 graduating engineering students, referencing "a growing body of evidence indicating that, in addition to their classroom-based cognitive growth, students develop higher-order thinking skills through a wide array of experiences *outside* the traditional classroom" (p. 968, emphasis in the original). Their results concluded that out-of-class experiences contributed to student learning in analytical skills and groups skills, the two areas they chose to study.

This chapter has been building a framework in which to think about where extracurricular project-based learning fits on the spectrum of various related learning activities and methods. Learning communities, service learning, extracurricular activities, group learning, active learning, and project-based learning all have varying success in promoting engaged, active learners who persist in college. These various experiences also have been shown to have significant commonalities and overlap with extracurricular project-based experiential learning. We also know that out-of-class experiences, including extracurricular activities contribute to student learning. Figure 3

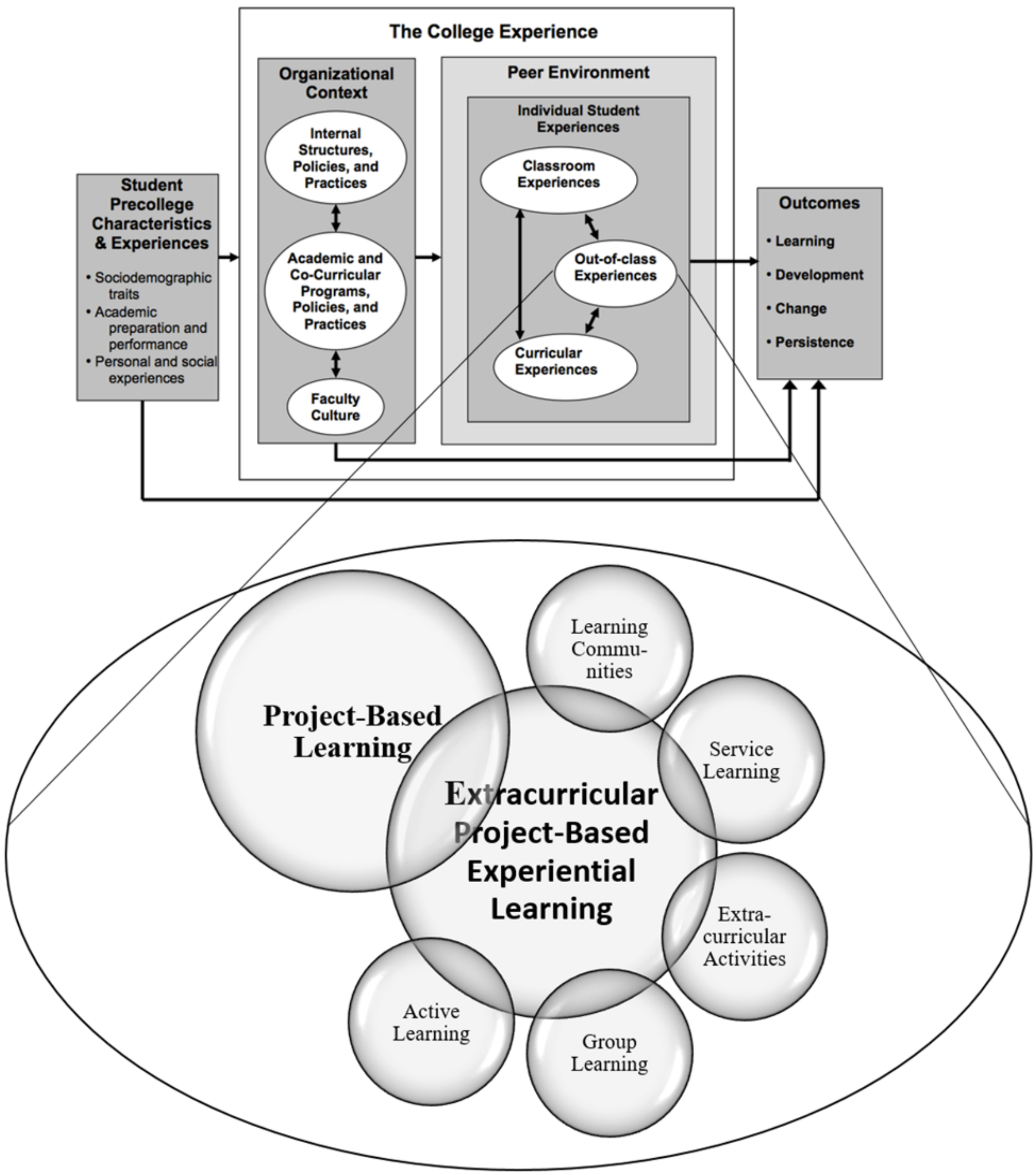

Figure 3: College Impact Model

represents these sets of relationships and where they exists within the College Impact Model, creating a useful engagement framework for extracurricular project-based learning. This particular framework provides a theoretical underpinning for the understanding of engineering students' perceived *outcomes* and experiences as related to EPBEL. Chapter Three outlines the method undertook to investigate the out-of-class student experience through extracurricular project-based learning and its reported outcomes within the peer environment.

Despite the challenges of implementation, the successes of other similar types out-of-class experiences show that extracurricular project-based experiential learning in the field of engineering is worthy of further study. In its ideal aggregation, EPBEL is the hands-on practice of engaging through one's own action, judgment, and observation in an intrinsically worthwhile, collaborative, and iterative process that ultimately transforms the very experience itself. Facing the challenges of the transition to a knowledge driven economy as described in chapter one, EPBEL theoretically shows promise in attracting and preparing students for their new-century roles as ethically responsible, environmentally aware, innovative, citizen engineers. Thus, it is worthwhile to examine the student experience to gain an understanding of how EPBEL contributes to their education.

CHAPTER THREE: RESEARCH METHODOLOGY AND METHODS

Methodology

The purpose of this study is to understand how extracurricular project-based experiential learning contributes to engineering students' college experiences. This study is a qualitative case study drawing on perspectives of engineering students at a single university. The questions for the study were developed to elicit comments regarding the learning experience of such projects, the effect on engagement, the effect on self-efficacy, and how the projects prepared students for their professional careers. This chapter provides a rationale for the method, describes the bounded case, and outlines the process of data collection and analysis.

A case study consisting primarily of interviews with engineering students is chosen due to the bounded nature of this study and the desire to obtain data with exceptional depth. Kvale and Brinkman (2009) explain that "the qualitative research interview attempts to understand the world from the subjects' points of view, to unfold the meaning of their experiences, to uncover their lived world prior to scientific explanations" (p. 1). To more fully understand the effect of extracurricular project-based experiential learning on students' experiences, it is imperative to foster complex and open conversation that produces, as Merriam (2009) puts it, "an in-depth description and analysis of a bounded system" (p. 40). In this study, a bounded system is comprised of engineering students who use a particular maker-space designated for experiential learning projects.

To further elucidate this particular case study methodology, it is useful to discuss Merriam's (2009) types of case studies. She distinguishes between historical organizational and observational for one typology. Historical organizational uses historical context and change for analysis whereas observational concentrates on a particular aspect of an organization in the present time. This study is of the latter type, studying a particular group of participants in a single organization. Relying on Stake (2005), Merriam also differentiates between intrinsic, instrumental, and collective case studies. Intrinsic describes a study undertaken to investigate that particular case, with little or no interest in generalization. On the other end of the spectrum, collective case studies have little or no interest in any particular case, but are interested in making sense across multiple cases to investigate a larger phenomenon. This study is best labeled as instrumental in nature, as the case study is meant to facilitate the understanding of an issue, more specifically here, extracurricular project-based experiential learning. However, it retains intrinsic properties as well, as this researcher is very interested and invested in this particular case.

Research Question

The research question guiding this study is, "How does extracurricular project-based experiential learning contribute to engineering students' experiences?" To answer this overarching question, these following four exploratory queries help examine the underlying issues:

1. Why do students choose to participate in extracurricular project-based learning?

2. What do students perceive that they gain from participating in extracurricular project-based experiential learning?
3. What do students perceive as the necessary conditions to create a successful experience?
4. How do experiences with extracurricular project-based experiential learning differ among men and women?

The first question explores the baseline motivation for students' participation in extracurricular project-based experiential learning. The second question elicits understandings about how and if student learning, engagement, self-efficacy, and new-century engineering skills are developed. The third question explores insights into the EPBEL experience as it relates to their success in college. The final question explores the possibility of gender differences, probing for differences in the way women and men experience EPBEL.

Beyond the guidance from the research question, the interview questions are derived from two interacting conceptual frameworks. The first was discussed at the end of Chapter Two, is represented by Figure 3, and grounds the study in the engagement literature, allowing for analysis and interpretation through that frame. The other framework is Kolb's Experiential Learning Conceptual Model represented by Figure 1. This framework allows for analysis of the students' perceptions of the learning through the EPBEL process and observations of their group interactions.

To expand on the Kolb Model's application for this study, it is important to understand the parallels between the basic iterative engineering design approach and how

Kolb models the advancement of learning through the navigation of the experiential learning iterative pathway. Relying on these models allows for understanding ways in which experiential learning contributes to knowledge and skills espoused as being critical for the new-century engineer.

The Bounded System and Study Participants

This case study site is the College of Science and Engineering (CSE) at the University of Minnesota. According to the Carnegie Classification of Institutions of Higher Education, the University of Minnesota is a research university with very high research activity offering a range of majors and experiences for students through curricular and extracurricular courses and activities. Unusual among U.S. universities, CSE not only hosts the 12 engineering majors on campus but also is home to majors in the physical sciences. CSE enrolls nearly 5,000 students of which 24% are women. Around 60% of graduating students in the college are engineering majors. Students who identify as engineering majors and have completed at least one year at the University of Minnesota constituted the sample set. The requirement for one year is to ensure enough time to take part in an extracurricular experiential learning project. In addition, the College of Science and Engineering hosts 75 extracurricular student groups, of which a significant, but unknown number, offer project-based experiential learning.

Within this large sample set, students were selected for this study through a number of factors, resulting in nonprobability sampling. Merriam (2009) explains that because generalizability is not a goal of most qualitative research nor this study, nonprobabilistic sampling is the most appropriate choice for the exploratory nature of the above research question. Instead, qualitative research is focused on "understanding how people interpret their experiences, how they construct their worlds, and what meaning they attribute to their experiences", which is most appropriate for addressing my research question (Merriam 2009, p. 5). Thus, I focused on a sample that allowed this researcher to understand the various ways in which EPBEL shapes the student experience.

The first method of identification was selecting students who have access to the extracurricular makerspace I oversee in the Department of Electrical and Computer Engineering, called the Exceed Lab. Opened in 2013, the Exceed Lab is a collaborative endeavor of the Department of Electrical and Computer Engineering, the College of Science and Engineering, and two active project-oriented student groups on campus called Tesla Works and Innovative Engineers. The initial remodeling of the lab and its continuing expenses are funded mostly by alumni and industry sponsors looking to provide space for students to work on experiential engineering projects. The Exceed Lab is open to all students and attracts mostly CSE students. Students must apply for access, complete online training, and indicate that they are working on an extracurricular engineering project. Each student was cross-referenced with academic data to determine if he or she is an engineering major, an undergraduate student, and has been on the University of Minnesota campus for at least one year. The list was further culled of any students that I have a current relationship with due to planning partnerships in the Exceed Lab, employment, or advising. This particular subset produced a list of 112 potential interview subjects, representing engineering students who have self-selected into extra-curricular experiential learning projects. However, as articulated in Chapter One, there is also a specific aim to differentiate the impact of EPBEL on women who are underrepresented in engineering in order to better understand how to rectify the disparity. Due to this, more women than men were represented, with four of the 10 participants being women. Table 1 lists the participating students using pseudonyms along with their gender identification, major, and year in college at the University of Minnesota. All students interviewed started as traditional freshmen.

Table 1: List of Participants

Pseudonym	Gender ID	Major	Year in School
Michael	Male	Computer Engineering	Second
Emily	Female	Computer Engineering	Third
Matthew	Male	Mechanical Engineering	Third
Jacob	Male	Electrical Engineering	Fourth
Christopher	Male	Mechanical Engineering	Fourth
Jessica	Female	Chemical Engineering	Second
Ashley	Female	Electrical Engineering	Fourth
Joshua	Male	Chemical Engineering	Fourth
Nicholas	Male	Material Science Engineering	Second
Sarah	Female	Biomedical Engineering	Third

Data Collection

Data collection consisted of three elements: interviews, observation, and artifact analysis, constituting the classic strategy of triangulation across multiple methods of data collection and which Merriam (2009) describes as a method to shore up the internal validity of a study. Interviews are the main element with the observations and artifact analysis serving the purpose of increasing credibility and validity. According to Kvale and Brinkman (2009),

> The very production of data in the qualitative interview goes beyond a mechanical following of rules and rests upon the interviewers' skills and situated personal

> judgment in the posing of questions. Knowledge of the topic of the interview is in particular required for the art of posing second questions when following up the interviewee's answers. (p. 82)

This study was approached with this view of interview craftsmanship, understanding that it is not simply mechanical preparation that is required but a full understanding of the subject matter meshed with a skillful and careful approach to the social interaction that is a qualitative research interview.

Interviews

The first interaction in the interview sequence is crucial to the craft of collecting valid and reliable interview data. To encourage students to participate in the interviews, the initial email (Appendix B) appealed to a sense of belonging to the community of inquiry and research at their university, while assuring participants that anything they say will be strictly confidential. Emphasis was placed on the importance of understanding the effect EPBEL has on their educational experience, appealing to their own sense of curiosity and desire to potentially advance knowledge in an activity they have freely chosen to participate in. Those who responded affirmatively were emailed a follow-up correspondence (Appendix C) asking to review the consent form (Appendix D) and to set up an interview time. All procedures and correspondence complied with the University of Minnesota's Institutional Review Board (IRB). The interviews were scheduled for 60 minutes and conducted at their convenience on campus, making it a relatively small commitment. At the beginning of the interview, the consent form was reviewed. Cognitive interviewing techniques were also employed before students signed their consent ensuring a fully engaged set of interviewees (Appendix E). A pre-interview script was read to the participant to start the interview (Appendix F). The audio was recorded for transcription purposes, and the audio was destroyed as soon as the transcription was completed (within a month).

The interview protocol (Appendix F) is intentionally designed to elicit answers that map to my conceptual framework. All questions are steeped in the *individual student experience*, more specifically, the *out-of-class experiences* that Terenzini and Reason (2005) describe and are illustrated by Figure 2. Question one asks the student to explain their project and their role in the project, while question two asks them to reflect on their choice to participate. Questions three through six explore students' perceptions of their learning, their engagement, their self-efficacy, and their career preparation, priming them for question seven, which asks them to talk about the process of "doing" their project. Question eight asks the students to explain the value of the experience, allowing for potential analytical connection between Kolb's model and perceived gains or losses in this educational experience. Finally, question nine queries the perceived conditions under which the students worked on their projects. The closing questions allow the student to express their thoughts in an open-ended manner and ask about a possible observation. These questions are intentionally designed to elicit responses that map to the rich conversation on engagement and experiential learning from chapter two, as well as potential mappings to Kolb's experiential model.

Interviews were conducted until saturation was achieved, meaning that no significant new information was coming from the most recent interview subjects and new themes were not emerging (Merriam, 2009; Lincoln & Guba, 1985). Twenty-seven students from the list of qualifying Exceed Lab users were randomly selected to be contacted for interviews. These contacts resulted in 10 interviews.

Observations

At the conclusion of several of the interviews, I sought permission to approach his or her peer group (if it existed) to consent to a thirty minute observation while working on their project. The observations were primarily used to verify and confirm the project build process that students described in their interviews. According to Merriam (2009), observation offers the advantage of direct firsthand interaction with the phenomenon of interest in its natural setting, rather than a secondhand account in an unrelated location, i.e. interview room. Merriam (2009) outlines the possible observational stances a researcher can take and in this case it is “observer as participant,” as the observer activities are known to the group but the level of information and the activity itself is controlled by the observed group (p. 124). Descriptive notes were taken with Kolb's experiential learning conceptual model in mind, paying special attention to what part of the iterative model the group was in and how they were working their way to the next.

Artifacts

Finally, after analysis of the interviews and observations, requests to inspect and collect photos of the various artifacts produced in the Exceed Lab makerspace were requested to complete triangulation. Twelve total photos were collected of projects the interviewees had worked on, many of which are featured in chapter 4. I was able to personally inspect six of the projects in person as well. Merriam (2009) refers to data triangulation as using multiple sources to compare and cross-check the collected data.

These artifacts provide more descriptive information and connections to interview and observation data, creating a concrete link between socially collected data and a primary stable source. In the cases where an artifact was available, inspection led to a complete triangulation of data for a particular interview subject, showing progress and providing additional evidence to corroborate responses in the interview or observations. At the very least, the artifacts add context, allowing this researcher and his readers a fuller picture of what the subjects are attempting to accomplish.

Data Analysis

Merriam (2009) tells us that “a case study is an intensive, holistic description and analysis of a single, bounded unit” (p. 203). With the help of computer software, analysis commenced with the first interview and continued through the analysis of produced artifacts, using a constant comparative technique. Heuristic, discrete units of data was coded and categorized, first through the note-taking process within the interviews and observations and later through the transcripts, once available. Constant categorization refers to revising the categorization as coding continues and as new information is added. As Merriam (2009) details, this process starts out very inductive, but becomes more and more deductive as themes develop and categories crystalize until a saturation point is reached in the interview process. The analysis was in response to the research question at all times and as Merriam (2009) suggests: (a) was as sensitive to the data as possible; (b) was exhaustive; (c) was mutually exclusive; and (d) was conceptually congruent. As described above, the college impact model, the engagement framework for EPBEL, and the experiential learning conceptual model informed the creation of the interview questions and the focus of the observations, and also provided theoretical context for this analysis. Of course, the goal of this analysis is to provide answers to the research question and bring about further questions and insights into how to educate the new-century engineer.

