TOWARDS A MODEL OF ACCELERATED PROJECT-BASED LEARNING (PBL) FOR INNOVATIVE TECHNOLOGY PROJECTS

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TOWARDS A MODEL OF ACCELERATED PROJECT-BASED LEARNING (PBL) FOR INNOVATIVE TECHNOLOGY PROJECTS

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Abstract

TOWARDS A MODEL OF ACCELERATED PROJECT-BASED

LEARNING (PBL) FOR INNOVATIVE TECHNOLOGY PROJECTS

Victor S. Sohmen, Ed. D.

Drexel University, September 16, 2016

Chairperson: Kristen S. Betts

An existing Engineering Technology (ET) framework of Project-Based Learning (PBL) was examined for structure and rigor as a springboard to propose a robust PBL model, guided by three research questions: (a) What is the extent to which self-directed learning (SDL) skills were applied by final-year ET students in PBL, as determined quantitatively through the Self-Directed Learning Readiness Scale (SDLRS-A®)?;
(b) How are self-directed learning (SDL) skills, project management (PM) efficiencies, and change leadership (CL) effectiveness applied in the implementation of ET capstone projects?; and, (c) What are the best practices to accelerate PBL by employing SDL skills, PM efficiencies, and CL effectiveness?

The mixed methodology research was conducted in two phases:

Phase 1—*Quantitative and qualitative:* The SDLRS-A® Survey incorporating a 58-item questionnaire, six demographic items, and three open-ended questions on change leadership/change processes was administered to 30 Senior Design students graduating from an ET program; and,

Phase 2—*Qualitative:* In-depth, one-on-one interviews with six student leaders from eight diverse, innovative capstone projects, and six faculty advisors who had facilitated these projects.

Using SPSS 24.0, the SDLRS-A® questionnaire assessed the 30 Senior Design students' SDL skills in project implementation, using factor analysis to ascertain and compare *a priori* evidence. Additionally, textual analytic software (NVivo 11) graphically analyzed responses to the three open-ended questions for the Senior Design students' understanding of change leadership/change processes of their capstone projects through the Fall, Winter, and Spring terms of 2015-2016. Similarly, the semi-structured, one-on-one PBL interviews of six student team leaders and six faculty advisors were iteratively analyzed using graphical textual analytic software, Leximancer 4.5.

The quantitative and qualitative analyses of the primary data identified essential elements of an accelerated PBL model through enhanced SDL skills, streamlined PM efficiencies, and, dynamic CL effectiveness. This PBL model is geared to yielding optimal outcomes with minimal loss of time and resources in rapidly evolving, technological environments in 21st century higher education. The study concluded that such an accelerated PBL model could also minimize the employment gap, fuel students' self-motivation, enable skill-building, and instill a deep commitment to life-long learning—in a competitive, technology-infused, and information-intensive world.

This dissertation is dedicated to

Professor William (Bill) F. Lynch

Former Dean

(2006-2013)

School of Education
&
Goodwin College of Professional Studies

Drexel University

With deep appreciation for his

Visionary zeal, Motivating spirit, and Large-hearted warmth

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Chapter 1: Introduction to the Research

Introduction to the Problem

Higher education of the 21st century is impelled by competitive global forces that require pedagogies, technologies, structures, and research to become truly innovative for dynamic progress. According to the International Labor Organization (ILO), innovation and technological change are recognized as powerful drivers of economic growth (ILO, 2010, p. 11). Consequently, technology diffusion is transforming higher education at an accelerating rate (Dennison, 2013). Educators at all levels are being called upon to meet this challenge, and to equip students with multiple skills to adapt to these apparently irreversible changes (Lane, 2007; Merriam, Caffarella, & Baumgartner, 2007; Parr, 2015). Indeed, change happens fast in the world of work today. Driven by innovation and by developments in technology, keeping up with this pace of change is indeed a continuing challenge for learning institutions (ILO, 2010, p. 6; Miller, Martineau, & Clark, 2000).

Evidently, technological innovation as applied to 21st century higher education needs to be harnessed and leveraged efficiently and effectively (Gonçalves, 2012; Kelley, 2005). For this, effective change leadership (CL) has become the source, catalyst, and driver of change energized by organization-wide creativity and innovation (Abgor, 2008; Fullan, 2011). CL will thus enable the diffusion of innovation (DOI) to result in changes in the ecosystem—despite possible resistance to change. Such resistance could be manifest in absenteeism, non-cooperation, and even insubordination (Fullan, 2011).

The decade of 2006 to 2016 can be considered more technology-infused than previous decades (Bureau of Labor Statistics, 2016). Therefore, it can be argued that infusion of technology in the economy has increased the demand for graduates from post-secondary, technology-intensive training programs. Innovative technology will therefore be a key economic driver and catalyst for both employability and for closing the employment gap—as two sides of the same coin (Gonçalves, 2012; Kelley, 2005; O'Kane, 2010). Indeed, there has been a sustained employment gap for the past decade (2006-2016); and there is persistent disparity between job openings and employability (Bureau of Labor Statistics, 2016). So it is incumbent upon both educational institutions and industry to increase employability, and to close the employment gap (O'Kane, 2010).

While most countries have seen an unprecedented expansion of their educational competencies and skill-bases over the past decades, there seems to be a persistent gap between the kind of knowledge and skills that are most in demand in the workplace, and those that training systems continue to provide (ILO, 2010, p. 6). Therefore, it is important to ensure that education and training focus on closing this gap between precise workplace needs, and the content, quality, and validity of educational programs geared for the workplace in a rapidly evolving ecosystem.

With innovative technology as a key economic driver to close this skills-and-employment gap in the economy, it is necessary to streamline the process of technology diffusion in higher education (Dennison, 2013; Hall & Elliott, 2003). In this context, the triple constraints of time, cost, and quality that comprise the core parameters of project management can be gainfully applied (Sohmen, 2007; Turner & Müller, 2005). This is because project management (PM) has inherent efficiencies due to its planned approach, goal-orientation, resource optimization, time compression, and phase-by-phase progress toward economical execution and successful realization of project goals. PM could therefore be a critical contributor to optimizing project-based learning (PBL) efficiencies.

Against this backdrop, it is germane to consider the learning process as a facilitator of technology diffusion in higher education (Dennison, 2013). Learning, an activity and process central to human behavior and progress, has been of interest to philosophers, psychologists, educators, and politicians for centuries (Merriam et al., 2007). Today, more scientific research is being done to understand the role of learning in terms of hard sciences such as neuroscience and emerging cognate areas including neuroplasticity that look at the relationship between the human brain and the dynamics of learning. Learning theorists have also studied the behaviorist, humanist, cognitivist, constructivist, and social cognitivist traditions (Appendix A, p. 193). In general, learning brings together environmental, cognitive, and emotional experiences for absorbing, building on, or modifying the learner's knowledge—as well as the learner's values, skills, and worldviews (Bessen, 2014; Illeris, 2004; Ormrod, 2012; Parr, 2015).

When it comes to adult learning, there seems to be a propensity toward the humanist and constructivist ontologies due to the preference for experiential, transformational, and self-directed learning (SDL). The purpose of learning in the humanist approach appears to be for learners to become self-actualized, mature, and autonomous—whereas, in the constructivist domain, the purpose is to construct knowledge (Appendix A, p. 193). Both of these perspectives are braided in adult learning and made available in post-secondary education today. Thus, SDL is a natural avenue of choice for adult learners. In this context, Project-Based Learning (PBL) with intrinsic elements of SDL is a model derived from the field of PM that systematically and purposively organizes education around learner-centric projects (Thomas, 2000). In recent decades, PBL has gained significant attention as a conduit for andragogy or a learner-centric approach. This perception has been due to the pragmatic, self-motivated, and result-oriented approach of PBL—ideally, with a formal, structured regimen. Indeed, such an orientation signals a clear departure from traditional learning (Thomas, 2000).

To amplify this further, PBL is an inquiry-based learning method in which students execute a technologically or entrepreneurially viable project to investigate and implement a solution to a complex, real-life problem (Glossary of Educational Reform, 2013). This andragogy or learner-centric approach—as opposed to the traditional pedagogical or teacher-centric approach—is therefore predicated on strong learner initiative with little direct supervision (Knowles, 1975; Vanajakumari, Johnston, Lawrence, & Menon, 2015). Though there is adequate literature commending the PBL approach, evidence is sparse on *how* it could be implemented to facilitate—and perhaps even accelerate—the diffusion of innovative technology. The necessity to overcome the well-known resistance to change in the environment is an added challenge to be overcome (Fullan, 2011; Mahoney, 2009; Thomas, 2000).

On the other hand, considerable self-motivation and self-discipline are inherent in SDL, especially when coupled with management of such PM parameters as time, cost, quality, scope, and risk. These PM dimensions could together contribute to enhanced PBL competencies, and to accelerated implementation. Further, effective Change Leadership (CL) would be needed to drive the project through layers of resistance—and steer the temporary organization successfully toward a realistic, predetermined goal (Söderlund, 2000). Thus, CL actualizes the leader's vision, drive, and change processes that fuel holistic transformation, together with a sense of urgency (Kotter, 1995).

Despite the expected resistance to change, a systematic effort such as propounded in Kotter's 8-Steps Change Model (Appendix B, p. 194) can be effectively applied. In Kotter's (1995) model, sequential steps to overcome conflict and resistance result in at least incremental and progressive changes in the project for a successful outcome.

Factoring the necessity to overcome the inevitable resistance to change, PBL can demonstrably benefit from an integrative infusion of SDL, PM, and CL to result in innovative products, services, or other deliverables (Fullan, 2011; Jones, Rasmussen, & Moffitt, 1997; Kerzner, 2013). It can be ventured that a combination of well-honed SDL skills, efficient PM, and effective CL could result in a powerful synergy that could contribute to a robust model of PBL. This could accelerate the project for optimal results. Individual scrutiny of each of the three components of PBL would therefore be in order.

Firstly, SDL *skills* include personal autonomy, willingness to manage self-learning, self-discipline, organization of instruction, and, taking the initiative to seek opportunities to learn (Candy, 1991; Merriam et al., 2007; Stewart, 2007). Secondly, PM *efficiencies* include the optimization of cost, schedule, and quality/scope for competitive learning outcomes (Muller & Turner, 2005). Thirdly, CL *effectiveness* calls for resolutely overcoming resistance to change, building a collaborative coalition, and leading change with a momentum that is relentlessly focused on visible and measurable goal realization (Fullan, 2008, 2011; Kotter, 1995). Figure 1 (p. 6) shows the overlaps among SDL, PM, CL, and PBL, reflecting the literature evidence in Chapter 2. Among these four related concepts (SDL, PM, CL, and PBL), SDL and PBL would overlap significantly as they are recognized in the literature as inquiry-based learning methods (Stewart, 2007). In fact, PBL enshrines substantial elements of SDL—in particular, autonomy (Stewart, 2007).

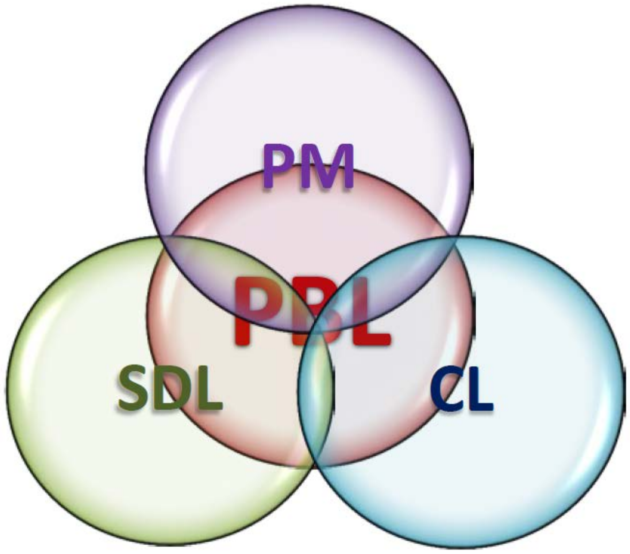

Figure 1. Overlaps of SDL, PM, CL, and PBL

Therefore, formal infusion of SDL into a PBL framework could contribute to tangible and autonomous progress in PBL. As for CL, it is actually a soft skill and a leadership competency that is useful for overcoming resistance to innovative ideas and actions. It also enables the steering of both PBL and SDL towards successful outcomes through necessary changes, as it is axiomatic that change is inevitable in a dynamic project (Sohmen, 1990). Furthermore, PM is an approach toward task accomplishment of a time-limited venture. It aids in economizing on resources and compressing time to accelerate the educational project undertaken by employing SDL and PBL. Therefore, to tackle both planned and unplanned changes in the innovative technology project, CL would be needed to realize PM efficiencies through control mechanisms spanning the project life cycle. Thus, overlaps among SDL, PM, CL, and PBL can be seen as synergizing a potentially robust, integrative model of PBL (Figure 1).

Statement of the Problem to be Researched

Over the past decade, there has been a host of technological innovations sustained by an explosion of creative enterprise, collaborative efforts, and global applications. There is every indication that this phenomenon is irrevocable, and will continue its relentless march into the future (Abigor, 2008; Maloney, 2009; Poole & Van de Ven, 2004; Zajda, 2015). As a result, radical and practically irreversible changes have taken place in the technological landscape. This has precipitated increasingly shortened product life cycles and hyper-competition in an innovation-driven, technology-infused, and time-compressed environment (McNamara, Vaaler, & Devers, 2003; Tierney & Landford, 2016). These complex forces may have cumulated in some measure to the employment gap in industry (Bureau of Labor Statistics, 2016). This employment gap is apparently exacerbated by insufficient, unsuitable, or unprepared recruits for jobs (O'Kane, 2010).

In fact, the U.S. economy is projected to add 15 million jobs by 2016—and half of these jobs will require postsecondary credentials, with technology being among 80% of the fastest-growing occupations requiring advanced skills (Harris, 2007). This is directly relevant to innovative technology that is intrinsic to the ET capstone projects using a PBL framework. Such Senior Design capstone projects are essentially innovative technology projects. They serve the function of "customized training" towards employability for potential graduates—thus curtailing the employment gap (CLASP, 2014, p. 6).

It is suggested that appropriate usage of PBL would make it possible to deliver both technical content and generic professional skills towards specialized learning such as that obtaining in the Senior Design course of ET (Hosseinzadeh & Hesamzadeh, 2012). The purpose of the Senior Design program is thus to provide skilled, hands-on training to students in engineering and technology with a view to reducing the employment gap. This will also enable them to become job-ready, and to “build solid bridges between the world of learning and the world of work.” (ILO, 2010, p. 2). Such innovative technology projects will yield both available and emerging employment opportunities for graduates in engineering and technology, as pointed out in a somber forewarning by the International Labor Office (ILO) in their 2010 report:

> The globalization of markets is accelerating the diffusion of technology and the pace of innovation. New occupations are emerging and replacing others. Within each occupation, required skills and competencies are evolving, as the knowledge content of production processes and services is rising. (ILO, 2010, p. 1).

Consonant with the cited prognosis, significant mismatches continue to exist between the actual supply of, and the demand for, key work-related skills. In fact, 38% of employers had reported difficulties in filling jobs in 2015 (Manpower Group, 2015). This highlights the need to minimize the employability gap through training and education appropriate to workplace needs. Such progress would be possible through such means as the Senior Design course using a well-crafted and tailored PBL approach for optimal results. Essentially, technological innovations need to be diffused in a deliberate manner, overcoming possible resistance to change through effective CL. This would enable discernible progress in imparting technology education (Fullan, 2008, 2011).

Essentially, this study investigated the overarching research problem of how diffusion of technological innovations through innovative technology projects in a competitive higher education environment can be accomplished by employment of SDL, PM, and CL as key components of PBL. Figure 2 (p. 9) serves as a graphic representation of a preliminary model of PBL, buttressed by these three literature-based components of PBL—SDL, PM, and CL. This model would be set in an environment of innovative technology, with Senior Design students having had a solid foundation in science and technology, building up to their final year of undergraduate studies.

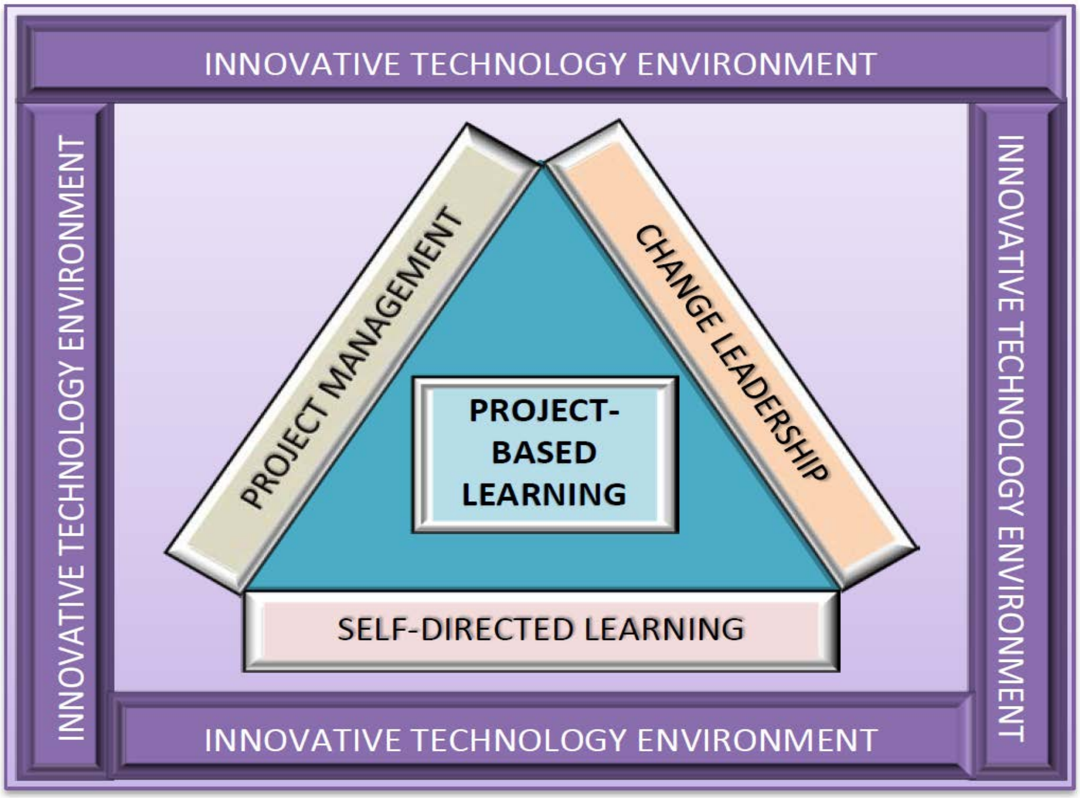

Figure 2. Proposed Model of Project-Based Learning (PBL)

Purpose and Significance of the Problem

Purpose Statement

The purpose of this study was to examine an existing, informal framework of PBL in an Engineering Technology (ET) program, and to propose a literature-based model of PBL synthesizing SDL, PM, and CL as key enablers and accelerators of innovative technology diffusion. This research was thus empirically accomplished by studying the implementation processes of eight capstone projects by small groups of three-to-four final-year ET students. These projects were slated to apply a loosely-structured PBL framework to produce innovative prototypes as a requirement for successful graduation. Figure 3 presents this framework for PBL as applied to the Senior Design capstone project. Such an innovative technology project represents an attempt to close the employability gap through hands-on, self-motivated, and employment-related PBL.

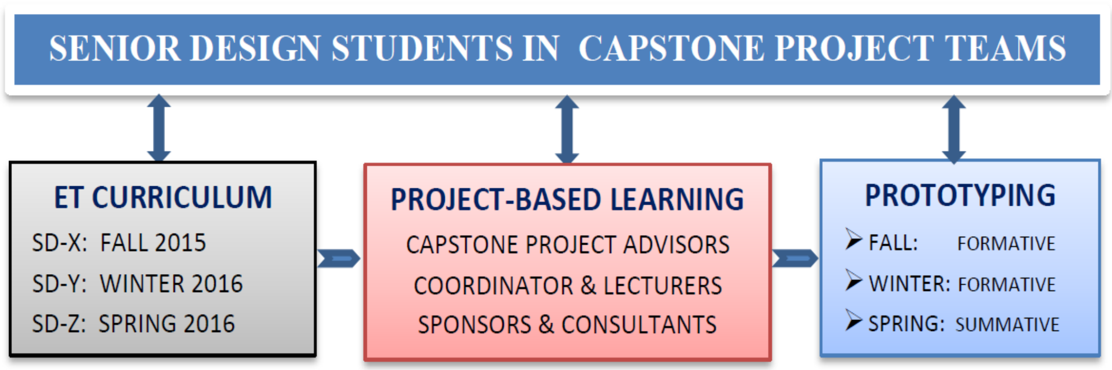

Figure 3. PBL Framework: Engineering Technology (ET) Senior Design course

Academic institutions are undergoing significant paradigm shifts in the delivery of knowledge, and in the training of increasingly mobile populations of versatile learners (Barr & Tagg, 1995; Liebowitz & Frank, 2016; Rajasingham, 2010). Research indicates that successful education needs to facilitate and deeply instill a desire for lifelong learning by these learners as a proxy for protracted SDL (Greveson & Spencer, 2005; Miflin, Campbell, & Price, 2000).

A sobering reality to underscore here is that a large part of the existing subject knowledge of the current workforce will be outdated in just a few years (Miflin et al., 2000). In fact, it is even estimated that nearly 50% of subject knowledge acquired during the first year of a four-year technical degree becomes outdated by the time students graduate (World Economic Forum, 2016). This rapid turnover calls for both best practices and acceleration in the delivery of innovative technology education (Gonçalves, 2012; Kelley, 2005; Zenger, 2015).

A global survey of more than 41,700 hiring managers in 42 countries to identify the proportion of employers having difficulty filling positions found that this is a perennial problem. Figure 4 shows that in 2015, there was a clear shortage of talent, especially in the technical trades (Manpower Group, 2015). Indeed, lifelong learning critically depends on a strong integration among education, training, and work (ILO, 2010, p. 28). Therefore, students, employees, employers, and educational institutions must adopt a lifelong commitment to learning new skills in cooperation and collaboration with each other (Yang, 2015). This can best be achieved by equipping students with the 21st century skills needed to adapt to rapid change. Among these skills are: a global mindset, curiosity, self-motivation, and, a propensity to life-long learning (O'Neill, Deacon, Larson, Hoffart, Brennan, Eggermont, & Rosehart, 2015; Rajasingham, 2010).

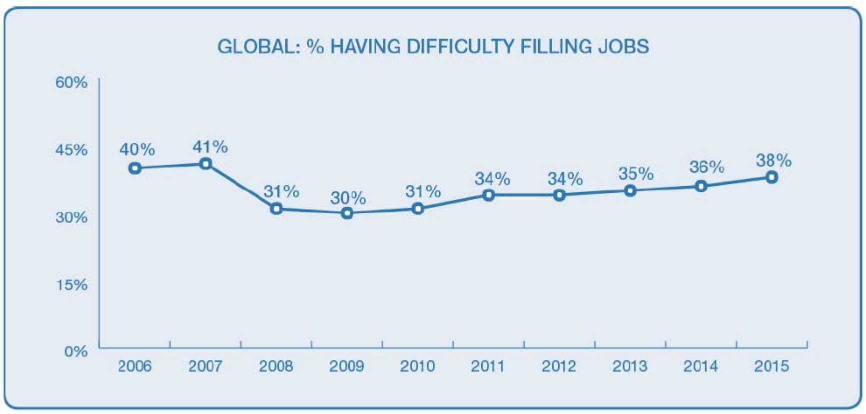

Figure 4. Percent of employers facing skilled talent shortage: 2006 to 2015.

Reproduced from "2015 Talent shortage survey," by Manpower Group.
Copyright 2015 by Manpower Group. Retrieved from www.manpower.com.

According to Rugarcia, Fielder, Woods, and Stice (2000), “Successful engineers will be those who can manage change—especially when change is thrust upon them” (p. 10). This implies that CL should be intrinsic to the management of technology diffusion. This change is usually not a linear or predictable process, but one that should be adroitly managed with effective CL.

Therefore, a rational solution needs to be found to the research problem (Booth, Colomb, & Williams, 2008). This will include overcoming conflicts and resistance to change through effective CL, optimization of competitive resources through PM efficiencies, and, significant autonomy accorded to learners through SDL. Thus, SDL, PM, and CL apparently comprise the essential components of a viable model of PBL.

Therefore, it is proposed in this study that SDL, PM, and CL incorporated in PBL could both facilitate *and* accelerate learning of innovative technology in higher education projects and programs. Consequently, this could translate into systemic, systematic, and accelerated diffusion of emerging technologies in an increasingly technology-infused and competitive higher education environment (Dennison, 2013).

Employers are becoming concerned about work-related practical skills or competencies that prospective graduates will be able to use in order to successfully perform various tasks on-the-job (Bessen, 2014). Table 1 (p. 14) depicts a core set of 35 work-relevant skills and abilities recognized to be widely used across all industry sectors and job groupings. Poignantly, even these will be subject to accelerating change and significant disruption in the foreseeable future (World Economic Forum, 2016).

Combating this disruptive trend will require well-planned, targeted, and accelerated training. This can be accomplished through rigorous application of the proposed PBL model composed of SDL, PM, and CL (see Chapter 1, Figure 2, p. 9).

Table 1 (p. 14) lists the 35 core work-related skills essential to the workplaces of today, grouped under the three headings of Abilities, Basic Skills, and Cross-functional Skills. *Abilities* include creativity, logical reasoning, and manual dexterity; *basic skills* comprise critical thinking, information and communication technology (ICT) literacy, and process skills; and, *cross-functional skills* encompass technology, emotional intelligence (EQ), and, people management.

It is estimated that in the foreseeable future, a wide range of occupations will require a higher degree of cognitive abilities—such as creativity, logical reasoning, and problem-sensitivity—as part of employees core skills-set (World Economic Forum, 2016). It can be surmised therefore, that most of these versatile abilities and skills will need to be imbibed by potential employees through post-secondary training, and applied to a wide range of innovative technology projects. The proposed PBL model could be a suitable tool for such competent, hands-on training in a higher education environment.

Table 1

Core Work-related Skills Used across Industry Sectors

Abilities	Basic Skills	Cross-functional Skills	
Cognitive Abilities » Cognitive Flexibility » Creativity » Logical Reasoning » Problem Sensitivity » Mathematical Reasoning » Visualization	**Content Skills** » Active Learning » Oral Expression » Reading Comprehension » Written Expression » ICT Literacy	**Social Skills** » Coordinating with Others » Emotional Intelligence » Negotiation » Persuasion » Service Orientation » Training and Teaching Others	**Resource Management Skills** » Management of Financial Resources » Management of Material Resources » People Management » Time Management
Physical Abilities » Physical Strength » Manual Dexterity and Precision	**Process Skills** » Active Listening » Critical Thinking » Monitoring Self and Others	**Systems Skills** » Judgement and Decision-making » Systems Analysis	**Technical Skills** » Equipment Maintenance and Repair » Equipment Operation and Control » Programming » Quality Control » Technology and User Experience Design » Troubleshooting
		Complex Problem Solving Skills » Complex Problem Solving	

Reprinted from: “Core work-related skills used across industry sectors,” by World Economic Forum, 2016. Copyright 2016 by World Economic Forum.