Reliability and Validity

Addressing reliability and validity is considered of utmost importance by this researcher. Below are some technical strategies that were undertaken to ensure reliability and validity were maintained. Commercial software, specifically *f4analyse,* was used to organize and analyze the interview data, as well as transcribe the data. A collection of rich, thick, descriptions was created so readers and the researcher are sure to understand what is being described at all moments. Utmost care was taken to code thoroughly and consistently so proper triangulation can occur across the various interviews. Member checks are built into the interview script. These checks ensure that the understanding of the interviewer comports with that of the interviewee. Data analysis utilized a method of constant comparison with the help of the software.

Beyond procedure, Merriam (2009) identifies multiple strategies for promoting validity and reliability. Member checks was employed to ensure that initial interpretations were consistent with the participant's recollection. Triangulation is also part of the design through the use of multiple methods, namely interviews, observation, artifact analysis. Adequate engagement in data collection is achieved through a saturation of the data. Rich, thick descriptions are also included in the analysis of the data. These strategies and procedures help to provide the reliability and validity necessary for a research study.

Researcher Bias and Assumptions

The final part of this section will address various ethical considerations. All collected data was safeguarded. The safeguarding was accomplished by interviewing in private rooms; keeping recordings, transcriptions, and notes encrypted; and giving clear assurances that anything said will not be associated directly with the interviewee and kept confidential. A detailed informed consent was sent prior to the interview and was reviewed before commencement of the interview (See Appendix D). Cognitive interviewing techniques were also employed before students gave their verbal consent to engage in the interview (See Appendix E). An important consideration is the self-selective nature of the student sample itself. Extracurricular activities are freely chosen by students and it is expected that they would view the experience in a positive manner. For this study it was important to design questions and conduct interviews in a way that gleans why EPBEL is attractive to students and whether it truly enhances their learning, engagement, and self-efficacy.

Finally, researcher bias should be acknowledged. As Merriam (2009) details, “investigators need to explain their biases, dispositions, and assumptions regarding the research to be undertaken” (p. 219). As an advocate for both students and extracurricular activities for students, I expected extracurricular project-based experiential learning to contribute positively to students’ experiences. I am aware of this bias, choosing language carefully and analyzing critically, with great care taken to ethically present the data in an unbiased and objective manner.

CHAPTER FOUR: FINDINGS

This study asks the question, “How does extracurricular project-based experiential learning (EPBEL) contribute to engineering students’ experiences?” To answer this larger question, this qualitative case study utilized the following exploratory questions in the design of interview questions and observations:

1. Why do students choose to participate in extracurricular project-based learning?
2. What do students perceive that they gain from participating in extracurricular project-based experiential learning?
3. What do students perceive as the necessary conditions to create a successful experience?
4. How do experiences with extracurricular project-based experiential learning differ among men and women?

Chapter Four lays the groundwork for the following chapter where the role that extracurricular project-based experiential learning plays in student engagement, engineering education and learning, and self-efficacy is discussed along with implications for colleges and universities, particularly schools of engineering.

Interview Participants and Observations

Ten students were interviewed in a structured interview environment and their interviews were transcribed. Six of the students were men and four were women. All of the students were engineering students who have had at least one full year at the University of Minnesota studying engineering. The students each had majors in one of the following: Electrical Engineering, Computer Engineering, Mechanical Engineering, Chemical Engineering, Biomedical Engineering, and Materials Science and Engineering. Three observations were also conducted, each involving one of the interview participants and a larger group of students working on an extracurricular engineering project. Photos of the various artifacts created by the interviewees and other EPBEL students were also collected to add context for the reader. The following findings draw the vast majority of their data from the interviews, except for the section on the experiential learning process, which also uses data from the observations.

Results of Data Analysis

As described in Chapter Three, data analysis consisted of the coding and categorization of the transcripts through a method of constant categorization. This method resulted in seven primary categories directly related to the larger research question, two additional categories worth discussion, and a bevy of themes under the umbrella of the seven overlying categories. The seven categories with their underlying themes developed by the sixth interview, retrospectively indicating that saturation had been reached. The remaining four interviews provided additional supporting data and allowed for a reasonable confirmation that few to no additional categories or even themes would be uncovered through additional interviews. The rest of this chapter weaves these seven primary categories and the two additional categories into a presentation of findings that aligns with the four underlying exploratory questions plus a summary description of the extracurricular project build process that incorporates data from the observations.

Reasons for Participating

The second interview question, asked immediately after students were asked about the extracurricular projects they are participating in, inquired as to why they choose to participate in extracurricular engineering projects. This directly addresses the first exploratory question. Their responses resulted in the identification of three themes that provide a window into why students choose to participate in extracurricular project-based experiential learning and why they often continue this experience for most or all of their college career. Those three themes are the challenge and intrigue of application, teamwork and mentorship, and a sense of balance.

The Challenge and Intrigue of Application

All ten students identified some aspect of wanting to apply their burgeoning engineering skills as a reason why they wanted to take part in EPBEL. This reason was especially common when they initially looked into doing projects outside the classroom, usually as freshmen or sophomores. As Ashley, a senior student put it:

> I don't know, same reason I'm doing electrical engineering from the beginning. I want to build these things, I have ideas and now I happen to know a lot, I don't want to say a lot, but I happen to know a lot about building these things, so naturally if I can do it, then I would like to do it. So that was kind of the reason I started to do more stuff on top of the class. Because the class doesn't necessarily incorporate your personal passions or your personal ideas so it’s just a great resource to have if people are motivated to do something more.

Ashley was not alone in expressing the sentiment that EPBEL was their only outlet for combining their own passions and interests with engineering. Students also implied that to get the full experience of learning to be an engineer, you need projects:

> I was interested in them and wanted to learn more basically. A lot of people say, pretty early on I was hearing about how in college you'll learn some, but not enough. You don't learn how to apply a lot of it. (Jacob)

Or, more succinctly put, “Because you learn a lot that you could never get out of your classes” (Jessica).

Relatedly, another common response was that building projects was interesting and fun: “And it’s just fun to do, help build or create something” (Jessica). Figure 4, a animatronic singing quartet of University of Minnesota President Erik Kaler, represents a creative project built for fun. Related to the project he was working on Michael remarked, “I find algorithm design and software design really interesting. It's a really interesting problem that involves a broad idea of things. So, putting all those software skills together and working on an idea I find interesting.”

Figure 4: An Animatronic Singing Quartet of the U of M President, Eric Kaler

Beyond the intrigue of applying their engineering skills, students were also drawn to the challenge of problem solving in the context of extracurricular projects. Here's Michael again:

> I think the most valuable part is really going through the really challenging part. …The perseverance to go through with those difficult challenges. I think that is a major thing you learn from doing projects like this. Where there's always some viewpoints where you think nothing will work out, because you get stuck at some critical point, but there's always a solution if you keep working hard enough.

Nicholas probably sums up why students are drawn to EPBEL and why they continue to find value in continuing to participate:

> I found myself writing a personal statement and cover letter recently and I started talking about this project learning and things like that. I surprised myself about how adamant I was about getting out of the classroom and doing stuff. I've been lucky enough to have a construction job over the summers and that's where a lot of engineering problems happen and its real world applications of engineering. It's one thing to have problems in the classroom … but you still aren't having to see it for yourself. You aren't watching the failures happen. In project based learning, outside the classroom, that's where you see, well shoot, you have this problem and how are we going to fix it. It's more drawing from a lot of different classes as opposed to focused on one thing.

Michael and Nicholas speak to the true challenge of engineering that EPBEL offers, solving critical problems when there is no manual or instructor with an answer or even certainty that a solution is possible.

Teamwork and Mentorship

Although most students seemed to seek out EPBEL because they wanted to find outlets to apply engineering outside the classroom, when probing questions asked them to reflect on why they choose to continue or what they find most valuable about the experience, many students focused on the teamwork aspect of project building. All 10 students mentioned the opportunity to work with others at some point in the interview as having value to them.

For some it was about friendship and companionship, as Emily related:

> Probably the companionship you gain through the projects. I really love learning all the technical skills and advancing my technical skills and learning hands-on things, but I don't think I'd make it through an entire intensive project like that without the pretty amazing people I get to work with and you get to know them very well and you get to work on a team and you end up sort of finishing the project with them. If you don't like your team or can't work with your team, it sort of all falls apart quite a bit.

For some, these connections to other students are valuable in their own right, regardless of how the project comes out. Matthew elaborates:

> I'm speaking for me, but also for a lot of students I see, the community aspect is probably the most important part from a day to day perspective, so you're connecting with other students and usually others students and faculty around you. So, regardless of what the project is, or if it completely fails, you still are meeting interesting people and learning things from each other.

Five students mentioned working on the CSE Light Show, an annual winter light show started by students in 2012 that now attracts thousands every year over multiple events (See Figure 5). The light show setup is a large communal effort over many evenings and nights in very cold temperatures, where long-lasting friendships are built.

Figure 5: CSE Light Show from December 2015

In a related manner, students were also drawn to projects due to the interdisciplinary nature of them as illustrated by this comment from, Jessica, a Chemical Engineering major, "it's all very interdisciplinary, so I've learned soldering and all sorts of skills that I would never have had access to otherwise." It is not just the exposure to other disciplines, but the opportunity for mentorship, as Matthew relates:

> I think that's another thing, just getting...finding a role for younger students on the team too, like underclassmen, who are excited to help but maybe don't know how to do something, but also telling them that that is OK and that they should jump in and this is there opportunity to learn that thing that they don't know. That's usually an odd step for people, they might not be used to saying or doing the project and proving that it is possible is how you learn it is possible.

and the spirit of communal assistance, or as Christopher volunteered:

> I guess a lot of the times you are working on a project and you don't have experience with something. The great part about being in a club or in a room like

> that, where it's just filled with people working on projects, there's a group knowledge. So, if I didn't know how to solder and someone else was at a soldering station, I could walk over and get a few pointers. Or if someone was working on a wiring diagram and they needed help, they could literally turn around and say "Hey, does anyone want to help me with this?"

The second to last question in the interview asked students to reflect on what they found most valuable about their EPBEL experiences. The most common answer was related to friendships and teamwork with comments on diverse backgrounds, various skillsets, and especially a shared passion to bring an idea to life, reiterating the importance of teamwork and mentorship for students.

A Sense of Balance

The final theme to emerge explaining why students choose to participate in EPBEL is a bit more nebulous to describe. Six students described their experiences building projects as a sort of antidote or restorative remedy to the focus of their school requirements. EPBEL allowed these students to restore a sense of balance into their lives, bringing their education together with other facets they deemed worthwhile or important. Emily sums up the feeling in general:

> For me it’s more of a balance tool. I go kind of stir crazy if I'm in class all day and all I'm focusing on is school work. My freshman year I got really burned out on school work and that's kind of when I found Tesla Works. I sort of learned that finding that activity outside the classroom that helps put what you're doing in the classroom into perspective.

The perspective that Emily mentions can vary from student to student. Ashley used EPBEL to do outreach to underrepresented communities:

> I think you guys do a good job to people who already have a mentality to be an engineer, like want to be engineers. Actually we need focus on people who don't have the privilege to come to this university, you know like make it this far.

Sarah emphasized throughout her interview that she was doing this because she wants to help people in developing countries:

> We also found a huge need for the medical equipment market in the developing regions of the world, just because...Minneapolis is a hub for all this medical device innovation and its coming more and more expensive and fewer and fewer people can have access to it. So we thought that that was a huge need.

The sense of balance took different forms but taken together they formed a final compelling theme to the questions of why students choose to do EPBEL. For some students it is critically important that engineering has context, that they see how their skills will be used in the broader community.

Perceptions of Gain in Learning

As detailed in Chapter Three, most of the interview questions were designed to solicit responses that would help answer the exploratory question, "what do students perceive that they have gain from participating in extracurricular project-based experiential learning?" The following three sections explore four of the primary categories identified through the interviews and two additional related categories. The first primary category identified is the perceived gain in learning and is generally aligned with interview question three (see Appendix H), "Can you tell me how your learning is affected by participating in this project?" Three themes developed from the responses to this question along with other comments throughout the interviews. Students saw themselves acquiring and using technical skills, enhancing their soft skills, and strengthening their problem-solving abilities.

The Acquisition and Use of Technical Skills

Whether they be technical skills taught in the classroom or technical skills deemed necessary but not formally taught, nine of 10 students mentioned some facet of acquiring and/or using relevant technical skills. Some students mentioned the augmentation of skills already introduced in the curriculum. For example Joshua said:

> Taking a step back and looking at the project-based design work that we did for the water design. Really kind of connecting that to the major of chemical engineering, actually made it so much more exciting knowing the knowledge I knew. It made it more exciting to go back to classes to learn more, because we used the exact equations we used in classes. It's almost like a cycle, a snowballing cycle. You applied it in that situation for something that had nothing to do with classes. You designed a water system in a village in Africa, that's fantastic!

Christopher made the explicit point that sometimes you independently learn technical skills that are introduced later in one's curriculum:

> There have been times where I've had the experience of building something similar, I've already learned how to solder, use this program, code an Arduino, outside the class through the club. Just kind of spending time in the Exceed Lab or back in someone's apartment working on a project. So it's definitely benefited me, being a little bit ahead of the curve on some of that stuff.

Further illustrating the potential for synergy between projects outside the classroom and the official curriculum, Jacob discusses how his classroom experience really enhanced what he was able to do with his project:

> Great example is last semester, I really enjoyed my class last semester. I think I had my best GPA in a while, because the project I was working on, which is the solar UAV, required exactly what I was learning in class. In class it wasn't applied, but it gave me the theory behind it, so it was a lot easier to understand. It was the first time I really ever read technical research papers online, because I could apply them because of the other skills I had picked up in the past.

Finally, students reported how the potential of application really helped to spark their interest in their courses, including Sarah's example:

> It enhances school coursework, just because I think I am more interested in it now. So, just an example, I'm in a signals and systems class right now and I never thought it was anything that interested me, until I read about how a lot of new prosthetic designs are using [embedded computers] for veterans when they have tremors, to help alleviate the tremor on the prosthetic. When I learn about these things that seem pointless at first, I don't know how they would be applied and then I can go back to my experience and understand how those are applied. I think it just enhances my interest in a lot of things that otherwise wouldn't feel interesting.

Students felt that they acquired and used various technical skills through EPBEL, aligning especially well with their reason to participate regarding the challenge and intrigue of application. That instinct to apply engineering in another context besides the classroom seems to provide these students with additional learning opportunities to bolster their technical skills.

The Enhancement of Soft Skills

In contrast, students also found that many skills not often or at all taught in their engineering and science classes were greatly enhanced by EPBEL. Skills such as leadership, project management, professionalism, networking, and communication were mentioned collectively by eight of the 10 interviewees. Michael sums it up succinctly:

> I guess it's just kind of personal growth and different skills. Normal soft skills, technical skills. You also work on concept reviews, designs, give presentations, so kind of also those skills.

Project management especially, is mentioned quite often:

> You learn a lot more about, I don't want to say management, but just kind of things like following a timeline or managing resources or managing people that

> you might not learn about in a traditional engineering class but are essential to getting a project done. (Matthew)

Leadership skills, especially as related to being able to get a project from start to finish also plays a prominent role:

> Leadership wise, when it comes to working on a group project in class, being used to...as president I ran all of our meetings, was constantly working on projects in groups of people, I kind of learned how to correctly manage it, how to divvy up tasks, not step on people's toes. So that definitely helped. (Emily)

EPBEL offers the opportunity to practice the types of important soft skills that classrooms aren't very capable at providing, skills that are very important to the new-century engineer.

The Strengthening of Problem-Solving Skills

Perhaps situated somewhere in the conceptual middle of improving technical skills and soft skills is the strengthening of problem-solving skills. In responses, students mention words like "perseverance," "determination," "challenge," and "accountability," while describing the necessity to apply technical skills while utilizing their networks, management skills, and other soft skills to persevere. For instance, Joshua discusses the problem-solving skill of asking the right questions:

> If you are asking the right questions, you know how to get to your goal faster in a sense. You aren't deviating into unnecessary sub-projects. If you are asking the right questions, you know where to get the right resources, to answer this obstacle, to get over the obstacle you're facing. You'll tackle obstacles a lot easier. If you are asking the right question there will be a lot less miscommunication with everyone and you'll have a lot less issues working together on a project, which is huge. Working together effectively, being able to ask the right questions in different situations. That even applies to when you are giving feedback to other projects. Being able to ask the right questions so that

> they can use that feedback to "oh, we didn't think about that" and improve their project process as well.

Those questions are a combination of technical and non-technical. Nicholas explains how problem-solving in EPBEL differs from the classroom:

> The most valuable part is probably, we've touched on it a little bit, is going through the process of solving the problem, defining it, finding solutions, testing solutions, coming up with...that entire process is something you don't get in a classroom setting. You can have a project, you can have a problem that you can write out. They are defining the problem for you. There's no searching out the problem and because there's only one solution you don't search through multiple solutions. So that's the kind of thing people who hire are looking for. And that's the kind of thing that's the most valuable part of doing project based learning.

As described earlier, students choose to take part in EPBEL to enhance what is offered in the classroom and students later find out that it was a good choice for them. Sarah illustrates how problem-solving skills develop outside the classroom:

> It's not just one problem that you are solving. When you work on a project its so many different kinds of problems that come together in the experience that comes out of that. Its super valuable and I think every building experience can be applied to a different building experience and you just get better at it.

The students interviewed for this study perceived genuine learning experiences across of spectrum of skills, many of which they felt aren’t sufficiently being taught or experienced in the classroom.

Perceptions of Gain in Engagement

The second category that developed relevant to the exploratory question on what students perceive they gain from extracurricular project-based experiential learning is engagement. Responses related to engagement were common throughout each interview but question four (See Appendix H), “Can you tell me how your connections to things like your major, college, university, peers or other parts of your life are affected?" was particularly correlated with the development of the three themes that made up the engagement category. Those three themes were student group and peer affinity, professional and disciplinary affiliation, and community involvement and spirit.

Student Group and Peer Affinity

Nine out of 10 students mentioned that their connections to their peers, often through student groups increased through EPBEL. As with the finding related to teamwork and mentorship above, students found a lot of value in simply making friends. Emily reports:

> My core friend group comes from who I started these projects with. My current boyfriend was on the first project I ever worked with. When you have a group of people that are that interested in doing the same tasks even if they aren't interested in doing the same way or with the same skills, it's a very bonding experience.

Six students used the word "community" in the context of their peers and many of the interviews had moments describing the friendships similar to how Ashley describes her experience:

> I have a lot of friends because I worked on these with a lot of my friends. Most of my friends are similarly motivated by these projects, building something, designing something. They love doing those things, I love doing those things. Exceed Lab was a great location to meet these people even if they're not immediately interested in my project. So, it was a great way to actually have awesome friendships. I have so many friends that I met from projects and I still keep contact with them. Family wise, I surround myself with people who like what I'm doing.

Figure 6 shows one room of the Exceed Lab on a Friday evening in April, full of students building projects. Friday night is usually the busiest time for the Exceed Lab.

Figure 6: The Exceed Lab on a Friday Night in April

Relatedly, the affinity for peers often extends to the student group that adds structure to these EPBEL projects. The combination of interesting projects and an organized student group offering support, engaged the students in quite meaningful ways:

> Students at the university tend to strongly identify with student groups which is surprisingly true in my mind. I identify very strongly with the people I work with out of class. I think it's just because college is the first time for a lot of people where they can work on something that they love and they know enough or they have enough skills where they can actually do good work. (Matthew)

The students emphasized the value of finding like-minded individuals who were similarly motivated to apply their engineering (and other) skills. For these students, EPBEL offered the type of engaged experience with their peers that they were seeking.

Professional and Disciplinary Affiliation

Similar to a desire to connect with peers, students indicated that their engagement with their chosen fields was positively affected. Nine out of 10 students reported how EPBEL drew them into their discipline or profession and played a role in building an affinity for engineering and their specific majors. Sometimes students were drawing from their own desires to apply what they are learning, which led to natural engagement in their disciplines. Matthew sees this sort of engagement as essential, saying, “I kind of have this philosophy that people should be applying what they learn while they're learning it or it doesn't really matter that much.” Ashley appears to be quite engaged with her major, including some of her professors and she relates it to her opportunity to work on extracurricular projects:

> Because a lot, actually all of my projects were inspired by my major. So, I worked really closely with many professors, to name a few, Prof. X, Prof Y, right now I'm working with Prof Z. These people have these projects and I need some place to work on these things and it kind of leads me to these resources like student groups or Exceed Lab or that kind of thing. So I think inherently they are very closely related.

For some students it is not as much about the major as it is about connecting to other knowledgeable people in engineering or beyond:

> I'm speaking for me, but also for a lot of students I see, the community aspect is probably the most important part from a day to day perspective, so you're connecting with other students and usually others students and faculty around you. So, regardless of what the project is, or if it completely fails, you still are meeting interesting people and learning things from each other. (Matthew)

Relatedly, Sarah is developing an appreciation for how the various engineering disciplines work in tandem, “biomedical engineering majors aren't the only people who care about global health problems. And when you all come together that's when big problems are solved.”

These developing affiliations go beyond engineering as well. Nicholas saw himself as having a career more closely related to his minor in sustainability and his projects helped him engage in that career trajectory. Referring to his affiliation with three renewable energy related projects he is involved with, he reports, “the U is very eco-minded and its sustainability oriented, so there's a connection there. That's why I came there, because it has that vibe.” EPBEL can sometimes be the outlet through which students can address and pursue career interests not represented by any major or program on campus.

Community Involvement and Spirit

For five students, engagement was about more than connections to friends and their chosen disciplines, but about a much broader community. Sometimes that broader community was related to school spirit, a developing affinity for their college or university:

> One of the coolest things was when we were in California for the ACV gunship (Figure 7) and it was the first time that a lot of people met anyone from the University of Minnesota and they're like "this is such a cool project, why weren't you guys here last year and are you going to be here next year too" and we were like "we don't know, we just kind of decided to do this." That's so cool. It just kind of gave me some school spirit, being a representative of a Gopher for something other than sports. (Jacob)

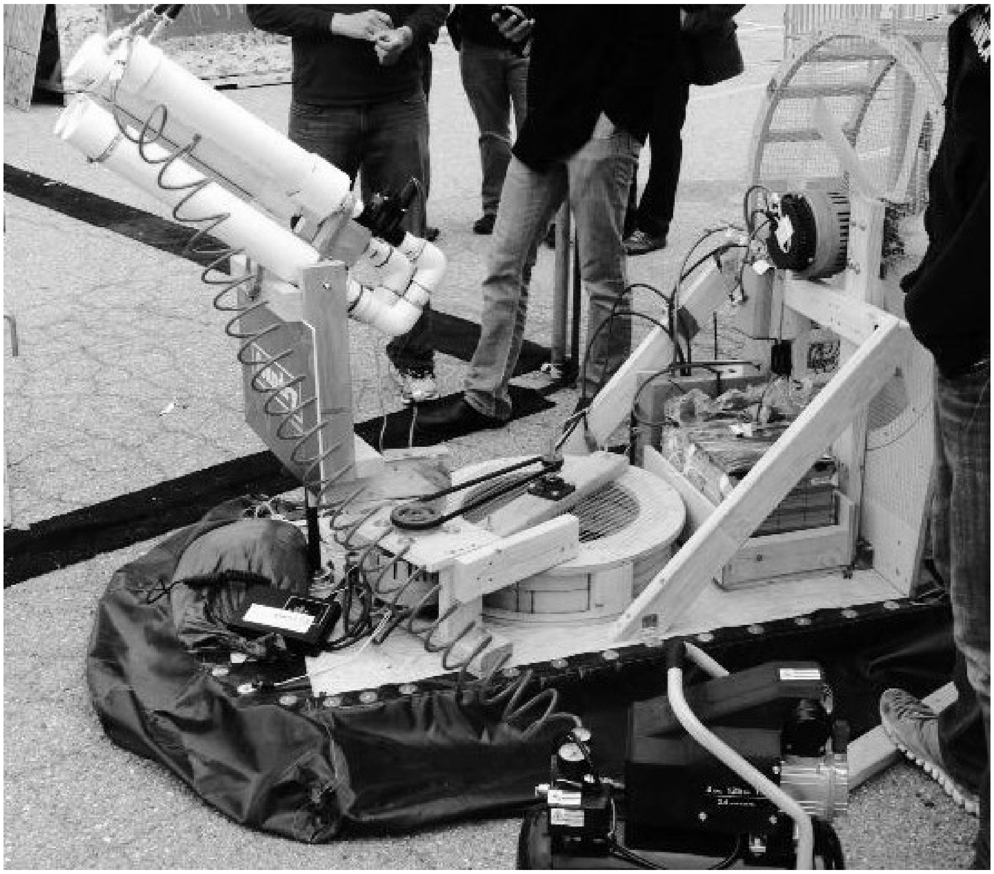

Figure 7: Hovercraft T-Shirt Canon at the Maker Faire in San Mateo, CA

For others, they found value in engaging in the community beyond the university, looking for ways to give back or help others locally and around the globe. Sarah had a concrete example of how she was planning to accomplish this type of broader engagement:

> We are actually planning an event right now where we are going to get a bunch of students, faculty, and community members together for one day to build the mechanical versions of these hands. They take donations and send them to developing regions in the world. I think that will be a very valuable step in our process. In just one day you can make 50 of these hands and donate them to people for free. And in just in one day they can have a prosthetic that works for them.

Ultimately, EPBEL led to multiple levels of social and academic engagement as students developed and nurtured passions for their network of friends, their engineering work, and often, the broader community.

Perceptions of Gain in Self-Efficacy

Another category that clearly developed was the effects on students' self-efficacy. Answers to question five (see Appendix H) provided most of the data for this finding, asking, "How do you think your confidence is affected related to being an engineer and/or your ability to do well in the classroom?" Overall, students reported a positive effect on their confidence with four separate themes developing: social confidence, technical confidence, creative confidence, and the reduction of inadequacy. The first three themes relate to specific areas that students, through experience, felt more confident asserting themselves, while the final theme was general in nature and related to overcoming the sense that one does not belong or bring any value.

Social Confidence

Eight students reported higher confidence in dealing with people usually derived from managing or participating in the progress and completion of a particular EPBEL project. Matthew pointed out that simply having a strong network was beneficial helping him feel confident he could successfully seek out any help he needed:

> I think confidence is definitely a word I use often when talking about these things with people in that I feel more confident that I have a support network around from doing these projects. I've met people being students, faculty, administrators who I know I can go to if I have questions about whether it's an extracurricular project or academic questions because I met them through an extracurricular thing.

Joshua demonstrated how his experience doing EPBEL helped him feel confident to take the lead in classroom situations:

> As we meet in our group of four people, we are all equal, we're all peers, but generally I have a little bit more input on what we're doing next to kind of get to our goal, for lining things up. I think that is because I had so much experience before trying to get to the goal, what do we need next, when are we going to have this by, what do we need to attempt this next goal.

Nicholas saw his EPBEL experiences as giving him a clear advantage over other engineers when it comes to beneficial and productive interactions:

> From a confidence of walking around and knowing other engineers and interacting with engineers and things like that, which I think is a really integral part of engineering, being able to talk and portray your ideas in such a way that people understand. I would say project learning has a much greater impact on that side of confidence than just the problem based learning. Even if people are taking classes and you know how to do problems but they can't tell people about it. In a job setting where they have to present their ideas, it's not very helpful. So that's the confidence a lot of people lack if they don't do project based learning and present their ideas in front of people.

Overall, students experienced large gains in confidence in dealing with people, and those gains often enabled them to take advantage of leadership opportunities.

Technical Confidence

Seven students mentioned gains in their confidence to successfully apply relevant technical skills. Jacob retells the progression of his skills and the confidence it gave him to move to the next challenge:

> Basically I learned some of the basics of circuits from [the audio amplifier project], which helped me feel confident getting onto the autonomous vehicle team, which then I felt more comfortable with the gunship, which I learned some skills that and combined them and got a really cool job now.

Jacob is a senior with a very high number of EPBEL experiences and his confidence is brimming as demonstrated by his comment in response to his worried teammates in his senior capstone course regarding what they consider to be a complex control system for their project, “If this doesn't work I'll just do it, just give me a weekend [laughing].” Not all students reach that level of technical confidence through their projects, but Michael explains the practical advantages of learning additional technical skills through EPBEL:

> It greatly helps in confidence terms of your ability, because you know you are working with these softwares and tools which are very useful for you. So you get that confidence that you can work on these applications.

Through the interviews, it became clear that, although EPBEL helps students pick up some specific technical skills, the real value comes from the added confidence to try and learn technical skills as needed.

Creative Confidence

Six students described boosts in self-efficacy that can be described as creative confidence. Their responses portrayed moments of ambiguity where they had gained the confidence to either generate ideas or turn ideas into something more concrete. Joshua sums it up well:

> You're able to give more insight on general questions, whether they’re project related or not, based that you have more experience kind of in different areas working on different projects, you generally have more insight that you are able than your classmates when you are trying to brainstorm different ideas. So maybe it helps with the creativity process. It just kind of helps being more on top of your things, because you've considered these things before, some of these things before when you're working on your projects outside the classroom.

For Ashley, her experiences working on various projects gave her the confidence to think big:

> I realized after 3 and a half years staying in this university that if I have a good proposal and if I have good motivation that I can do this for other people and this project will work. It's just about how much devotion you can put into it. I think that on that term, so as long as you are willing to put in your effort, then I think that these projects, that the environment can be successful easily.

For Jessica, her EPBEL experiences carried over to the classroom:

> In my analytical chemistry lab right now, I'm usually, I'm more willing to just try something even if it won't necessarily work, because I've been in groups before that just get caught up in talking about how we don't know how something is going to go and then we just talk about and talked about it and talk about it and never do anything.

Creative confidence seems to be a lot about learning from the repetition of having participated in multiple projects for these students. They gain a deeper understanding of how to progress from a vague sense of what needs to be done to an actual finished artifact.

Reduction of Inadequacy

In the category related to self-efficacy, the final theme to discuss has to do with combatting and reducing a sense that one does not belong. These feelings of inadequacy were mentioned by seven students and can be connected to being an engineer in general or having something to contribute to a particular project. For some, EPBEL helped them gain experience that gave them confidence. Emily explains:

> I've just learned how much hard work matters so if I really take the time to dedicate myself to my studies like I do to a lot of other more projects, I'm more confident that I'll do well, especially before tests and things. If I spend some time studying and some time dedicated to the material, I feel more confident than I would have without these outside experiences that have shown how much hard work can pay off.

Jessica describes the fear she faced stepping into projects, “I think confidence is definitely up, because there is a lot of stuff I came in with absolutely no idea how to do and it was really scary to take the first step to actually try doing something.” But as Ashley relates, engineers get used to that fear and learn to deal with it positively:

> I think it's always scary when you are faced with unknown. That's like kind of everything about engineering basically. I think it is also very thrilling once you get used to not knowing. Honestly, if you don't know and you don't get it for the longest time it is discouraging. But I think it would be great if people would kind of be more tolerant to that fear. If you stick through it a little bit more or even talk to other people a lot more and ask questions, then you can actually figure it out.

This paper will return to the subject of inadequacy in a later section looking at gender differences in EPBEL. Overall, gains in self-efficacy are a very significant part of the EPBEL experience for students, as they navigate a path from hesitant outsider to confident insider.

Perceptions of Gain in Career Preparation

The final category clearly related to perceptions of gain was how extracurricular project-based experiential learning prepared students for their future careers. Question six (See Appendix H) asked students, “tell me how you think your project experience will affect your preparation for your career after you graduate?” The themes around this category primarily developed from this questions although students often brought up their future job prospects in other parts of the interview. The three themes that emerged were Resume and Interview Enhancement, Project Management Experience, and Relevant Technical Skills.

Resume and Interview Enhancement

Eight students thought that their EPBEL experiences helped them secure jobs or would help them get a job in the future. For the most part, this related to the interview process where students thought they were at an advantage due to having an outside the classroom project to discuss with potential employers. Christopher tells his experience:

> The hands-on club experience, most employers will ask about that right away, what you do in the club, what projects you've worked on and they have you explain the projects and everything. I had a co-op a year or so ago and 90% of my interview with them was about the club and what I had worked on. I think that was a big part of me getting that job.

Joshua explains why being able to talk about your project experience works so well in an interview:

> Talking about projects is an awesome way to talk about your passions. Everyone has something you are passionate about, but it's easy to talk about something you are passionate about. So when they mention the projects, you can really go into depth, how you problem solve, things you got stuck on, how you overcame them, worked together as a team, and its things they don't necessarily always hear, because the projects aren't always the same things every year in your classroom, they're different. Everyone enjoys talking about it.

Emily sums up what she thinks employers are thinking when one of them reacted positively to EPBEL and offered her a job before she had the course experience they generally seek:

> At least with my internship this summer, I was hired a lot more from that experience I had on my resume and in working with a team, and in organizing groups and doing hands-on group already, than they necessarily cared about my classes, at least at a sophomore level. You didn't really have the class experience they were looking for. I guess, just with the things I've learned from those outside projects, they seem to be things that employers value a lot in the workplace and they are obviously things that coincide pretty strongly with my core goals.

It is not surprising that employers look to EPBEL experiences as a strong indicator for quality employees, as traditional measures such as grades can only indicate so much. Extracurricular projects not only provide students with additional soft skill enhancing opportunities, but they signify to employers a self-motivated and independent learner.

Project Management Experience

In Emily's quotation above, there is a sense of the other theme that emerged in the interviews. Seven students felt that EPBEL gave them lots of valuable experience managing real-world projects that would translate to their careers. In direct response to the question regarding career preparation, Christopher goes right to his project management experience, "I guess you could say, being able to divvy up your time and plan ahead for projects, you are able to make a responsible timetable for things, get things done on time, organize your tasks, prioritize things," and later expounds adding:

> Most valuable part is probably the planning, like the making your bill of materials, picking out parts, organizing when you need to get things done by setting up build days. That kind of stuff. I've seen that draw more parallels with the co-ops I worked at and employers were probably most interested in that.

Sarah adds the element of networking and teamwork stating:

> I think a big part of these projects is bringing resources together, so its knowing that you can't build something like this by yourself, but you need funding, you need faculty and you need a very multidisciplinary group to be able to build something. So we are working on an electric hand right now and so we need electrical engineers and with this blood glucose meter we need chemical engineers and it's not just this biomedical engineering project, but just working with people from different disciplines I guess.

Students felt that EPBEL prepared them well for a future career getting projects from start to finish.

Relevant Technical Skills

As might be expected, students reported on learning direct technical skills that they thought would directly impact their career. However, only four students discussed these relevant technical skills as their answers more commonly went in the direction of the two previous themes. Michael, however, thought his EPBEL experiences are really helping him develop the direct technical skills he needs for his career, reporting on what he thinks employers are looking for:

> It is about what kind of experience you have had. Have you actually worked with the tools that they use, have you made any useful projects, so that they don't have to spend hours and hours of training? They know what kind of skills you have. So that's something that you can directly advertise in your resume that I worked on this project which creates this software and has been used with the full testing and stuff. So it kind of shows your direct ability to work in that field.