The shrinkage of employability and the need for upgraded training has unfortunately resulted in the median job tenure for workers aged 20 to 24 to be less than 16 months (Yang, 2015). Indeed, the accelerating pace of demographic, socio-economic, and technological disruption of the 21st century is rapidly transforming traditional industries and business models (World Economic Forum, 2016).

Significance of the Problem

In view of these facts, this study is significant because research suggests that PBL is ineffective or suboptimal without the core constituents of SDL, PM, and CL (Fullan, 2008, 2011; Stewart, 2007; Thomas, 2000). This study investigated and explained best practices in SDL, PM, and CL for learners employing PBL to pursue innovative technology projects. It has also explored their *accelerating* role in the implementation of PBL by studying eight final-year capstone projects in an ET program of a reputed university that is anonymously designated in this study as 'M University'.

Research Questions Focused on Solution-finding

This study has examined the relative roles of Self-Directed Learning (SDL), Project Management (PM), and Change Leadership (CL) within Project-Based Learning (PBL) as key drivers and accelerators of PBL. These four research streams in the contemporary literature were found to significantly interlink and overlap with each other (see Figure 5, p. 20).

In concert, the research streams of SDL, PM, CL, and PBL impinged on the research problem of how to go about investigating and explaining their critical roles for learners pursuing innovative technology projects that employ a PBL framework or model. To unravel the research problem, and to enable its systematic resolution through this study, three inter-related research questions were posited as follows:

1. What is the extent to which self-directed learning skills were applied by final-year Engineering Technology students in project-based learning, as determined quantitatively through the Self-Directed Learning Readiness Scale (SDLRS-A®)?
2. How are self-directed learning skills, project management efficiencies, and change leadership effectiveness applied in the implementation of Engineering Technology capstone projects?
3. What are the best practices to accelerate project-based learning by employing self-directed learning skills, project management efficiencies, and change leadership effectiveness?

The Conceptual Framework

Researcher's Stances

The researcher's ontological stance was that of *relativism*—whereby truth is constructed by humans and situated within a social context. In this research, the social interactions among the students and faculty participants were studied, and truthful observations, reflections, and interpretations were made. The researcher's epistemological stance was that of understanding the experiences of research participants by constructing knowledge together with them through empirical study (Creswell, 2003). Such a stance was buttressed by the fact that the researcher as well as the participants were learning and building new knowledge together throughout the research process by exchange of ideas and experiences.

As for methodological stance, the *mixed methodology* adopted by the researcher to enrich the research sought to yield both breadth and depth of the research findings (Creswell, 2003). This was accomplished through a validated quantitative instrument (the SDLRS-A® Survey) supplemented by three qualitative, open-ended questions on change leadership and change processes.

The *lived* experiences of the students through the three terms of the Academic Year 2015-2016 were thus qualitatively gleaned through the open-ended questions, and subsequently, through one-on-one semi-structured interviews. This pragmatism was helpful in unraveling the construction of reality through shared assumptions, and within the ontological (relativist) domain. It also defined the participants' skills in SDL, efficiencies in PM, and, effectiveness in CL, as demonstrated through competence in PBL.

The participants did not act in isolation, but in small groups of three-to-four students in a technologically innovative, yet social setting. This was aided by secondary interactions with advisors, sponsors, lecturers, and consultants. The participants were thus a networked community of interpreters of socially-constructed phenomena, harmoniously integrating these ontological, epistemological, and methodological stances.

In sum, the ontological, epistemological, and methodological paradigms have been congruent to, and commensurate with, a philosophical stance that suits this mixed-methods research with its pragmatism. What follows is a brief overview of the conceptual framework undergirding this study.

Conceptual Framework through Four Research Streams

Four research streams were reviewed as underpinnings to craft a conceptual framework focusing on innovative technology projects in 21st century higher education: (a) PBL competencies with an expected output (Bell, 2010; Gratch, 2012; Larmer & Mergendoller, 2001; Thomas, 2000); (b) SDL skills to foster learner autonomy (Candy, 1991; Gibbons, 2002; Guglielmino, 1997; Stewart, 2007); (c) PM efficiencies to economize on time, cost, and quality (and scope) constraints in the project (Kerzner, 2013; Packendorff, 1995; Sohmen, 2007; Turner & Müller, 2003); and, (d) CL effectiveness to overcome resistance and to precipitate change in the project (Fuller, 2008, 2011; Kotter, 1995). These four research streams served to capture the essence of the study embarked on by critical review of relevant literature.

Consequently, the four research streams contributed to the construction of a robust model of accelerated PBL. Conceptual and empirical advances in these four literature streams, as well as logical links and overlaps among them, were explored in-depth in Chapter 2 (Literature Review). It was ensured however, that a boundary was drawn around the scope of the study for focus and conciseness. Chapter 3 (Research Methodology), was thus sharply focused on the three Research Questions posed in Chapter 1 (p. 16), buttressed by the literature evidence of the four literature streams of SDL, PM, CL, and PBL in Chapter 2.

To accomplish efficient progress of learning, as well as to understand how to accelerate student-led capstone projects, a deeper understanding of PM efficiencies, SDL skills, and CL effectiveness was deemed essential. Also, resistance to innovative technology adoption could be minimized through PM efficiencies, SDL skills, and CL effectiveness, as well as project team collaboration to effect the needed change.

Study of the four streams of literature and evidences of their overlaps resulted in their synergistic integration through the mixed methodology approach employed for resolution of the research problem (Chapter 3), and analysis of the qualitative and quantitative data in Chapter 4. Together with the results, conclusions, and recommendations in Chapter 5, a cogent and intelligible map was drawn for the research agenda to serve as a blueprint and mental model for reflection (Gibbs, 1988; Johnson-Laird, 1983; Norman, 1983).

To capture the essence of the four research streams towards constructing a model of accelerated PBL and to provide direction and boundary to the study, a succinct research topic was crafted as follows: “Towards a Model of Accelerated Project-based Learning (PBL) in Innovative Technology Projects.” These four contemporary research streams (SDL, PM, CL, and PBL) contributed to a sound understanding of how PBL could be conducted competently, and even accelerated.

This study is timely as these four research streams are conceptually rich, topical, and contemporary. Consequently, long-term benefits can be expected from the adoption of a robust model of accelerated PBL, incorporating best practices in SDL, PM, and CL. Figure 5 (p. 20) depicts the four interlinked streams of literature: SDL, PM, CL, and PBL.

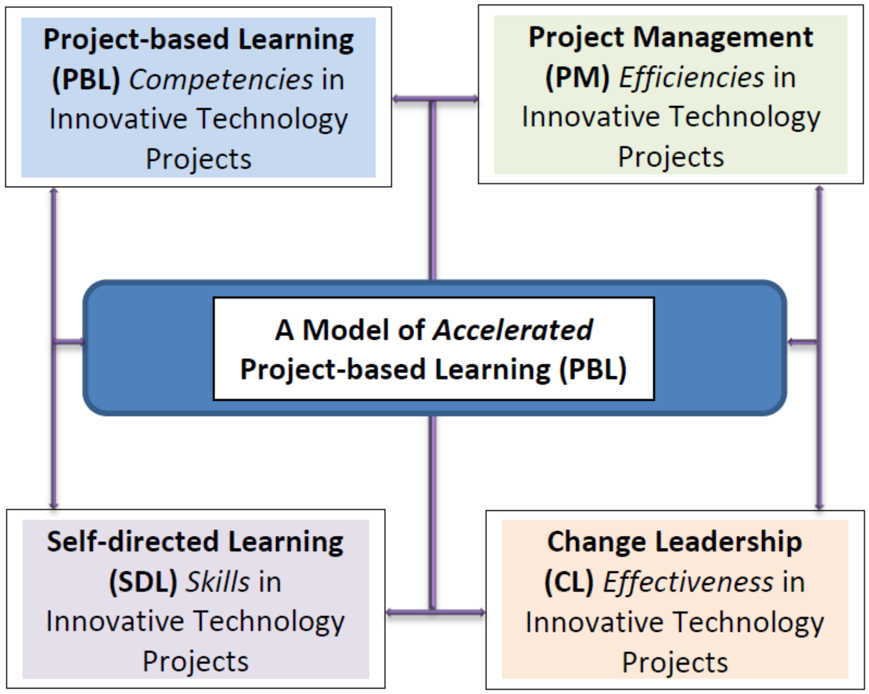

Figure 5. The four interlinked research streams undergirding the study

Definitions of Key Terms

Capstone Project: A long-term, multifaceted, investigative project that culminates in a final product and presentation, typically during the final year of an academic program

Change Leadership (CL): Describes leadership that concerns driving forces, vision, and processes that fuel change and transformation in an organization (Kotter, 1995)

Diffusion of Innovation (DOI): Occurs when an innovative product spreads through an environment in successive, overlapping waves (Business Dictionary, 2014)

Engineering Technology: Emphasizes the application of existing scientific and engineering skills and techniques to real-life issues and problems

Innovative Technology: New technology that can be incremental, radical, or disruptive

Project-Based Learning (PBL): Refers to any programmatic or instructional approach utilizing multifaceted projects as a central organizing strategy for educating students; an inquiry-based teaching method in which students execute a project to investigate a real-life, complex problem (Glossary of Educational Reform, 2013)

Project Management (PM): A methodical approach to execute a project within time, cost, and quality constraints through the phases of initiation, planning and design, execution, commissioning, and, closing (Turner & Müller, 2005)

Self-Directed Learning (SDL): Learning characterized by personal autonomy, management of self-learning, and, viewing problems as challenges; a self-disciplined approach with a high degree of curiosity, self-confidence, and diagnosis; and, having a strong desire to learn, evaluate the learning, and make necessary changes (Candy, 1991; Guglielmino, 1978; Knowles, 1975)

[See Appendix D, p. 196, for the definitions; and Appendix E, p. 197, for abbreviations.]

Assumptions and Limitations

As with any study of this nature, this research was based on some assumptions, delimitations, and limitations. These were due to the precise location of the research, as well as available time-frames, deadlines, and access to personnel. These delimitations and limitations were also predicated on necessary restrictions of scope and structure of the research, its resource constraints, and also its human limitations and ethical strictures.

Assumptions

It was assumed that PBL is the best option as a methodology to execute undergraduate capstone projects in an ET program. Yet, there may be other methodologies that could render comparable results. It can be assumed however, that the entire research process and reporting of the results were based on due veracity and truthfulness on the part of the researcher. It can also be assumed that the research participants have been truthful and thorough in their responses, especially as every attempt was made to ensure protection of their identities.

Efforts were made to eliminate ambiguous and sensitive elements from the interview questions through expert-testing in Phase 2 of the study. The statistical modeling through SPSS 24.0 was assumed to be constrained by sample size, distributions, degrees of freedom, and correlations. Such concerns have been considered in the study findings, results, and interpretations in Chapter 4. However, the limitation in sample size for quantitative analysis was significantly countervailed qualitatively by students' responses to three open-ended questions in the SDLRS-A® Survey, and the in-depth interviews of six student capstone project leaders and six capstone project advisors. Textual analysis of this rich data employed both Leximancer 4.5 and NVivo 11 for sophisticated tabular and graphical outputs (see Appendices S, p. 211, to HH, p. 226).

Delimitations

This research was bounded by a narrowly focused topic that enabled control over the resources, data, and time involved in the study. Thus, the goals were rendered attainable, while retaining their usefulness. This was accomplished by limiting the study to three research questions and four corresponding literature streams to explore these research questions, and to resolve these through empirical study.

The literature review was focused on these four streams of literature as primary areas of inquiry, with support from widely accepted theories (Chapter 2). These contemporary theories included the Theory of Temporary Organizations (Packendorff, 1995; Söderlund, 2000; Turner & Müller, 2003), the Theory of Diffusion of Innovation (Rogers, 2003); and, Kotter's 8-Steps Change Model (1995). As a result, the variables used in the study were also limited to those that were manageable within the available time-frame, consistent with accessibility to the pool of research participants.

This research topic was chosen to extend existing perceptions and uses of PBL to see how, and to what extent, SDL, PM, and CL can be employed for PBL to efficiently enable and accelerate innovation diffusion. Also, it incorporated overcoming possible resistance to change through CL. For practical reasons, the research was conducted within a specific location, and with a reasonably accessible population. The research paradigm was that of pragmatism (Creswell, 2003), using a mixed-methods approach with an integrated model to explore a narrow area as a springboard with significant potential for further study.

Limitations

This study had a few limitations born of necessity. The sample size for quantitative analysis was relatively small, though all 30 students in the sample pool participated in the study for a 100% result. Also, only one innovative technology course (Senior Design course) was considered in the ET undergraduate program of one university ('M University'), which was located in one country, that is, the USA.

These factors may limit generalizability of the empirical research findings, pending extended follow-up studies. As this cross-sectional research was scheduled on a stringent timeline with resource limitations, iterative refinements of the model of accelerated PBL has been recommended as a follow-up in future studies using larger samples across programs, disciplines, and even geographical borders (Chapter 5).

Summary

Innovative technology is being introduced and diffused widely in 21st century higher education. For progress of learning in the prevailing competitive environment, change leadership (CL) consequent to changes attending this diffusion needs to be successfully executed by overcoming resistance and facilitating innovative output. Among inquiry-based methods considered to accomplish this diffusion of technology in higher education, PBL has been chosen for its hands-on, result-oriented approach.

This study therefore sought to go a step further in studying and seeking accelerated diffusion of innovative technology by employing project-based learning (PBL)—infused by Self-directed Learning (SDL) skills, Project Management (PM) efficiencies, and Change Leadership (CL) effectiveness.

This is significant because in a competitive, resource-constrained, and technology-infused higher education environment, accelerated progress is critical. This would enable adaptation to the rapid turnover of technology, enhance employability, and foster successful life-long learning propensities.

After all, the most obvious indicator of quality for a career education program is whether students transition successfully into jobs and careers (McCarthy, 2014). The unpalatable alternative could be severe and measurable attrition of students, underutilization of resources, and potential lack of employability of graduates (Bureau of Labor Statistics, 2016; Harris, 2007; IWNC, 2012; Sheets, Crawford, & Soares, 2012). This research therefore sought to identify PBL as a robust and synergistic synthesis of SDL, PM, and CL towards best practices, and possible acceleration of learning.

Chapter 2: Literature Review

Introduction to Chapter 2

Higher education in the 21st century has undergone a tremendous metamorphosis in a globalizing, knowledge-intensive, and technology-infused world. Edging out traditional classroom methods, teaching and learning are now made possible through the vehicle of cutting-edge technology in a competitive ecosystem (Adams, 2001).

A persistent challenge in this milieu is that these new and evolving technologies will need to be effectively diffused throughout a higher education organization, system, program, or project. It is nonlinear, unpredictable, and uneven. To complicate this further, diffusion of technology in the ambient society and economy has hardly been uniform. Rogers' (2003) model of Diffusion of Innovation (DOI) features several sequential processes through which diffusion of innovation percolates (Appendix F, p. 198). This classic DOI model consists of five groups of technology adopters (Innovators, Early Adopters, Early Majority, Late Majority, and Laggards). Each of these members of the socioeconomic system makes innovation decisions via a five-step process:

1. *Knowledge*—Awareness of an innovation with an idea of how it functions;
2. *Persuasion*—A favorable or an unfavorable attitude towards the innovation;
3. *Decision*—activities that lead to a choice to adopt or reject the innovation;
4. Implementation—Putting into use an innovation that has undergone the previous steps; and,
5. *Confirmation*—Evaluating the results of an innovation decision.

   [See Appendix F, p. 198, for a graphic view of Rogers' (2003) DOI Model].

The generally uneven progress of this phenomenon of DOI (Afolayan, 2011) may be suggestive of undercurrents of resistance to change in the innovative environment. Lyytinen and Damsgaard (2001) suggest that complex innovative technology solutions should be understood as socially constructed and learning-intensive artifacts which can be tailored to adapt to volatile DOI arenas such as the higher education environment.

In fact, the reality of innovative technology diffusion being riddled with pockets of resistance—in organizations, industries, and academic institutions—is underscored in the book *Change Leader* by Michael Fullan (2011). This resistance to change—due to fear, cynicism, and reluctance to alter the status quo—will need creative solutions through resolute CL that is facilitated by collaborative efforts (Fullan, 2008, 2011; Kotter, 1995). In sum, it is widely perceived and accepted that people resist change, and this can slow down the rate of progress of innovative projects wrought with uncertainties and novelty. Therefore, the delivery of sustainable learning outcomes cannot be assumed.

In view of these realities, it is not surprising that the largest single factor retarding the adoption of innovation in educational institutions is *resistance to change* (Vanwyck, 1976). Therefore, Change Leadership (CL) is becoming increasingly relevant to dynamic and progressive academic environments—and this is certainly applicable to innovative, technology-infused projects. CL provides the necessary vision, urgency, collaboration, and momentum needed to steer the change efforts toward fruition by achievement of the leader's goals. For goal attainment, the collaboration of team members could be critical.

Pragmatic models to overcome resistance to change—such as the widely applied Kotter's (1995) 8-Step Change Model (Appendix B, p. 194)—enable us to recognize that CL needs to be exercised through a systematic and pragmatic approach to overcome possible resistance. Though generally recognized and critiqued as a ‘top-down’ model, it provides nonetheless a blueprint for constructive and enduring change under sound CL. In support of the change initiative, the self-motivation inherent in SDL becomes an ally toward this goal. A deep desire for new learning, innovation, and progress can help minimize such resistance on the part of learners, and in fact motivate them to become partners and partakers of the change agenda. The learners will then be more inclined to embrace change with a positive mindset and self-motivation as catalysts for progress.

For best results, change needs to be managed both efficiently and effectively. To accomplish this, a systematic, scientific, and phase-by-phase Project Management (PM) approach would be quite appropriate (Figure 6). PM efficiencies through control of cost, schedule, and quality effectively optimize limited resources to steer the project relentlessly—overcoming resistance—toward the predetermined goal (Kerzner, 2013).

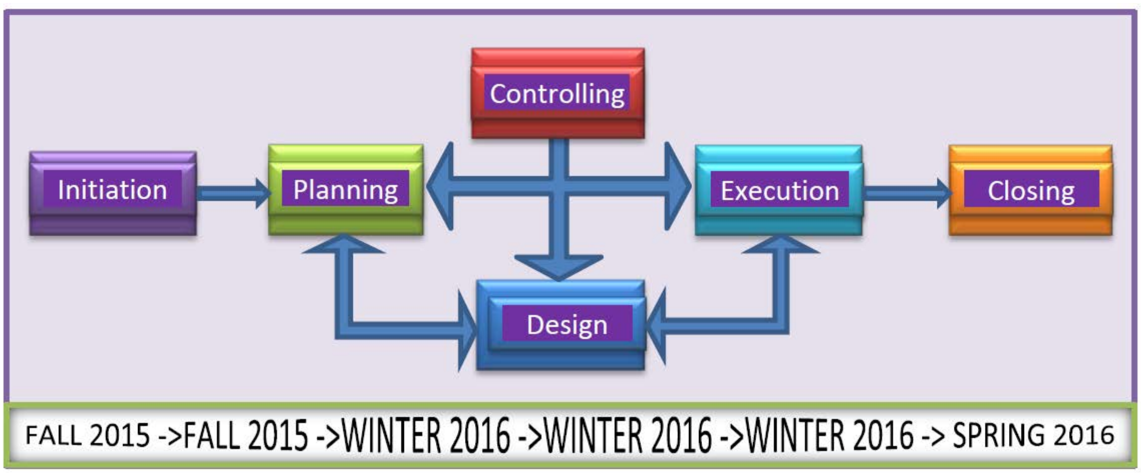

Figure 6. Sequential and iterative phases of the Senior Design projects

Though the exact nomenclature may vary, the sequence of project phases follows a typical pattern from initiation to closing. The capstone projects in the ET program apparently have the following phases: Initiation→Planning→Design→Execution (Prototyping)→ Closing (final product, evaluation, and presentation). Traditionally, the phases between *Initiation* and *Closing* can overlap substantially in a waterfall fashion to avail of cost, schedule, and quality efficiencies (Kerzner, 2013; Turner & Muller, 2003). However, in the case of the capstone projects, it should be noted that 'controlling' is not actually a phase, but an overarching *facilitator* in ensuring that planning, design, and execution are optimized—often through iterative efforts as depicted in Figure 6 (p. 27). Thus, iterative cycles of (re)planning, (re)design, and execution (prototyping), with controlling as the orchestrator, can be expected through the PBL process.

As can be seen in Figure 6 (p. 27), this means that project implementation may likely involve changes to planning and design through monitoring and controlling for deviations, creativity, and economy—which in turn will involve changes in executing the prototype. In fact, this process promotes innovative knowledge transfers between the team members on the one hand, and various experts on the other hand—including faculty advisors, lecturers, project sponsors, and external consultants (Figure 7, p. 29).

As a consequence of expected or unexpected constraints in the essential project parameters—namely cost, schedule, and quality—major changes or minor tweaks can be expected throughout the life of the capstone project. Controlling of revisions in prototyping is thus a nonlinear, iterative activity through the strongly interlinked planning-design-execution phases. Indeed, controlling serves as the catalyst in the iteration. This dynamically looped sequence embodies planned *and* unplanned changes.

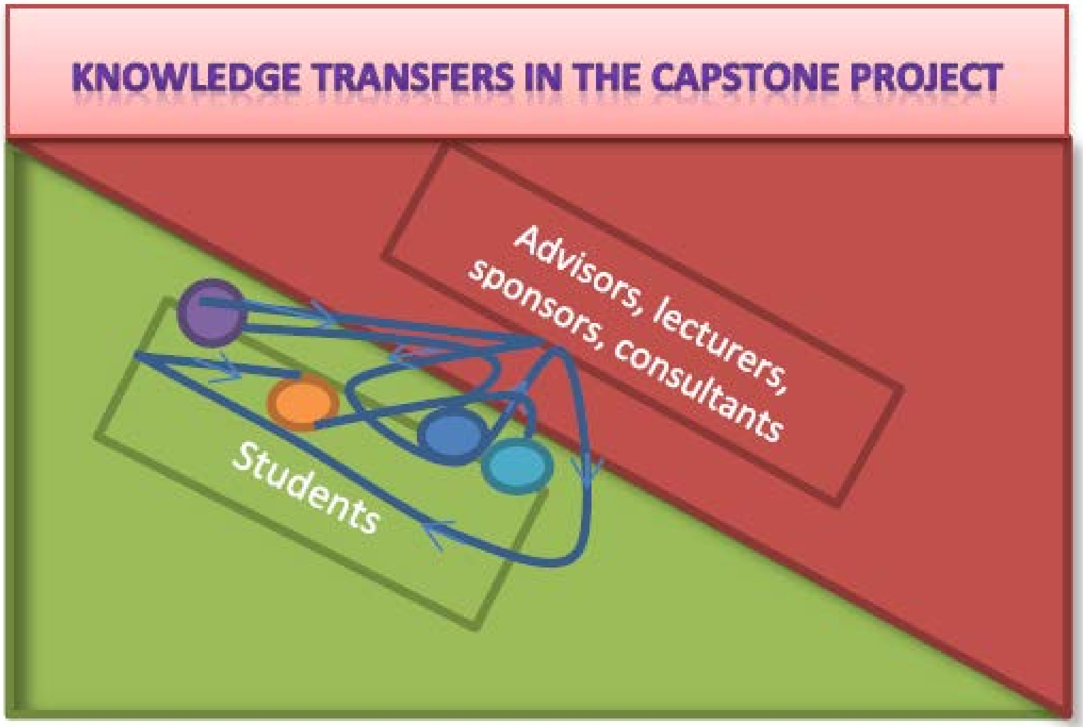

Figure 7. Knowledge transfers between students and experts

It can be deduced that SDL, PM, and CL are closely interlinked due to a creative combination of innovation, change, self-motivation, resource constraints, and leadership—and the need to overcome resistance through collaborative team efforts and relentless goal-oriented leadership to successfully execute the project (Kouzes & Posner, 1987). From the definition of PBL as a hands-on, self-directed learning approach requiring change leadership and using project management principles (Thomas, 2000), it is not surprising that application of SDL skills, PM efficiencies, and CL effectiveness contribute to robust PBL competencies (Thomas, 2000; Turner & Müller, 2005). Such a sturdy PBL model can be expected to proactively serve a technology-infused academic program such as Engineering Technology. Therefore, this study postulates that a fortified PBL approach will facilitate innovative and focused learning (Thomas, 2000).

It is encouraging to note in this context that in a recent study comparing PBL and traditional curricula, it was reported that PBL students contributed more actively to team learning processes, employing a wider range of resources than those in traditional programs (Lycke, Grottum, & Stromso, 2006). It has also been observed that the ability to direct and regulate one's SDL experience is crucial to success (Mast & Davis, 1994).

However, in an empirical study of 93 undergraduate students, a blend of PBL and SDL was used, but the results were inconsistent with the complex learning processes involved (Lee, Mann, & Frank, 2010). The study has thus exposed the lack of PM efficiencies and CL effectiveness in the learning paradigm. Other studies have confirmed that PBL has a large and potentially long-lasting impact on SDL skills and life-long learning (Candy, 1991; Norman & Schmidt, 1992). Considering the discernible links among SDL, PM, CL, and PBL, it is quite plausible for such a composite approach to successfully orchestrate change by overcoming resistance to DOI in academia.

In a competitive environment, it is not enough to merely harness technological innovation in 21st century higher education: it will also need to be leveraged productively through the efficiencies of Project Management (PM) for acceleration of innovation diffusion. This is because of the inherent efficiencies of time, cost, and quality that propel projects as goal-oriented, strategic initiatives through a critical path by projectized organizations that launch these ventures (Sohmen, 2007, 2010; Turner & Müller, 2005).

Therefore, in a competitive, resource-constrained, and dynamic higher education environment, both PM and CL need to work in tandem to accommodate resource constraints and combat inertia and resistance in order to achieve measurable progress.

Furthermore, *accelerated* progress has become necessary today (Zenger, 2015). This is due to technological turnovers, increasing resource constraints, and the consequent need for successful learning outcomes within compressed timeframes. This in turn will serve to reduce the employability gap for learners by embedding employability in the ET curriculum (Bureau of Labor Statistics, 2016; Merriam et al., 2007; Parr, 2015).

Therefore, effective PBL infused with SDL, PM, and CL will be needed to enable diffusion of technological innovations in higher education. This is supported by the reasoning that PBL is inherently autonomous (Thomas, 2000). In seeking best practices, it was determined in an Australian study that PBL is strengthened by infusion of SDL in engineering undergraduate programs (Stewart, 2007). This underscores the need for competence in PBL, self-motivation in SDL, leadership in CL, and efficiencies in PM.

In view of these considerations, this literature review investigated the research problem of how diffusion of technology in a higher educational setting could be geared to overcome resistance to change—and even be accelerated through effective PBL infused with SDL, PM, and CL. This research therefore examined innovative technology application in capstone projects that were executed by small groups (with 3-4 members) of final-year undergraduate students in an innovative, technology-intensive Engineering Technology (ET) program. In sum, to accomplish efficient progress of learning and to accelerate the capstone projects, resistance to technology adoption should be minimized through employment of SDL skills, CL competencies, and collaboration by project teams.

The research design in Chapter 3 informed by this literature review will exercise appropriate synergy and synthesis to convincingly address the research problem and research questions described in Chapter 1, and reiterated here. Further, the literature review will be geared to provide understanding of the four streams—SDL, PM, CL, and PBL—to underscore the need for a model of accelerated PBL introduced in Chapter 1, and proposed in Chapter 5 (p. 170).

Literature Review

In this literature review, four broad research streams were succinctly examined in terms of background, antecedents, and solutions to explore, evaluate, critique, synthesize, and build upon underlying paradigms. The four research streams examined in logical sequence were as follows (Figure 8): (a) Project Management (PM); (b) Project-Based Learning (PBL); (c) Self-Directed Learning (SDL); and, (d) Change Leadership (CL). These four streams were shown to overlap and iterate to draw substance from each other and capture nuances, complementarity, and interactions for synergy and synthesis.

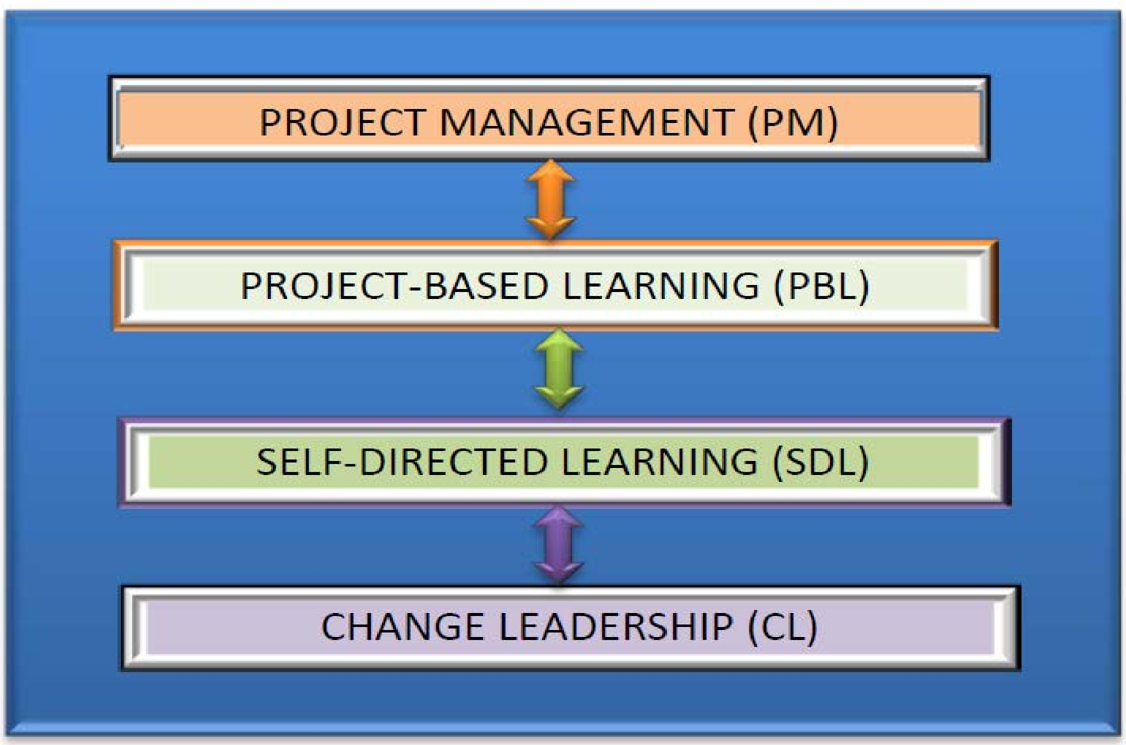

Figure 8. Iterative sequence of literature reviews of the research streams

Project Management (PM)

Project management research and practice have drawn from a pool of interdisciplinary studies among the social sciences—including management, technology, group dynamics, economics, logistics, and engineering (Sohmen, 2010; Turner & Müller, 2003). A viable theoretical basis for PM is the *Theory of Temporary Organizations* which describes projects as *temporary* organizations, with a stated goal and output of value to advance the strategy of the parent organization that spawns the project (Packendorff, 1995; Söderlund, 2000). A project has also been described as not only a temporary endeavor, but also one undertaken to create a *unique* product or service (PMBOK, 2013). This is emphasized by Turner & Müller (2005) who describe a project as both a unique, and an *innovative*, transient endeavor to achieve novel objectives, and involving considerable risk and uncertainty. In a nutshell, projects are viewed as *complex* tasks broken down into smaller parts, resulting in a successfully executed outcome—within constraints of cost, time, and quality (PMBOK, 2013; Sohmen, 2007, 2010; Thomas, 2000; Turner & Müller, 2005). This is applicable to the eight time-bound ET capstone projects (see Appendix C, p. 195, and Appendix H, p. 200) with their lifecycles spanning three consecutive terms of the final year, with a limited budget, unique design requirements, and scheduled completion by May 20, 2016. Students and advisors mutually became co-learners as they transferred knowledge among them (see Chapter 2, Figure 7, p. 29). Thus, students' attitudes and actions became honed to innovation, economy, and efficiency. Most of them were deeply instilled with a penchant for life-long learning as a sequel to the valuable and challenging hands-on experience on the capstone projects of the ET program at M University.

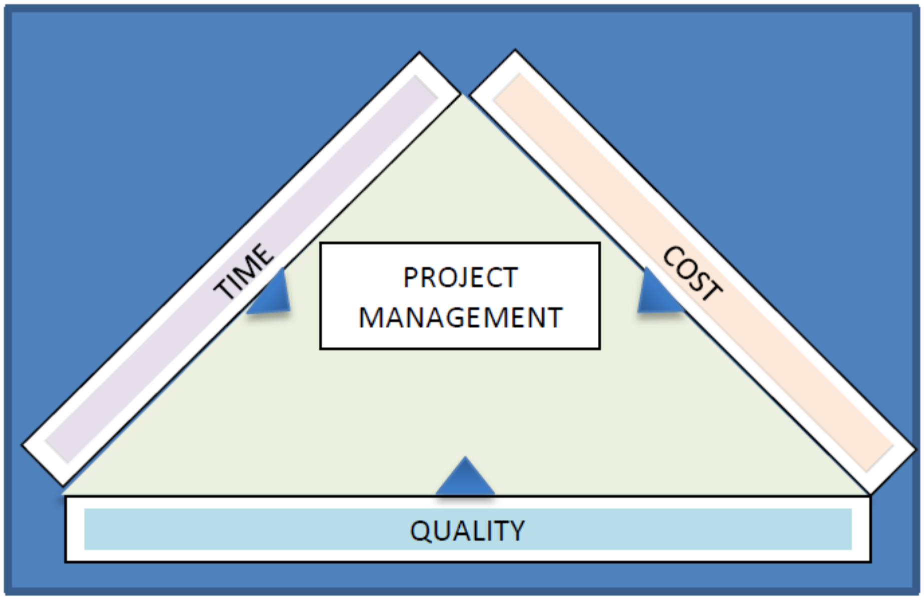

*Figure 9.*The dynamic Triple Constraints of project management

Project management necessitates thorough front-end planning, execution, and closing—all within constrains of the dynamic ‘Triple Constraint’ of cost, time, and quality (Figure 9). Yet these have to be accomplished through changes in the project. Indeed, two axioms have been forwarded and widely accepted as essential to project management: (a) change is inevitable in a project; and, (b) communication is the lifeblood of a project (Sohmen, 1990).

This is applicable to the ET capstone projects, as planned (and unplanned) changes with possible risk elements, can be expected to occur in these evolving, innovative, unique, and temporary ventures; also, optimal communication among team members and their project advisors was necessary to maximize knowledge-sharing and to minimize conflicts while promoting successful project execution. This hands-on approach enabled creative and efficient knowledge acquisition by the students along the experience curve—for real-life application, ready employability, and life-long learning (Puccio, Murdock, & Mance, 2011).

Turner and Müller (2005) have compiled a meta-review of the literature on project success—and the role of the project leader's leadership style to realize successful project outcomes. The meta-review considered various contemporary schools of leadership. These included visionary, transformational, and transactional leadership in chronological order from the 1980s (Bass, 1985). Even the cultural context of leadership was examined.

Turner and Müller (2005) concluded that the project leader's emotional intelligence (EQ) is most likely to have the highest impact on project success (Freedman, 2010; Salovey & Mayer, 1990). Bridges and Bridges (2003) also focused on the EQ necessary to guide people in organizations to make the relentless transitions required in the CL process that is laced with punctuated changes. It should not be surprising therefore that CL and PM are closely intertwined (Lines, Sullivan, Smithwick, & Mischung, 2015).

In sum, Turner and Müller (2005) have taken a panoramic review of various modern leadership styles, and have clearly identified the need for *emotional intelligence* (EQ) as a strong contributor to project success. It was conjectured that successful implementation of technologically intensive PBL for diffusion of innovation would ideally be complemented by the soft skill of EQ (Salovey & Mayer, 1990). Thus, students and advisors in the ET capstone program at M University would be well-advised to utilize and develop EQ skills in every aspect of PBL—not only in the interpersonal aspects of PM, but also for the application of people skills in SDL, CL, and PBL.

Despite sparse evidence of operationalizing this concept of EQ in the literature, it is practically important in terms of desired leadership behavior in the context of managing time-limited projects through professional peers under pressure of limited resources.

Apart from EQ, it can be surmised that skillfully managing the triple constraints of time, cost, and quality in PM is essential to accelerating PBL (Turner & Müller, 2005).

Project-Based Learning (PBL)

PBL refers to any programmatic or instructional approach that utilizes multifaceted projects as a central organizing strategy for educating students (see definition in Appendix D, p. 196). PBL is among several inquiry-based teaching methods in which students execute a project to investigate and respond to a real-life, complex problem (Blumenfeld, Soloway, Marx, Krajcik, Guzdial, & Palincsar, 1991; Savin-Baden & Major, 2004).

Deriving from the principles of project management, PBL has been recognized as an appealing instructional strategy by which students solve real or simulated problems. This is accomplished through experiential learning, critical thinking, and collaborative efforts within a planned timeframe. PBL is thus a powerful educational strategy resulting in learners acquiring new knowledge and skills that would be transferable to the real-world workplace—and even beyond this, into life-long learning (Mergendoller, Maxwell, & Bellisimo, 2006).

From a learning theory perspective, PBL employs a social constructivist paradigm, in that knowledge is built through experiential and transformational learning. This is facilitated by the hands-on experience of the learner to construct meaning and knowledge (See the Five Orientations to Learning in Appendix A, p. 193). PBL has been successfully used in education for over a couple of decades, emphasizing a knowledge-intensive, student-centered strategy (Blumenfeld et al., 1991; Thomas, 2000). Indeed, PBL promotes meaningful, enriched learning that enhances inquiry and problem-solving skills in a rich, authentic environment. In this context, optimized and streamlined designing of capstone projects can benefit both the study and use of technology to facilitate and accelerate successful outcomes (Guy, 2009).

In a meta-review of published literature on PBL, projects were seen as vehicles resulting in a successfully executed product, event, or other outcome related to an academic goal (Thomas, 2000). PBL is based on student initiative and is constructive, knowledge-building, and investigative toward innovative resolution of a problem (Larmer, 2014). As students are held responsible for choosing, designing, and managing their own project, the learning through PBL (as well as SDL) they experience is expected to be superior and more profound than that of students engaged in traditional learning.

As a result, students can be expected to become critical thinkers and life-long learners with a hands-on approach to learning (Mergendoller et al., 2006). This is precisely what would be optimal for ET students undertaking their capstone projects that are designed to equip them for real-world, technological challenges. The ET advisors guiding the capstone projects act as facilitators of change (with the student leaders of groups functioning as the de facto change leaders). Thus, the faculty advisors monitor and mentor groups of students in each innovative project.

PBL research spanned nearly a decade at the time of the meta-review by Thomas (2000). This theoretical study explored underpinnings, effectiveness, evaluation, and future directions of PBL. The succinct meta-review also served as useful background reading to the pragmatic subject of PBL, and confirmed the role of technology in its successful delivery. Thomas (2000) did a masterful job of abstracting several themes within PBL, and had commented succinctly on the development of the field since its inception in the 1990s. He answered the question: “What must a project have in order to be considered an instance of PBL?" with five essential criteria for what PBL should evidence: (a) centrality; (b) driving question(s); (c) constructive investigations; (d) autonomy; and, (e) realism" (Thomas, 2000, p. 4). On the obverse, as PBL is intensely practitioner-oriented, Larmer and Mergendoller (2001) took a pragmatic view of PBL and abstracted two essential tenets: (a) students must perceive the given project as a *personally meaningful* task; and, (b) a meaningful project should fulfil an *educational* purpose to prepare learners for real-world applications.

Thus, a well-designed and executed PBL experience should fulfil both personal and educational goals, with student autonomy and a constructive focus. Fittingly, yet another study crafted seven guidelines for effective implementation of PBL: (a) 21st century skills; (b) inquiry and innovation; (c) free choice of expression; (d) a keen desire to learn; (e) a driving question that captures the heart of the project; (f) feedback and revision; and, (g) public presentation and accountability (Larmer & Mergendoller, 2001). These practical insights were inspired by a real-life project that was successfully carried out by students in San Diego, California, and comprised a PBL framework that reflected the existing structure for the ET capstone projects at M University. Whereas Thomas (2000) penned a theoretical article that looked at the evolution of PBL over a couple of decades, researchers of the two empirical studies reviewed contributed to a holistic picture of PBL from both theoretical and pragmatic standpoints.

Further, Gratch (2012) examined teachers' perceptions of the use of PBL technology in a nontraditional environment. The authentic, economical, and pragmatic approach of PBL evidenced was seen to resonate with students' preferred method of learning and productivity inside and outside the classroom. Gratch (2012) concluded that at the Texas high school studied, the entire curriculum was based on this *technology-infused* PBL approach. In similar vein, ET students at the undergraduate level were relied upon by industry, not only to apply technology, but also to vigorously drive its implementation (Vanajakumari et al., 2015).

It is evident from these studies that the key ideas of collaboration (in CL), pragmatism (in PM), and authenticity (in SDL) drive the PBL approach toward rapid knowledge-building and experience along a steepened learning curve. PBL thus promises progressive outcomes that can be achieved in similar academic environments that are open to applying the PBL approach. This is a clear departure from traditional, pedagogical practice in teaching and learning. The PBL method can be linked to the subject areas of PM (for economy), SDL (for autonomy), and CL (for change). Thus, dynamic change, autonomy, economy, and leadership reside in, and energize, the crucible of PBL.

In this context, the Theory of Temporary Organizations propounds that temporary organizations such as projects, teams, and joint-ventures are created with the time-limited mandate to accomplish a task—and then to close out (Lundin, & Söderholm, 1995; Packendorff, 1995). These temporary organizations are bounded by the cost-time-quality parameters in a focused, dynamic, and goal-oriented manner.

The earlier discussion of PM based on the Theory of Temporary Organizations pertaining to projects is clear about the unique features of resource-efficient, fast-paced, and goal-oriented projects of predetermined duration (Packendorff, 1995). By extension, the PBL methodology stands to benefit significantly by incorporating the laudable features of PM. In addition, the self-motivation needed to accomplish PBL can be shown to be embedded in SDL to foster a well-rounded experience for the Senior Design students.

Self-Directed Learning (SDL)

The earliest definitions of SDL show that it is a continuous engagement by an individual in acquiring, applying and creating knowledge and skills through personal initiative, self-motivation, and autonomy (Stewart, 2007). There are four dimensions to SDL: (a) personal autonomy; (b) learner self-management; (c) independent learning; and, (d) learner's control of their own learning (Candy, 1991). Consequently, SDL has existential elements steeped in individual freedom, responsibility, and authenticity (Savin-Baden & Major, 2004).

As self-directed, lifelong learners, SDL practitioners have been studied in terms of their degree of self-control as individual learners—apart from the skills, competencies, and abilities they seek to possess for optimal learning (Candy, 1991). Consequently, SDL reflects elements that attract innovative thinking, self-motivation, and a desire to change the status quo (Stewart, 2007). These ideas and qualities describing such SDL initiatives as self-motivation, self-control, self-management, and autonomy in learning would contribute significantly to student learning and competence in the ET capstone program.

From a learning theory perspective, SDL comes under the humanist and social cognitive paradigms (Appendix A, p. 193). Thus, it promotes autonomous, *transformational* learning with a focus on andragogy—which is learner-centric with supervision by an instructor or advisor (Knowles, 1968). The relationship between SDL and PBL connotes significant overlap. It is reflected in the assertion that SDL is "the preparedness of a student to engage in learning activities defined by him- or herself, rather than by a teacher" (Schmidt 2000, p. 243). Thus, planning, identification of learning needs, time management, and self-discipline are all involved in SDL.

It stands to reason that these attributes and activities are also critical for successful PBL. Therefore, the nature of SDL skills as contributory to readiness for PBL is patently obvious. When SDL is integrated into PBL, deep-level processing takes place, and the learner decides how and when to learn (Candy, 1991; Stewart, 2007). Indeed, through information-seeking, these learners become flexible and adaptive students.

Therefore, learners who seek to enhance their learning experience through PBL should ideally have a propensity to the autonomy of SDL, which can be integrated into PBL. This in turn can help in accelerating technology diffusion in higher education settings such as the ET capstone projects executed by small-group participants.

The SDLRS-A® questionnaire shown in Appendix O (p. 207) as a partial instrument (to protect its copyright) helps to identify SDL skills in learners. The factorial essentials of this widely-used instrument are encapsulated in three groups: (a) Desire for learning; (b) Self-control in learning; and, (c) Self-management of learning. The SDLRS-A® instrument derived from SDL principles has pre-eminence in the literature on SDL, as it has enjoyed high reliability and validity—and hundreds of worldwide applications in multiple languages (Guglielmino, 1978).

Chapter 3 will expand more on these aspects of the SDLRS-A® instrument which has been used widely to operationalize SDL in diverse educational settings—across geographical, cultural, and socioeconomic boundaries. SDL is predicated on the propensity to effect change—within oneself, relating to the project at hand, and in the ambient education environment. For these changes to be spearheaded with collaborative effort coupled with momentum, a sense of direction and CL competencies would be needed (Puccio et al., 2011).

Change Leadership (CL)

Change leadership (CL) concerns the driving forces, vision and processes that fuel change and transformation in an organization (Fullan, 2008, 2011; Kotter, 1995). It has been noted that the prime purpose of the project as a temporary organization is to effect constructive change with a defined output (PMBOK, 2013; Turner & Müller, 2005). Thus, Kotter's 8-Steps Change Model (Kotter, 1995—see Appendix B, p. 194) and the CL framework by Fullan (2008, 2011) contribute to the theoretical support undergirding the CL research stream.

Taking a historical view across the centuries—up to recent decades of technology-infused developmental surges—society has rather magically rearranged itself into radically different scenarios of the 21st century. In both its incremental forms, and in its turbulent manifestations as propounded by the farsighted economist Schumpeter (1954), change has significantly altered our environment.

When we consider the paradoxical, Heraclitan (535 B.C.-475 B.C.) cliché that change is a *constant*, it is surprising that people tend to resist change (Kahn, 1979). Yet, this should not surprise us because people prefer to seek the known—and the tried and tested—for security and maintenance of the status quo despite the promises that may be inherent in change. This dilemma is captured in the theories of chaos and organizational change which consider a measure of chaos as a harbinger of change (Wheatley, 1996).

The paradox of change is that even when the benefits become discernible, change is not easy at any level (Lamar, 2003; Poole & Van de Ven, 2004). Considering that change itself is a learning experience, CL is by default also a process that intuitively involves learning—with due allowance for some failure as a catalyst in this learning process. Indeed, learning efforts can be considered as stimulants of changes in the ET capstone projects at M University.

As Fullan (2011) in his prescriptive *Change Leader* has asserted, the essence of the change process is the capacity of organizational leadership—in the face of uncertainty, chaos, and rapid change—to generate organization-wide energy and passion through action (Kouzes & Posner, 1987). Change is therefore action-oriented, and not merely a theoretical concept: it has to be pushed persistently with a forward momentum by the leaders, sponsors, and supporters who initiate and embrace the change (Kotter, 1995). Despite pockets of resistance, relentless and enthusiastic actions, as well as efficient diffusion of knowledge, are needed. After all, change cannot take place without the participants learning about what the outcome is, from the vantage point of present reality.

Therefore, for lasting impact, effective change leaders need to examine and drive best practices through continual learning with allowance for mistakes as part of the learning process. According to Kotter (1995), sustainment of change is based on incorporating and applying this multistage process enshrined in the 8-Steps Change Model via "leadership, leadership, and still more leadership" (p. 31). The need for CL in PBL cannot therefore be overemphasized.

Thus, change leaders courageously transform familiar, present reality into a new, unfamiliar, and altered state of envisioned reality. To leverage change effectively, the leader needs to "ask tough questions, get people to come out of their comfort zones, and actively encourage positive change." (Heifetz & Linsky, 2002, p. 111). Transformational leadership that inspires followers to perform *beyond their expectations* is necessary to articulate and leverage sustainable change in a progressive environment (Bass, 1985).

Thus, the destination of the leader and those who follow is a picture of irrevocable—and often unrecognizable—change in the world within the leader's sphere of influence.

Fullan (2011) presents guideposts for successful CL, as it is axiomatic that change is largely met with resistance (Kotter, 1995). These ideas find resonance with contemporary issues for progressive implementation of PBL in an educational setting (Larmer & Mergendoller, 2001; Thomas, 2000).

It can be concluded that effective, pragmatic, and resolute CL could be the catalyst that will render PBL effective in the long run. This is because CL is needed to overcome inertia and resistance to changing the current state through innovation. This reinforces the stated research purpose in this study, of accelerating technology diffusion in a higher education setting through PBL while overcoming the inevitable resistance to change (Fullan, 2008, 2011; Senge, Cambron-McCabe, Lucas, Smith, & Dutton 2012).

According to Kotter (1995) each phase in the change process needs to be managed with adequate planning, collaborative efforts, and drive. Skipping steps may give an illusion of speed, but is unlikely to yield plausible and enduring results. Thus, eight steps to successful change are described at length in Kotter's 8-Steps Change Model, starting with establishing a sense of urgency, to creating and communicating a vision, to finally institutionalizing new approaches (see Appendix B, p. 194). Many developments have been made since Kotter's seminal work, but the essential tenets of CL—employing a phase-by-phase, systematic, and systemic approach—are still widely applied (Fullan, 2008, 2011; Kotter International, 2011).

Inasmuch as change is fluid and dynamic, leadership itself is anything but a static mental model (Johnson-Laird, 1983; Norman, 1983): leadership skills and behaviors evolve—and studying best practices will certainly serve to nurture and hone leadership abilities. With experience, one recognizes the complex nature of leadership and change, and the art and science behind leading masterfully.

In looking at *accelerating* the diffusion of innovation, it needs to be reiterated that caution must be exercised against speed without sustainable results (Kotter International, 2011). The exposition of the complexities of organizational change as propounded skillfully by Kotter (1995) needs to be weighed alongside the ideas (and ideals) of Fuller (2011), Senge et al. (2012), and other thought leaders. This will enable garnering a balanced perspective on how innovative change initiatives can utilize a systematic, phase-by-phase approach as proposed by Kotter (1995). A headlong rush to change could be unproductive. Therefore, such a systematic approach to CL should serve to accelerate diffusion of technology *with* sustainability in the ET program through a formalized PBL.

It is not surprising that change management has been popularized in the literature for several decades (Kennedy, 2013). With constructive change, the social and ethical aspirations of constituents within the institutional environment and the external community can be met (Bess & Dee, 2007). In this context, though there is scholarly work on organizational change in education, little research has been done on the specific experiences of those engaged in technology-infused change processes using PBL in a higher education environment. Kennedy (2013) identifies and describes the experiences and perceptions of participants involved in a collaborative technology project employing PBL. The location was that of a state land grant university and a large, urban community college. The study explored the areas of both agreement and disagreement among participant groups in discerning patterns of change and leadership through PBL.

Among results reported in this study by Kennedy (2013) were perceptions and experiences of faculty, staff, and project managers pertaining to changes in the project purpose and the roles of individuals. Faculty and staff reported feeling a sense of disengagement as a result of these changes, citing poor communication by project managers about such changes. They also reported a desire for concrete project management tools such as timelines, specific deliverables, as well as budgetary guidelines. In fact, faculty and staff preferred to contribute their discipline-area content without being held responsible for learning new technology skills or instructional design.

The project managers in the study by Kennedy (2013) took the position that faculty should be held accountable for at least some baseline technology skills and knowledge of pedagogy sufficient to aid in course redesign. While there was disagreement in terms of degree, all participants saw an important role for institutions to play in technology-infused projects using PBL. They called for resources to be made available—such as faculty release time, technology training, robust systems, and, networks.

Further, an institutional layer of proficient staff was recommended to provide support for both faculty and students in the transition to technology-mediated teaching and learning. These complex issues from this real-life case point to the need for educational leaders to balance routine needs with practical skills, including appropriate use of technology to meet the expectations of stakeholders (Bess & Dee, 2007; Bessen, 2014).

Synthesis of PM, PBL, SDL, and CL

The sequence of the research streams (SDL, PM, CL, and PBL) studied in this literature review, and as depicted in Figure 5 (Chapter 1, p. 20) has clearly demonstrated the strong—and even systemic and logical—linkages among them. The efficiencies of PM with the dynamic Triple Constraints of cost, time, and quality undergird the pragmatic PBL methodology with its time-limited mandate as a temporary, organized endeavor.

The self-motivation and desire to change the status quo that is inherent in SDL is naturally embedded in PBL to help overcome likely resistance to change. The resoluteness needed for forward momentum through collaborative and persistent effort to overcome resistance finds resonance in CL. Kotter’s 8-Steps Change Model (Kotter, 1995) and the empirical study by Kennedy (2013) has reinforced the dire need for more sensitivity and caution regarding change leadership and change processes in higher education settings.

Faculty, students, and administrators tend to approach change from different standpoints—though these stakeholder groups agree on the *need* for change. In a technology-infused ecosystem, it is incumbent upon learners and educators, namely students and instructors—to imbibe and embrace new technologies. Clearly, PM efficiencies with cost, time, and quality can economically transfer innovative technology.

There is indisputable evidence of resistance to change despite the obvious need for change—thus confirming the significant literature evidence of this paradox (Kahn, 1979; Kennedy, 2013; Kotter International, 2011; Senge et al., 2012). In this context, the importance of a collaborative approach to technology diffusion through capstone projects in the ET program cannot be overemphasized.

In sum, change is inevitable in a dynamic ecosystem as a rich medium and vehicle for diffusion of innovation. This change can be embraced through a robust PBL model that is buttressed by best practices in SDL, PM, and CL.

In synthesizing the four literature streams, the enlightening concepts of Theory U Leadership as propounded by Otto Scharmer (2009) can be considered. Change agents are urged to suspend superficiality, judgmental attitudes, and preconceptions in order to delve deep into the inner self and unravel the 'blind spot.' Thus, the true source of the inner self of the inquisitive learner is revealed through self-reflection and introspection. The essentials of SDL (Candy, 1991) and CL (Fuller, 2008, 2011; Kotter, 1995) work in concert to motivate this inner self to overcome resistance, and to inspire self-motivation. These in turn serve to streamline PM efficiencies to enhance best practices in PBL.