Joshua, in response to the career preparation question, makes the point that it is not necessarily about perfectly relevant technical skills but about general technical experience:

> You are working on equipment and doing projects with these equipment, you're not just doing equations. So really having more project experience outside the classroom, even if isn't on that specific equipment makes you confident with handling biggest things than just a pencil. Whether its tools in the Exceed Lab or just tons of lights, just handling things on a big scale rather than just pen and paper makes you confident to handle equipment.

Students were able to quickly make connections between EPBEL and their future careers, which is not surprising since they take part in these experiences to get real world experiences as discussed earlier. They may not do this for purposes of preparing for after graduation, but EPBEL seems to be an important component of that preparation, especially when it comes to creating engineers willing and able to learn new and changing technical skills in the information age.

Value-Added Beyond the Classroom

One additional category that emerged from the analysis is the comparison to what happens in the classroom, especially lab courses. Usually without prompting, all 10 students compared their EPBEL experiences to their classroom experiences in a form that explained the value added by the former. Some of the quotations from earlier already demonstrated how students believe that EPBEL adds important value beyond what the classroom is able to provide. Sarah and some of her fellow students felt that the curriculum was not thorough enough:

> The reason we decided to establish Engineering World Health because it was something we thought was missing from the biomedical experience here. We spent a lot of time just learning math and stuff, but we actually weren't building anything that had to do with medical devices.

Often the comparison had to do with how projects, usually in the form of lab experiments, didn't provide the full experience students desired, as Nicholas explains:

> I guess they're giving you a problem in a lab setting and you are graded on your answer. From that perspective there is a correct answer, there is a correct solution. I've never liked that concept and so from the standpoint of project learning or Exceed Lab, there are more than one way to skin a cat.

Related to a full project experience, Michael wishes that it happened from the very beginning in his curriculum, "I think one thing the university might be able to do is integrate such projects early on with the coursework itself … That would have been a very good thing if it was from the very start, the freshman year."

Emily uses extracurricular activities, including EPBEL, as a recruiting technique:

> When I talk to people about going to the university, I have a cousin or two that are here and some friends from outside the university that are thinking about transferring, I've talked to them about these outside opportunities a lot more than the coursework. The coursework is going to be hard no matter where you are, but those outside opportunities can kind of make or break your college experience.

Other students discussed how the social experience is better through EPBEL. Matthew elaborates on that facet:

> In extracurricular projects, the people who show up have to want to be there. So the people who come are the right people because they want to be there and they want to contribute. Whereas in a classroom you have to be there, you have to be there, and to a certain extent you sign up for a class to get your degree or whatever. So I think that is an inherent difference. So there's just so many things about how classes are structured. If it's a lecture class, I've had to work very hard to get a study group going consistently. What I mean by that is you're not solving problems, overcoming obstacles, that kind of camaraderie through the successes or defeats of a project.

Inherent in this answer is also the different kind of challenge that EPBEL provides. The projects are not necessarily technically more challenging than those in courses, but some students pointed out that the overall scope tends to be more complex, requiring better organization and planning to pull off a successful project. For these students, this added complexity fueled by internal motivation worked very well to deliver a valuable experience. Another often overlooked experience of value for young engineers is experiencing failure as Matthew alluded to above. Of course, these are only 10 students self-selected into EPBEL and their responses do not offer solutions to how to scale their positive experience to more of their peers.

Negative Impacts

Leaving aside the scalability of such experiences, six students did mention the same basic negative impact of participating in EPBEL. That negative impact is the time-consuming nature of many of their projects that often affected their grades or relationships. Ashley reports, “I actually have a problem with my GPA, especially earlier in my college life, because I weighed things too heavily toward these projects.” Jacob admits:

> I tried to do too much which meant I didn't remember any of it. I was sleeping maybe, on average five hours a night or something like that, maybe four, I don't know. It was a typical all-nighter a week. I know other people can remember things when they don't get much sleep. I cannot. So even though I was involved my sophomore year, I don't remember much of anything I did.

Those were the two most severe examples, but it was a common volunteered response that the demands of the projects took time away from other important elements of their life. Almost all of the students said it was worth it however. Regarding grades in particular, the two senior level students above connected their previous extracurricular project experiences to their increasing GPA later in their academic careers. So, two students who reported negative GPA impacts early, then reported gains later in their careers.

Conditions for a Successful Experience

The students interviewed were mostly positive about the environment set up around EPBEL on the University of Minnesota campus, although they had some definite ideas about how to improve the situation. For most of the students, having a space to meet and build with the necessary tools was key. In these cases, all students took advantage of the Exceed Lab makerspace in some form, although not necessarily for all their projects. Michael explains how the Exceed Lab works for him:

> So the reason I went to the Exceed Lab, was for these types of projects, electronics projects, you need some really small parts or things that would cost you a lot if you sourced them from different sources. In the Exceed Lab you can find a different range of things that you can try out. Let's say you are working with some mason work, you don't want to order a part that will take 3 days to come and then see that it is not the right size. You can go to the Exceed Lab and you can see the different variety and pick one, see the right one and you can use it or not use it. It kind of makes a lot of things easier because you have all those resources laid out for you.

This represents a typical answer about having a stocked makerspace, so having the correct tool or part becomes less of a barrier to making progress. Another benefit of the Exceed Lab and spaces like it is the built-in networking available as described by Christopher:

> A lot of the times you are working on a project and you don't have experience with something, the great part about being in a club or in a room like that, where it's just filled with people working on projects, there's kind of like a group knowledge. So, if I didn't know how to solder and someone else was at a soldering station, I could walk over and get a few pointers. Or if someone was working on a wiring diagram and they needed help, they could literally turn around and say "Hey, does anyone want to help me with this?"

In addition, two students mentioned the advantages of being around students from other disciplines in the Exceed Lab.

However, students acknowledged that there were not enough of these spaces available, that sometimes they are not open or tools are too locked down, and other similar situated schools have better resources than the University of Minnesota. Another common perception was that even when useful resources existed on campus, it was very difficult to find out about them.

Another common response regarded storage space and funding. Storage space for on-going projects was mentioned as inadequate by four students. For some, funding was not an issue for their projects, but others indicated that getting the appropriate level of funding to purchase the necessary parts or tools for a project had been difficult or impossible for at least one of their projects. Overall, students felt the conditions existed for them to be successfully practicing EPBEL, but acknowledged that they had become accustomed to persevering when necessary. Perhaps that is part of the point, but there are worthwhile questions to ask about what amount of resources is appropriate for EPBEL for nascent engineers.

The Different Experiences of the Six Men and the Four Women

The experiences for men and women did not seem to differ greatly according to an analysis of the interview data. However, there were two discernable themes that the women mentioned more often than the men, the importance of balanced and varied experiences; and reporting on overcoming feelings of inadequacy as related to self-efficacy.

Emily, who is also pursuing a minor in a non-engineering field, explains the concept of balance, which was alluded to by two other women, but no men:

> For me it’s more of a balance tool. I go kind of stir crazy if I'm in class all day and all I'm focusing on is school work. My freshman year I got really burned out on school work and that's kind of when I found Tesla Works. I sort of learned that finding that activity outside the classroom that helps put what you're doing in the classroom into perspective, made what you're doing in the classroom a lot

> easier. I found ways I was using what I was learning and ways to apply what I was learning in the classroom through hands-on experiences. It sort of just made my whole educational experience a lot better.

Jessica emphasized the value she placed on varied experiences especially involving students from disparate disciplines, not just engineering. Ashley is very interested in outreach to local schools to introduce engineering to young people. Sarah is very passionate about using engineering to help people in need and connecting people with different expertise to make it happen. Although it took different forms, the commonality for these four women lies in a desire to be inclusive through involvement, gain experiences that offer perspective, and have an impact beyond their individual discipline, in-group, or university. For the men interviewed, this type of emphasis did not emerge, even if there were answers here and there that fit this pattern.

On the question of self-efficacy, there was a definite response pattern related to reducing feelings of inadequacy and being an outsider as an engineer. When asked about how her confidence is affected by EPBEL, Sarah replied:

> I think that women in engineering can have a really unique response to this because we're not the typical demographic that's in engineering. And so whenever people ask what I'm studying in school, they seem to be surprised that it is engineering, like I don't fit the mold in it. So I think that at first I took that as a negative when I started going to school here, but it’s turned into a confidence booster because engineering is seen as something smart people do, but I think it takes a while for women to internalize that and know that it was them.

Tellingly, she doesn’t even mention EPBEL, but feels like she needs to explain how it is different to be a woman in engineering. A follow-up question yielded a response that applying schoolwork through projects was a great way to boost confidence. Emily discussed the process of getting over being the dumbest person in the room:

> You sort of learn to love being the dumbest person in the room, because you have so much to learn from the people around you, but at the same time you are a little downtrodden. I guess how much you can bring to the group, but you sort of learn to get past that. Through work everyone has stuff to bring to the group.

None of the six men mentioned anything remotely close to being the dumbest person in the room, even if they mentioned moments where they had doubts or sought help. And Emily is a very accomplished student, rising to president of a large and significant student group among other honors. Ashley came across quite confident but her passionate focus on outreach to pre-college students hinted at an understanding that some people need a little extra understanding and motivation before they can see themselves as potential engineers, perhaps emerging from her own feelings of being an outsider as an engineer. Both Jessica and Ashley used the word “scary” and “fear” to describe experiences with extracurricular engineering projects, colloquial language for sure, but also indicative of being some place one doesn’t belong. Jessica did feel compelled late in her interview to tell this interesting story:

> Along with just willingness to jump in and try stuff, I guess I'm going to use me and my roommate as an example. We both joined Tesla at the end of last year and we were doing minor projects and stuff like that. But at the beginning of this year, and this is super random, but we decided we wanted to de-loft our lofted bunk beds. So you've got a chemical engineer and a math engineer, just two girls with these giant beds up in the air. And we are like "we want to de-loft these.” So last year we know there is the same process where you can contact administration and fill out a form and wait a week and they'll send the janitors and take them down. You have to move all your stuff out of the way and put it back and whatever. And we're like "No, we can do it ourselves." And we just went for it and between the two of us, it took us a couple hours but we got both of our beds down, put back, and that was something I would never have even thought to try before I joined Tesla Works and started working on projects, because I would have just said there is no way we can do it, we need someone qualified or whatever. But this year, we just looked at it and you look at how it is actually put

> together and just break it down into steps. "Like, we can do this." And we totally could.

Jessica is really starting to think she belongs as an engineer and attributes it directly to her EPBEL experiences. For women, EPBEL can be a particularly powerful experience, allowing them to apply utilize engineering for their true passions and, in parallel, develop the self-concept and self-efficacy that makes for an effective and successful new-century engineer.

The Experiential Learning Process in Extracurricular Projects

This final section in the findings chapter analyzes answers almost entirely in response to interview question 7 (see Appendix H), "Thinking about how you work on your project, by yourself or with your team, tell me about the process? For example, how you solve problems, figure out the next step, or simply get things done." There was a concerted effort to ask follow-ups for the purpose of probing and enticing detailed recollection. Analysis yielded a clear pattern of iterative sequences in the process of taking an idea for a project to fruition. Four parts of the process were identified, brainstorming, researching, prototyping, and testing; while it also became clear that the entire process was iterative in nature.

Brainstorm

Almost without exception, the projects the students participated in had a brainstorming stage. Often the brainstorming started an ideation session regarding what to build:

> I guess the first part, and sometimes the most difficult part is coming up with the idea that you actually want to pursue. A lot of our projects we kind of get stuck

> there, someone had a cool idea of something, but they weren't sure how to apply or they weren't sure they wanted to follow through exactly with that. So we all kind of work together and a lot of times it's just like, your sort of hanging out and bouncing ideas off each other at the same time, until you find one that really sticks, everyone gets really excited over and, you are willing to dedicate a lot of time to, because if you aren't excited about it to begin with, it's not going to go very far. (Emily)

This part of the process stands in contrast to almost all courses students take, where if they build a device, there are clear guidelines as to what to build. Students mentioned “big sky” and “blue sky” ideation sessions and Sarah even mentioned her work on understanding how best to brainstorm:

> I think a huge part of our process is just brainstorming. So we brainstorm everything and I've done a lot of research, not research, but reading in general about how brainstorming works and how to do it most effectively. I think that's been so valuable to all problems that we've ever come to. Ok, let's stop doing this and think about it and any ideas how we're going to do this. So, I think that is the biggest part of our problem-solving process is just sitting together with a whiteboard and just thinking about it.

As the Iterate section makes clear later, sometimes the brainstorming is returned to after a full iterative process that have gone through the other three stages discussed later. Jessica gives an example:

> The Pyroboard (Figure 8) went all the way back to step one basically. They actually had a board made last year, but they found out it was leaky, the wind blew it out, and like all these other problems and they kept trying to stitch up the seams a little tighter, whatever, and finally they just gave up and at the beginning of this year they started completely over, just start fresh. So you'll always keep a couple ideas from the first time around, but you can go as far back in the process as you want sometimes.

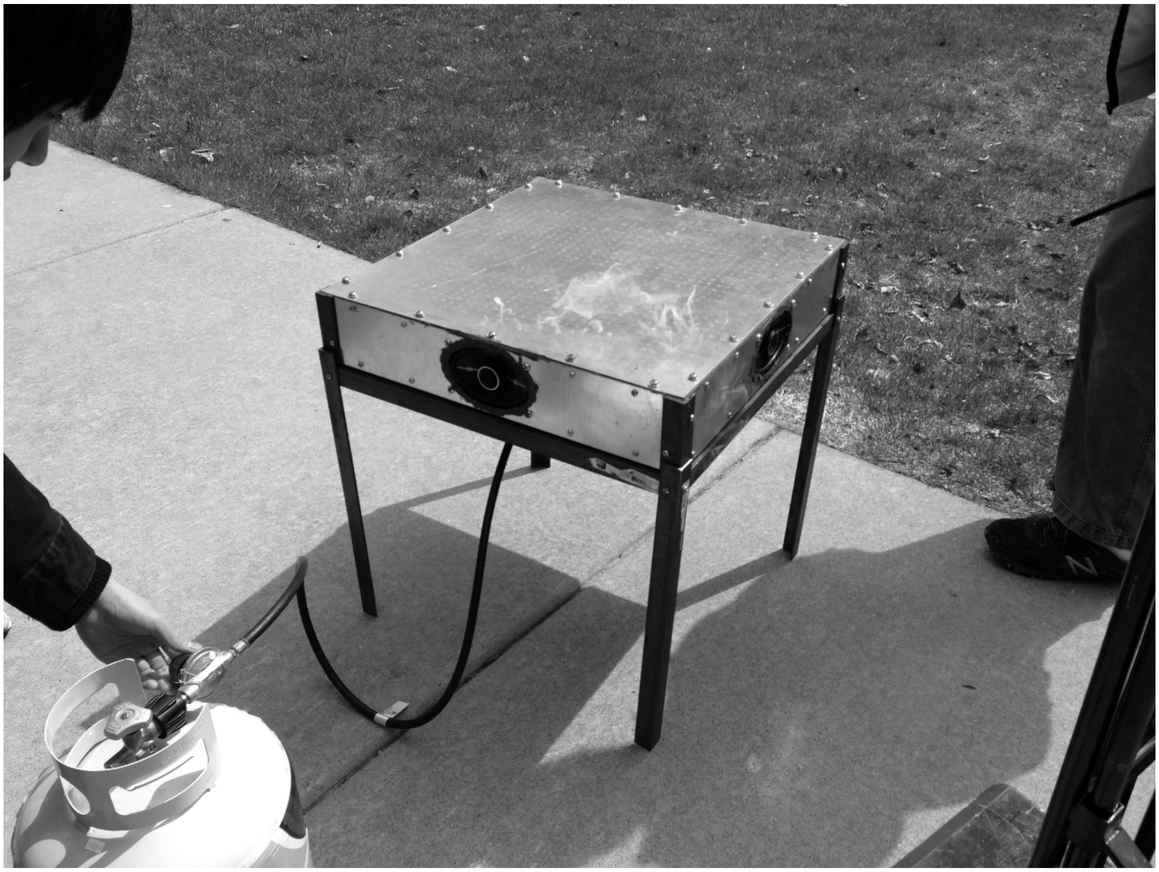

Figure 8: The Pyroboard, Version 2, a Fire Generating Device that" Dances" to Music

As the brainstorming advances, students try to take all the generated input and start to collect and analyze it, “Then we kind of grade them on merit, is it feasible, cost-effective, do we actually think it will work. We can usually narrow it down to a few different ideas. Then we'll vote on which one we want to explore further.” This evaluation period helps move the process along to the next step in the process.

<u>*Research*</u>

Once the idea of what to do is in place, the students related how they often went off in smaller teams or by themselves to gather more information. Emily describes this step:

> From that point, it's a lot of research, split up between a group of us. So we'll each be researching our own section, but we come back with whatever information we learned and put it all together so that we have a pretty broad base of knowledge about whatever we are trying to do.

Some students described how their research involved learning a new skill they would need to move the project forward, like learning some software or how to use a specific tool. Others described the process of understanding how other parts of the team, especially on very large projects, were going to accomplish their goals to ensure that different elements worked together and were done efficiently. Here is Michael describing his work on the Solar Vehicle Project (Figure 9), where students build an entire solar powered car from scratch:

> The 2nd part would be to see how it fits with other parts of the project, so does your part require other people to complete certain things? Is it isolated from the rest of the parts or is it something that is completely integrated with the car that would determine how much you want to work with the other team? Maybe, in my case, I would be using a lot of information, like GPS information, so I would need to work closely with the sensor team, so I need to make sure that they are collecting that information, and that my device can use that information when it wants.