Such self-motivation can be deepened by empathic listening with an open mind, open heart, and open will to 'presence' (presence + sense) the emerging future even as it occurs (Scharmer, 2009). This change has to be inclusive, collaborative, and sustainable in order to have optimal impact in the ecosystem, and in the global arena.

Thus, both Fullan (2011) and Scharmer (2009) emphasize the need for group collaboration to effect meaningful change. Indeed, the need for a collaborative and cooperative approach in an environment of efficient learning cannot be underestimated (Kotter, 1995; Wurm, 2005). Such a synergy could facilitate evolving changes in the capstone project of the ET program.

Despite the classic but simplistic unfreeze-change-refreeze model of change popularized by Lewin (1947), leveraging successful change is indeed complex. In his 8-Steps Change Model, Kotter (1995) debunks ineffectual attempts at organizational change in the industry, and expands on the paramount need for step-by-step momentum of the change process and CL. Kotter (1995) underscores the essential urgency, dynamism, vision, synergy, and empowerment needed to enable change to annul potential resistance. It would then be possible to steer towards the altered and improved state as exposited by Scharmer (2009). This not only demonstrates the complexity of the change process, but also the need to leverage the change in a *future-oriented* manner through sustained and tireless efforts. This will work admirably toward a successful PBL experience for the students and their advisors—constructively undergirded by the integration of SDL, PM, and CL.

There is also a necessity to craft practical strategies to accelerate the diffusion of innovation in an academic setting (Dennison, 2013; Gonçalves, 2012; Lew, 2002). For this study, the ET program at M University will benefit immensely from employing a robust, integrated model of PBL incorporating SDL, PM, and CL, that will accelerate the learning process and deepen the experience. Clearly, acceleration of PBL would be coextensive with the relentless exercise of systemic, systematic, and synergistic change.

It has been demonstrated through concise review of the four inter-related streams of literature that effective change and acceleration of an innovative technology project in higher education can be accomplished through employment of a rich and robust PBL model. Indeed, such a robust model can incorporate best practices in SDL, PM, and CL to craft an *accelerated* model of PBL.

Summary

Innovative technology is being introduced widely in higher education, but resistance to change can retard progress in delivery of sustainable learning outcomes. This is contextually significant because in a competitive, resource-constrained, and technology-infused higher education environment, accelerated progress is necessary to ensure successful learning outcomes in the long run. The alternative is attrition of students, underutilization of resources, and potential lack of employability of graduates.

The Engineering Technology (ET) program at M University was chosen as the venue to address the research problem, as innovative technology is employed in this program. Therefore, this study was intended to examine the feasibility of accelerating the diffusion of innovative technology using PBL—based on student initiative, creativity, and investigation toward resolution of real-life problems. This research therefore presented PBL as a viable method to accelerate technology diffusion in a higher education program through effective change management for successful outcomes.

The four interlinked research areas identified (SDL, PM, CL, and PBL) were supported by theories and models such as the Theory of Temporary Organizations and the 8-Steps Change Model. The four streams were broadly delineated, and succinctly discussed with additional support from cognate literature—both theoretical and empirical. This review of the four literature streams has provided a deeper understanding of the research problem and related research questions in Chapter 1. The concise study of relevant literature in Chapter 2 guides the research methodology in Chapter 3. The mixed-methods research design is substantiated by the data analysis in Chapter 4, and contextually elucidated in the concluding findings of Chapter 5.

Chapter 3: Research Methodology

Introduction

This chapter outlines the research methodology used in this study, which in turn derives from the research problem and research questions of Chapter 1. In accordance with the purpose of this study, the research problem of how diffusion of innovative technology in higher education can be accelerated was investigated in Chapter 2. Thus, the succinct yet thorough literature review in Chapter 2 of Self-Directed Learning (SDL), Project Management (PM), Change Leadership (CL), and Project-Based Learning (PBL) provided the foundation for theoretical support towards a robust PBL model. This enabled the appropriate positioning of the study to drive the research agenda.

To operationalize this research, a pragmatic, mixed methodology approach utilizing an explanatory research design was undertaken. It studied the practical diffusion of technological innovation in an Engineering Technology (ET) program through its final-year Senior Design capstone projects using PBL. The ET program at M University was chosen as the institution to empirically investigate the research problem, as effective innovative technology diffusion is a core purpose of the university's ET program.

The typical capstone project encompasses student initiative, creativity, and investigation toward resolution of real-life problems through project implementation (see detailed definition in Appendix D, p. 196). To operationalize these four concepts (SDL, PM, CL, and PBL) from Chapter 2 that impinged on the three research questions from Chapter 1, a mixed-methods approach has been outlined in this chapter. The research design and rationale presented in the following sections have been tailored to address and resolve the three research questions—hence the overall research problem in Chapter 1.

Research Design and Rationale

To address the three research questions in light of the literature review from Chapter 2, a mixed-methods approach was adopted in two successive phases (see Figure 10, p. 53). Phase 1 had a predominantly quantitative approach using a Likert-style instrument, together with a nested qualitative component comprising three open-ended questions; Phase 2 was qualitative, using seven semi-structured interview questions.

Phase 1 employed the SDLRS-A® Survey, a widely validated quantitative questionnaire on SDL. All the 30 students of the graduating Senior Design class participated in the survey. The nested qualitative component of Phase I that consisted of three open-ended questions focused on change leadership and change processes experienced by the same pool of 30 students over the three consecutive terms of the Academic Year 2015-2016.

Phase 2 employed a one-on-one, semi-structured interview that was posed to: six student leaders leading their respective capstone projects out of the eight projects represented in Phase 1; six faculty advisors of the capstone projects, from a pool of nine available advisors (eight advisors and one economic advisor for all eight capstone projects—see Appendix C, p. 195 and Appendix H, p. 200). Thus, 75% of student leaders (representing 6 out of 8 projects) and 67% of faculty advisors (representing 6 out of 9 faculty advisors) participated in the Phase 2 interviews.

The two phases were undertaken consecutively, with Phase 1 providing quantitative, SDL-related data through the SDLRS-A® questionnaire, as well as qualitative, CL-related data through three open-ended questions. In Phase 2, rich and in-depth qualitative information on SDL, PM, CL, and PBL was collected.

As outlined, the research was carried out in two phases—Phase 1 and Phase 2 (Figure 10). In Phase 1, the SDLRS-A® instrument was administered towards the end of the last term (Spring 2016) of the Academic Year 2015-2016 using a PBL framework. The SDLRS-A® instrument assessed all 30 students' skills in SDL which were assumed to contribute to equipping them for life-long learning after graduation from the ET program of M University.

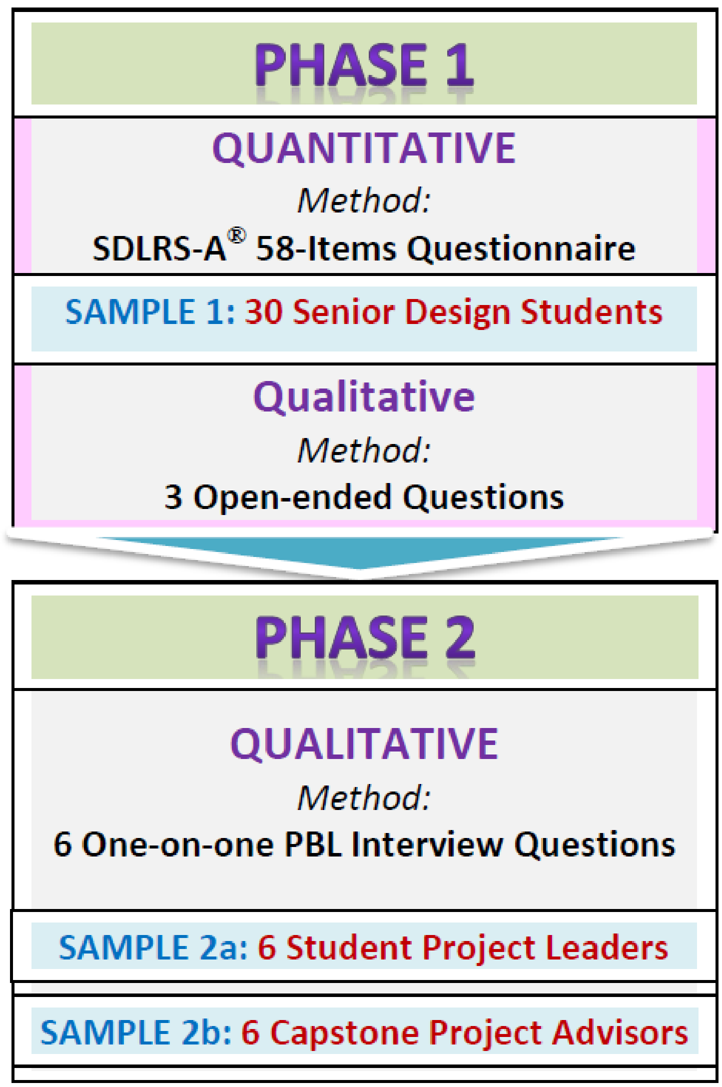

Figure 10. Mixed-methods research design employed in the study

Phase 1 (Quantitative & qualitative): In Phase 1, Research Question 1 was the main focus, as it pertained to SDL. (The nested qualitative component of three open-ended questions addressed CL). Thus, the significantly validated Self-Directed Learning Readiness Scale (SDLRS-A®) Survey was employed to determine SDL skills accumulated through the students' scholastic experience over the years in terms of attributes, attitudes, and aptitudes (for a sample questionnaire, see Appendix O, p. 207).

Phase 2 (Qualitative): For Phase 2, semi-structured interviews were prepared (see Appendix Q, p. 209, for the seven interview questions). The interview questions were expert-tested by the Research Director of the ET Department and three anonymous faculty members familiar with the concepts of SDL, PM, CL, and PBL. The finalized PBL interview questionnaire was used for the one-on-one, face-to-face interviews of the six student leaders and six faculty advisors. These interviews were audio-recorded for subsequent transcription, and then coded, grouped, and analyzed (Chapter 4).

These in-depth interviews in Phase 2 with twelve diverse participants yielded strong subjective data. This interview data contributed to understanding the practice of PBL in the capstone projects, along with further insights into SDL, PM, and CL. Specifically, these interviews were deliberately geared to yielding rich, qualitative data towards an understanding of how SDL skills, PM efficiencies, and CL effectiveness identified best practices, and served to *accelerate* PBL in innovative technology projects.

The Phase 1 mixed-methods findings through the SDLRS-A® Survey contributed to this cumulative richness of data. Together with the Phase 2 interviews, greater depth of understanding was drawn from cogent synthesis and interpretations of the interrelated phenomena of SDL, PM, CL, and PBL (see Chapter 1, Figure 5, p. 20).

Site and Population

Site Description

The site for the research was the ET department suite of offices, classrooms, laboratories, and boardrooms located in X building at M University. These spaces were well-equipped, temperature-controlled, and adequate for the research. All ET laboratories were equipped with sophisticated engineering lab equipment, and the final-year undergraduate students attended face-to-face classes, assessments, and labs through the weekdays. ET faculty members were available for consultation regarding classwork, lab experiments, and research modalities through the weekdays.

The Head of Department of Engineering Technology, the ET faculty members, and the Senior Design students were apprised of the research topic as well as the nature of the empirical research methods that were to be employed. The schedule of project presentations through the Academic Year 2015-2016 was provided to the students, the advisors, and the researcher by the coordinating instructor of the Senior Design course.

To ensure anonymity and efficient conduct of the empirical research, the identities of participants were protected using abbreviated codes instead of actual names (see Appendix C, p. 195). Also, the researcher had only indirect access to the 30 students during Phase 1 through their advisors and coordinating instructor who acted as 'honest brokers' for the capstone projects. The role of these 'honest brokers' in this research was to serve as liaison between the researcher and the participants to minimize bias, enhance trust, and to facilitate voluntary participation in the research.

The honest brokers were provided SDLRS-A® questionnaires that were simply identified numerically from #S1 to #S30 to ensure absolute anonymity of the participants.

This cautionary procedure ensured that the completed surveys were collected by ET faculty advisors. These surveys were shuffled and sealed in an envelope so that they would not be traceable to specific participating individuals. This eliminated possible bias or influence in the responses to the survey, and on individual participants' evaluations.

For Phase 2, the in-depth interviews were conducted in the ET department premised, entirely on the campus of M University. From the pool of 30 students who were administered the SDLRS-A® questionnaire, six students who led their respective Senior Design projects through the final year of the ET program were administered the semi-structured interviews with seven questions (see Appendix Q, p. 209). This was carried out through a one-on-one, face-to-face interview format in a designated, noise-free office with no distractions or interruptions. Similar interviews were also conducted separately with six of the nine capstone project advisors, using the same semi-structured interview questions for comparability and compilation.

The actual interview sessions were conducted twice for each participant as depicted graphically in Figure 11 (p. 57). Prior to the first interview session was an informal, socializing stage that solicited only the voluntary consent of the participants to undertake the interview sessions, and to schedule appointments for the first, main interview session, and a subsequent follow-up session. The main interview and the follow-up session were recorded on a digital voice recorder for immediate transcription. This enabled a direct, face-to-face, and exclusive engagement of the researcher with each interviewee. After reviewing the transcribed interview text following the first interview session, specific ideas were identified and highlighted for clarification and expansion in a follow-up session. The first sessions of the interviews were in-depth, and lasted up to over an hour-and-a-half, with most of them lasting over an hour. The follow-up sessions were also generally face-to-face, with the exception of two phone interviews and one Skype interview (for out-of-town or traveling participants). The voice-recorded information was transcribed and compiled as files in Microsoft Word 2016 format. They were then organized, classified, and analyzed using the latest versions of sophisticated content-analysis software, namely Leximancer 4.5. Results of these analyses were reflected upon by the researcher, summarized, and presented in Chapter 4. Figure 11 is a graphic, 'waterfall' sequence of the Phase 2 interview program in its sequence.

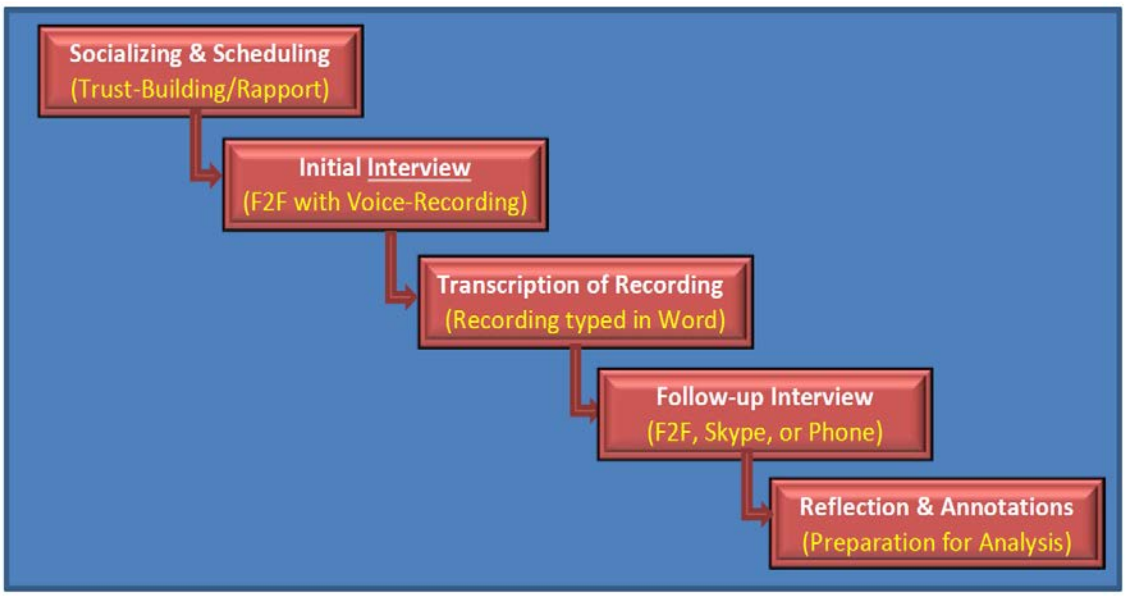

Figure 11. Projectized Waterfall design of the Phase 2 interview program

Table 2 (p. 59) presents the schedule of 24 interview sessions within a three-week timeframe (May 13 to June 3, 2016). The three-week schedule was necessitated as the student participants were graduating within a week thereafter, and faculty advisors were preparing to leave for their summer vacations.

The interview program and projectized sequence depicted in Figure 11 (p. 57) were devised by this researcher to meet all targets to complete the interviews within the three weeks' window of time. It was ensured that there was no compromise on richness, completeness, and high quality of data. The 'stair-step' project phasing adopted for the interview sequencing strategy as presented in Figure 11 (p. 57) has been identified in Chapter 5 as a contribution of this study to projectized interview scheduling.

Briefly, the socializing and scheduling phase was geared to enhance *trust-building* and rapport with the interview participants, and to assure them of complete confidentiality and anonymity. The initial 12 interviews were carried out face-to-face, followed by a typed transcript from the 12 respective voice-recordings. The transcripts were thoroughly scrutinized, annotated, and marked for follow-up clarifications (see Appendix R, p. 210, for a sample of an annotated transcript). The follow-up interviews were brief and mostly face-to-face in the same office venue for familiarity and ease of the participants. Two of the respondents who were unavailable for face-to-face follow-up were contacted via phone interviews, and one respondent by Skype (see Table 2, p. 59).

Population Description

Participants in this empirical research comprised a sample frame of 30 undergraduate seniors in the last term of their final year in the ET program at M University. There were a total of nine faculty advisors for the eight (8) Senior Design capstone projects, including one economic advisor for all the eight projects. The remaining eight ET faculty members had served as advisors to one, two, or three capstone project groups (see Appendix C, p. 195, and Appendix H, p. 200). Of these, five faculty advisors volunteered to undertake the interviews, in addition to the economic advisor for the projects, to make a total of six faculty interviewees.

Thus, two categories of interviewees (six students and six advisors) took the same interview in two successive rounds according to the schedule in Table 2. The table shows the interviewees as identified only by S1-S6 for student leaders and FA1 to FA6 for advisors to maintain their anonymity (see Appendix C, p. 195). Thus, in the analysis of Chapter 4 and the conclusions of Chapter 5, student leaders and faculty advisors were respectively de-identified with designations of SL1 through SL6, and FA1 through FA6, in chronological order of the sequence of the one-on-one interviews.

Table 2

Schedule of the Phase 2 Interviews of Students and Advisors

No.	STUDENTS	ADVISORS	ROUND 1	DURATION	ROUND 2	DURATION
1	SL1		05-13-2016	1 hr. 14 mins.	05-17-2016	21 mins.
2	SL2		05-14-2016	1 hr. 23 mins.	05-18-2016	45 mins.
3	SL3		05-16-2016	0 hr. 56 mins.	05-19-2016	33 mins.
4	SL4		05-23-2016	0 hr. 43 mins.	05-25-2016	18 mins.**
5	SL5		05-24-2016	0 hr. 52 mins.	05-27-2016	26 mins.
6	SL6		06-01-2016	0 hr. 33 mins.	06-03-2016	27 mins.*
7		FA1	05-13-2016	1 hr. 28 mins.	05-16-2016	37 mins.
8		FA2	05-19-2016	1 hr. 03 mins.	05-24-2016	18 mins.
9		FA3	05-27-2016	1 hr. 31 mins.	05-30-2016	46 mins.
10		FA4	05-27-2016	1 hr. 17 mins.	05-30-2016	22 mins.
11		FA5	05-28-2016	0 hr. 39 mins.	05-31-2016	29 mins.*
12		FA6	06-01-2016	1 hr. 22 mins.	06-03-2016	46 mins.
**By Telephone **By Skype*						

Site Access

The site was accessible through the ET classrooms in Building X during the last term of the ET program. For Phase 1, the coordinating instructor and capstone project advisors (‘honest brokers’) distributed hard copies of the quantitative survey instrument

(SDLRS-A®) submitted by the researcher and serial numbered from #S1 to #S30. The voluntary participation of the students was emphasized, without any form of coercion, and with solemn assurance of confidentiality and anonymity.

For Phase 2, appointments were made with six of the nine advisors of the eight capstone projects to schedule the one-on-one interviews as reflected in Figure 11 (p. 57) and Table 2 (p. 59). These six students and six advisors were assured of anonymity and data security by de-identification and secure, encrypted storage of their interview data.

Research Methods

Description of Methods Used

A mixed methodology approach was employed for this research. Phase 1 comprised a mixed-methods approach and was primarily quantitative, with a nested qualitative component to address three open-ended questions in handwritten format (see Appendix M, p. 205), and Phase 2 was entirely qualitative. The quantitative research of Phase 1 was conducted through administration of the SDLRS-A® instrument, together with basic demographic data (see Table 5, p. 81). This widely-used SDLRS-A® instrument was designed by then doctoral researcher Lucy Guglielmino for her Ed. D. dissertation in 1977 (Appendix J, p. 202, presents her personally signed letter permitting use of the copyrighted SDLRS-A® instrument to survey the 30 students).

The SDLRS-A® Survey has been translated into several languages and used since commercialization by more than 500 major organizations and 120,000 adult researchers around the world (Long, 2006). The SDLRS-A® instrument addresses attributes, attitudes, and aptitudes in SDL, with adequate literature evidence of its reliability—as well as construct, content and criterion validity (Long, 2006; Maltby, Lewis, & Hill, 2000).

Although criticism of the structure, validity, and reliability of the SDLRS-A® instrument exists (Brockett, 1987; Field, 1991), a majority of studies have shown that the instrument is the most reliable measure of readiness for self-directed learning that is currently available, and therefore used globally (Delahaye & Choy, 2000; Durr et al., 1994; Graeve, 1987; Posner, 1991; Russell, 1988).

Responses to the 58-item Likert-style SDLRS-A® Survey during the final weeks of their Senior Design course provided evidence of the skill-sets that the final-year ET students should ideally have cumulated through the years. This included the three-term, final-year Senior Design capstone project experience employing the existing PBL framework (and demonstrably, applying SDL, PM, and CL to some extent).

The scores obtained from the SDLRS-A® questionnaire provided a profile of SDL skills that quite likely contributed to the students' PBL competence. SDL skills were considered to enable facility in extracting higher levels of learning from the PBL environment of the Senior Design capstone projects (Stewart, 2007). The instrument used 41 positively-phrased questions and 17 negatively-phrased questions for a total of 58 questions. The administration of the SDLRS-A® questionnaire was thus deemed relevant in assessing the cumulated SDL skills of ET students through their innovative, final-year Senior Design capstone project.

Data Analysis Procedures

The most recent versions of industry-leading analytical software packages (Microsoft Excel 2016, SPSS 24.0, Leximancer 4.5, and NVivo 11.0) were used to analyze quantitative and qualitative data. Microsoft Excel 2016 is part of the Microsoft Office 2016 suite, and is widely used for complex spreadsheet calculations and graphics.

SPSS 24.0 is the latest version of a comprehensive system for analyzing a variety of quantitatively-oriented data. These include descriptive statistics, distributions and trends, reports, charts, and complex statistical analysis. NVivo 11 is a recently released popular textual (content) analysis software and is used widely for qualitative and mixed-methods research. Leximancer 4.5 is the latest version of this software used for transforming lexical co-occurrence information from natural language into semantic patterns. This is done by Leximancer 4.5 mining large volumes of qualitative textual data, and inductively extracting information from it through an iterative process (Smith & Humphreys, 2006).

Data analysis of Phase 1 SDLRS-A® questionnaire.

The quantitative data from the Phase 1 SDLRS-A® Survey (see Appendix O, p. 207) was analyzed using Microsoft Excel 2016 for the demographic data, and the statistical package, SPSS 24.0 for Windows for the 58-item SDLRS- A® questionnaire. (The qualitative segment of the SDLRS-A® Survey was analyzed separately, using NVivo 11). Appendix M (p. 205) presents sample Demographic data of a female Student (#S28). Microsoft Excel 2016 was used for compiling the basic demographic profile of the 30 students who took the SDLRS-A® Survey (see Appendix N, p. 206). Further, the six demographic items—age groups, ethnicity, gender, cumulative GPAs, study majors, and study year—were computed for summary analysis using Microsoft Excel 2016 (see Appendix N, p. 206, and Chapter 4, Table 5, p. 81).

The SPSS 24.0 software package was employed for Exploratory Factor Analysis (EFA), to assess reliability and validity of the SDLRS-A® instrument which generally has an internal consistency/reliability coefficient ranging from 0.79 to 0.96—as well as strong content validity, good construct validity, and good predictive validity (Courtina, 1993; Guglielmino, 1997; Long, 2006; Stewart, 2007). These statistics were tested using EFA, which explores the underlying structure of the phenomena investigated by reducing the data to a smaller set of variables without need for multivariate normality. The validity measures for the SDLRS-A® instrument typically yield factor groupings such as: Self-Management; Desire for Learning; and, Learner Self-control (see Appendix P, p. 208). In this research, such an *a priori* pattern with three factors found resonance in the EFA output through Principal Components Analysis (see Appendix AA, p. 219). From the extensive SPSS 24.0 output, various statistical parameters were scrutinized, tabulated, and analyzed to present the results in textual and graphical formats in Chapter 4.

Data analysis of Phase 1 SDLRS-A® open-ended questions.

The qualitative data from Phase 1 of the three open-ended questions prefacing the quantitative, 58-item SDLRS-A® instrument was analyzed by NVivo 11. These three questions had been introduced by the researcher to extract textual information from the Senior Design students on change leadership and change processes observed and experienced by them through the three terms of the Academic Year 2015-2016 (Fall 2015, Winter 2016, and Spring 2016). A handwritten sample of responses to the three open-ended questions by a female student, anonymously designated only as #S28, has been presented in Appendix M (p. 205).

The handwritten text was typed into a Microsoft Word 2016 document. It was then classified into three sub-documents: (a) a compilation of responses to all the three open-ended questions by each student; and, (b) a compilation across the sample, of cumulated responses to each of the three open-ended questions by all the students.

These transcripts were then reviewed and reflected upon to capture themes, connections, and trends in annotated form.

The transcripts were also analyzed through NVivo 11 software for graphical and tabular outputs to enable further analysis, comparisons, and summarizations [see Appendix S (p. 211) and Appendix T (p. 212) for sample NVivo outputs]. The findings were examined against the literature evidence on CL to study change leadership and change processes, and to identify evidences of leadership and the process of changes made during the capstone project cycles.

Data analysis of Phase 2 interview questions.

Similar to the responses to the open-ended questions, the interview transcripts of six Senior Design student leaders of capstone projects, and six ET faculty members who were designated as capstone project advisors were also coded, grouped, analyzed, reflected upon, and synthesized. Each of the five capstone project advisors had oversight of one, two, or three capstone projects; in addition, one faculty member who was the economic advisor for all the projects was also included as the sixth faculty advisor with an overall view of all the projects. Thus, a total of six faculty advisors were interviewed. Reasonable interpretations were drawn against literature support from Chapter 2 and empirical evidence from the multi-faceted analyses in Chapter 4.

The electronic file format of the documents in MS Word 2016 enabled the textual analysis. This was accomplished using manual tallies, as well as Leximancer 4.5 software to study conceptual patterns and frequency distributions with graphical and numerical outputs for meticulous examination (see Appendix BB, p. 220, for a sample Leximancer output). Reflexivity was employed in grouping, classifying, coding, and filing the data in a secure personal database in the researcher's office.

The results of the data analysis in Chapter 4, employing Leximancer 4.5 were organized and compiled to assess the resolution of the three research questions presented in Chapter 1 (p. 16). This analysis was made in terms of the contributions of SDL, PM, and CL in facilitating PBL. Evidences of overall acceleration of PBL due to individual accelerations of SDL, PM, and CL pointed to high proficiency levels of SDL, PM, and CL that were synergistically exercised in concert (see Figure 20, p. 170).

Stages of Data Collection

Phase 1 of the research was explanatory, and related directly to resolving Research Question 1. Phase 2 was qualitative in nature and also explanatory, comprising the administration of seven semi-structured interview questions in a one-on-one, face-to-face interview format. To maintain optimal engagement with the 12 interview participants, the researcher, instead of taking notes, recorded each interview on a digital/electronic device. This audio data was subsequently transcribed by the researcher on the office computer and stored as encrypted files in a secure database.

Thus, the nature, extent, and skills in SDL and CL as understood and demonstrated by the 30 student participants were respectively captured quantitatively and qualitatively through the SDLRS-A® instrument in Phase 1. Data on SDL and CL were also obtained qualitatively through the interview data in Phase 2 from six student project leaders, and their six faculty advisors. The participants' understanding and application of their SDL skills, PM efficiencies, CL effectiveness and PBL competencies were recorded through the interviews in Phase 2.

Careful observations of the participants' nonverbal cues were made by the researcher, and reflections of key behaviors and interactions were textually recorded in parenthesis. Each initial interview session averaged about one hour in duration, and was followed up for clarifications by a second round of shorter interview sessions. These follow-up interview sessions comprised nine face-to-face interviews, two telephone interviews, and one Skype interview, totaling 12 follow-up sessions (see Table 2, p. 59).

In sum, the reflections of the researcher following the Phase 1 SDLRS-A® Survey and open-ended questions, and the Phase 2 semi-structured interviews, precipitated necessary reflexivity and deeper understanding of the phenomena of PBL, SDL, PM, and CL. The purpose was to assess the efficiency with which final-year ET students absorbed innovative technology learning through a dynamic combination of SDL, PM, and CL for their capstone projects. The interviews also elicited best practice toward accelerating PBL through the combined synergies of enhanced SDL, streamlined PM, and dynamic CL.

Based on quantitative and qualitative research evidence through the two contiguous and inter-related phases of this study, Phase 1 and Phase 2 were integrated (see Figure 10, p. 53). Thus, the diverse data from the final-year undergraduate students in the ET program were analyzed by comparing and combining the results of Phase 1 and Phase 2 evidences (Chapter 4). In concert, they assessed the participants' perceptions of how the SDL, PM, and CL components of PBL could have accelerated learning through implementation of their respective capstone projects. The scores and various quantitative and qualitative analytical outputs of Chapter 4 reflect the application, practice, and acceleration of PBL—informed by the students' enhanced SDL skills, streamlined PM efficiencies, and dynamic CL effectiveness.

Ethical Considerations

In this research, the researcher’s professional and academic integrity and professional competence were deemed to be integral parts of the research paradigm. The utmost concern was accorded to ethicality by this researcher that also reflects on the current and long-term reputation of the researcher’s degree-granting institution, and that of relevant faculty involved in guiding and overseeing this study.

The Belmont Report (1979) highlights three basic ethical principles for all researchers: (a) Respect for the persons; (b) beneficence; and, (c) justice. These principles were guideposts that ensured absolute ethicality, respect, and fairness in the research. The area of review in the case of this social science research was identified by the Institutional Review Board (IRB) as IRB #3: Adult Social/Behavioral. This corresponded to conducting research of adult learners in the age range between 20 and 60 years (see Table 5, p. 81) who were undergraduate seniors in the ET program at M University.

According to the IRB, unless a waiver is obtained a signed written consent in paper or electronic form is required from the subjects before embarking on the empirical research (see Appendix K, p. 203). Stringent ethical standards were strictly followed per IRB regulations, as human subjects were involved in this social science research. This called for a sensitive and respectful approach toward the participants.

Extensive IRB training and certification was completed by this researcher on June 6, 2015, for familiarity with the policies and procedures required to ethically conduct all aspects of this study (see CITI Certification in Appendix G, p. 199). Also, the research design, together with a sample SDLRS-A® instrument (Likert-style) and the seven semi-structured interview questionnaire on PBL, were submitted to IRB for approval on May 6, 2016 after ensuring that these instruments followed stringent ethical parameters.

A permission letter from the ET Head of Department (see Appendix I, p. 201) was obtained to conduct this research with ET senior students and faculty advisors. This letter was also included in the application for IRB clearance. Additionally, a permission letter dated May 4, 2016 was obtained from the SDLRS-A® instrument author, owner and publisher, Dr. Lucy M. Guglielmino, and was included in the IRB application (see Appendix J, p. 202). The IRB clearance was obtained on May 11, 2016 (see Appendix L, p. 204, for approval from the IRB to conduct research involving human subjects).

The subjects for the research—undergraduate seniors and their project advisors from M University's ET program—were briefed to make an informed decision freely and without coercion, as to their willingness to participate in the research. This was formalized in a written (or electronic) informed consent document, signed and dated by each of the research participants. The draft pro forma of this informed consent document was among the composite documentation submitted to the IRB (see Appendix K, p. 203).

Fortunately, there was no formal or informal relationship between this researcher and any of the students who participated in the research, as they were undergraduates unrelated to this researcher. Similarly, there was only limited informal acquaintance with the faculty advisors who had oversight of the Senior Design capstone projects. This provided sufficient objectivity and emotional space between the researcher and subjects.

Several layers of anonymity were introduced to further insulate the students from being personally identified, including: codification of personal identities (from #S1 to #S30) for the Phase 1 SDLRS-A® Survey, and from SL1 to SL6, and FA1 to FA6 of the student leaders and faculty advisors respectively in the Phase 2 one-on-one interviews; negligible personal interaction; and, the mediatory role of the capstone project advisors and coordinator as ‘honest brokers’. The honest brokers served as conduits for the research, and served as trusted intermediaries between the researcher and students.

For the SDLRS-A® Survey, only serial numbers from #S1 to #S30 were used for each of the 30 students at random; and for the semi-structured interviews, the six student leaders were designated from SL1 to SL6, and the six faculty advisors from FA1 to FA6. The capstone course coordinator, capstone project advisors, and the researcher saw only the serial numbers from #S1 to #S30 when administering and collecting the SDLRS-A® Survey response sheets in small batches over a two-week period during May, 2016.

Similarly, for the semi-structured interviews, the researcher saw only the coded SL1 to SL6 notations for the six student leaders, and FA1 to FA 6 notations for the six faculty advisors of the capstone projects to identify each person interviewed. Following explicit instructions, the students and faculty interviewed did not express any personal identification details.

The ET capstone project coordinator and faculty advisors (as ‘honest brokers’) gave the students direct access to the quantitative surveys at their convenience. A specific student’s participation (or non-participation) was not traceable, or known to the capstone projects’ coordinator, advisor, or the researcher. The students were assured of these protective measures. Every effort was made to keep interview data confidential in a secure database in the researcher’s office, and participants were de-identified promptly.

Clearly, ethical considerations are necessary in a social sciences research of this nature, especially with the qualitative research methods of Phase 2 where there was face-to-face interaction between the researcher and the participants (Patton, 1990; Streubert & Carpenter, 1999). To vouch for the ethical soundness of this research, the IRB guidelines were revisited frequently throughout the research process, and strictly observed.

The research focus was on ascertaining the extent of application and acceleration of SDL, PM, CL, and PBL by senior undergraduate students in an ET program. The venue of the research was the suite of offices, classrooms, laboratories, and boardrooms of the ET department at M University—where the students normally attend their classes, workshops, and laboratories. To secure the confidentiality and privacy of the participants, several layers of anonymity were thus incorporated.

Johnson and Christensen (2012) underscore that the interviewer needs to establish trust and rapport with the interviewee through impartiality and transparent conduct of the research. From the outset, participation in this study was deemed to be entirely voluntary. Participants received full disclosure of the study and its goals, and had the ability to opt out of the study at any time without penalty, or knowledge of their instructor or of the researcher. This was clearly stated in the research instruments, consent letter, and also expressed through verbal assurances.

All recordings, transcripts, and documentation were encrypted and kept in the researcher's secure personal electronic file, and in a digitally locked filing cabinet. The participants were briefed about the study's purpose and timeframe, and were guaranteed an opportunity to view the results on their request. They were assured that their participation, and the information provided by them, would in no way affect their course or program evaluations, grading, or progress reports.

Summary

In Chapter 3, the mixed methodology approach used for the research was outlined, with the research problem and research questions as the basis to determine the research methodology. The research design, population, samples, and data collection methods during Phase 1 (quantitative and qualitative), and Phase 2 (qualitative) were briefly described (see Chapter 3, Figure 10, p. 53 for the schema).

Phase 1 was primarily a quantitative survey using the widely-tested and validated SDLRS-A® instrument. Nested within this phase were three open-ended questions for qualitative (textual) analysis, along with anonymous demographic data for quantitative analysis.

Phase 2 was entirely qualitative, with identical semi-structured interviews of six senior undergraduate student team leaders and six capstone project advisors in the Engineering Technology (ET) program at M University. Results of the SDLRS-A® questionnaire in Phase 1 have been analyzed in Chapter 4 using the SPSS 24.0 software. For the Phase 1 open-ended questions, and for the Phase 2 interview questions, the textual software NVivo 11 and Leximancer 4.5 were respectively used with graphical support as presented in Chapter 4 (see Appendix S, p. 211, to Appendix HH, p, 226). Ethical considerations as mandated by the Institutional Review Board (IRB) at M University have been strictly adhered to in this research.

Chapter 4 looks at the quantitative analysis and corresponding statistical output, as well as qualitative analysis and corresponding graphical and tabular output. The findings, results, interpretations, conclusions, and recommendations emanating from this mixed-methods empirical research have been presented in Chapters 4 and 5.

Chapter 4: Findings, Results, and Interpretations

Introduction

In a fast-paced, knowledge-intensive, and technology-infused environment, it has become imperative to craft and apply the most efficient and accelerated learning methods to optimize resources, close the employment gap, and instill a propensity to life-long learning among students. From among learner-centric and inquiry-based learning methods of the 21st century, project-based learning (PBL) has become increasingly popular as a conduit for pragmatic learning in progressive educational settings. However, a workable and tested model of PBL has not been developed in the literature despite frameworks of PBL that have been formally or informally applied in a range of academic settings in higher education (Thomas, 2000).

Therefore, a formal and robust model of PBL was necessary to incorporate best practice, and to accelerate delivery of learning outputs. This was especially relevant in an environment of innovative technology diffusion as prevailing in the Engineering Technology (ET) program of M university that employed a loosely-structured and informal PBL framework. This was a viable basis for a more formal and robust PBL model geared for wide application in innovative technology education environments.

Research Purpose

The purpose of this mixed-methods research was to empirically examine the current, informal approach to PBL in the ET program at M University in light of the literature evidence, and to propose a robust model of PBL with scope for acceleration. It was contended that such a model would render innovative technology programs more competitive, enhance the employability of graduates from the program, and thus minimize the employment gap prevalent in the industrial economy. These results could be assessed through research instruments such as interviews, focus groups, and surveys. It was also hoped that the insights obtained from this study could inform progressive educational institutions at large in their quest to enhance innovative technology program quality, and to meet the growing needs in industry for suitably qualified and employment-ready graduates.

The insights from this study could perhaps be promulgated through suitable publications of these findings for access in the public domain—such as the ProQuest Database, conference publications, and peer-reviewed journal articles. The graduates of innovative technology-intensive programs could also benefit substantially from applying PBL by improving their SDL, PM, CL, and PBL skills in the future. Additionally, they would likely be imbued with a propensity to lifelong learning.

The literature review of four literature streams in Chapter 2 delved into project management (PM) efficiencies, self-directed learning (SDL) skills, and, change leadership (CL) effectiveness. A theoretical model of PBL undergirded by SDL, PM, and CL was proposed (see Figure 2, p. 9). The groundwork provided by this newly proposed PBL model was intended to be the springboard for developing a reliable and valid quantitative survey instrument to measure PBL in the future, incorporating SDL, PM, and CL as essential components based on the PBL model. This PBL instrument for quantitative analysis could be designed to measure PBL readiness and competence of learners in a technology-intensive educational setting (see Recommendations for Future Research in Chapter 5, p. 176).

Research Design

The research design for this study consisted of two contiguous phases: Phase 1 and Phase 2 (see Chapter 3, Figure 10, p. 53). Phase 1 was conducted entirely with up to 30 student participants from the ET program of M University. Phase 2 was conducted with six student leaders of the eight capstone projects, and with six faculty advisors.

Phase 1 comprised a nested, concurrent mixed-sampling method, whereby both quantitative and qualitative data were collected simultaneously through the SDLRS-A® instrument from the same population of 30 Senior Design students (Johnson & Christensen, 2012). The quantitative data was derived from responses by 30 students to the 58 Likert-style items in the SDLRS-A® instrument. This primary part of Phase 1 addressed Research Question #1, focusing on SDL.

The focus of the empirical research in Phase 1 was the SDLRS-A® Survey consisting of three components: (a) Six-Item Demographic Data; (b) 58-Item SDLRS-A® questionnaire on SDL; and, (c) Three open-ended questions on CL.

The qualitative data in Phase 1 was drawn from students' responses to three open-ended questions crafted in this research immediately following the demographic data section of the SDLRS-A® Survey (see Appendix M, p. 205 for a completed sample of demographic data by Student #28). These three open-ended questions targeted the students' experience with change leadership and change processes through the final year of their study, term-by-term—Fall 2015, Winter 2016, and Spring 2016. This qualitative part of Phase 1 was focused on the role of CL from Research Questions #2 and #3.

Phase 2 of this study consisted entirely of qualitative research through in-depth, one-on-one, semi-structured interviews of six capstone project leaders and six faculty advisors of the eight Senior Design projects. The rich data compiled from this empirical exercise was collated and codified through reflexive content analysis, supplemented by employment of Leximancer 4.5 software for a slew of graphic and tabular outputs (see for example, Appendix BB, p. 220). These outputs reflected concepts, frequencies, rankings, relationships, and patterns in the research data addressing all three research questions. The findings analyzed data pertaining to the three research questions that emerged from in-depth responses to these 12 semi-structured interviews.

Based on the analysis and discussions, cogent interpretations and syntheses have been made. This was done in light of the three research questions from Chapter 1—enlightened by the four literature streams of Chapter 2, operationalized by the research methodology of Chapter 3, and investigated through the analytic computations, graphics, and tabulations of Chapter 4. Chapter 5 will focus on the interpretations of the results and recommendations issuing therefrom. Table 3 (p. 76) identifies the raw study data in terms of the mixed methodology used, and the corresponding instruments employed.

Table 3

Empirical Data for Analysis

PHASE	<Instruments	METHOD: Quantitative	METHOD: Qualitative
Phase 1	SDLRS-A®	6 Demographic Items x 30 = 180	3 Open-ended Questions: Responses: 22+25+20= 67
		58 SDLRS-A® Survey Items x 30 = 1,740	
Phase 2	Interview		7 Semi-structured Questions x 12 = 84

In this chapter, the findings from the quantitative and qualitative analyses of the data collected for this study have been reported and discussed. Thus, the findings of Phase 1 and Phase 2 have been presented as comprehensive responses to the three research questions. The sequence, instrumentation, methodology, participants, and technology used for Phase 1 and Phase 2 of the study are summarized in Table 4 (p. 77). These elements of the research were employed to obtain the findings, results, and interpretations of this empirical study which have been presented in detail in this chapter.

Table 4

Summary Sequence and Profile of the Analytical Methods

SEQUENCE	INSTRUMENT	METHODOLOGY	TYPE	# OF ITEMS	# PARTICIPANTS	TECHNOLOGY
1	SDLRS-A®	QUANTITATIVE	Demographic	6	30	Microsoft Excel 2016
2	SDLRS-A®	QUANTITATIVE	Likert-Style	58	30	SPSS 24.0
3	SDLRS-A®	QUALITATIVE	Open-Ended Questions	3	22-25	NVivo 11
4	PBL Interview	QUALITATIVE	Semi-Structured Questions	7	12	Leximancer 4.5

Findings

The Two Phases of the Study

Findings from this mixed-methods study were based on the outputs of Phase 1 and Phase 2 of the study (see Chapter 3, Figure 10, p. 53). These involved respectively the SDLRS-A® Survey in three parts, and the PBL interview.

Phase 1 of the Study

Demographic data analysis.

Microsoft Excel 2016 was used to analyze the six-item demographic data in the SDLRS-A® instrument in Phase 1 of the research. The findings have been described and summarized in tables in this chapter to capture the statistics in a meaningful manner.

The SDLRS-A® Survey was composed essentially of the 58-item SDLRS-A® questionnaire, a globally used instrument with significant *a priori* validity and reliability measures for support (Chapter 3). The structured, six-item Demographic Data items and the three unstructured, textual Open-ended Questions were designed by the researcher and included in the survey set. This three-part, anonymous SDLRS-A® Survey was distributed to all the 30 ET Senior Design students through the mediation of their capstone project advisors as ‘honest brokers’. As the surveys were numbered from #S1 to #S30 and had no student names or any other identifying information on them, they were deemed to be strictly anonymous. The survey was open for three weeks near the end of the Spring 2015-2016 term. A response rate of 100% was achieved for the 58-item SDLRS-A® questionnaire with all 30 students completing and returning the instrument. Due to the anonymity and completeness of the surveys, no follow-up was conducted with the participants for the 58-item SDLRS-A® questionnaire.

The demographic data was compiled into a Microsoft Excel 2016 spreadsheet, and analyzed by Excel computation using appropriate formulae. This raw data is presented in Table 6, p. 83 (see also the partial Excel 2016 spreadsheet screenshot in Appendix N, p. 206). The sample pool of 30 Senior Design students were classified along six dimensions as follows: (a) Gender; (b) Ethnicity; (c) Age group; (d) Study Major; (e) Cumulative GPA; and, (f) Year of Study. The findings under each corresponding category in the demographics section of the SDLRS-A® Survey were tabulated, summated and averaged to yield comparable statistics to record the results of the analysis.

All the 30 students were in their undergraduate senior year. However, notable diversity was found in the sample of these 30 students in terms of ethnicity, age groups, and cumulative GPAs, as presented in Table 5 (p. 81). Evidence of two of the age groups being predominant in the sample—those in their early twenties, and those in their mid-thirties—indicated that ET students could either be following the academic study track, or could be returning adults with some work experience. This was a reasonable expectation for the competitive ET program at M University.

For a relatively small group of 30 Senior Design students in the ET program at M University, there was also reasonable diversity. The ethnic groupings seemed to follow the general campus-wide population profile at M university, though trending to a larger percentage of the ethnic Caucasian (70%) segment of the population in the study against the 60% of Caucasian segment of the campus-wide population.

However, there was representation of several ethnicities from the larger university population, even in this small group of 30 ET Senior Design students. These ethnic proportions apparently reflected those of the general population of students on campus at the multicultural M University.

A notable exception was that the female representation in the ET Senior Design class was only 3 out of 30 students. This was clearly disproportionate to the gender representation at the university campus, which had approximately a 50-50 split of male and female students. Contextually, the sample of 30 ET students can be considered too small to extrapolate these anomalous findings.

However, on average only around 20% of students in engineering and technology programs campus-wide were female. It should be noted however, that in the US, only about 18%-20% of engineering *students* are women, which is an increase over what it was 25 years ago (Crawford, 2012). In 2014, women in the US represented 24% of the engineering workforce (down from 25% in 2001). Fully 36% of the computing workforce (flat since 2001) and 18% of the advanced manufacturing workforce were women (Bidwell, 2015). This suggests that on a national scale, the under-representation of women in technology among the US workforce continues to be a concern that needs to be addressed across various constituencies, agencies, and higher education institutions.

As for study majors, the results showed that 90% (3 out of the 30 Senior Design students) were ET majors, with only one student with a mechanical engineering major, and two from bio-medical engineering majors. The data also revealed that 50% of the students had cumulative GPAs below 3.00, and 50% had cumulative GPAs above 3.00.

In studying the demographic data in its six dimensions, a summary finding can be made (see Table 5, p. 81)—keeping in view that this is an overall gist of the profile of the small sample of 30 ET students. Thus, the demographic findings may not be generalizable to the larger population of students across the campus of M University.

Table 5

Senior Design Students' Demographics

DEMOGRAPHIC INFORMATION	**Students**	
N=30	n	%
1. Gender		
Male	27	90%
Female	3	10%
2. Ethnicity		
White (Caucasian)	21	70%
Black (African-American)	4	13.33%
Hispanic (Latino)	3	10%
Asian	1	3.33%
Native	1	3.33%
3. Age Group		
20-22	3	10%
23-25	12	40%
26-28	2	6.67%
29-30	2	6.67%
31-35	6	20%
36-40	4	13.33%
41-60	1	3.33%
4. Major		
Engineering Technology (ET)	27	90%
Mechanical Engineering (ME)	1	3.33%
Bio-medical Engineering (BME)	2	6.66%
5. Cumulative GPA		
3.80-4.00	4	13.33%
3.50-3.79	3	10%
3.00-3.49	8	26.67%
2.50-2.99	9	30%
Below 2.50	6	20%
6. Year of Study		
Senior (Final) Year	30	100%

Finding #1. *ET students have a demographic profile that mirrors that of the low campus-wide female student population in engineering and technology programs. This under-representation of females is also reflected on a national scale as there are only around 25% of females among US engineers.*

The SPSS 24.0 software was used for the Phase 1 SDLRS-A® questionnaire analysis. Though the sample was relatively small with a student pool of 30, the response rate was 100 percent (Baruch, 1999). Also, there were only four (4) missing scores in the SDLRS-A® questionnaire items. As recommended by the SDLRS-A® instrument suppliers, up to five missing items could be replaced by the median Likert-scale score of three out of five (3/5). This was done for the four (4) missing scores, which were considered negligible (0.002) out of the 1,760 individual entries. The descriptive statistics tables have been reproduced below with brief explanations based on literature evidence.

SPSS 24.0 was run using the collated data from the Microsoft Excel 2016 spreadsheet for the 58 items of the SDLRS-A® Survey. The SDLRS-A® questionnaire with its 58 Likert-style items (ranging from 1=Strongly Disagree; 5=Strongly Agree) was designed to measure the attitudes and readiness of adult learners (Durr et al., 1994; Guglielmino, 1978, 1997; Merriam et al., 2007).

Exploratory Factor Analysis (EFA) of the SDLRS-A® questionnaire data was conducted using Principal Components Analysis (PCA) with Varimax rotation to measure reliability, construct validity, mean scores, t-statistic, F-score, and item-to-total correlations for uni-dimensionality. The results indicated that all of these measures were found consonant with *a priori* expectations (Durr et al., 1994; Guglielmino, 1978, 1997; Guglielmino, Long, & Hiemstra, 2004; Merriam et al., 2007). [See Appendix AA, p. 219].

For instance, Cronbach's Alpha was used to test for reliability and internal consistency of the data. The overall reliability of the analysis was high, with a Cronbach's Alpha of 0.920 as shown in the SPSS 24.0 output in Table 6. This confirms that the internal reliability of the data is close to the upper limit of the *a priori* reliability range of 0.79 to 0.96 for the SDLRS-A® instrument (Merriam et al., 2007).

Table 6

Reliability of SDLRS-A® Scores

Reliability Statistics	
Cronbach's Alpha	N of Items
.920	30

It was also observed that the item-to-total correlations for uni-dimensionality and the construct validity were sound, yielding a three-factor structure of the SDLRS-A® questionnaire data with an underlying factor structure (see Appendix AA, p. 219). This factor structure was generally consonant with the three *a priori* dimensions measuring readiness for SDL: (a) Desire for learning [DL]; (b) Self-control in learning [SC]; and, (c) Self-management of learning [SM] (Durr et al., 1994; Guglielmino et al., 2004; Williams & Brown, 2013). An exemplar grouping of these three factors is shown in Appendix P (p. 208) which groups 41 positively-worded attributes in abridged and modified format (to maintain copyright protection of the SDLRS-A® instrument).

Table 7 (p. 84) is an SPSS 24.0 output that presents the mean scores on the 58-item SDLRS-A® questionnaire for each of the 30 students, together with the respective standard deviations. It can be seen from Table 7 (p. 84) that the raw scoring ranged from a minimum of 1 to a maximum of 5 (with one exception of 4) out of 5 for each item on the 5-point Likert Scale (see also the collated, raw data entries in the Excel spreadsheet in

Appendix N, p. 206). In Table 8 (p. 85), the mean scores across 58 items for each student thus ranged between the highest score of 4.62 for Student #S10 to the lowest score of 3.05 for Student #S16. The overall mean score was relatively high at 3.94 (nearly 80%) out of a maximum of 5 on the Likert Scale.

In terms of readiness for SDL, Guglielmino (1978) has categorized the mean SDLRS-A® questionnaire score ranges as follows (minimum score per item=1; maximum score per item=5): (a) 1.00-3.46=Below Average; 3.47-3.89=Average; and, 3.90-5.00=Above-average. According to this categorization, five (5) students (17%) were below average; six (6) students (20%) were average; and 19 students (63%) were above-average in their SDL skills. In comparison with the *a priori* mean score 214/290=3.69 for adults (Merriam et al., 2007), 24 students out of 30 (80%) were above this *a priori* mean score, and six (6) students (20%) were below this score. Table 7 summarizes these results for the 30 ET students in the Senior Design course. It provides the range of *a priori* mean scores, and the distribution of students in mean SDLRS-A® questionnaire score ranges on the Likert scale of 1-5.

Table 7

Categorization of SDLRS-A® Scores of 30 students

SDLRS-A® **Raw Score** (Max. 58x5=290)	**Mean Score** (Min. 1-Max 5)	**Readiness for SDL**	**No. of Students In Each Category**	**Percentage of Students**
227-290	3.91-5.00	Above-average	19	63%
202-226	3.48-3.89	Average	6	20%
58-201	1.00-3.47	Below average	5	17%

Table 8

Mean SDLRS-A® Scores of 30 Students

Descending Order of Student Scores					
STUDENTS	**N**	**Minimum**	**Maximum**	**Mean**	**Std. Deviation**
STUDENT#10	58	1	5	4.62	.914
STUDENT#8	58	1	5	4.57	.975
STUDENT#14	58	2	5	4.40	.990
STUDENT#28	58	2	5	4.33	.825
STUDENT#9	58	1	5	4.31	1.046
STUDENT#5	58	2	5	4.24	.823
STUDENT#21	58	1	5	4.22	.956
STUDENT#26	58	1	5	4.19	.999
STUDENT#6	58	1	5	4.17	.920
STUDENT#11	58	1	5	4.14	.963
STUDENT#24	58	2	5	4.10	.831
STUDENT#17	58	1	5	4.10	.788
STUDENT#7	58	2	5	4.07	.856
STUDENT#23	58	2	5	4.03	.936
STUDENT#13	58	1	5	4.02	.964
STUDENT#27	58	1	5	3.95	.944
STUDENT#29	58	1	5	3.93	1.282
STUDENT#3	58	1	5	3.91	.978
STUDENT#2	58	2	5	3.90	.447
STUDENT#4	58	1	5	3.88	1.201
STUDENT#1	58	1	5	3.86	.907
STUDENT#30	58	2	5	3.83	.881
STUDENT#12	58	1	5	3.81	1.051
STUDENT#20	58	1	5	**3.69***	1.030
STUDENT#18	58	1	5	3.64	.968
STUDENT#19	58	1	5	3.40	.771
STUDENT#25	58	1	5	3.31	1.111
STUDENT#15	58	1	5	3.31	1.173
STUDENT#22	58	1	5	3.09	.923
STUDENT#16	58	2	5	3.05	.605
Valid N (listwise)	**58**			**3.94**	

Note: **A priori* mean SDLRS-A® score for the adult population

The data collected for the SDLRS-A® Survey was anonymously recorded, yet free of known errors; notably, all the 30 Senior Design students in the ET program returned completed surveys for a 100% result. The raw scores (for the 58 items in the SDLRS-A® questionnaire) and mean scoring range for SDL readiness are shown in Table 8 (p. 85).