Figure 9: The Solar Vehicle Project, Daedalus

Observation One, arranged through one of the interviewees, was a group of students working on an extracurricular project, mostly in the research stage. Their previous meeting was reported as a brainstorming activity and each member had been tasked with some research activities. Now the group was attempting to determine what the facilitator referred to as the “prioritization of constraints.” Through discussion, the group was attempting to set priorities for their design, weighing the pros and cons of various designs in the light of what they determined to be their larger goals. Multiple students brought up papers they had read related to the topic to bring context to the conversation. By the end, the group had decided that a few more areas needed to be researched, but with that additional information, they would be able to create a crude two-dimensional prototype, thereby preparing them to move onto the next stage, prototyping. The observation served to illustrate the fluidity of these stages and the process of moving from one stage to the next. Brainstorming, in many ways, was not completed and so, revisited, while the meeting served to clearly identify what research was needed, but not assigned previously.

All this knowledge acquisition is eventually turned into some sort of design or conceptual framework that can be used to build a prototype. A simple prototype was the goal of the next meeting following Observation One. Ashley explained how she turns what she knows into a design for prototyping:

> I don't do anything on the breadboard or anything like that until I actually have everything written down. So I make block diagrams. Actually, no, even before that I read through the problem and kind of reiterate what it is saying in my own terms.

Once the necessary information is thought to be gathered and some sort of design document is created, the process moves on to the prototyping stage.

Prototype

The prototyping stage was often the simplest to describe for the students while taking the longest to complete. This is the stage where the proper resources such as space, tools, and funding become essential to success. Joshua sums up the purpose of the prototyping stage, “proving the proof of concept is super crucial before moving on to the next part.” Matthew adds this description:

> Usually, it’s a lot of trying things and ... with an engineering project it's usually not caring too much how it looks or if it came together perfectly and just trying to get that first prototype done is usually more progress than just thinking too hard about it.

When students reported that they take part in EPBEL for the challenge and intrigue of application, they are probably mostly referring to this prototyping stage.

Observation Two took place during an early prototyping stage where the group of students had identified the tools and materials needed and were starting to assemble a working device. This session didn't go as planned for the students involved as they were testing output values as they were assembling to make sure each connection was working as they expected. There were three students present of which one clearly took the lead. They often had to negotiate what and how to test various connections and even what measurement tool to use, usually verifying measurements when they didn't get what they expected. Some of the time went toward understanding how to use various tools correctly with some guidance and a bit of conflict emerging at points. As frustration built, team members definitely tried to act professionally and think about the various factors that could be causing their researched design not to work. This often sent them back to the research stage to check on assumptions they had about the materials. In the time observed they managed to determine a working theory as to what was wrong, namely a misunderstanding of the specifications of the circuit board they were using.

As Observation Two suggested, this stage often involved multiple build days over weeks or even months, and therefore differed quite substantially from the fairly contained and relatively quick brainstorming sessions, and the more independent research stage. If in an early prototyping or proof of concept stage, the students learned to recognize the constraints of the process, "[Prototypes] can tell you something, but it's never going to behave exactly the same way when you build it 10 times bigger out of the actual materials you are going to use" (Jessica). In large projects where smaller proof of concept prototypes needed to be built, iteration played a large role in getting to a final working device. Jacob described his work on his project as full of many iterations, choosing to get to a "minimum viable product" and then working on that product slowly making it better and better. Regardless, the prototyping process is where students take their acquired knowledge and apply it, literally using their hands to build a device.

Testing

The path from prototyping to testing is also very fluid and identifying the difference is not always straightforward, although it does seem to exist as a different stage. Jacob describes his process as such:

> Because you've looked into it a lot, what you could do and what you want to do. You basically just start making bits and pieces nicer. So like the tracking algorithm I'm working on, right now it checks, has power changed the voltage, has power increased. Yes, then upstepping that way, step down the other way. It's very very basic, but there are some other fancier control techniques that you can use, but that requires a lot more time to get all the details worked out, because there is a lot more than some simple logic behind them, values you have to tweak, that sort of thing, that's all very time-consuming.

In Jacob's case, there is a working prototype and he is actively testing it. He's using that testing phase to figure out how to "make it nice." The difference between prototyping and testing here seems to be the difference between getting something to work and getting something to work well. Observation Three offered a glimpse into the transition from the prototyping stage to the testing stage. There were four students set to improve a working prototype by trying to reassemble the device in a different way as to not lose functionality but make it more aesthetically pleasing. There was a bit of back and forth argument as to the necessity of this step and constant reassessment on how to accomplish it while maintaining functionality. Jessica described this part of the process as such, "you try to stick to the original plan as much as you can when... something looks like it's not going to work so you try and fix it, try and go back to the original plan."

Iterate

There's a clear desire to stick to the original plan during the prototyping and testing phases, but there is awareness of the possibility that the process will all start over again for the same project. Observation Three focused on a project in its second generation that had gone completely back to the drawing board. During Observation Three, one of the students started talking about a possibility for the third generation of the device, perhaps joking, perhaps not.

Christopher told of his experience with an unanticipated need for a complete iteration in a shortened period of time. His team was designing a robotic chess board (see Figure 10) and during the build process they discovered that some of the parts were faulty with no time to order replacements. After setting a deadline for further testing and debugging to see if they could get it to work, they moved back to a quick brainstorming stage. They were able to concoct a new plan that utilized the parts that were working and had emerged from one member's reading of a chess strategy book. Instead of a fully playable person versus computer robotic chess game, they decided to implement the Knight's Journey via their robotic chess board, a mathematical chess problem whereby the knight visits each spot on the board exactly one time. So they set about researching and designing the algorithm that would make it work, implementing a quick prototype, and tweaking it, even adding an educational element that challenged middle-school kids, the audience they were preparing the project for, to attempt the knight's journey themselves on paper. Christopher was still disappointed that their original plan did not end up working, but was satisfied with their ability to salvage the situation.

Figure 10: Chess Playing Robot in an Early Build Stage

The story stands as an example of what became clear in the interviews and observations—each extracurricular project described roughly went through the same four-part process and that process often went through multiple iterations. Although these projects do not benefit from a direct structure guiding students on the most efficient and effective way to complete their projects, they seem to gravitate toward the process described.

Summary

This chapter has provided multiple findings related to engineering students participating in extracurricular project-based experiential learning at the University of Minnesota. Although not definitive, numerous insights can be derived from this analysis. The following chapter will use the literature review and conceptual framework to discuss the significance of these findings.

CHAPTER FIVE: CONCLUSIONS AND IMPLICATIONS

With technology becoming more and more embedded in daily life as the information age matures and the world transitions to more of a knowledge-based economy, the importance of increasing the quantity and quality of science and engineering grows. Toward that end, this study focuses on understanding a potential effective and efficient method to educate nascent engineers at a large research university, asking the question, “How does extracurricular project-based experiential learning contribute to engineering students’ experiences?” This final chapter will put the study’s findings in the context of the literature explored in chapter two, discuss the implications for practice and policy, and provide thoughts on future implementation and research directions.

Discussion of Findings in the Context of the Relevant Literature

The end of chapter two introduced a theoretical framework for understanding and investigating how extracurricular project-based experiential learning (EPBEL) impacted student engagement, learning, and the overall college experience. Terenzini and Reason’s (2005) College Impact Model serves as the basis for the framework, as it considers how the characteristics of the entering student along with the organizational context of the university and the peer environment of the student work to affect the outcomes for each student related to learning, development, change, and persistence. This section will concentrate on the peer environment, specifically the out-of-class experience that is EPBEL, and the reported outcomes that emerged from those experiences. The organizational context will also be touched on later in this chapter.

EPBEL as an Impactful Engagement Activity

Regarding student engagement, Tinto (1975) found that integration of the individual student is key while Astin (1984) illustrated that involvement, especially that which a student devotes plenty of physical and psychological energy to, is important for positive student outcomes for college graduates. Findings from the interviews show that EPBEL offers an accessible outlet for integration and involvement in various areas, including applying the engineering discipline, developing peer affinity, and connecting with the broader community.

EPBEL offered a rich and diverse way for students to engage in their chosen discipline. Students were intrigued and challenged by projects they considered to be more related to the real-world problems they would have to solve once they fully entered the workforce. They also saw it as a way to connect their burgeoning engineering skills with their passions, whether that be building interesting devices, learning particular skills, or helping people in the broader community.

For all students interviewed, developing connections to their peers was reported as important to their experience. Many saw it as the most important and valuable part. Their integration into this particular student community happened for various reasons. Some students were drawn to the interdisciplinary nature of EPBEL because their engineering courses were sub-discipline specific in regards to both topic and people. Others were drawn to the particular challenges and rewards of teamwork and mentorship. Sharing a passion—where students self-selected onto a team to exert large amounts of, as Astin would say, physical and psychological energy—was also important and positive for many of the students interviewed. This experience parallels that of learning communities set up as co-curricular environments where students studying similar fields live and learn together. EPBEL adds the additional element of shared passion for a specific task, which serves to drive deep and quality involvement for the participating students.

For some of these students it was important that the energy was directed at helping the broader community. Here, one can especially see the overlap with service learning, as many of the student projects described involved some kind of interaction with stakeholders outside the university or had an aim to aid individuals in the local community or across the globe. Students engaged in the notion of utilizing their developing engineering skills in the service of others.

In total, providing the opportunity to make friends and integrate into a larger community that shared similar values sums up how EPBEL engaged students. One unique contribution from these findings is that EPBEL is an especially impactful engagement activity for students. Relatively speaking, there can be a high barrier of entry into the activity as the peer group expects non-trivial minimum levels of dedication that need to be balanced with a difficult curricular load. However, it is that higher barrier to entry that likely leads to such high quality involvement and integration for students, which provides an environment ripe for persistence, social development, and learning. This finding is consequential to policy makers looking at the implications for practice and will be discussed later in the chapter.

EPBEL as an Effective Tool for Increasing Self-Efficacy and Motivation

EPBEL provides a particularly engaging experience for students, but another important question is how it develops self-efficacy. As stated in Chapter Two, Bandura (1977) describes self-efficacy as the measure of "conviction that one can successfully execute the behavior required to produce the outcomes" desired (p. 193). Also discussed in Chapter Two, the Academic Pathways of People Learning Engineering Survey (APPLES) found that high levels of motivation and confidence are important indicators for success in engineering and that students who participate in extracurricular activities are more likely to have high levels of motivation and confidence (Sheppard, et al., 2010). Is EPBEL simply providing a discipline related social experience or does this engagement go further and instill lasting confidence, motivation, and conviction related to engineering that will aid the student in her or his coursework and carry through beyond graduation? Although this study does not explicitly measure levels of motivation and confidence, there is strong evidence from the interviews that students are highly motivated and perceive a growth in confidence as they navigate the EPBEL experience.

In regards to the evidence for increasing confidence, the findings show confidence growth in multiple areas. Students reported that they had an advantage in group activities occurring in their classes, because they were more likely to take the lead and had the additional experience and skills to push forward the process. Students also reported feeling more confident in communication and presentation due to EPBEL. Throughout the interviews, there was a tangible sense that these students and the students they worked with were confident that they could find answers to questions they had, take the lead when necessary, meet deadlines, and manage resources.

Technical and creative confidence was also reported to have been increased through EPBEL. Much of this growth can be traced to the accumulation of experiences in EPBEL. Students who had been at it for over two years exuded a confidence that they knew exactly how to get their projects staffed, funded, and built. EPBEL seems to add the unique element of instilling a sense of independent accomplishment due to the project not being connected directly to curriculum or workplace requirements. This especially applied to the experienced students who were currently in leadership positions for their student groups, had been previously, or had seen successful projects go from ideas to working artifacts. EPBEL, similar to other extracurricular activities that rely entirely on student planning and effort, offers engineering education a particularly strong method to develop independence and entrepreneurship by building confidence through project successes.

It is possible that EPBEL is simply attracting highly motivated students rather than increasing motivation, but when coupled with the reported confidence gains, it stands to reason that they are interconnected. As Leslie, McClure, and Oaxaca (1998) found, increasing levels of self-concept—the belief that one has the ability and desire to do, in this case, engineering—leads to self-efficacy. Some of the student interviews illustrated this point by relating how they were hesitant to start doing EPBEL and didn't participate at near the level they did later. As their confidence increased and they started to conceptualize themselves as engineers, their motivation increased as well. Women especially reported gains in confidence and self-concept that seemed to impact their motivation. EPBEL seems to offer an outlet where the women could experiment with belonging, quickly learn that they were capable, and then go on to flourish. One became president of the largest project-based student group on campus, another started her own project-based student group, while the other two were deeply involved in a myriad of projects in which they were taking the lead. All four commonly expressed memories of doubt that they had to overcome and EPBEL played a large role in their changing sense of belonging. For the men, elements of increased confidence leading to motivation also was present, but the men were much less likely to express that they lacked confidence or didn't belong. This study supports Leslie, McClure, and Oaxaca's (1998) suggestions to build women's confidence through accomplishment, peer reinforcement, and challenges and builds off of Kilgore, Yasuhara, Saleem, and Atman's (2006) conclusions that hands-on experiences for women help them build self-concept and ultimately self-efficacy.

Recalling the research that Sheppard et al. (2010) did in regards to intrinsic motivation and engineers, they showed that exposure to project-based learning correlated highly with increases in (a) intrinsic-psychological motivation for men and (b) intrinsic-behaviorial motivation for men and women. Couple this with their results showing that students report self-directed learning, hands-on and applicable problem-solving, applying diverse knowledge, owning their experiences, and being challenged as their five most significant learning experiences, and it is not surprising that EPBEL proves to be quite successful at motivating students. The students interviewed for this study all reported putting in significant time to their projects, with many of them reporting multiple all-nighters. It is beyond the scope of the research design to fully differentiate what motivational types (see list on page 36) were being affected and how, but the interviews seem to indicate that psychological, behavioral, social good, and mentor influence motivation increases happened for these students at varying levels.

EPBEL can be a very powerful tool for educators who want to provide pathways for students to independently increase their confidence and motivation related to engineering and other facets important to engineering like communication skills, working in teams, and broader civic engagement. Many of the interviewed students were looking for ways to have an impact but didn't know how to effectively do that. EPBEL, like service-learning, offers an outlet to use their burgeoning skills in ways that feel impactful to them. Whether it be putting on a massive light-show that attracts thousands, making prosthetic hands for people in poor countries, reaching out to high school students considering careers in engineering, or building a device and competing against others across the U.S. or even the world, these EPBEL projects provided an avenue for meaningful impact and success. Alongside that impact and success, comes important growth in motivation and confidence, two essential elements to producing quality engineers.

EPBEL as Career Preparation

It became clear through the interview process that students felt they had an advantage in the job hiring process for internships and post graduate jobs due to their EPBEL experiences. Generally, these advantages do not stem from direct technical experience gained from the projects, although that does happen, but from the more general skills students pick up such as working in teams, project management, communication, and independence. The findings indicate that employers are very keen to hire students with EPBEL experiences. Contemplating the discussion from the previous two sub-sections on engagement and self-efficacy, it follows that if employers want to hire highly engaged, confident, and motivated students, an accurate marker for those types of students is a well-articulated EPBEL experience.

The EPBEL Learning Process

Learn by doing. This simple yet lasting paraphrase of John Dewey and others' work continues to resonate with educators and the general public today. Defining "doing" is key in the phrase and probably why Dewey likely never uttered his philosophy on education quite so succinctly. Instead Dewey (1959) saw freedom as key to learning by doing, writing, "the only freedom that is of enduring importance is freedom of intelligence, that is to say, freedom of observation and of judgment exercised in behalf of purposes that are intrinsically worthwhile" (p. 69). For the learning to happen, the doing must have value and its value derives from the freedom to observe, reflect, judge, experiment, research, create, and dream (among others). At its core, extracurricular project-based experiential learning is one of the purest exercises in doing, in the Dewey sense, that nascent engineers do at college. There is no requirement to take part, hence the extracurricular nature. If one does decide to take part, there is rarely direct or even indirect guidance from staff or faculty. The projects may be constrained by time, resources, and skill, but never by imagination or curricular and grade pressures. This study sought to understand how this freedom to build whatever, whenever, in the EPBEL context resulted in a tangible learning process. Kolb's model of experiential learning seemed to offer the likeliest parallel to the EPBEL experience and the interviews and observations backed up that assertion.