The SDLRS-A® questionnaire scores indicate present levels of the participants' readiness for SDL. As seen in Figure 12, the average score for adult participants completing the SDLRS-A® questionnaire is 214/290 (3.69). In comparison, the mean SDL score of the sample of 30 students was a relatively high score of 3.94/5.00 or 229/290 (with 58 questionnaire items as the divisor for both numerator and denominator).

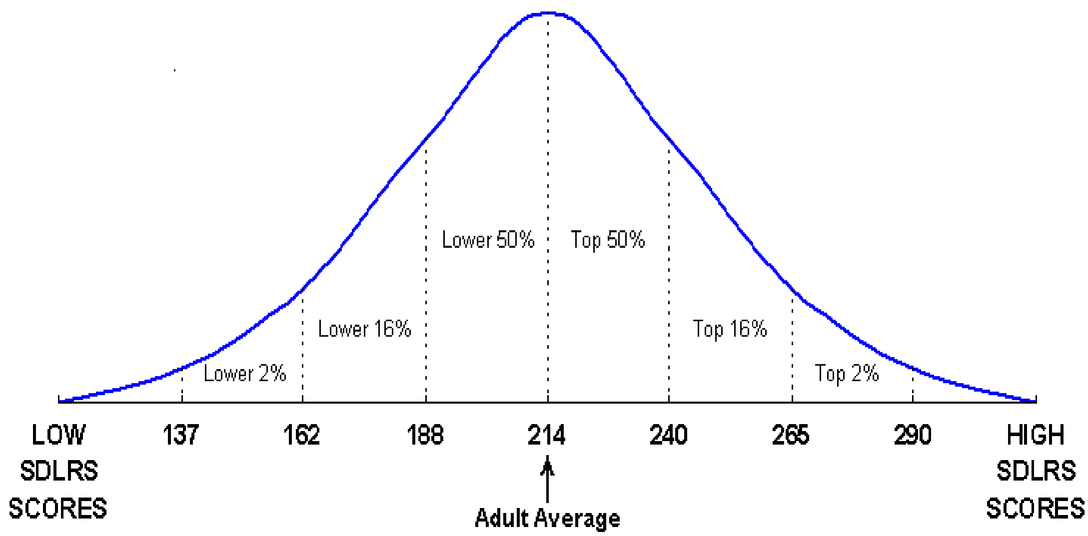

Figure 12: Typical distribution of SDLRS-A® adult scores for SDL

Source: Merriam, S.B., Caffarella, R.S., & Baumgartner, L.M. (2007). *Learning in adulthood: A comprehensive guide.* San Francisco, CA: Wiley & Sons.

This mean SDL score for the 30 Senior Design students was actually nearly 7% above the *a priori* mean SDL score for adults in the population (214/290=3.69/5.00). The students' SDLRS-A® questionnaire scores may have also benefited from their SDL experience through the Senior Design capstone project during their final year, as the survey was administered shortly before their graduation in Spring 2016. In quantitative terms, this reflects an above-average evidence of SDL skills for the student sample as compared to SDLRS-A® participants in the predominantly academic adult population.

According to Guglielmino (1978), the originator of the SDLRS-A® instrument, a 'High' SDLRS-A® score suggests well-developed SDL skills and a tendency to perform better in jobs that necessitate significant problem-solving ability, creativity, and adaptability to change. Such individuals are self-starters in determining their learning needs and their planning to implement their own learning. However, they would still be open to seeking some structure and training.

Persons with 'Average' SDLRS-A® questionnaire scores may succeed in more independent situations, but would not be quite comfortable with identifying their learning needs, and planning and implementing them (Guglielmino, 1978). Students with 'Below Average' SDLRS-A® questionnaire scores are deemed to have a preference for more structured learning experiences involving traditional lectures in a classroom environment. However, according to research, SDLRS-A® questionnaire scores can be enhanced through appropriate training to hone individual SDL skills (Guglielmino, 1978).

Over the scholastic life of a learner, SDL grows along a time continuum, and can vary widely in terms of situations, cultures, attitudes, aptitudes, and abilities. Structurally, practice of SDL skills can vary from minimal evidence in classroom learning, to higher achievements through self-motivated, self-planned, and self-learning projects. Thus, each situation is different from the others in terms of self-direction in learning. Ultimately, it is the individual learner's attitudes, values, and abilities that will define their propensity toward, and practice of, SDL in a higher education environment. This will determine such a learner's learning objectives, priorities, resources, activities, commitment, and energy levels (Merriam et al., 2007).

When set against mean results for the adult population (Guglielmino, 1978; Merriam et al., 2007), results of the SDLRS-A® Survey of the 30 Senior Design students indicate that 20% were in the ‘Average’ category, and 17% in the ‘Below Average’ category. The majority of students (63%) were in the ‘Above Average’ category. These evidences point to generally above-average formalization and inculcation of SDL among the undergraduates through the first three years of their undergraduate ET curriculum. Results of the analysis for the three open-ended questions of the SDLRS-A® Survey have added a qualitative dimension to these findings. Table 9 shows the summary statistics for the 58 items of the SDLRS-A® instrument based on the SPSS 24.0 outputs.

Table 9

Summary Statistics for the 58 SDLRS-A® Items

Summary Item Statistics	Mean	Minimum	Maximum	Range	Maximum/ Minimum	Variance	N
Item Means	3.940	3.047	4.617	1.600	1.570	.141	58

Finding #2. *Based on the SDLRS-A® Survey, ET students have on average, self-directed learning skill levels that are slightly above those evidenced by overall mean scores for the adult population in predominantly higher education academic environments.*

Table 10 (p. 89) lists the 27 items (out of the 58 items) in the SDLRS-A® questionnaire that scored an average of 4.00 or above (that is, to represent on average, “Agree (4)/Strongly Agree (5)” on the SDLRS-A® Likert Scale). Appendix Z (p. 218) provides the complete list of mean scores for all the 58 SDLRS-A® items. The last column of the table also indicates the percentage of students who scored “Agree” (a score of 4 out of 5 on the Likert scale) or “Strongly Agree” (a score of 5 out of 5 on the Likert scale). These percentage scores of distinctly positive responses ranged from 70% to 90%, and have been grouped into the 70's, 80's, and 90's for the purpose of stratifying the ET students' overall skills in self-directed learning (SDL).

Table 10

Rank Order of Items According to Mean Scores of 30 Students

ITEMS	Factor	Item Description (Abridged)	Mean Score	% Positive Responses
Q. 1	Desire for Learning[DL]	I look forward to lifelong learning.	4.67	90%
Q. 56		Learning makes a major difference in my life.	4.63	93%
Q. 49		I want to learn more to keep growing as a person.	4.60	90%
Q. 30		I am very curious about things.	4.47	93%
Q. 45		I have a strong desire to learn new things.	4.40	90%
Q. 55	Self-Management of Learning [SM]	I learn several new things each year.	4.37	87%
Q. 7		I am self-directed in a class setting.	4.33	87%
Q. 52		It is never too late to learn new things.	4.33	83%
Q. 6		I am a quick starter on new projects.	4.30	83%
Q. 14		Difficult study does not deter me if I am interested in it.	4.30	87%
Q. 23		I think libraries are exciting places.	4.30	83%
Q. 43		I enjoy discussing ideas.	4.27	87%
Q. 39		I think of problems as challenges, not as stop signs.	4.23	83%
Q. 16		I can tell whether I am learning something well or not.	4.23	83%
Q. 50		I take personal responsibility for my own learning.	4.20	83%
Q. 46		Learning makes the world exciting.	4.20	83%
Q. 37		I like to think about the future.	4.20	80%
Q. 26		I try to relate my learning to my long-term goals.	4.17	83%
Q. 4		If there is something I want to learn, I find a way to do it.	4.17	80%
Q. 47	Self-Control in Learning [SC]	Learning is fun.	4.13	77%
Q. 2		I know what I want to learn.	4.13	70%
Q. 51		Learning methods are important to me.	4.07	73%
Q. 34		I like to try new things, even if unsure of the outcome.	4.07	73%
Q. 17		There are so many things to learn, I wish for longer days.	4.07	70%
Q. 24		The people I admire are always learning new things.	4.03	70%
Q. 8		Goal setting and direction are important for education.	4.03	77%
Q. 15		I take personal responsibility for my own learning.	4.00	70%

Table 10 (p. 89) shows a good distribution of ranked SDLRS-A® scores, with 4.67 being the highest for Q. 1 ("I look forward to lifelong learning"), and with the Q. 15 item leveling at a mean score of 4 out of 5 on the Likert Scale ("I take personal responsibility for my own learning"). A review of the 27 items indicates a relatively high level of motivation for SDL by the Senior Design students in the ET program. This reflects significant conformance to the three confirmed *a priori* factors of self-management, desire for learning, and self-control (see Appendix P, p. 208; Appendix AA, p. 219).

Finding #3. *Based on the SDLRS-A® Survey, ET students can manage their learning well, have a high desire for learning, and demonstrate adequate self-control in their learning experience.*

The section of the SDLRS-A® Survey with the three open-ended questions is the entirely qualitative part of Phase 1. Shifting away from the focus on SDL in the quantitative SDLRS-A® questionnaire, this section analyzes the essence of handwritten responses in the SDLRS-A® Survey. These verbal responses relate to the evidence and practice of CL in the development and implementation of the Senior Design prototypes.

The open-ended questions offered an opportunity for the 30 students taking the SDLRS-A® Survey to textually record their understanding of CL leadership and CL processes for each of the three terms of their final year (Fall 2015, Winter 2016, and Spring 2016). It presents three findings (for each of the three terms—Fall 2015, Winter 2016, and Spring 2016) that emerged from coding and analysis of the transcripts that were filed in Microsoft Word 2016. This was conducted as parallel, qualitative research on CL alongside the quantitative data collection on the demographics and the 58 items from the SDLRS-A® Survey focused on SDL skills and attitudes of the senior students.

At the end of the demographic information of the SDLRS-A® Survey instrument, three open-ended questions were presented for the voluntary response of the 30 students surveyed through the SDLRS-A® Survey. These responses in writing ranged from one word to a complete paragraph (see handwritten sample in Appendix M, p. 205).

The three parallel questions were crafted to elicit responses regarding the students' understanding of the change leadership and change processes observed or experienced through each of the three terms (Fall 2015, Winter 2016, and Spring 2016) of the Senior Design project. Thus, Question #1 pertained to change leadership and change processes in Fall 2015, Question #2 to Winter 2016, and Question #3 to Spring 2016:

What was your experience with changes made to the Senior Design project as a team leader/team member?

Q. 1. Experience with changes made to the Senior Design project (X-1) during ***Fall 2015:***

Q. 2. Experience with changes made to the Senior Design project (X-2) during ***Winter 2016:***

Q. 3. Experience with changes made to the Senior Design project (X-3) during ***Spring 2016:***

The overall response rate to the above three open-ended questions was between 20 and 25 (67% to 83%) out of 30 surveys. Thus, there were 22 responses (73%) for Q. 1 (Fall 2015); 25 responses (83%) for Q. 2 (Winter 2016); and, 20 responses (67%) for Q. 3 (Spring 2016). The handwritten textual data from each response to the open-ended questions were typed into a Microsoft Word 2016 file to record all the responses for each of the three questions. The findings were processed logically and analytically as follows:

(1) Transcription in MS Word 2016; (2) Manual review and coding; (3) NVivo 11 analysis and outputs; (4) Reflection on findings; and, (5) Summarization. Table 11 summarizes the Phase 1 qualitative data analytics for the three open-ended questions.

Table 11

Phase 1: Qualitative Data Summary for the Open-ended Questions

Question #	Number of Responses	Percent of Responses	Term	Most Frequent Concepts (NVivo)
1	22	73%	Fall 2015	'Project'
2	25	83%	Winter 2016	'Design'
3	20	67%	Spring 2016	'Spring'
Combined	**67**	**74%**	**AY 2015-2016**	**'Project'**

The latest version of the textual software NVivo 11 was employed to analyze the consolidated responses to each of the three questions, with tabular and graphical outputs. The NVivo outputs consisted of ranking of Word Frequency, which was the basis for the manual review and coding. Additionally, the NVivo Word Clouds (see Appendix W, p. 215) for all the three questions—respectively corresponding to the Fall 2015, Winter 2016, and Spring 2016 terms—shows by the size of the lettering, the relative frequency of the words and concepts of various colors in interlocked, juxtaposed format.

The Word Cloud is thus a pictorial representation of the Word Frequency table. Each of the four Word Frequency tables created in these discussions has a reflective synopsis composed at the bottom, crafted to capture the key words and associated cognate words. This presents a cameo of the findings for each of the three academic terms (Fall 2015, Winter 2016, and Spring 2016). The three crystallized statements of findings (Finding #4 through Finding #6) presented subsequently are condensed from this synopsis, the direct quotes from students responses, and, the researcher's reflections.

Appendix V (p. 214) is a screenshot in NVivo of the *combined* Word Frequency of all 67 of the responses to the three open-ended questions, consolidated for all three CL questions. Appendix W (p. 215) is the screenshot of the NVivo Word Cloud for Fall 2015, Winter 2016, and Spring 2016 for all three CL questions.

Table 12 is a summary tabulation of frequency of occurrence of key words from the textual data pertaining to Fall 2015, representing the students' observations and experiences regarding change leadership and change processes in their capstone projects.

Table 12

NVivo Analysis of Responses to Q. 1 on CL (Fall 2015)

RANK	KEY WORDS	FREQUENCY	COGNATE WORD PATTERNS
1	**Project**	16	Proposal, Plan, Tasks
2	**Design**	9	Purpose, create, prepare
3	**Group**	7	Learn, struggle, team
4	Time	4	Timing, started, ended
5	Changes	3	Switched, alternative, accomplished
6	Ideas	3	Research, experience, support
7	Life	2	Fail, frustrating, succeed
8	Leader	1	People, progress, monitoring
Synopsis based on coding and review of key words, frequencies, and patterns			
During Fall 2015, members of the newly formed groups became interdependent team members with an accepted leader. The projects were planned as proposed, and tasks with specific durations were allocated and monitored by the leader. Despite struggles, the student teams depended on experience, learning, and research to make progress. For this, they considered alternatives to accommodate changes by switching plans, and thus accomplishing tasks—through a cycle of frustration, failure, and success.			

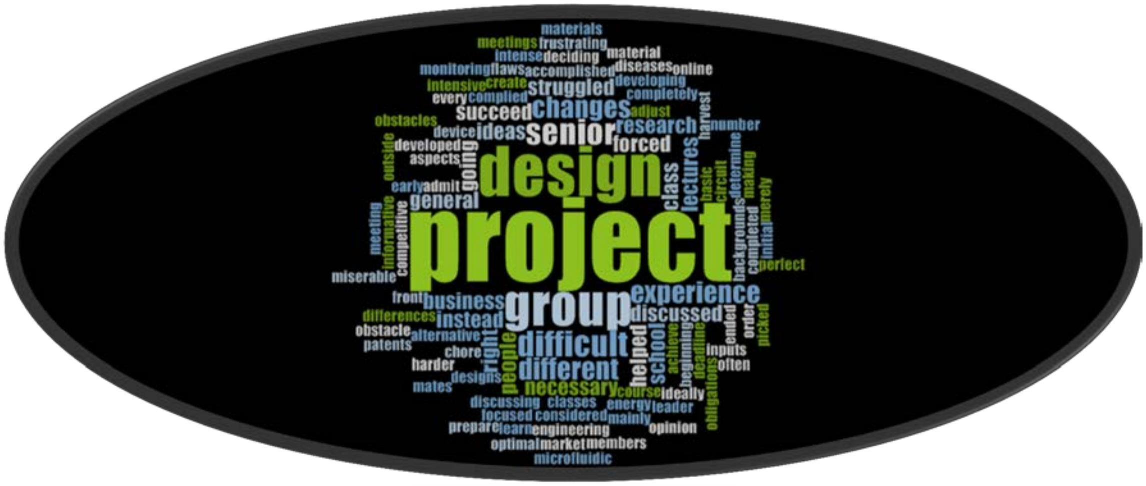

Figure 13: NVivo Word Cloud of frequency of concepts on CL in Fall 2015

The NVivo results in Table 12 (p. 93) and Figure 13 indicate that the newly commenced capstone project in Fall 2015 was the main focus of the Senior Design students. The students' collective autonomy was apparent from the intensive group dynamics and making of necessary changes as a new team to get the project off the ground. In terms of change leadership and change processes, team members felt the need to "adjust and plan," and as a consequence, "many alternative designs were considered and done" (Student #S14). The Senior Design students agreed that the Fall 2015 term was quite intense. A team leader (Student #S22) stated, "As leader of this design project, the *changes made during the fall term were necessary for the project to succeed.*"

The Fall 2015 quarter was the hardest and most intensive for many students. As Student #S22 commented further:

> The most time spent on the project was upfront during the Fall. During this time we worked hard doing all the research necessary to come up with our initial design, and to see if the project was reasonable. This was by far *the most work-intensive quarter* for the Senior Design class.

Based on the synopsis of Q.1 responses that has woven together the key words and word pictures extracted through NVivo, students' direct quotations, and the researcher's reflections, the following concise finding has been presented.

Finding #4. *The change leadership and change processes during the Fall 2015 term were shaped by team development and team dynamics, frequent changes, and team success, despite struggles through the work-intensive term.*

Student #S6 confirmed that during Winter 2016 their team "spent more time with the advisor to discuss and design." Thus, there was some exchange of ideas and sharing of knowledge among the students, and between the students and the advisor (or advisors, as the eight teams had one, two or three advisors—see organization chart in Appendix H, p. 200). In Chapter 2, Figure 7, p. 29 a graphic of this knowledge exchange is presented.

During the Winter 2016 term, team dynamics were stronger than they were during the Fall 2015 term. As a consequence of enhanced team functioning and interactions even through the previous Fall 2015 term, several capstone project teams were well-coordinated by Winter 2016, and began to share responsibilities according to their skills and abilities. Student #S21 wrote:

> During the Winter 2016 term we did most of the detailed design and manufacturing. Our group began to take on unique roles, where two of us focused on design, one member on project management, and the fourth on manufacturing and testing.

Table 13 (p. 96) is a summary tabulation of the frequency of occurrence of key words in the textual data representing the students' observations and experiences regarding change leadership and change processes during Winter 2016. Figure 14 (p. 97) presents the NVivo Word Cloud representing the frequency of occurrence of key words and concepts on CL in Winter 2016. These key concepts included ‘Design’, ‘Project’, ‘Team’, and, ‘Changes’, in order. The top concept was ‘Design’ as is reflected in Table 13 (see also Appendix T, p. 212).

It can be seen from the NVivo results in Table 13 and Figure 14 (p. 97) that resolute progress with the *design* of the prototype for presentation as work-in-progress at the end of Winter 2016 was the main preoccupation of the Senior Design students. The basic prototype had to be *functional* as soon as possible during this second term. Building the prototype, testing its functionality, doing the economic analysis, generating ideas as a team, and ensuring project progress—all of these began to take on some urgency and momentum during the Winter 2016 term.

Table 13

NVivo Analysis of Responses to Q. 2 on CL (Winter 2016)

RANK	KEY WORDS	FREQUENCY	COGNATE WORD PATTERNS
1	**Design**	11	Advising, figuring, presentation
2	**Project**	10	Parameters, scope, progress
3	**Team**	7	Roles, meetings, analysis
4	Changes	5	Review, problem, solution
5	Presentation	5	Topic, discuss, knowledge
6	Prototype	5	Unique, functionality, financing
7	Time	5	Management, started, continue
8	Testing	2	Methods, resources, ideas
Synopsis based on coding and review of key words, frequencies, and patterns			
During Winter 2016, the Design took precedence, as the prototype had to be figured out, and the topic discussed and presented as work-in-progress with knowledge gained from the faculty advisors. The project parameters, scope, and progress were monitored, and changes reviewed as problems were overcome with viable solutions. The prototype had to be unique, with adequate financing and functionality. It had to be tested using appropriate methods, resources, and ideas. Time management was necessary for meetings, and in the testing, changes, and starting of the prototype.			

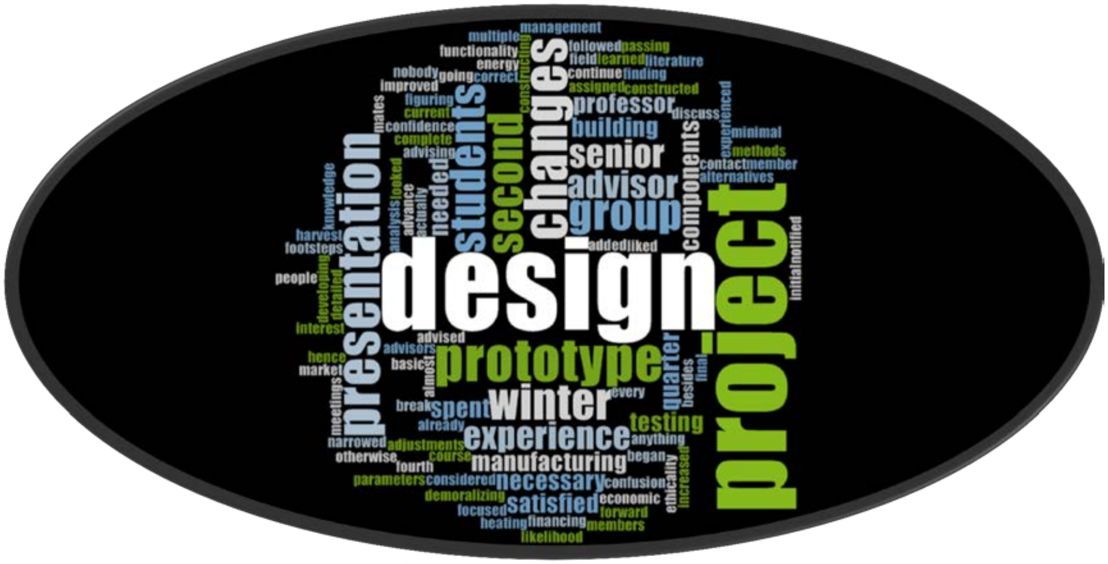

Figure 14: NVivo Word Cloud of frequency of concepts on CL in Winter 2016

In the process of planning, designing, and constructing the prototype, iterative changes were inevitable but necessary, and even useful (see Chapter 2, Figure 6, p. 27). Student #S13 wrote: *"The changes made to the project actually pushed the project forward."* On the other hand, Student #S5 felt like "things were being rushed more than was necessary"; however, this pressure seemed to have enabled the teams to make timely changes with escalation of team dynamics among team members to complete a working prototype in due time for testing.

Finding #5. *During Winter 2016, iterative changes had to be made to the work-in-progress prototype, with shared work by team members, and input by faculty advisors.*

Table 14

NVivo Analysis of Responses to Q. 3 on CL (Spring 2016)

RANK	KEY WORDS	FREQUENCY	COGNATE WORD PATTERNS
1	**Term**	7	Advisor, focused, experience
2	**Project**	6	Task, challenges, success
3	**Working**	5	Testing, Results, Solution
4	Changes	4	Assess, forced, finalize
5	Time	4	Continuously, proactive, deadlines
6	Design	4	Complex, elegant, overall
7	Prototype	3	Functioning, created, presentation
8	Group	2	Meetings, weekly, dynamics
Synopsis based on coding and review of key words, frequencies, and patterns			
During Spring 2016, the (Spring) 'Term' took precedence, as it was the final term before graduation. Passing the Senior Design project was compulsory to graduate. Therefore, the final, Spring 2016 term involved working with focus by the group with the advisor, pooling all their mutual experiences together. The design of the project was complex, with overall efforts geared towards an elegant outcome. Changes had to be assessed—and sometimes forced and finalized. The time constraints and the fixed deadlines in this critical term required the student teams to work relentlessly in a proactive manner. The group had weekly meetings, and group dynamics was at its highest. The project required testing for results and solutions to ensure that the prototype created was functioning per design and for final presentation. The tasks and challenges of the Senior Design capstone project were focused on project success.			

Table 14 depicts a summary tabulation of frequency of occurrence of key words from the textual data representing the students' observations and experiences on change leadership and change processes during the final term of the academic year, Spring 2016.

The NVivo results in Table 14 and Figure 15 (p. 99) show that the main focus of the Senior Design students was to make resolute progress to complete the working prototype by the end of Spring 2016. The students were generally impelled by the fact that completing the Senior Design course successfully was a condition for graduation. It is not surprising that Student #S2 stated, "I put it all together in the end with success."

Figure 15 presents the NVivo Word Cloud showing frequency of occurrence of concepts on CL in Spring 2016. These concepts included ‘Term, ‘Project’, ‘Working’, and, ‘Changes’, in that order. The top concept was ‘Term’ as was also correspondingly reflected in Table 14, p. 98 (see Appendix U, p. 213, for a comprehensive word-list as a screenshot of the NVivo output for Table 14, p. 98, & Figure 15 for Spring 2016).

Figure 15: NVivo Word Cloud of frequency of concepts on CL in Spring 2016

Tests of the prototype were continually done to improve existing solutions through the changes. Many meetings took place to assess changes—and possible challenges. Student #S5 felt that her team did not need to make changes in the final term, as the prototype was substantially ready by the end of the previous (Winter 2016) term:

> The Spring 2016 quarter was by far the *easiest* for our group. By this point we already had our prototype built, so we just had to get it in working order. Once it was working, we then went into the testing phase, which was the *most fun* for us.

The data indicated that *the groundwork laid in the Fall 2015 and Winter 2016 terms was necessary to have a successful final, graduating term in Spring 2016.* This was underscored by Student #S18 who asserted that, “The Spring term went well, since we did most of the upfront work in the Fall and Winter terms.” There was now much more focus on *quality* improvement of working prototypes. As Student #S6 stated: “Since we had the design working in the Winter term, we focused on improvement of its qualities and functioning. We were able to develop a more elegant solution to it.”

Clearly, the Senior Design projects required regular testing for results and solutions to ensure that the prototypes created were functioning well, and ready for final presentation. The minimal time at hand in this critical final term required the students to work continuously as teams in a proactive manner. Appropriately enough, Student #S6 stated that, “tests were continuously done to improve existing solutions *through changes*.” Many meetings took place to assess variables and possible challenges. By the third and final term of the senior year, group dynamics were high, with productive weekly meetings and continuous work in a proactive manner. Thus, the Spring 2016 term involved focused working by the teams under the advisors’ guidance for project success.