In deconstructing student responses to questions on taking a project from idea to working device, the process described by each was remarkably similar despite no structured guidance as one would see in a course. Perhaps the engineering design process has already been ingrained through their courses, or engineering projects simply lend

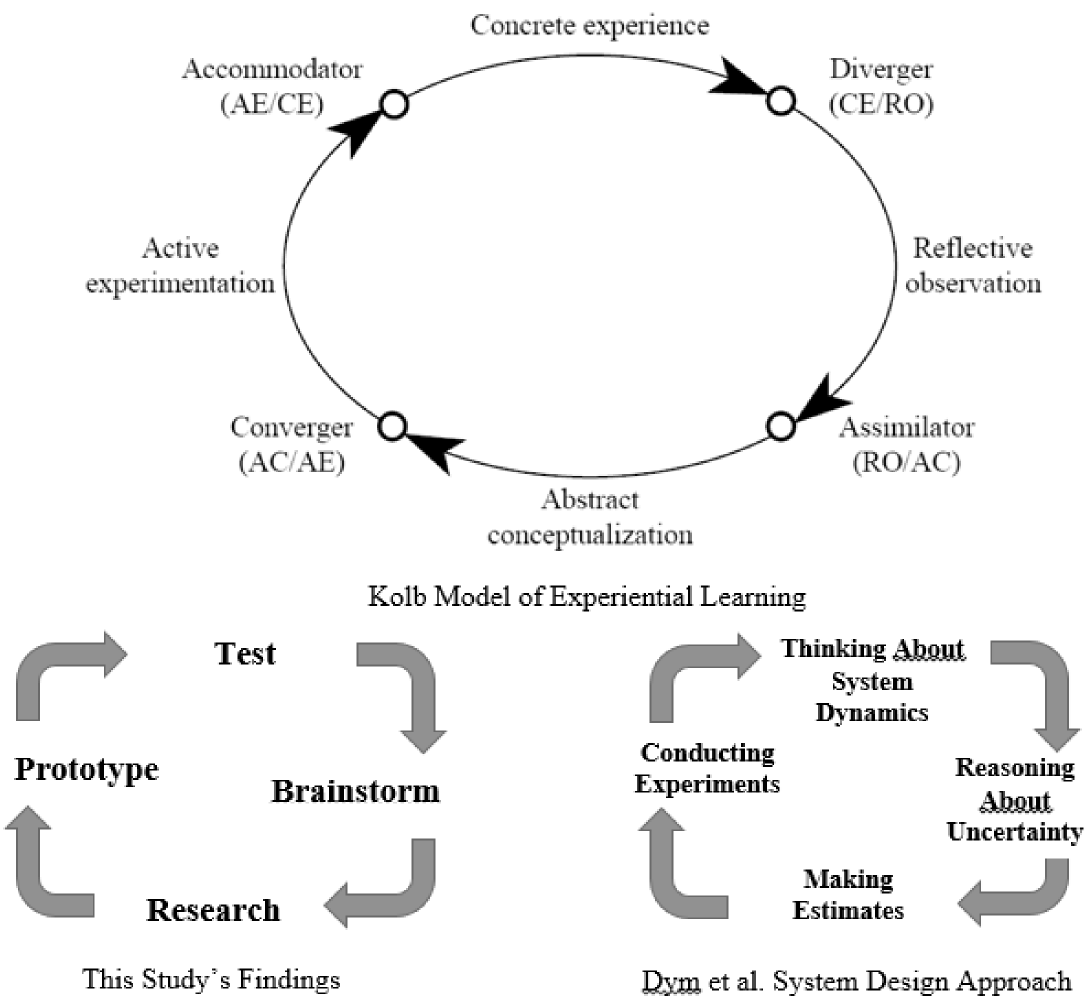

Figure 11: The Experiential Learning Model and the Engineering Design Process

themselves to this type of process, but regardless, there was continuity of process across the descriptions from students. As the findings in chapter four showed, their process fit into four stages moving from brainstorming to researching to prototyping to testing. Figure 11 correlates this finding with Kolb's model of experiential learning and the engineering design process that Dym et al. (2005) emphasize as key experiences that new-century engineering students need.

Breaking down the process individually, EPBEL projects usually start in the brainstorming stage, a divergent thinking stage, where students tend to be their most creative, building on their previous experiences to imagine the outer limits of what they can accomplish. In this stage students are contemplating what to build or what problem to solve; or if part of an iterative cycle, may be thinking about how to improve a previous design by starting over with a new design. Some of the ideas to emerge from this stage among the students interviewed for this study include fire that dances to music, very inexpensive blood glucose monitors for citizens of poor countries, a hovercraft that shoots t-shirts, and a wind turbine that could be fixed by uneducated poor people in remote non-electrified regions of the world. This stage aligns with Kolb's reflective observation stage and what Dym and his colleagues describe as reasoning about uncertainty. As Kolb's experiential learning theory generally posits, EPBEL students, even though their projects generally start in this stage, do not come to it as blank slates. Instead they are building upon their previous experiences. In EPBEL, the teams usually consist of diverse members in terms of experience enabling for modeling and mentoring to occur. In practice, this is very much a group social activity for EPBEL students where excitement is built for ideas, and whiteboards and sticky notes play a prominent role.

After this divergent stage, EPBEL groups would move into assimilating their various requirements for their project and devise a plan to research what they needed to know. This stage tends to be more independent and involves reading papers, sketching rudimentary models, consulting with experts, and understanding how an individual solution fits into a larger system, among other abstractions. Kolb refers to this as abstract conceptualization while Dym et al. (2005) discuss making estimates. This stage often serves as a reality check, necessitating revisiting what can be accomplished. After the research is gathered, priorities are set in terms of what is most important to accomplish and what methods or designs are most likely to align with those priorities. The research stage in EPBEL is often repeated throughout the entire process as problems or opportunities emerge. However, some of the interviewees did correlate project success with solid preparation in the research stage.

Once there is consensus that enough is known, real convergent learning starts to occur as students take what they know and set out to build a working prototype, a proof of concept. Kolb calls this active experimentation and Dym et al. (2005) refer to as conducting experiments. This part of the process tends to be more group oriented than the research stage, but can still involve a fair amount of independent work if there are multiple parts to a project. This is also the stage where resources are important, especially access to appropriate materials, tools, space, and storage. It is the most hands-on stage and I suspect the stage that caused many of the all-nighters mentioned by some of the study subjects. Sometimes the prototype is a simpler version of the future finalized device, a true proof of concept, while other times it is the first iteration of the final device. Regardless, students are taking the ideas from the brainstorming stage and the knowledge from the research stage and creating an artifact.

All this active experimentation sets the students up for the testing stage, where they can immerse themselves in the concrete experience, as Kolb calls it, of turning a prototype into a fully functioning and finished device. Dym et al. (2005) refer to thinking about system dynamics, as students now have to poke and prod what they have created, ensure its various parts work together, and consider if it fully meets the goals they had in mind when they were in the brainstorming stage. This is a slight move away from the convergent thinking they engaged in during the prototyping stage and is what Kolb referred to as the accommodator learning style. Here EPBEL students start to wonder what can or needs to be improved, how is it going to work in different environments, and how can it work even better. Sometimes this prompts an iterative move back to the brainstorming stage for a new design if enough dedication remains in the group or new motivated students have cycled in. Other times, groups simply tinker and perhaps decide they have achieved their goals. Although not asked of the interviewees or indicated in the findings, the testing phase of the process is probably most student’s first interaction with EPBEL, but not as members of the student group or a particular project. When recruiting for their project-oriented student groups, demos of current projects play a major role, as they entice students to test their devices. It is this concrete experience that precedes further commitment and future participation in a brainstorming session for a new project or a new design on an old project.

One final note on the iterative nature of this building and learning process. Kolb (1984) writes, "ideas are not fixed and immutable elements of thought but are formed and re-formed through experience" (p. 28). An engineered device is not so different. Its final build state is not pre-determined, but formed and re-formed through the entirety of the iterative build process. If learning itself is accomplished through a cyclical process moving from concrete experience, to reflective observation, to abstract conceptualization to active experimentation, and back to concrete experience; then it stands to reason that an educational activity that starts with testing and moves to brainstorming and then to research and then to prototyping before starting over, is uniquely suited to educate engineers, as it mimics both experiential learning and the engineering design process. This is not a new finding, as many have connected the two, even if not explicitly. What this study contributes to our understanding of engineering education is that encouraging the extracurricular nature of project-based experiential learning enhances the value of the project building experience even further. Inherent in EPBEL is a high level of freedom for the students, helping greatly to foster, as Dewey (1959) says, "purposes that are intrinsically worthwhile" (p. 69). Because the purposes and the projects are wide-open and generated by the students, or at least the students self-select into on-going projects, EPBEL is always functioning in an environment of free choice—an environment Maria Montesori (1967/1995) would endorse because, paraphrasing her, it is rich in motives which lend interest to activity and invite students to conduct their own experience.

Limitations of the Study Findings

Despite strong findings for extracurricular project-based experiential learning providing impactful engagement, increasing self-efficacy, preparing students well for careers in engineering, and being an effective learning process, there are many limitations to this study's methods. Challenges to implementation will be discussed later in the chapter.

Regarding the research methods, the key limitation is the sampling method. Utilizing the Exceed Lab makerspace to identify a sample does not capture all student participating in EPBEL. Within that sample there is likely selection bias. Twenty-six students were asked in total to sit down for an interview to get to 10 interviewees. Those that agreed to participate may have had a different experience than those who refused to participate or did not respond. It can be argued that those who chose to participate were more highly engaged students overall and that their EPBEL experiences were affecting them more positively than the median case. Furthermore, students who participate in EPBEL at all also self-select into such experiences, casting further doubt on what the actual impact would be on a typical engineering major. These limitations are important to consider when thinking about the transferability of study findings across all engineering students at the University of Minnesota or to engineering students at other institutions. However, as a qualitative study, generalizability is not the goal, but rather understanding individual interpretations of experiences and what meaning individuals are attributing to those experiences.

Implications for Practice

If this is the information age—an age driven by empowered individuals better able to connect to others, access knowledge, and tailor an environment best suited for her or him—then it is no surprise that makerspaces are appearing in multiple contexts all over the world. With the knowledge at their fingertips, a handful of creative, imaginative, and motivated individuals are designing and producing devices and ideas that were once limited to the selectively trained, operating in industrial oriented laboratories or corporate offices, solving problems in a linear and variable constrained environment. Now, citizens and consumers are also part of this new knowledge-based economy, and it takes a new-century engineer to navigate an interconnected, heterogeneous, and multi-dimensional society. Therefore, institutions of higher education must adapt to this new reality, not just by adjusting the technology and knowledge present in the classroom, but adjusting the way students interact with technology, knowledge, and most importantly, each other. Extracurricular project-based experiential learning offers multiple opportunities for expanding the tools with which we educate engineering students but is also limited by a number of challenges. This final section explores those opportunities and challenges.

Opportunity: Foster Meaningful Experiences

As reported earlier, Astin (1993) found that engineering majors were, in many ways, the least satisfied students upon graduation, despite often having the best and most lucrative job opportunities. These students were less satisfied with their student life experiences, interdisciplinary experiences, cultural awareness, instruction and other facets. It’s not difficult to understand why this is the case. Engineering students typically take the most difficult courses while taking the most required courses, leaving less time to have the quintessential college experience. Courses are generally technical in nature and, although improving, there is little integration of larger societal or pedagogical context such as considering the natural environment, the teaching of communication or design, or working with the larger community. Some students have found their own outlets for this additional context through extracurricular activities that retain a discipline connection. This study shows how successful they can be at creating highly-engaged, confident, and motivated students. Considering strategies for getting more students involved in EPBEL can be a powerful path forward to foster more meaningful experiences for engineering majors.

Opportunity: Expand the Pathway

Bandura (1977) defined self-efficacy as the measure of "conviction that one can successfully execute the behavior required to produce the outcomes [desired]" (p. 193). Facing a STEM student shortage, it is more important than ever for the engineering discipline to open itself up to all potential students. In order to attract students that haven't historically looked at engineering, programs need to promote and teach the facets of engineering that increase self-efficacy. If students see engineering as only applied math and science, rather than a discipline of hands-on design innovating solutions for the world, many will not be drawn to the field. This is especially true for under-represented minorities and women who have to first develop the self-concept that they belong in engineering. EPBEL is a potentially powerful tool in promoting the hands-on community focused nature of engineering, thereby attracting a more diverse set of students that participate in their own meaningful and confidence building extracurricular engineering projects.

Opportunity: Connect Outside the University

Closely related to the concept of expanding the pathway for a diverse set of future engineers, EPBEL offers a natural conduit for pre-college outreach. Student led and student built projects provide a relatable window for young people to see the potential of engineering and their own potential as engineers. Engineering programs that coordinate connections between local primary and secondary schools and extracurricular student projects can foster a local outreach environment that creates excitement and a clear pathway for youth. Mentorship can also grow out of such connections and EPBEL students only enhance their own sense of community engagement and spirit.

Having a strong culture of EPBEL can also provide the flexibility and boldness among students to find and enter national and world competitions. Government agencies, non-profits, and industry all sponsor design competitions meant to increase interest and experience in engineering design. Building off previous project experiences and knowing that the resources exist, encourages students to engage with the larger engineering community who are also putting in resources to cultivate an exciting design and build culture across the nation. Extracurricular projects, whether part of a competition or not, can attract industry sponsorship and mentorship as companies see value in students solving problems relevant to their technologies, students using their devices, or being able to evaluate and recruit students in a relevant context.

Alumni engagement with current students is a final fruitful opportunity provided by EPBEL. Alumni returning to campus are often personally excited by the concept of students taking their extra time to engineer extracurricular projects. For colleges and universities, these meaningful alumni experiences—ranging from seeing student project artifacts to mentoring projects—are excellent methods to foster the type of alumni engagement that leads to significant giving.

One concrete avenue for implementation is tapping into the funding and excitement around the language of grand challenges. Grand challenge funding and support opportunities are already available at many institutions including this study's case study site, the University of Minnesota, and the National Academy of Engineering also has a set of 14 engineering grand challenges. Grand challenges seek to frame problems in broad, inclusive, and recognizable terms that inspire cooperation and action. EPBEL is ideally suited as an educational activity to tackle the grand challenges of our times, due to the interdisciplinary and malleable structure of the technique. If combined with committed faculty and courses to initiate excitement and projects, EPBEL could excel at helping students connect to the outside world and build meaningful experiences.

Opportunity: Fostering Entrepreneurship

Wagner (2012) writes that the way to create talented innovators is to develop a learning culture with the values of "collaboration; multidisciplinary learning; thoughtful risk-taking, trial and error; creating; and intrinsic motivation: play, passion, and purpose" (p. 200). This study found all of those elements present in EPBEL. Colleges and universities can enhance EPBEL by offering support for taking a product to market, through connections with business students, technology commercialization resources, and access to venture capitalists. EPBEL and the makerspaces in which such learning takes place are natural incubators for young innovators and efforts should be made to connect existing campus entrepreneurial education and support to these students.

Opportunity: Enhancing the Regular Curriculum

Sheppard, Macatangay, Colby, and Sullivan (2009) found that the engineering curriculum is overcrowded, theoretically heavy, pedagogically stale, and highly structured; or as Duderstadt (2008) put it, "an obstacle course" (p. 34). EPBEL offers the opportunity to put some of the joy back into the young engineer's journey through their program, replacing theory with practice and structure with freedom. In addition, EPBEL provides students with an outlet to apply what they have just learned in class. At the University of Minnesota, there has been a recent conscious effort by the College of Science and Engineering to introduce project design experiences in the freshmen year and the Department of Electrical and Computer Engineering, as one example, has introduced more multiple week project-oriented lessons into entry level courses. EPBEL allows for students to build on these early experiences, continuing to enhance their design and build skills until they reach the typical capstone design courses found in the senior year.

For this study, the interviewees also indicated that their EPBEL experiences added value beyond what they could get from their courses. They suggested that meaningful project building was missing from the curriculum altogether and that EPBEL filled in that hole. Some felt that labs, even when project oriented, had single paths to solutions, instead of multifaceted approaches to a working answer in an interdisciplinary context. Others liked the added complexity and length of extracurricular projects. In addition, the EPBEL learning process, as stated earlier, is uniquely suited for educating young engineers. If supported well, the evidence points toward EPBEL enhancing, rather than hindering, the engineering curriculum, that some experts believe would be improved by a shake-up.

Challenge: Scalability

Extracurricular project-based experiential learning was a great experience for the students interviewed for this study. However, they represented a small subset of all students studying engineering. There is a strong possibility that extracurricular activities appeal to only a portion of students and since, by the nature of it being extracurricular there is no way to compel students to participate, EPBEL's impact will always be limited. The success of EPBEL as a strategy worthy of investment largely turns on the challenges of scalability and is worth exploring both in future research and in practice.

Challenge: Space and Resources

The challenge of providing enough space, funding, materials, and tools in a safe environment is straightforward. In order for EPBEL to scale appropriately and for students to be successful, there must be makerspaces available and they must be available at times corresponding with when students have time and want to build. Professionally staffing an 18-24 hour a day facility is likely prohibitively expensive, so colleges and universities will need to be creative in addressing this particular challenge. It is likely that student paid and unpaid labor will be depended on heavily and that access will need to be largely unsupervised.

Challenge: White Male Privilege

White males make up the disproportionate share of engineering students and due to higher levels of self-concept and self-efficacy, they are generally more motivated and confident to jump into unstructured projects. They may have more experience with the tools and materials used as well, opening the gap in readiness between white males and others even further. The challenge for EPBEL is how to attract and include women and underrepresented men into these experiences that have traditionally been the domain of white men in the United States. Navigating this challenge successfully becomes crucial to taking advantage of the opportunity to expand the pathway, as mentioned above.

Challenge: The Organization

Higher education institutions are hard-to-change organizations, often with long histories, that are subject to complex and intractable governance (Birnbaum, 1988). The engineering curriculum resembles an obstacle course (Duderstadt, 2008). Revisiting Terenzin and Reason's (2005) College Impact Model (see Figure 2), the above references represent barriers for effective EPBEL implementation related to the organizational context of the university, both institutionally and disciplinarily. Considering that there is likely to be (a) skepticism to the scalability of EPBEL; (b) concern that it requires investment and resources not generally allocated for unproven new educational endeavors; and (c) uncertainty regarding whether it will help at all with increasing the diversity of the student body, resistance to organizational change that allows for a sustainable and scalable version of EPBEL may be quite strong.

Perhaps the most immediate and important organizational challenge lies with engineering faculty. If institutions are to maximize the potential of EPBEL, curriculum changes must occur. Right now, some engineering students have difficulty finding the time to engage in activities outside the classroom, no matter their value. To really take advantage of extracurricular projects, engineering faculty will need to rethink the status quo in their educational techniques. There is reason to believe that EPBEL would be able to be scaled and delivered to many more students if faculty shift some of their attention from delivering technical knowledge in lectures to supporting project-based learning inside and outside the classroom. The support would entail a few facets. The one likely to meet the least resistance is including project-based learning in the classroom. Faculty know the value here through the literature and their own personal experiences, while most engineering programs have already implemented project oriented course early in the curriculum and the vast majority require it in senior capstone projects at the end of the program. The more challenging organizational change will be making the choice to eliminate the total number of required courses to free up room for a more varied experience outside the classroom. Faculty time can be redirected to providing mentorship and consultation on specific projects, and toward the development of a structured program that entices students to participate in projects outside the classroom and gives them the necessary support to have an educational and impactful experience. If engineering educators can alter how they think about the value that extracurricular projects offer, engineering programs can possibly deliver a more engaging and valuable experience that will attract a more varied kind of student attracted to the full range of what a new-century engineer does.

Recommendations for Implementation

Opportunities to enhance the education of engineers exist for a properly supported and encouraged culture of extracurricular project-based experiential learning, but much is still unknown. This study has shown that at least for a self-selected subset of engineering students at the University of Minnesota, there is high educational value in extracurricular project-based experiential learning. It provides high levels of discipline specific engagement, increases self-efficacy, prepares students for their careers, and provides a learning process that uniquely fits the engineering design and build process. Based on these findings, it is worth the time of practitioners to experiment with strategies that provide the proper resources and cultivates the lasting culture that allows for EPBEL to scale to a level of participation that creates a broad impact.

To implement EPBEL at a basic level, colleges and universities need to consider the following elements. The most important element is the proper space for students to build and store their projects. This type of space is critical, both from a resource standpoint for successful projects and as a centerpiece for a culture of experimentation, innovation, and teamwork. Funding is the next critical element to ensure that students do not feel an additional financial burden to buy the materials necessary to complete a project. Also important is the fostering of strong and supported student groups, as student groups often provide the structure and organization that attracts students into EPBEL and sustains projects. These first three elements are the minimum necessary components for a working EPBEL infrastructure, but are not enough to make EPBEL much more than a small component of the engineering educational experience.

In order for EPBEL to make a broad impact, the following additional elements should also be considered. Often space is allotted to single-project build groups. Ideally, space should be expansive, centrally-located, and shared across multiple entry points into EPBEL. Those entry points may be through established student groups, projects related to a course or competition, or independent projects, but efforts would be made for all these project groups to interact in common space. This type of organization has the added benefit of being resource efficient. Efforts should also be made to make projects interdisciplinary, not just across engineering disciplines, but across the entire scope of a particular campus. Faculty participation is another element that should be fostered and can be done in multiple ways. Faculty can encourage project building in their courses and even provide the class assignment that leads to a first prototype that is then developed further through EPBEL. They can also serve as active advisors on projects or as consultants to assist with difficult problems. Though it would be important to maintain the independent nature of EPBEL, certain projects should become eligible to be turned into meaningful credits for students if additional requirements are met. As mentioned earlier, the most impactful step would be a fully engaged faculty that is willing to reduce course requirements in exchange for fully developed outside the classroom project experiences.

Other services are also important, including education on entrepreneurship and technology transfer, information on additional build resources on and off campus, assistance with purchasing, and trainings for various tools. In order for these additional services to be communicated and developed, a robust system of administration must be supported that includes the ability to provide technical services, maintain communication and marketing, and develop the elements that will grow and sustain a lasting EPBEL culture. Also important are meaningful connections to the university, local community, and the wider world, through design shows, outreach events, and service projects. EPBEL can connect with industry and alumni through mentorship, judging, and sponsored projects. Underlying all of these elements is a concerted effort to encourage students to engage in EPBEL from the moment they step on campus while specifically targeting the underrepresented.

Avenues for Future Research

Beyond experimentation on campus, there are multiple avenues of additional research that will provide key information for practitioners. In particular, there are opportunities to design surveys that find the participation rate of engineering students in EPBEL and look for differences in satisfaction, engagement, self-efficacy, and performance, among others. Understanding the current landscape of EPBEL across the nation is also important, so comparative research that provided information on the different EPBEL opportunities available at different engineering schools would inform the current levels of penetration and support. Another consideration is the particular nature of project oriented student groups, so research that looked at their structures and practices and proposed a taxonomy would be of particular interest. In order to scale EPBEL to a large proportion of engineering students, research that looks at why students choose or do not choose to take part in extracurricular project building would provide important implications for implementation. Relatedly, understanding the particular effectiveness of EPBEL with populations that are currently underrepresented in engineering is important information for decision makers. Finally, understanding the impact EPBEL participation has on job prospects would provide excellent evidence for the investment or non-investment in EPBEL.

Conclusion

For those tasked with educating the next generation of engineering students, there are two critical concerns, (a) that not enough students will choose engineering as a career due to demographic changes and other factors, and (b) that students are not being properly trained for the complexities and challenges of the information age. A new-century engineer is needed who has a more diverse background and has the ability to not just engage with the constrained problem in front of him or her, but to engage as a citizen engineer who understands how their role impacts a knowledge-driven, global economy. It is within this context that this study explores how extracurricular project-based experiential learning contributes to engineering students' experiences, looking for an understanding of how this unexplored area of higher education could impact the important concerns above.

The findings were clear that EPBEL contributes positively to student experiences, showing particular promise in providing impactful engagement, increasing self-efficacy, preparing students for their careers, and providing an effective learning process well-suited for engineers. There are multiple opportunities for practitioners to encourage and implement EPBEL experiences in ways that contribute to the crafting of a new-century engineer who is adept with people, undaunted by complexity, and understands the global context of their actions.

Perhaps what EPBEL is really providing is the opportunity for faculty, staff, and administration to get out of the way and let students' natural curiosity and motivation take over without the typical constraints of the classroom. In fact, student project teams often meet in makerspaces like the Exceed Lab, a sort of anti-classroom where knowledge is gained through experience and there are no textbooks or experts to guide you. EPBEL can in no way be a replacement for what is learned in the classroom, but it can be the supplement for what the classroom cannot achieve and the antidote for the sometimes suffocating structure the classroom must provide to function. This is not meant to imply a hands-off approach, but rather an approach that provides the basic scaffolding from the institution for students to find, as Dewey (1959) wrote, "purposes that are intrinsically worthwhile" (p. 69). If we find the proper balance, there is potential to enhance experiences for students and prepare a generation of diverse and broad thinking engineers—new-century engineers.

References

ABET. (2016). Criteria for Accrediting Engineering Programs, 2016 – 2017. Retrieved from http://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2016-2017/

Astin, A. W. (1975). *Preventing students from dropping out*. San Francisco: Jossey-Bass.

Astin, A. W. (1985). Student involvement: A developmental theory for higher education. *Jourrnal of College Student Personnel, 254*(4), 297-308.

Astin, A. W. (1993). *What matters in college?: Four critical years revisited*. San Francisco: Jossey-Bass.

Astin, A. W., Vogelgesang, L. J., Ikeda, E. K., & Yee, J. A. (2000). *How service learning affects students* (Rep.). University of California, Los Angeles: Higher Education Research Institute. Retrieved from http://heri.ucla.edu/service_learning.html

Atman, C. J., Sheppard, S., Turns, J., Adams, R., Fleming, L., & Stevens, R. (2010). *Enabling engineering student success: The final report for the Center for the Advancement of Engineering Education*. San Rafael, CA: Morgan & Claypool.

Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavioral change. *Psychological Review, 84*(2), 191-215. doi:10.1037/0033-295x.84.2.191

Barrows, H. S., & Tamblyn, R. M. (1980). *Problem-based learning: An approach to medical education*. New York: Springer Pub.

Baxter Magolda, M. (1992). *Knowing and reasoning in college: Gender-related patterns in students' intellectual development*. San Francisco: Jossey-Bass.

Baxter Magolda, M. (1999). *Creating contexts for learning and self-authorship: Constructive-developmental pedagogy*. Nashville: Vanderbilt University Press.

Baxter Magolda, M. (2001). *Making their own way: Narratives for transforming higher education to promote self-development*. Sterling, VA: Stylus.

Beal, S. J., & Crockett, L. J. (2013). Adolescents' occupational and educational goals: A test of reciprocal relations. *Journal of Applied Developmental Psychology, 34*(5), 219-229. doi:10.1016/j.appdev.2013.04.005

Bergsteiner, H., Avery, G. C., & Neumann, R. (2010). Kolb's experiential learning model: Critique from a modelling perspective. *Studies in Continuing Education, 32*(1), 29-46. doi:10.1080/01580370903534355

Besterfield-Sacre, M., Shuman, L., Wolfe, H., Atman, C., Mcgourty, J., Miller, R., . . . Rogers, G. (2000). Defining the outcomes: A framework for EC-2000. *IEEE Trans. Educ. IEEE Transactions on Education, 43*(2), 100-110. doi:10.1109/13.848060

Birnbaum, R. (1991). *How colleges work: The cybernetics of academic organization and leadership*. San Francisco: Jossey-Bass.

Blumenfeld, P. C., Soloway, E., Marx, R. W., Krajcik, J. S., Guzdial, M., & Palincsar, A. (1991). Motivating Project-Based Learning: Sustaining the Doing, Supporting the Learning. *Educational Psychologist, 26*(3-4), 369-398. doi:10.1080/00461520.1991.9653139

Boyte, H., & Spencer, J. P. (2012, May 31). Civic science: Beyond the knowledge wars. Retrieved from http://www.huffingtonpost.com/harry-boyte/civic-science-action-_b_1556076.html

Butz, W. P., Kelly, T. K., Adamson, D. M., Bloom, G. A., Fossum, D., & Gross, M. E. (2004). *Will the scientific and technology workforce meet the requirements of the federal government?* (Rep.). Rand Corporation.

Carini, R. M., Kuh, G. D., & Klein, S. P. (2006). Student Engagement and Student Learning: Testing the Linkages*. *Research in Higher Education Res High Educ, 47*(1), 1-32. doi:10.1007/s11162-005-8150-9

The Carnegie Classification of Institutions of Higher Education. (n.d.). About Carnegie classification. Retrieved from http://carnegieclassifications.iu.edu/

Carnevale, A. P., Smith, N., & Strohl, J. (2013). *Recovery: Job growth and education requirements through 2020* (Rep.). Georgetown University: Center on Education and the Workforce.

Cech, E. A. (2013). Culture of Disengagement in Engineering Education? *Science, Technology & Human Values, 39*(1), 42-72. doi:10.1177/0162243913504305

The Center for the Advancement of Engineering Education. (2011). About. Retrieved from http://www.engr.washington.edu/caee/index.html

Charette, R. N. (2013). The STEM crisis is a myth. *IEEE Spectrum, 50*(9), 44-59. doi:10.1109/mspec.2013.6587189

Chi, M. T. (2009). Active-constructive-interactive: A conceptual framework for differentiating learning activities. *Topics in Cognitive Science, 1*(1), 73-105. doi:10.1111/j.1756-8765.2008.01005.x

Chickering, A. W., & Gamson, Z. F. (1987). Seven principles for good practice in undergraduate education. *AAHE Bulletin, 39*(7), 3-7.

Chickering, A. W. (1969). *Education and identity*. San Francisco: Jossey-Bass.

Cooper, H. (2011, June 13). Obama offers training plan designed for high-tech jobs. *The New York Times*. Retrieved from http://www.nytimes.com/2011/06/14/us/politics/14obama.html

Daempfle, P. P. (2003). An analysis of the high attrition rates among first year college science, math, and engineering majors. *Journal of College Student Retention: Research, Theory and Practice, 5*(1), 37-52. doi:10.2190/dwqt-tya4-t20w-rcwh

Dewey, J. (1959). *Experience and education*. New York: The Macmillan Company.

Diefes-Dux, H. A., Hjalmarson, M. A., Miller, T. K., & Lesh, R. (2008). Chapter 2: Model-eliciting activities for engineering education. In J. S. Zawojewski, H. A. Diefes-Dux, & K. J. Bowman (Eds.), *Models and modeling in engineering education: Designing experiences for all students* (pp. 17-35). Rotterdam: Sense.

Dimaggio, P. J., & Powell, W. W. (1983). The iron cage revisited: Institutional isomorphism and collective rationality in organizational fields. *American Sociological Review, 48*(2), 147. doi:10.2307/2095101

Duderstadt, J. (2008). *Engineering for a changing world: A roadmap for the future of engineering practice, research, and education* (Rep.). The University of Michigan, Ann Argor: The Millenium Project. Retrieved from http://milproj.dc.umich.edu/publications/EngFlex_report/download/EngFlex%20Report.pdf

Dutson, A. J., Todd, R. H., Magleby, S. P., & Sorensen, C. D. (1997). A Review of Literature on Teaching Engineering Design Through Project-Oriented Capstone Courses. *Journal of Engineering Education, 86*(1), 17-28. doi:10.1002/j.2168-9830.1997.tb00260.x

Dym, C. L., Agogino, A. M., Eris, O., Frey, D. D., & Leifer, L. J. (2005). Engineering Design Thinking, Teaching, and Learning. *Journal of Engineering Education, 94*(1), 103-120. doi:10.1002/j.2168-9830.2005.tb00832.x

Educause Learning Initiative. (2013, April 9). Seven things you should know about makerspaces. Retrieved from https://library.educause.edu/resources/2013/4/7-things-you-should-know-about-makerspaces

Electrical and Computer Engineering, the University of Minnesota. (n.d.). Dream big, design intensely, build exceptionally: Exceed lab opens. *Signals, XIII, Issue 3*. Retrieved from http://ece.umn.edu

Eris, O., Chachra, D., Chen, H. L., Sheppard, S., Ludlow, L., Rosca, C., . . . Toye, G. (2010). Outcomes of a longitudinal administration of the persistence in engineering survey. *Journal of Engineering Education, 99*(4), 371-395. doi:10.1002/j.2168-9830.2010.tb01069.x

Eyler, J., Giles Jr., D. E., & Gray, C. J. (1999). At a glance: What we know about the effects of service-learning on students, faculty, institutions and communities, 1993-1999. *Bibliographies*. Paper 5.

Froyd, J. E., Wankat, P. C., & Smith, K. A. (2012). Five Major Shifts in 100 Years of Engineering Education. *Proceedings of the IEEE, 100*(Special Centennial Issue), 1344-1360. doi:10.1109/jproc.2012.2190167

Gallup and Purdue University. (2014). Great jobs great lives: The 2014 Gallup-Purdue index report. Washington, D.C.: Gallup.

Gerber, E. M., Olson, J. M., & Komarek, R. L. (2012). Extracurricular design-based learning: Preparing students for careers in innovation. *International Journal of Engineering Education, 28*(2), 317-324.

Harrisberger, L. (1976). *Experiential learning in engineering education*. Washington, D.C.: American Society for Engineering Education.

Hurtado, S., Eagan, K., & Chang, M. (2010). Degrees of success: Bachelor's degree completion rates among initial stem majors. Higher Education Research Institute at UCLA, January.

Hurtado, S., Newman, C. B., Tran, M. C., & Chang, M. J. (2010). Improving the rate of success for underrepresented racial minorities in STEM fields: Insights from a national project. *New Directions for Institutional Research, 2010*(148), 5-15. doi:10.1002/ir.357

Institute of Medicine, National Academy of Sciences, & National Academy of Engineering. (2007). *Rising above the gathering storm: Energizing and employing America for a brighter economic future*. Washington, D.C.: National Academies Press.

Johnson, D. W., Johnson, R. T., & Smith, K. A. (1991). *Active learning: Cooperation in the college classroom*. Edina, MN: Interaction Book.

Jones, B. F., Rasmussen, C. M., & Moffitt, M. C. (1997). *Real-life problem solving: A collaborative approach to interdisciplinary learning*. Washington, DC: American Psychological Association.

Kilgore, D., Yasuhara, K., Saleem, J., & Atman, C. (2006). What brings women to the table? Female and male students' perceptions of ways of thinking in engineering study and practice. *Proceedings. Frontiers in Education. 36th Annual Conference,* 1-6. doi:10.1109/fie.2006.322585

Knight, D. W., Carlson, L. E., & Sullivan, J. (2007, June). Improving engineering student retention through hands-on, team based, first-year design projects. In *Proceedings of the International Conference on Research in Engineering Education*.

Kolb, D. A. (1984). *Experiential learning: Experience as the source of learning and development*. Englewood Cliffs, NJ: Prentice-Hall.

Kuh, G. D. (1995). The other curriculum: Out-of-class experiences associated with student learning and personal development. *The Journal of Higher Education, 66*(2), 123-155. doi:10.2307/2943909

Kuh, G. D. (2001). The National Survey of Student Engagement: Conceptual framework and overview of psychometric properties. Bloomington, IN: Indiana University Center for Postsecondary Research, 1-26.

Kuh, G. D. (2003). What we're learning about student engagement from NSSE: Benchmarks for effective educational practices. *Change: The Magazine of Higher Learning, 35*(2), 24-32. doi:10.1080/00091380309604090

Kuh, G. D. (2009). What Student Affairs Professionals Need to Know About Student Engagement. *Journal of College Student Development*, *50*(6), 683-706. doi:10.1353/csd.0.0099

Kuh, G. D., Cruce, T. M., Shoup, R., Kinzie, J., & Gonyea, R. M. (2008). Unmasking the effects of student engagement on first-year college grades and persistence. *The Journal of Higher Education, 79*(5), 540-563. doi:10.1353/jhe.0.0019

Kuh, G. D., Kinzie, J., Buckley, J. A., Bridges, B. K., & Hayek, J. C. (2006, July). What matters to student success: A review of the literature. In *Commissioned Report for the National Symposium on Postsecondary Student Success: Spearheading a Dialog on Student Success*.

Kuh, G. D., Kinzie, J., Schuh, J. H., & Whitt, E. J. (2010). *Student success in college: Creating conditions that matter*. John Wiley & Sons.

Kvale, S., & Brinkmann, S. (2009). *Interviews: Learning the craft of qualitative research interviewing*. Los Angeles: Sage Publications.

Langdon, D., McKittrick, G., Beede, D., Khan, B., & Doms, M. (2011). STEM: Good jobs now and for the future. U.S. Governement Department of Commerce, Economics and Statistics Administration.