Finding #6. *During the final Spring 2016 term, residual changes had to be accelerated to meet the completion deadline for the evolving prototype to arrive at an ‘elegant’ solution.*

Summary of the open-ended questions on CL for Academic Year 2015-2016. In reviewing the change leadership and change processed as observed and experienced by the Senior Design students in their respective capstone projects, it can be inferred that during Fall 2015, the newly formed groups became interdependent team members, each with an accepted, referent leader. The functions of the project teams thus formed were planned as proposed, with the student leader monitoring the task durations allocated. The project teams depended on experience, learning, and research to make progress and to accommodate changes by considering alternatives, switching plans, and accomplishing tasks. In the NVivo output for Fall 2015 (see Appendix S, p. 211), the word 'Project' was the most prominent, suggesting the centrality of the capstone project as the core of the Senior Design learning and experience.

During Winter 2016, the faculty advisors guided the change process. Project parameters, scope, and progress were monitored, and changes were reviewed as problems were overcome with solutions. The prototype design had to be unique, with adequate financing and functionality. It had to be tested using appropriate methods, resources, and ideas. Time management was necessary in the starting, continuation, and completion of the design elements. During Winter 2016, the concept of 'Design' took precedence in the NVivo output (see Appendix T, p. 212); the prototype had to be figured out, and the topic was discussed and presented as work-in-progress that required several iterative changes.

During Spring 2016, there was heightened realization that passing the Senior Design project was compulsory for the students to graduate from the ET program. Consequently, the final, Spring 2016 term involved focused work by the group with the advisor's guidance as necessary, and pooling of all their collective experiences together.

The design of the project was complex, with overall efforts geared toward an 'elegant' outcome. Changes had to be assessed—and sometimes forced and finalized. The minimal time at hand in this critical term required the students to work continuously in a proactive manner. The group had weekly meetings, and group dynamics were high.

The project required testing for results to ensure that the prototype was functioning and ready for successful final presentation on May 20, 2016. According to the NVivo output (see Appendix U, p. 213), the final, Spring 2016 ‘Term’ took precedence, as it was the critical term for successful completion of the capstone project for graduation.

Table 15 (p. 103) shows a summary table of frequency of occurrence of key words across the whole Academic Year 2015-2016. This was based on the data representing the students’ observations and experiences regarding change leadership and change processes experienced by them during the whole Academic Year 2015-2016—combining Fall 2015, Winter 2016, and Spring 2016. Additionally, a Tree Map (see Appendix X, p. 216) and Cluster Analysis (see Appendix Y, p. 217) were reviewed to craft the synopsis as presented in Table 15 (p. 103).

The NVivo outputs enabled deeper analysis to extract conceptual nuances and experiences germane to the research three questions of this study (see Chapter 1, p. 16), and as embedded in the responses to the three open-ended questions discussed here. Figure 16 (p. 103) presents the NVivo Word Cloud showing the frequency of key words on CL through the Academic Year 2015-2016. These concepts included ‘Project’, ‘Design’, ‘Term’, and ‘Group’, in that order. It can be seen from Figure 16 (p. 103) that ‘Project’ was the most prominent concept in the *combined* Word Cloud for all the responses to the three open-ended questions on change leadership and processes (see Appendix W, p. 215, for a comprehensive screenshot of the NVivo output from which Table 15, p. 103, is extracted).

Table 15

NVivo Analysis of Responses to All Questions on CL (2015-2016)

RANK	KEY WORDS	FREQUENCY	COGNATE WORD PATTERNS
1	**Project**	32	Plan, task, succeed
2	**Design**	24	Figuring, functionality, perfect
3	**Term**	19	Weeks, classes, completed
4	Group	13	Meeting, experience, dynamics
5	Time	13	Beginning, proactive, target
6	Changes	12	Needed, focused, vigorous
7	Prototype	8	Create, test, presentation
8	Advisor	7	Student, team, learn
Synopsis based on coding and review of key words, frequencies, and patterns			
Through the Academic Year 2015-2016, 'Project' was the prominent key word with respect to change processes and change leadership. It was important to start the project from the beginning of the Fall 2015 term, and to continue it proactively. The driving purpose of the Senior Design course through the three terms of the academic year was to design, build, test, and present a unique and innovative technology prototype. The design had to be figured out through iterative trials to ensure the functionality of the prototype to an acceptable level of perfection. The proposal by each group was turned into a detailed project plan. This was executed through tasks and team roles toward successful completion through the weeks of each term by the targeted end of Spring 2016. Changes were needed, and were focused for rigorous follow-up action to create, test, and present the prototype. The student teams had regular meetings, shared their experiences, and developed their group dynamics well.			

Figure 16: NVivo Word Cloud of frequency of concepts on CL (2015-2016)

In the comprehensive outputs in Table 15 and Figure 16 (p. 103), the overriding concept was ‘Project,’ followed by ‘design’ and ‘term’. This was plausible, as these concepts were integrated as the *project* progressed through the three *terms* to culminate in the Senior *Design* project (innovative technology prototype) as a graduation requirement.

Table 15 (p. 103) provides a cogent synopsis of evidences of change leadership and change processes, drawing from the most frequently occurring themes and cognate word patterns in NVivo; also, from reflective reviews of the recorded responses for all three open-ended questions across the Fall 2015, Winter 2016, and Spring 2016 terms.

Summary of the Phase 1 Findings

Phase 1 of this study comprised a mixed-methods approach, yielding interesting findings. The Phase 1 findings were substantially aimed at throwing light on the SDL skills and CL effectiveness of the 30 Senior Design students of the ET program at M University. Table 16 (p. 106) presents a summary of Phase 1 of this study, using a mixed methodology approach for breadth and depth of the findings. The six concise findings from Phase 1 are presented together as follows:

Finding #1. *ET students have a demographic profile that mirrors that of the low campus-wide female student population in engineering and technology programs. This under-representation of females is also reflected on a national scale as there are only around 25% of females among US engineers.*

Finding #2. *Based on the SDLRS-A® Survey, ET students have on average, self-directed learning skill levels that are slightly above those evidenced by overall mean scores for the adult population in predominantly higher education academic environments.*

Finding #3. *Based on the SDLRS-A® Survey, ET students can manage their learning well, have a high desire for learning, and demonstrate adequate self-control in their learning experience.*

Finding #4. *The change leadership and change processes during the Fall 2015 term were shaped by team development and team dynamics, frequent changes, and team success, despite struggles through the work-intensive term.*

Finding #5. *During Winter 2016, iterative changes had to be made to the work-in-progress prototype, with shared work by team members, and input by faculty advisors.*

Finding #6. *During the final Spring 2016 term, residual changes had to be accelerated to meet the completion deadline for the evolving prototype to arrive at an 'elegant' solution.*

Table 16

Summary of Phase 1 of the Study Using Mixed Methodology

PHASE 1 OF THE STUDY			
METHODOLOGY	**QUANTITATIVE**		**QUALITATIVE**
Instrument Used: SDLRS-A® Survey	**SDLRS-A® Likert-Style Questionnaire**	**Demographic Items**	**Open-ended Questions**
Number of Items	58	6	3
Analytic Technology	SPSS 24.0 for Windows	Microsoft Excel 2016	NVivo 11
No. of Participants	30	30	22-25
Participant Profile	Senior Design (ET) Students	Senior Design (ET) Students	Senior Design (ET) Students
Outputs	Descriptive Statistics Cronbach Alpha Factor Analysis	Table of Demographic Statistics	Word Frequencies Word Cloud Tree Map Cluster Analysis
Summary of the Six (6) Phase 1 Findings	➢ ***Cronbach α:*** High Score: **0.92** (*A Priori* Range: 0.79-0.96) ➢ ***SDL score:* 3.94** Above-average ➢ ***SDLRS-A® factors*: SM, DL,** & **SC** concur with *a priori* evidence	➢ ***Ethnicity:*** Mirrors Campus-Population ➢ *Females:* Low:**10%** ➢ ***Cumulative GPA:*** Split **50%-50%**: above/below **3.0** ➢ ***Max. Age-groups:*** 21-24 yrs.: 40% 31-35 yrs.: 20% **21-35 yrs.: 60%**	➢ ***Foundation*** needed in Term 1 for success in Terms 2 & 3. ➢ ***Iterative changes*** necessary for prototyping ➢ ***Networking*** crucial—with Stakeholders/ Experts

Table 16 summarizes Phase 1 of this study, showing the methodology used, quantitative and qualitative analyses, outputs, and summary of the findings. The participant profiles and analytic technology used in these phases are also presented. Following the Phase 1 findings based on mixed-methods research, the study has also presented the *qualitative* research findings of the semi-structured, one-on-one interviews of Phase 2, delving deeply into the four research streams presented in Chapter 2 (SDL, PM, CL, and PBL), to address the research questions initially posed in Chapter 1 (p. 16).

Phase 2 of the Study

Phase 2 consisted of in-depth, semi-structured interviews of six student leaders of capstone projects and six faculty advisors who advised student teams on one to three projects each. Individual face-to-face interviews were conducted in two sessions (see Chapter 3, Table 2, p. 59). The in-depth responses recorded during the 12 semi-structured interview sessions and 12 follow-up sessions yielded rich insights into the three research questions introduced in Chapter 1 (p. 16). These responses also addressed the related four literature streams (SDL, CL, PM, and PBL) discussed in Chapter 2.

The transcripts from these interview sessions were reviewed iteratively, reflected upon, and annotated for resolution of the three research questions. The interviews were also reviewed for discernment of empirical substance to the four theoretical research streams (see Appendix R, p. 210, for a sample annotated interview transcript page). The voluminous text was coded, grouped, and synthesized to draw the essence and nuances of the interviewees' thought processes and experiential insights on SDL, CL, PM, and PBL.

The responses of the students and advisors were kept in separate files, as their views were expected to be at two different levels of abstraction. The seven interview questions (actually six, with Q. 1 split into 1A and 1B) and their corresponding responses were organized into files for each person in the two respective categories of students and advisors (see Table 17, p. 108). The six students' responses were collated for each of the seven questions and analyzed in seven batches respectively by question numbers; correspondingly, the six advisors' responses were also collated for each question and analyzed in seven batches by question numbers. Individual student leaders' and faculty advisors' responses were not analyzed in order to maintain the anonymity of each of these one-on-one interview participants. However, they were designated as SL1 to SL6 for each of the six student leaders, and as FA1 to FA6 for each of the six faculty advisors (see Appendix C, p. 195). Also, there was no intention to compare the competencies of individuals. The focus was on the empirical practices explaining and throwing light on the four literature-based research streams: SDL, CL, PM, and PBL. The aim was to address the research problem by resolving the research questions that issued therefrom.

Table 17 presents a tally of responses to the seven interview questions by students and advisors to highlight the substantial database of the interview data. With two one-on-one interview sessions for each respondent (6 students and 6 advisors) for seven questions covering the four research streams embedded in the three research questions, the total number of responses to the seven questions in two sessions for 12 interviewees was 168 as shown in Table 17.

Table 17

Tally of Responses to Interview Questions: Students and Advisors

Question Nos.	**No. of Student Leaders (SL)**	**Cumulated Responses/ Question**	**No. of Faculty Advisors (FA)**	**Cumulated Responses per Question**	**Cumulated Responses to 7 questions**
Q. 1A	**Six (6):** SL1 SL2 SL3 SL4 SL5 SL6	6+6 follow-up	**Six (6):** FA1 FA2 FA3 FA4 FA5 FA6	6+6 follow-up	24
Q. 1B		6+6 follow-up		6+6 follow-up	24
Q. 2		6+6 follow-up		6+6 follow-up	24
Q. 3		6+6 follow-up		6+6 follow-up	24
Q. 4		6+6 follow-up		6+6 follow-up	24
Q. 5		6+6 follow-up		6+6 follow-up	24
Q. 6		6+6 follow-up		6+6 follow-up	24
TOTAL		**84**		**84**	**168**

The responses of the six capstone project student leaders (SL1 to SL6) were somewhat different from those of the six faculty advisors (FA1 to FA2), due to their different roles and perspectives. The students' perspectives were task-oriented and based on day-to-day working and reworking of the prototypes; whereas, the faculty advisors' perspectives were broader, and commensurate with their experience in guiding the research process and helping with trouble-shooting on an as-needed basis. Each faculty advisor was responsible for one, two, or three capstone projects. As the questions were the same for students and advisors, respective responses were placed close together or side-by-side according to sequence of questions in order to compare and contrast them.

The Leximancer 4.5 concepts were represented by colored bubbles positioned according to relative importance of each concept with supporting concept clusters within the bubbles. The straight lines between the bubbles indicated the frequency of connections (by number of lines) and density of interactions (by thickness of the lines) among the concepts. Also, the bold-faced words represented key concepts; the lighter words showed supporting concepts; and, the lines showed the frequency and density of interactions among individual concepts. In contrast, NVivo provides the Word Cloud with relative magnitude of the printed words in color, but does not show their relationships or their frequency of interactions with each other.

Leximancer 4.5 also outputs a horizontal bar chart of Ranked Concepts that prioritizes overarching concepts and lesser concepts according to frequency of occurrence. Unlike the NVivo 11 output (see analysis of the three open-ended questions under Phase 1—Qualitative), Leximancer 4.5 thus provides *interrelationship*s between concept bubbles, and, a *bar chart* corresponding to each of the Concept Maps showing a *hierarchy* of frequency of occurrence of the concepts. Thereby, the results of the Leximancer 4.5 analysis show graphical outputs that facilitate more nuanced and comprehensive interpretations of complex interrelationships among concepts.

The findings from the Leximancer 4.5 analysis have been sequenced in the order of the seven questions. Each interview question has been presented in turn for reference, followed by the two related Leximancer 4.5 outputs: the Concept Maps for student leaders and faculty advisors in order, and the bar charts of Ranked Concepts for six student leaders and six faculty advisors, positioned side-by-side for comparison (see Appendix BB, p. 220, for Q. 1A; Appendix CC, p. 221, for Q. 1B; Appendix DD, p. 222, for Q.2; Appendix EE, p. 223, for Q. 3; Appendix FF, p. 224, for Q. 4; Appendix GG, p. 225, for Q. 5; and, Appendix HH, p. 226, for Q. 6). Data comprising the collated responses to each of the stated questions by the six student leaders were analyzed first, followed by similar analysis for the six faculty advisors with their responses to the same question as for the student leaders (see Appendix BB, p. 220, for a sample of Leximancer 4.5 graphical outputs for Q. 1A).

What follows is a concise and sequential presentation of the findings for each of the seven interview questions. They will be in the order of student leaders first, followed by faculty advisors for Concept Maps; then, student leaders and faculty advisors side-by-side for the Ranked Concepts (see Appendices BB to HH—pp. 220-226). As the concepts embedded in the responses for each question are numerous and their inter-relationships complex, only the four most prominent concepts will be used to support the information from the researcher’s in-depth review and reflection of the rich, transcribed text.

In the following qualitative analyses of the seven interview questions, Leximancer 4.5 was used to report essential findings for the voluminous textual data, but the key discussions were based on iterative reviews and reflections on the transcripts, and direct quotations from the student leaders and faculty advisors that were used for support.

For the interview questions, the Leximancer 4.5 outputs have been shown in the Appendices BB to HH (pp. 220-226) for support of the transcribed data as necessary. The data analysis resulted in findings as in the Phase 1 analysis, for a total of five findings in Phase 2 of the study as shown in Table 18.

Table 18

Sources of Phase 2 Findings from Interviews

Finding #	Interview Questions #	Research Question #	Research Stream
#1	#1A, #1B, & #5	#3	PBL (Best Practices)
#2	#2	#1, #2, & #3	SDL
#3	#3	#2 & #3	PM
#4	#4	#2 & #3	CL
#5	#6	#3	PBL (Acceleration)

Finding #1. *The Senior Design capstone project was loosely structured and informal, yet with initial research, a project plan, design of an innovative prototype, milestones, and final report to complete the project within the timeframe. Significant changes and iterations were needed through the uneven phases of the project, necessitating strong commitment and expertise on the part of the team members.*

PBL was practiced in the capstone project with a viable design and team dynamics developed through each term. However, there was no formally structured PBL framework or model. Student leader SL4 highlighted this by stating that, “the PBL model was not strictly clarified; rather, it was *assumed to be inherently understood.*” This was echoed by faculty advisor FA2 who clarified that he was "unaware" of the existence of a "PBL framework" until late in the third and final (Spring) term. Faculty advisor FA2 defined PBL informally: "It is a project with milestones, and students are learning through the project; therefore, it is project-based learning." Student leaders SL1, SL2, and SL6 emphasized this informality by stating that there were a number of unstructured changes to the prototype *"according to the problem."*

The prototype was revised several times and benefited from external sponsorship and consultancy, as well as the "good learning curve" (FA4) due to the valuable inputs availing of the internal expertise of faculty advisors. In sum, the overall impression was that there was no formal integration of the Project-Based Learning (PBL) framework through the three terms of the Senior Design Course; however, there were indications of informal practice of PBL with loosely structured planning, design, teamwork, and learning with the help of advisors, sponsors, lecturers, experts, and consultants.

The PBL framework was applied in various ways through the project phases in the capstone projects. The early phase of planning and iterative re-planning, were considered critical by both student leaders and faculty advisors. In the design phase during Fall 2015 (Term 1), the basic prototype diagram was completed, together with its components.

Similarly, in the construction phase of PM during Winter 2016 (Term 2), the prototype took prominence. In fact, the prototype had to be designed, built, tested, redesigned, and refined until ready to be presented at the end of Spring 2016 (Term 3). These involved significant changes and iterations. The Project Report, though submitted as evidence of PBL at the end of the project, was also work-in-progress that chronicled the PBL experience. Student leader SL4 considered the Project Report to be "a detailed translation of the PBL framework." Through all of this, the communication and collaboration of the team members were crucial, and plans had to be modified. According to student leader SL3, work plans had to be tailored to "each team member's skills, strengths, and expertise". A faculty advisor (FA5) pointed out that the phases were uneven, and the activities were sometimes unpredictable. This should not be surprising, as a typical project can be unpredictable due to uncertainties at the front-end, with uneven phases, and with the construction phase being the most innovative and protracted (Kerzner, 2013). The Leximancer 4.5 output (see sample in Appendix BB, p. 220) also confirms this with the high frequency of the words 'project' and 'design', suggesting a focus on iterative designing to refine the prototype (see Figure 6, p. 27).

For best PBL competencies with PM efficiencies, SDL skills, and CL effectiveness, both student leaders and faculty advisors agreed that more detailed structure, formalization, and hard work were necessary. A major challenge was scheduling the project execution, as team members comprised full-time students, part-time students, and working professionals.

There was general agreement that face-to-face meetings were more efficient than virtual meetings: "We determined that face-to-face meetings were important for establishing accountability for completing tasks and communicating information. Telecommuting, though in some ways time-saving, created a sense of detachment from the group." It was also clear that SDL was necessary for efficient PBL—as argued from the literature in Chapters 2, and as echoed by student leader SL5:

> If I had been given the choice, *I would apply more SDL skills for PBL efficiency* as it relates to the desire for learning and taking initiative to understand the topic. I would do so by seeking people with interests in the project who will *prioritize their time* accordingly.

To enhance project efficiency, competent team members, adequate resources, and advisors' guidance were needed even before start of Fall 2015 (Term 1). This was astutely elaborated by student leader SL4:

> *I would find the most appropriate team members; I would get resources ready before start of the project; (I would) give individual roles for each person; and, I would set performance standards for each person. We would plan more frequent meetings with our advisors, and attempt to get more field data.*

Thorough front-end research of project feasibility, contingency plans, and resource requirements could have expedited each project. As student leader SL2 rued:

> In the first term of Senior Design we should have done more research into our main component in order to get a better idea of the final results we could expect. There was a *lack of additional information* for what we were attempting to study. If we were to get all of the necessary equations and calculations and other research on the topic, then we would have had a much smoother start—I wish we had this information at the beginning—with more *assistance from the advisors*, and if we did not wait and *underestimate the time* required to complete the project.

In hindsight, there was clearly a need for more information. Timely assistance from faculty advisors and better scheduling could have helped to complete the project with more satisfaction. Thus, there was significant scope to accelerate the project by rendering it more *efficient*. A somewhat frustrated student leader SL6 argued thus:

> To be perfectly honest, I am only 75% happy with the project. *The 25% is what could have been done to make it a much better product.* A lot of time was wasted. No money was really wasted. The quality of the project met the minimum requirement, but it could have worked better.

Several faculty members had good suggestions for best PBL competencies. Faculty advisor FA1 suggested that proactive *conflict management* could go a long way towards enhancing best practices in PBL by helping the team to resolve disagreements quickly and efficiently through discussion and voting. Another advisor underscored the need for *strong team leadership* by appointing a competent leader, who could motivate the team to exceed their own individual expectations (Bass, 1985).

Faculty advisor FA4 advised better *stakeholder management* to support PBL best practices externally; and internally, to *provide clear goals and agreement* amongst the team members, advisors, and other faculty. Faculty advisor FA3 highlighted the need for each team to secure *prompt and constructive feedback* from the advisor(s) for detailed guidance on specifications and deliverables as early as possible. Faculty advisor FA3 *warned against frequent scope changes* and urged strong control of these changes. Both faculty advisors FA3 and FA4 pointed out that as each team member had unique strengths, it was important to understand and adjust to the skills and strengths of individual students.

From a review of the key concepts and their supporting concepts in the Leximancer outputs for Q. 1A (Appendix BB, p. 220), Q. 1B (Appendix CC, p. 221), and, Q. 5 (Appendix GG, p. 225) in conjunction with the comments of student leaders and faculty advisors, it was clear that *thorough front-end planning* and preparation were necessary, along with a focus on project progress and completion. Increasing commitment was expected on the part of team members to complete the designed (and redesigned) prototype successfully, and on time.

Finding #2. *SDL skills comprise open communication, a competitive spirit, autonomy, an altruistic motive, and initiative to seek knowledge; SDL is not a solo effort, but one that requires interdependence, encouragement, and self-discipline to excel.*

The caring shown by faculty advisors and colleagues were crucial for SDL among the Senior Design students. As stated by student leader SL3, the simple question, “How is your project progressing?" was highly encouraging, resulting in self-motivation by the students. *Open communication and a competitive spirit* from proposal to design to finished prototype among team members were also crucial drivers for SDL. As student leader SL2 argued, "I did not like to be left behind compared to other capstone project leaders—we had open communication among Senior Design class members."

According to student leaders SL1 and SL3, 'autonomy of effort,' 'self-motivation,' and 'self-discipline' are inherent in PM and SDL. Similarly, *taking initiative to seek knowledge* was necessary to conduct research, and discuss findings among team members. These individual and team efforts were needed to prepare the design, and to finalize the prototype well in time. Working together as a team and *pooling skills* were therefore important collaborative team activities.

Overall, there was a lot of *interdependency in learning.* As student leader SL5 observed matter-of-factly, "learning is not a solo act". From a performance standpoint, student leader SL6 captured the idea of SDL as being driven by a *quest for excellence:*

> For me, wanting to engage in work that interests me is Self-Directed Learning (SDL). If it is not interesting, I will not be directing myself to learning it. If I want to excel in something, I will want to learn and apply it, even if it is not interesting. I will *put 100% of efforts to apply SDL skills.*

As faculty advisor FA2 commented, the role of the faculty advisors was not to "hand-hold" the students in each team, but "to offer guidance, knowledge and help with any technical aspects that were needed." There was also an *altruistic* motive to SDL in the Senior Design project. This was motivated, according to student leader SL2, to "expose others to this field." Such a larger motive also suggested a propensity to life-long learning and ongoing dissemination of relevant knowledge.

The four most significant concepts based on the Leximancer Concept Maps and Ranked Concepts for Q. 2 (see Appendix DD, p. 222) were as follows: *Project*, *Design*, *Team,* and, *Time*. Within the most prominent theme 'Project'—as reflected in its first rank among the Ranked Concepts for both students and advisors—three most outstanding subordinate concepts were: 'PBL', 'students', and, 'working'. The complex connecting lines indicate interactions of these most significant themes with several supporting concepts—such as 'team members', 'learning', 'faculty', 'skills', 'time', 'design', 'proposal', and, 'prototype'. These key concepts and their interrelated supporting concepts with contribute to the essence of SDL in a project environment.

Finding #3. *PM efficiencies were driven by strong project leadership and multi-pronged efficiencies through thorough front-end planning, tight deadlines, modularization, relentless cost-cutting, stakeholder support, regular monitoring & reporting, and, acceptable quality.*

PM efficiencies included control of *cost, schedule,* and *quality* by optimizing all resources and completing the working prototype within the deadline. Front-end planning, feasibility studies, and design of the prototype had to be proactive and streamlined. Also, reporting had to be regular and clear for better project control under strong leadership. According to faculty advisor FA2, "PM efficiencies depend a great deal on the strength of the team leader." Strong team leadership was therefore critical for efficient PM. The students, with the guidance of their advisors, applied PM efficiencies in various ways.

The student leaders admitted that the predetermined milestones and the final deadline for project completion in Spring 2016 were the real drivers to stay on schedule, under budget, and with acceptable quality. Student leader SL5 conceded: "With these major milestones, and the fact that our Capstone Project grade depended on meeting them, we had to ensure we stayed on schedule for the duration of the project." Faculty advisor FA5 stressed that it was more important to produce a working prototype in time, than to focus on quality—and thus miss the deadlines: "The students are tasked with making a *working prototype*, not a polished, manufacturable (sic) end-product."

Most of the advisors agreed that the focus should be more on getting a working prototype built and tested early, and then documenting the project activities. To increase project efficiency, faculty advisor FA1 suggested more use of modular components, as this would increase speed, lower costs, and even improve quality. In the final analysis, as faculty advisor FA5 asserted, "PM efficiencies depend a great deal on the strength of the team leader." The lecturers and faculty advisors helped with efficient design of the projects, whereas willing and available sponsors assisted with financing and cost-cutting. Telecommuting also helped with controlling the schedule. An incentive for cost-efficiency was to make the prototype product available at the lowest possible cost.

The four most significant themes based on these Leximancer Concept Maps and Ranked Concepts for Q. 3 were as follows (see Appendix EE, p. 223): *Project*, *Design*, *Team*, and, *Time*. Within the most prominent theme 'Project'—as reflected in its first rank among the Ranked Concepts in Appendix EE (p. 223) for both students and advisors—three most outstanding subordinate concepts were: 'PBL', 'students', and, 'capstone'. The complex connecting lines indicate interactions of the most significant concepts with several supporting concepts—such as 'team members', 'learning', 'skills', 'prototype', 'working', 'time', and, 'planning'. When applied in concert with feedback from the interviewees, these concepts confirmed the need for *multi-pronged PM efficiencies.*

Finding #4. *Effective CL accepts the inevitability of change, but takes proactive measures to succeed through goal-setting, collaboration, cooperation, scheduling/ rescheduling, and constant communication under strong change leadership.*

Changes were inevitable in the Senior Design capstone project in constructing the prototype. These changes required adequate CL of the project team to resolve the issues involved through PM. Student leader SL1 underscored the inevitability of changes: "We tried to follow the initial schematic of the project, but we *had* to make changes—No matter what your plans are, they *will* change!" Student leader SL5 concurred, stating that, "It seemed we were in a *constant state of change*". Student leader SL6 suggested that *changes were not only disruptive, but time-consuming as well:* "These changes required constant supervision and follow-up."