Lattuca, L., Terenzini, P., & Volkwein, J. (2006). Engineering change: A study of the impact of EC2000. *Proceedings. Frontiers in Education. 36th Annual Conference*. doi:10.1109/fie.2006.322520

Leslie, L. L., Mcclure, G. T., & Oaxaca, R. L. (1998). Women and minorities in science and engineering: A life sequence analysis. *The Journal of Higher Education, 69*(3), 239-276. doi:10.2307/2649188

Lincoln, Y. S., & Guba, E. G. (1985). *Naturalistic inquiry*. Beverly Hills, CA: Sage Publications.

Lord, S. M., Camacho, M. M., Layton, R. A., Long, R. A., Ohland, M. W., & Wasburn, M. H. (2009). Who's persisting in engineering? A comparative analysis of female and male Asian, black, Hispanic, Native American, and white students. *Journal of Women and Minorities in Science and Engineering, 15*(2), 167-190. doi:10.1615/jwomenminorscieneng.v15.i2.40

Lozez, M. H., & Gonzales-Barrera, A. (2014, March 6). Women’s college enrollments leave men behind. Pew Research Center. Retrieved from http://www.pewresearch.org/fact-tank/2014/03/06/womens-college-enrollment-gains-leave-men-behind/.

Merriam, S. B. (2009). *Qualitative research: A guide to design and implementation*. San Francisco: Jossey-Bass.

Meyer, J. W., & Rowan, B. (1977). Institutionalized organizations: Formal structure as myth and ceremony. *American Journal of Sociology, 83*(2), 340-363. doi:10.1086/226550

Montessori, M. (1967/1995). *The absorbent mind*. New York: Holt, Rinehart and Winston.

MyCollegeOptions and Stemconnector. (2013). Where are the STEM students? Retrieved at https://www.stemconnector.org/sites/default/files/store/STEM-Students-STEM-Jobs-Executive-Summary.pdf

National Research Council. (2010). Rising above the gathering storm, revisited: Rapidly approaching category 5. Washington, DC: The National Academies Press.

National Science Board. (2003). The science and engineering workforce: Realizing America’s potential. Washington, DC: National Science Foundation. (NSB 03–69).

National Science Board. (2012). Science and engineering indicators 2012. Arlington VA: National Science Foundation. (NSB 12-01).

National Science Board. (2014). Science and engineering indicators 2014. Arlington VA: National Science Foundation. (NSB 14-01).

Olds, B. M., & Miller, R. L. (2004). The effect of a first-year integrated engineering curriculum on graduation rates and student satisfaction: A longitudinal study. *Journal of Engineering Education, 93*(1), 23-35. doi:10.1002/j.2168-9830.2004.tb00785.x

Pace, C. R. (1984). *Measuring the quality of college student experiences: An account of the development and use of the college student experiences questionnaire*. Los Angeles: Higher Education Research Institute, Graduate School of Education, University of California.

Pascarella, E., & Terenzini, P. (2005). *How college affects students: Findings and insights from twenty years of research. Volume 2. A third decade of research*. San Francisco: Jossey-Bass.

Pascarella, E. T., & Terenzini, P. T. (1991). *How college affects students: Findings and insights from twenty years of research*. San Francisco: Jossey-Bass.

Pike, G. R., & Kuh, G. D. (2005). First- and second-generation college students: A comparison of their engagement and intellectual development. *The Journal of Higher Education, 76*(3), 276-300. doi:10.1353/jhe.2005.0021

Ropers-Huilman, B., Carwile, L., & Lima, M. (2005). Service-learning in engineering: A valuable pedagogy for meeting learning objectives. *European Journal of Engineering Education, 30*(2), 155-165. doi:10.1080/03043790410001664363

Salzman, H., Kuehn, D., & Lowell, B. L. (2013). Guestworkers in the high-skill U.S. labor market: An analysis of supply, employment, and wage trends. Washington, D.C.: Economic Policy Institute, Briefing Paper #359.

Schreiner, L. A. (2013). Thriving in college. *New Directions for Student Services, 2013*(143), 41-52. doi:10.1002/ss.20059

Schreiner, L. A., & Louis, M. C. (2011). The engaged learning index: Implications for faculty development. *Journal on Excellence in College Teaching*, *22*(1), 5-28.

Sheppard, S. D., Gilmartin, S., Chen, H. L., Donaldson, K., Lichtenstein, G., Lande, M., et al. (2010). Exploring the engineering student experience: Findings from the academic pathways of people learning engineering survey (APPLES). Center for the Advancement of Engineering Education Technical Report. Available at http://www.engr.washington.edu/caee/.

Sheppard, S. D., Macatangay, K., Colby, A., & Sullivan, W. M. (2009). *Educating engineers: Designing for the future of the field.* San Francisco: Jossey-Bass.

Shuman, L. J., Besterfield-Sacre, M., & Mcgourty, J. (2005). The ABET "professional skills" - Can they be taught? Can they be assessed? *Journal of Engineering Education, 94*(1), 41-55. doi:10.1002/j.2168-9830.2005.tb00828.x

Springer, L., Stanne, M. E., & Donovan, S. (1997). Effects of cooperative learning on academic achievement among undergraduates in science, mathematics, engineering, and technology: A meta-analysis. Univ. of Wisconsin-Madison. *National Center for Improving Science Educ., and National Inst. for Science Educ., Madison, WI.*

Stake, R. E. (1995). *The art of case study research*. Thousand Oaks: Sage Publications.

Stine, D., & Matthews, C. (2009). *The U.S. Science and Technology Workforce.* Washington D.C.: Congressional Research Service.

Strauss, L. C., & Terenzini, P. T. (2007). The Effects of Students' In- and Out-of-Class Experiences on their Analytical and Group Skills: A Study of Engineering Education. *Research in Higher Education Res High Educ, 48*(8), 967-992. doi:10.1007/s11162-007-9057-4

Su, R., Rounds, J., & Armstrong, P. I. (2009). Men and things, women and people: A meta-analysis of sex differences in interests. *Psychological Bulletin, 135*(6), 859-884. doi:10.1037/a0017364

Terenzini, P. T., & Reason, R. D. (2005, November). Parsing the first year of college: A conceptual framework for studying college impacts. Proceedings from annual meeting of the Association for the Study of Higher Education, Philadelphia, PA.

Tinto, V. (1975). Dropout from higher education: A theoretical synthesis of recent research. *Review of Educational Research, 45*(1), 89-125. doi:10.3102/00346543045001089

Tinto, V. (1987). *Leaving college: Rethinking the causes and cures of student attrition*. Chicago: University of Chicago Press.

Tinto, V. (2010). From theory to action: Exploring the institutional conditions for student retention. In *Higher education: Handbook of theory and research* (pp. 51-89). Springer Netherlands.

Tinto, V. (2012). *Completing college: Rethinking institutional action*. Chicago: The University of Chicago Press.

U. S. Census Bureau. (2011). Most children younger than age 1 are minorities, census bureau reports. Retrieved from https://www.census.gov/newsroom/releases/archives/population/cb12-90.html.

U.S. Department of Education, National Center for Education Statistics (2013). Digest of Education Statistics, 2012. Table 381.

Wagner, T. (2012). *Creating innovators: The making of young people who will change the world*. New York: Scribner.

Walker, C. O., Greene, B. A., & Mansell, R. A. (2006). Identification with academics, intrinsic/extrinsic motivation, and self-efficacy as predictors of cognitive engagement. *Learning and Individual Differences, 16*(1), 1-12. doi:10.1016/j.lindif.2005.06.004

Yildirim, T. P., Shuman, L., & Besterfield-Sacre, M. (2010). Model eliciting activities: assessing engineering student problem solving and skill integration processes. *International Journal of Engineering Education*, *26*(4), 831-845.

Zawojewski, J. S., Diefes-Dux, H. A., & Bowman, K. J. (2008). *Models and modeling in engineering education: Designing experiences for all students*. Rotterdam: Sense.

Zhao, C., & Kuh, G. D. (2004). Adding value: Learning communities and student engagement. *Research in Higher Education, 45*(2), 115-138. doi:10.1023/b:rihe.0000015692.88534.de

Appendix A- ABET Student Outcomes

General Criteria 3. Student Outcomes

The program must have documented student outcomes that prepare graduates to attain the program educational objectives.

Student outcomes are outcomes (a) through (k) plus any additional outcomes that may be articulated by the program.

(a) an ability to apply knowledge of mathematics, science, and engineering

(b) an ability to design and conduct experiments, as well as to analyze and interpret data

(c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability

(d) an ability to function on multidisciplinary teams

(e) an ability to identify, formulate, and solve engineering problems

(f) an understanding of professional and ethical responsibility

(g) an ability to communicate effectively

(h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context

(i) a recognition of the need for, and an ability to engage in life-long learning

(j) a knowledge of contemporary issues

(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

Appendix B – Initial Solicitation Email to Participants

Hello [Name],

I am so glad that you are utilizing the Exceed Lab and I hope your project is going well. I have a favor to ask. I am pursuing a doctoral degree and working on a research dissertation, trying to better understand how working on projects in the Exceed Lab contributes to students' educational experiences. I am very interested in your opinions and am hoping you are willing to participate in an interview. I understand that you are busy, but I can work around your schedule to conduct an interview of less than 60 minutes here on campus. You will be helping me out and contributing to the base of knowledge in engineering education as researchers like me try to offer insights into how best to deliver quality experiences for students.

It is important to understand that your interview answers will be kept strictly confidential and that your answers, whether negative or positive, will have no effect on your standing in any class or at this university. Your privacy is strictly protected by federal law and will not be violated if you choose to participate. Additionally, this is your chance to help out a fellow student and scholar while having an impact on the future improvement of engineering education at the University of Minnesota. If you would like to participate please indicate as such by simply responding to this email. Feel free to ask any questions if you have them. I will respond with some scheduling details. Thank you for your consideration.

Appendix C - Follow-up Script by Researcher for Those Selected for Sample

Thank you for choosing to participate in my study on how working on projects in the Exceed Lab contributes to students' educational experiences. In case you don't remember, you agreed to a maximum 60 minute interview. You certainly do not have to participate if you have changed your mind, but I would really like to hear your opinions.

I have attached a consent form for you to look over. We will be able to review this in more depth when we meet for our interview. I want to make sure you have no qualms or concerns related to privacy or the nature of this study before you answer any questions. I have set up some interview times from which you can select by clicking the link below. Please select a day and time that works for you. We will meet in my office in Keller Hall 4-178J. Please let me know if you have any questions or concerns.

[Insert Link to Online Scheduling Tool]

Appendix D - Consent Form for Interviews

You are invited to be in a research study of engineering students at the University of Minnesota. You were selected as a possible participant because you were randomly selected from engineering students who utilize the Exceed Lab in Keller Hall. We ask that you read this form and ask any questions you may have before agreeing to be in the study.

This study is being conducted by Kyle Dukart, Electrical and Computer Engineering's Administrative Director and graduate student pursuing an Ed.D. emphasizing Higher Education from the University of Minnesota

Background Information

The purpose of this study is to understand how extracurricular projects, such as the ones that commonly occur in the Exceed Lab, contribute to engineering students' experiences.

Procedures:

If you agree to be in this study, you are agreeing to take part in a one-hour interview with Kyle Dukart. The interview's audio will be recorded for purpose of later transcription but will never have your name associated with it and the audio will be deleted after transcription (within a month).

Risks and Benefits of being in the Study

This study is devoid of any significant risks to its participants. All comments will be kept strictly confidential.

The benefits to participation include the opportunity to share your thoughts on the role of project learning in engineering education and possibly have a role in affecting future changes to engineering education. Additionally, you will be playing a small, but significant role in the university's community of inquiry, helping a fellow scholar investigate his chosen area of research.

Confidentiality:

The records of this study will be kept private. In any sort of report that may be published, there will not be any information that will make it possible to identify a subject. Research records will be stored securely and only researchers will have access to the records. Study data will be encrypted according to current University policy for protection of confidentiality. Access to audio recordings will be available only to Kyle Dukart or a professional hired by him for the sole purpose of transcription. These transcripts will be used for this study only and will be erased upon completion of the study. Neither the audio recording nor the transcription will ever have your name associated with them.

Voluntary Nature of the Study:

Participation in this study is voluntary. Your decision whether or not to participate will not affect your current or future relations with the University of Minnesota. If you decide to participate, you are free to not answer any question or withdraw at any time without affecting those relationships.

Contacts and Questions:

The researcher conducting this study is Kyle Dukart. You may ask any questions you have now. If you have questions later, **you are encouraged** to contact him at Keller Hall 4-178, 612-625-9829, kdukart@umn.edu.

If you have any concerns that you feel you cannot discuss with the researcher, you may contact Dr. David Weerts, Doctoral Advisor, Department of OLPD, University of Minnesota, 612-625-2289 or dweerts@umn.edu. If you have any questions or concerns regarding this study and would like to talk to someone other than the researcher, **you are encouraged** to contact the Research Subjects' Advocate Line, D528 Mayo, 420 Delaware St. Southeast, Minneapolis, Minnesota 55455; (612) 625-1650.

You will be given a copy of this information to keep for your records.

Appendix E - Consent Form for Observation Participants

You are invited to be in a research study of engineering students at the University of Minnesota. You were selected as a possible participant because you were part of a project group with a fellow student who was randomly selected from engineering students who utilize the Exceed Lab in Keller Hall. We ask that you read this form and ask any questions you may have before agreeing to be in the study.
This study is being conducted by Kyle Dukart, Electrical and Computer Engineering's Administrative Director and graduate student pursuing an Ed.D. emphasizing Higher Education from the University of Minnesota

Background Information
The purpose of this study is to understand how extracurricular projects, such as the ones that commonly occur in the Exceed Lab, contribute to engineering students' experiences.

Procedures:
If you agree to be in this study, you are agreeing to be observed while you work on your project for 30-60 minutes. Your name and your project will not be associated with the field notes taken.

Risks and Benefits of being in the Study
This study is devoid of any significant risks to its participants. All comments will be kept strictly confidential.
The benefits to participation include having a role in affecting future changes to engineering education by providing observational data. Additionally, you will be playing a small, but significant role in the university's community of inquiry, helping a fellow scholar investigate his chosen area of research.

Confidentiality:
The records of this study will be kept private. In any sort of report that may be published, there will not be any information that will make it possible to identify a subject. Research records will be stored securely and only researchers will have access to the records. Study data will be encrypted according to current University policy for protection of confidentiality.

Voluntary Nature of the Study:
Participation in this study is voluntary. Your decision whether or not to participate will not affect your current or future relations with the University of Minnesota. If you decide to participate, you are free to not answer any question or withdraw at any time without affecting those relationships.

Contacts and Questions:

The researcher conducting this study is Kyle Dukart. You may ask any questions you have now. If you have questions later, **you are encouraged** to contact him at Keller Hall 4-178, 612-625-9829, kdukart@umn.edu.
If you have any concerns that you feel you cannot discuss with the researcher, you may contact Dr. David Weerts, Doctoral Advisor, Department of OLPD, University of Minnesota, 612-625-2289 or dweerts@umn.edu. If you have any questions or concerns regarding this study and would like to talk to someone other than the researcher, **you are encouraged** to contact the Research Subjects' Advocate Line, D528 Mayo, 420 Delaware St. Southeast, Minneapolis, Minnesota 55455; (612) 625-1650.

You will be given a copy of this information to keep for your records.

Appendix F - Cognitive Interview Questions

To be Asked When Reviewing Consent Form

1. Can you tell me in your own words what this study is about?
2. Do you feel any pressure to take part in this study?
3. Do you feel comfortable enough to be open and honest with your answers?

Appendix G - Pre-interview Script

Thank you for agreeing to participate in this study. First we will review the informed consent form. [Review form, ask cognitive interview questions, ask if the participant has any further questions, and hand a copy to participant]. This study is about ultimately understanding how participating in an extracurricular engineering project affects your educational experience at the University of Minnesota. I am interested in why you chose to take part in a voluntary project, if you plan to continue, and how you think the project experience benefits you and your learning. Just to reiterate, everything you say will be kept strictly confidential. The recording and subsequent transcription will not have your name associated with them at all. If you are uncomfortable with any questions, feel free to pass. Do you have any questions before I begin?

Appendix H – Primary Interview Questions

1. Tell me a little bit about the project in which you are participating in the Exceed Lab?
    a. What is your role?
2. Can you tell me why you chose to take part in this extracurricular project? [Exploratory Question 1]
    a. Would you make the same choice today?
    b. If you had to pick one primary reason for choosing to participate in your project, what would it be?
3. Can you tell me how your learning is affected by participating in this project? [Exploratory Question 2]
4. Can you tell me how your connections to things like your major, college, university, peers or other parts of your life are affected? [Exploratory Question 2]
5. How do you think your confidence is affected related to being an engineer and/or your ability to do well in the classroom? [Exploratory Question 2]
6. Tell me how you think your project experience will affect your preparation for your career after you graduate? [Exploratory Question 2]
7. Thinking about how you work on your project, by yourself or with your team, tell me about the process? For example, how you solve problems, figure out the next step, or simply get things done. [Exploratory Question 2]
8. Tell me about the most valuable part of your project experience? [Exploratory Question 2]

9. Can you talk about whether or not you have the necessary support to make your project successful? [Exploratory Question 3]
    a. How could the university better support you in this context?

Closing Questions

1. We've covered a lot of ground, but I want to give you a moment to think about anything related to your experience with engineering projects that you would like to add. Take a moment and then let me know if you come up with anything.
2. Would it be OK if I followed up with you to arrange a thirty minute observation of your team working on your project? I would need to ask your team for consent as well.
3. I want to thank you for participating. My memory and my notes indicate that [give quick overview of student's experience with experiential learning project]. Please let me know if you would characterize it any differently. Thank you. I will follow up with a more detailed summary via email giving you another chance to correct my impression or add to the record. Thank you for coming.