It was necessary for the team members to *have face-to-face meetings frequently*—often twice a week—in order to meet all the project requirements. A working relationship was established with team members by allocating work according to their skills and strengths in executing the prototype through PBL from planning to design to proposal.

Students were thus able to cope with changes, and to complete the capstone project in time for presentation near the end of the Spring 2016 term, on May 20, 2016. For this, goal-setting, collaboration, and scheduling/rescheduling were critical. Economic use of time was also necessary through self-motivation and team dynamics.

Faculty advisor FA2 advised that change is not necessarily beneficial or an "improvement". The main goal of the Senior Design project was *to build a working prototype,* and to provide students with valuable project-based design and testing experience. As for team leadership (hence CL), such a role gravitated to the most capable team member, or one with the best people skills as faculty advisor FA6 portrayed:

> Typically, one student takes the lead voluntarily. I don't recall an instance when I had to intervene and change the student leadership. There is no need to force anyone to be the leader. Some students are good at people skills and become natural leaders of their teams.

The four most significant concepts based on the Leximancer Concept Maps (see Appendix FF, p. 224) for Q. 4 were as follows: *Project*, *Design*, *Students,* and, *Team*. Within the most prominent concept 'Project'—as reflected in its first rank among the Ranked Concepts in Appendix FF (see p. 224) for both student leaders and faculty advisors—three most outstanding subordinate concepts were: 'PBL', 'prototype' and, 'working'. Taken together with examination of interview responses, they point to the importance of focusing on building a working prototype through the student teams.

In fact, faculty advisor FA2 captured this idea by stating that, "The main goal of the Senior Design project was to build a *working prototype*, and to provide students with valuable project-based design and testing experience."

It was clear that building a working prototype was of paramount importance, and required a complex of actions, attitudes, aptitudes, and, skills. As for skills, together with technical skills, people skills were deemed necessary for both the leader and the team.

Finding #5. *Acceleration of PBL can actually be less stressful and doable under the following conditions: strong leadership; competent and adequate human resources; networking support with sponsors, consultants, advisors, and other stakeholders; speedy conflict resolution; clear communication; tight scheduling; unflinching discipline and hard work; and, relentless momentum.*

Finding #5 addresses several outcomes of the study related to acceleration of PBL (Chapter 5). Adequate human resource support was considered essential for acceleration of PBL. One student leader (SL6) with three members in her team reasoned that they could have used one more student in the team for equitable distribution of tasks.

Also, *networking with outside sources of assistance* such as the project sponsors and consultants throughout the project saved much time by minimizing trial-and-error in the design of the prototype. Student leader SL4 expressed this succinctly as follows:

> The distribution of manpower for each project was disproportionate to the actual complexity. The projects should be those sponsored by companies. Students chose easy projects that were not sponsored. *Sponsored projects move forward faster, as the sponsors' advanced facilities are made available for more efficient, sophisticated, and faster work.*

The faculty advisor's supportive role enabled project efficiency by provision of *technical and strategic assistance.* Class lectures helped with learning secondary functioning—such as legal matters, liability issues, economics, literature citation, and, accessing appropriate reference material for research. Meeting with experts prior to the project for their advice could also have enabled accelerated progress with PBL. In this context, prior acquisition of foundational and specialized knowledge could speed up PBL by obviating the need to learn relevant fundamental material *after* project start.

According to student leader SL4 and faculty advisor FA5, for transparent, clear, and fluid communication and speedy conflict resolution, at least two face-to-face meetings were necessary for satisfactory problem-resolution. Conflicts had to be nipped in the bud through face-to-face discussion and mediation to avoid delays and low morale caused by miscommunication and misunderstandings.

Resources for the project needed to be acquired *before* the start of the project to save time and uncertainty at a later stage of the project, and to ensure availability of the inventory. The assistance of sponsors helped to minimize purchase of costly higher quality material as student leader SL1 candidly admitted: “Our budget was $850, but we actually spent only around $300 due to company sponsorship.” Faculty advisor FA3 suggested that the students maintain a tight schedule with some slack for contingencies, and to “*stick to the schedule*” to ensure an accelerated PBL: the project schedule needed to be “locked down” rather than be allowed to “float”. Student leader SL1 commented that there was “less stress” when there is such acceleration:

> *There is actually less stress when there is acceleration under strong leadership.* There is greater satisfaction with the product developed if we can plan it out and get it done speedily with enough time to fully analyze it and [to ensure that] the product is as the team wanted it. We should not overestimate the available time.

Acceleration of PBL also impacted quality of the product in terms of time. This was reflected by student leader SL4 who offered the following advice:

> If I can do something with the *same quality in half the time*, we can put the product out in the real world. For instance, if I can produce the best graphics card in half the time, I am going to be ahead of the competition.

Faculty advisor FA1 suggested that for *acceleration of PBL, there was no substitute for hard work and momentum*:

> *I would help expedite (the project), and push team members real hard. To accelerate, I would first find the best people, motivate them, then push them to their limits—and challenge them to achieve high goals and expectations.*

Overall, student leaders and faculty advisors of the capstone projects conceded that *acceleration of PBL was possible with hard work, discipline, prior preparation, tight control of changes, biweekly meetings, and, a relentless focus on time management.*

The four most significant concepts based on the Leximancer Concept Maps and Ranked Concepts for Q. 6 (see Appendix HH, p. 226) were as follows: *Project*, *Design*, *Term*, and, *Team*. Within the most prominent theme 'Project'—as reflected in its first rank among the Ranked Concepts in Appendix HH (p. 226) for both students and advisors—three germane subordinate concepts were: 'students', 'skills', and, 'learning'.

The complex connecting lines between the concept bubbles in the Leximancer output (see Appendix HH, p. 226) indicate interactions of the most significant concepts with supporting concepts—such as 'team members', 'planning', 'PBL', 'time', 'quality', 'term', 'design', 'problem', and, 'prototype'. Considered together with the comments of the interviewees, these key concepts and supporting concepts reinforce the need for acceleration of PBL through early research, planning, and design of the prototype.

Summary of the Phase 2 Findings

Phase 2 of this study comprised a qualitative approach with one-on-one, semi-structured interviews with six student leaders and six faculty advisors, yielding interesting findings. The Phase 2 findings were aimed at throwing light on all the three research questions and their four embedded research streams: SDL, PM, CL, and PBL.

The five findings from Phase 2 (p. 124) add to the six findings from Phase 1 (see p. 105) to make a total of 11 findings. These 11 findings are captured in the five themes under 'Results and Interpretations' of the study in the following section.

Table 19 (p. 125) summarizes the Phase 2 study and encapsulates its findings. These findings confirm that PBL was practiced informally in the capstone projects with viable design and team dynamics through each term. The overall impression though, is that there was no formal integration of the Project-Based Learning (PBL) framework through the three terms of the Senior Design course, but there were indications of *informal* practice of PBL with planning, design, teamwork, and learning with the help of advisors. The findings from Phase 2 of the study are presented together as follows:

Finding #1. *The Senior Design capstone project was loosely structured and informal, yet with initial research, a project plan, design of an innovative prototype, milestones, and final report to complete the project within the timeframe. Significant changes and iterations were needed through the uneven phases of the project, necessitating strong commitment and expertise on the part of the team members.*

Finding #2. *SDL skills comprise open communication, a competitive spirit, autonomy, an altruistic motive, and initiative to seek knowledge; SDL is not a solo effort, but one that requires interdependence, encouragement, and self-discipline to excel.*

Finding #3. *PM efficiencies were driven by strong project leadership and multi-pronged efficiencies through thorough front-end planning, tight deadlines, modularization, relentless cost-cutting, stakeholder support, regular monitoring & reporting, and, acceptable quality.*

Finding #4. *Effective CL accepts the inevitability of change, but takes proactive measures to succeed through goal-setting, collaboration, cooperation, scheduling/ rescheduling, and constant communication under strong change leadership.*

Finding #5. *Acceleration of PBL can actually be less stressful and doable under the following conditions: strong leadership; competent and adequate human resources; networking support with sponsors, consultants, advisors, and other stakeholders; speedy conflict resolution; clear communication; tight scheduling; unflinching discipline and hard work; and, relentless momentum.*

Table 19

Summary of Phase 2 of the Study Using Qualitative Methodology

Phase 2 of the Study		
Methodology	Qualitative	
Instrument	Semi-structured Interviews	
Number of Questions	7 (with Q. 1 split into 1A & 1B)	
Analytic Technology	Leximancer 4.5	
Participants	ET Senior Design Student Group Leaders	ET Faculty Advisors
Number of Participants	6	6
Outputs	Concept Maps Ranked Concepts (Bar Charts) Annotated Interview Transcripts	
Summary of the Phase 2 Qualitative Research Findings	*Though the PBL framework was informal and loosely structured, it evidenced above-average practices in SDL, PM, CL, and PBL but with a necessity to minimize iterative changes, while enhancing capstone project formalization and acceleration through expert support, networking, disciplined effort, hard work, and, relentless momentum.*	

The PBL framework was applied in various ways through the project phases in the capstone projects. However, the project phases were uneven, and the activities were at times unpredictable. Significant changes and iterations were involved through the research, planning, design, prototype construction, completion, and reporting phases. The Project Report was considered as a proxy to verbalizing the project phases.

The external motivation by the project advisors and other faculty translated into *self-motivation* inherent in SDL by the Senior Design students. *Open communication* and a *competitive spirit* from proposal to design to finished prototype among team members were also drivers for SDL. A *quest for excellence* was seen to be a strong self-motivator for SDL, as well as *altruistic motives* such as acquiring and sharing knowledge with others. An interesting finding was that SDL was not viewed as a solo act, but one that required communication, interdependence, and encouragement from stakeholders.

PM efficiencies including control of cost, schedule, and quality depended significantly on the strength and competence of the team leader. The planning, designing, prototyping, and reporting phases were streamlined by optimizing all resources, and completing the working prototype within the deadline through the project milestones. Using modular components externally and assembling them for the prototype increased speed, lowered costs, and even improved quality.

Changes were inevitable in the Senior Design capstone project in constructing the prototype. Strong CL of the project team by the team leader was required to resolve conflicts through efficient PM and people skills. Frequent face-to-face meetings—often twice a week—were necessary in order to meet all the project parameters successfully. A working relationship was established with team members by allocating work according to their skills and strengths in executing the prototype through PBL—from planning to design to proposal. The CL role gravitated to the most capable student for strong leadership, or a student with the best people skills to motivate the team.

For best PBL competencies with SDL skills, PM efficiencies, and CL effectiveness, both student leaders and faculty advisors agreed that more detailed structure, formalization, and hard work were necessary. A major challenge was that of efficient scheduling, as team members comprised both full-time students and working professionals. It was confirmed that face-to-face meetings were more efficient than virtual meetings—despite the time commitment and coordination necessary for face-to-face meetings. It was also agreed that SDL was integral to, and crucial for, efficient PBL.

Adequate human resource support was considered essential for acceleration of PBL. The networking with outside sources of assistance such as the project sponsors and consultants throughout the project could save much time by minimizing trial-and-error in the design and prototyping, as well as providing economic support for the project.

Class lectures helped with learning secondary functioning—such as legal issues, liability concerns, economics, literature citations, and reference material necessary for research. In this context, prior acquisition of foundational and specialized knowledge could speed up PBL by obviating the need to learn relevant material anew on the project.

Resources for the project needed to be acquired before project start to save time and uncertainty at a later stage of the project, and to secure necessary inventory. Finally, the project schedule needed to be “locked down,” rather than be allowed to “float”.

Paradoxically, *less* stress can be expected with such acceleration of PBL through various efficiencies. This is indeed a paradox, as some studies generally indicate that increasing the speed of an activity is associated with stress (Stults-Kolehmainen, & Sinha, 2014). On the other hand, there is also evidence that activity considered to be useful and pleasurable can be stress-relieving (Wike, 2015).Therefore, minimizing stressors through self-efficacy (SDL), project efficiency (PM), and leadership effectiveness (CL) can promote acceleration of PBL with consequent reduction of stress.

Overall, both student leaders and faculty advisors of the Senior Design capstone projects conceded that acceleration of PBL was indeed possible with hard work, discipline, prior preparation, control of changes, biweekly meetings, collaboration, and, focus—as well as relentless momentum towards the project goal. A robust model of accelerated PBL would therefore be both feasible and necessary.

Results and Interpretations

The findings of this mixed-methods research have provided rich information through data from both Phase 1 and Phase 2 of the study. Summary demographic data composed of six dimensions were extracted (Finding #1 of Phase 1), followed by analysis of the SDLRS-A® questionnaire data (Findings #2, and #3 of Phase 1), and then textual information from the three open-ended questions (Findings #4, #5, and #6 of Phase 1). Thereby, from the comprehensive data collection, this mixed-methods study of Phase 1 yielded six (6) succinct findings as follows: one from the demographic profile; two from the SDLRS-A® questionnaire, and three from the open-ended questions—for a total of six findings in Phase 1.

The Phase 2 qualitative study with seven interview questions yielded five (5) concise findings. Thus, a total of 11 findings were extracted altogether from the empirical study in Phases 1 and 2. These findings explored the four literature streams of SDL, PM, CL, and PBL, and demonstrated their practical implications through both quantitative and qualitative lenses. From these 11 Phase 1 and Phase 2 findings, five (5) themes emerged.

These Themes related directly to the three research questions introduced in Chapter 1, and the four research streams expounded in Chapter 2. The five (5) Themes that emerged from Phase 1 and Phase 2 of the study were as follows: (a) Self-directed learning skills;

(b) Project management efficiencies; (c) Change leadership effectiveness; (d) Project-based learning [best practices]; and, (e) Project-based learning [acceleration]. These five (5) Themes were embedded by five (5) subthemes each—with all of them being derived from the 11 Findings to inform the subsequent Results and Interpretations.

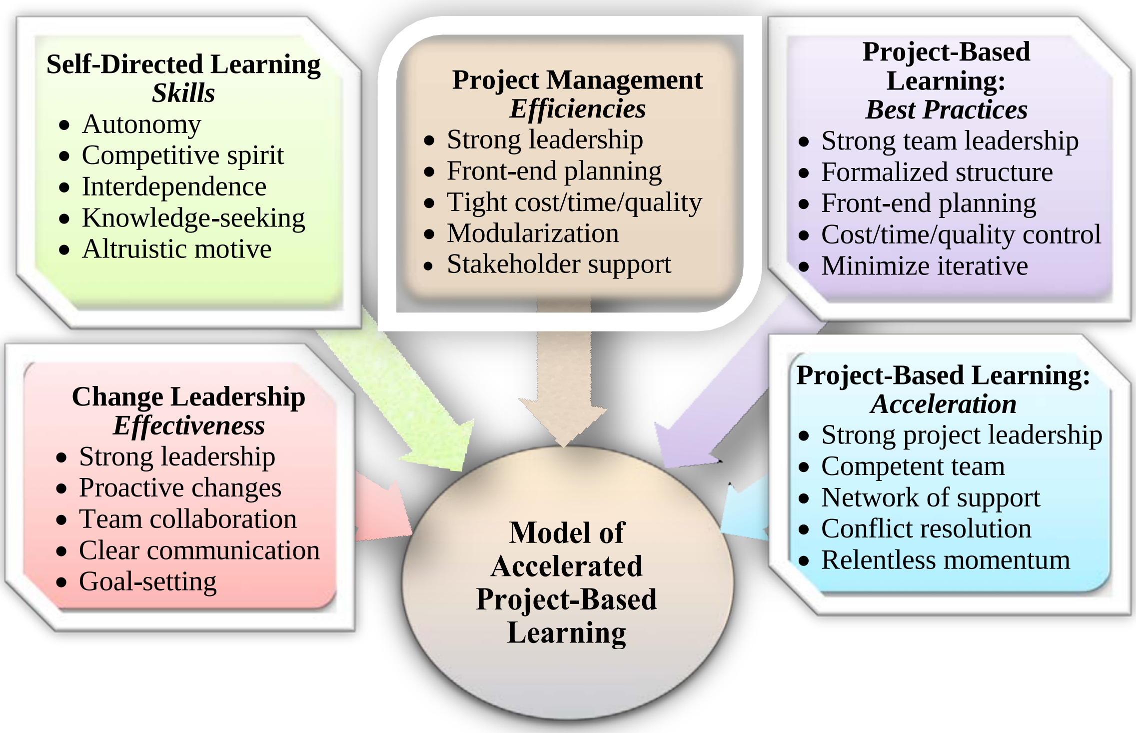

Figure 17. Themes and subthemes derived from the study

The Results and Interpretations were thus developed from the five Themes (each theme with five subthemes) as presented in Figure 17. These five Themes were derived from the 11 Findings. These Findings in turn were abstracted from Phases 1 and 2 of the study to focus on the five succinct Results of the study described in this section of Chapter 4 (see the graphic funnel illustrating this sequence in Figure 18, p. 130).

An insightful and interpretive discussion has been provided to elucidate and support the five (5) Results. Also, relevant contemporary literature evidence from Chapter 2 was used to inform the Results and Interpretations that emerged from the five (5) Themes and 11 Findings. This provided the necessary foundation for the ensuing Conclusions and Recommendations of Chapter 5. Figure 18 presents the sequence of these outputs in order.

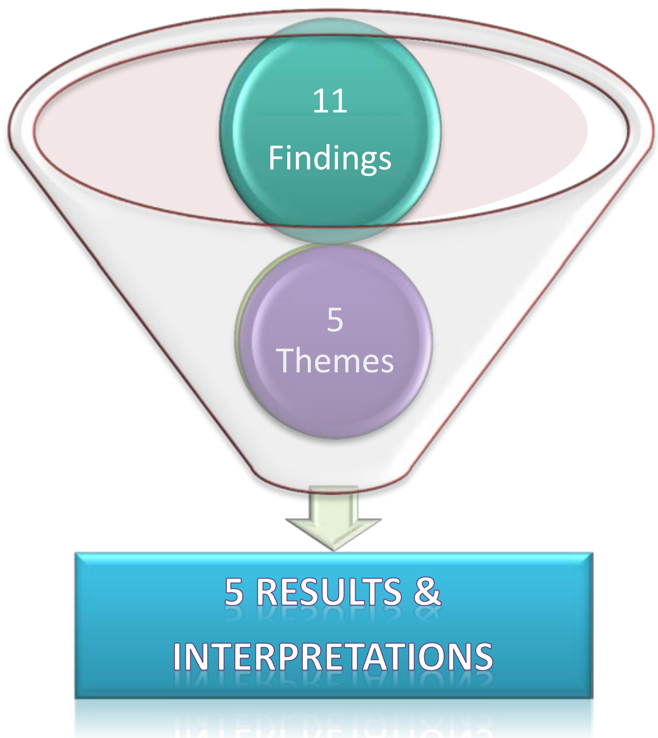

Figure 18. Sequence of Findings, Themes, Results, and Interpretations

Result #1: *SDL skills are essential to PBL as it motivates autonomous performance, desire for learning, self-efficacy, and interdependence in a project team.*

Contemporary literature on inquiry-based learning includes both SDL and PBL (Stewart, 2007). SDL involves learner autonomy, self-management of learning, a genuine desire for learning, self-efficacy in learning, and, a propensity to life-long learning (Candy, 1991, Merriam et al., 2007). Thus, SDL comes under both the humanist and the social-cognitive orientations to learning (see Appendix A, p. 193). The nature of PBL demands all the essential characteristics of SDL, along with other qualities, skills, and attitudes that provide a collaborative, pragmatic, learner-centric, and results-oriented ethos. The SDL characteristics that impel a self-motivated learner to seek knowledge with both curiosity and self-confidence are invaluable traits in PBL. This is because PBL involves *collective* effort that requires *both* independence and interdependence, as was evident in this empirical research. The rationale is that *both individual work and team dynamics are needed by learners in a PBL environment.*

The interview results brought forth two interesting aspects of SDL that were not evident in the literature. A *competitive spirit* was indicated as a motivator for SDL by an articulate student leader. This extends and translates self-motivation to *learn*, into a motivation to *accomplish* worthwhile results in a competitive environment. Such a competitive spirit helps in teamwork for within-teams and between-teams competition which can enhance and *accelerate* the project outcomes. Another finding from this empirical study is that SDL can engender an altruistic motive with the laudable goal of being of service to others. The incorporation of SDL into PBL would be aligned to this egalitarian motive, as PBL outcomes ultimately serve evolving community needs.

Result #2: *PM efficiencies are needed in PBL for optimal cost, time, and quality management to minimize cost overruns, to avoid delays, and to enhance quality.*

According to the Theory of Temporary Organizations (Lundin & Söderholm, 1995; Packendorff, 1995; Söderlund, 2000; Turner & Müller, 2005), projects are temporary organizations with predetermined mandates of time, cost, quality, and scope.

As PBL is driven by PM, the scientific application of PM becomes crucial for efficient execution and delivery of the project. Two axioms have been forwarded in the PM literature with direct relevance to PBL: (a) Communication is the lifeblood of a project; and, (b) change is inevitable in a project (Sohmen, 1990). Empirical evidence from this research that is based on the interviews of student leaders and faculty advisors has underscored these realities in the capstone projects. Further, *strong project leadership* is critical in PBL. However, as evidenced in the remarks of a faculty advisor in this study, leadership in a PBL situation gravitates to a technically competent person, and/or to a team member with the best interpersonal and communication skills.

Unlike the case of an industrial project, the learner-centric setting of small groups of learners appears to seek leadership through such referent power (French & Raven, 1959), rather than formal leadership. In a competitive and resource-constrained higher education climate, control of the ‘Triple Constraints’ of cost, schedule, and quality have become critical (Sohmen, 2007; Turner & Müller, 2003).

It seems to be axiomatic that with the uncertainties and risks inherent in a project, as the adage goes, ‘failing to plan’ is equivalent to ‘planning to fail’. Therefore, as PM is applied to PBL, *proactive and thorough front-end planning* is of paramount importance. Indeed, the interviewed student leaders confirmed that this was a key lesson learned, and the solid front-end planning and preparation of the first term was what enabled them to succeed in subsequent terms.

Modularization was helpful for early development of the prototype in some of the Senior Design projects. This is an important aspect of modern project management to optimize time, cost, quality, and manpower with attendant flexibility.

Finally, *strong stakeholder support* that is vital for PM success is also applicable to PBL, as attested by several student leaders in the Senior Design project. These students benefited from the critical role of their project sponsors who assisted them considerably in optimizing cost, time, and quality.

Result #3: *CL effectiveness enables tackling of inevitable and necessary changes proactively, collaboratively, and resolutely.*

As Heraclitus, the ancient Greek philosopher (535 B.C.–475 B.C.) said, “Change is a constant” (Kahn, 1979). This is true of a PBL environment as it is based on PM principles. The uncertainties at the beginning of a project make it difficult to accurately predict resources, manpower needs, exigencies, and regulatory changes during the life of a project. Moreover, for CL strong leadership is critical (Fullan, 2008, 2011). CL has to be proactive, with good team collaboration and a coalition of support to make the changes effective, and even productive (Kotter, 1995).

As changes can be expected or unexpected, *CL has to be anticipative and proactive* in order to minimize any negative fallout from the change(s). Resolute progress is needed towards making the changes a reality against possible resistance (Fullan, 2011; Maloney, 2009). Resolute CL needs the active collaboration of the team members, avoidance of needless changes, and marshalling of resources proactively to brace for inevitable changes. Regular rescheduling and goal-setting would be needed in the PBL environment to incorporate CL in the most effective manner.

In general, the primary task of CL should be to *minimize changes and to recoup rapidly* from unexpected and deleterious changes in the project environment. Above all, *clear communication and speedy conflict resolution* are crucial for effective CL as a key component of PBL that can accommodate both expected and unexpected changes. It is also important to factor the inherent risks associated with changes in the project, and to minimize the negative impacts of these risks.

Result #4: *Best practices in PBL require strong leadership, coupled with holistic competence in SDL, PM, and CL.*

Best practices in PBL require strong leadership. Fortunately, leadership skills can be acquired and strengthened through internal or external training, workshops, study, observation, and deliberate practice (French & Raven, 1959; Northouse, 2016). This is needed not only to rally the troops, but also to avail of a holistic view of the project, capitalize on the strengths and expertise of team members, and to exercise emotional intelligence and people skills (Turner & Müller, 2005).

A formalized structure of PBL learning is needed to forestall tendencies to suffer cost and schedule overruns, or detriments to quality. A structure with explicit roles, responsibilities, and accountability relationships, formal planning and scheduling, and a work breakdown structure (WBS) would go a long way towards effecting best practices in PBL through PM. Thorough front-end research, planning, and preparation of resources and stakeholder support would also be essential to effect best practices in PBL. Similarly, astute, proactive, and resolute CL would enable rigorous project controls in the event of both expected and unexpected changes.

In effective CL, best practice would require minimization of iterative changes to economize on time, cost, and tangible resources. Monitoring the project and consistently controlling for cost, time, and quality at all times is a necessary best practice in PM. Finally, the literature-based and observed SDL skills of autonomous learning, competitive spirit, and relentless quest for learning would contribute concretely to best practices in PBL.

Result #5: *Acceleration of PBL optimizes SDL skills, maximizes PM efficiencies, and enhances CL effectiveness to enable competitive and relatively stress-free outcomes.*

Acceleration of PBL is rooted in extreme efficiency and effectiveness in demonstrating best practices in PBL. First and foremost, *strong project leadership* is critical to rally the troops and move the project forward with a clearly set goal and minimal waste of time, funds, and other resources of the temporary organization. It is necessary to *induct competent and highly motivated team members* with prior knowledge of the essential features and requirements of the project, together with a reasonable diversity of expertise.

The PBL experience is not only team-oriented; it also needs a constant and *strong network of external support*, including that of the project sponsor, consultants, and advisors. Thus, PBL involving innovative technology projects would have both internal *and* external support. Such a reliable network of internal and external support enables acceleration through availability of needed funding, specialized knowledge, equipment, and facilities. An extended network can also garner recognition for the team members, and enhance employment opportunities for them towards closing the employability gap.

From an interpersonal perspective, a PBL environment that is riddled with festering conflict could thwart efforts at acceleration. Therefore, *speedy conflict resolution*, high morale, and a convivial atmosphere would be essential for acceleration of PBL. Finally, there is no substitute for every member of the PBL team being *committed to excellence*. In this context, a relentless momentum in executing the project is of paramount importance. This requires zero tolerance for slackness, delays, miscommunication, slipshod work, needless iteration, and a reactive approach. Thus, a proactive, resolute, and positive approach to PBL is critical to acceleration of the project.

The five results and interpretations discussed will contribute cogently and in concert, to resolving the three research questions in Chapter 5. The resolved research questions set the stage for the proposal of an accelerated model of PBL. They also formed the basis for the final recommendations laid out in Chapter 5.

Summary

The data analysis undertaken was that of a comprehensive, mixed-methods approach to derive both breadth and depth of findings in this explanatory study of project-based learning (PBL). The essential goal of this research approach was to tackle the given research questions from multiple angles. Where appropriate, this holistic endeavor availed of previous research and practice and plural investigative perspectives. The mixed-methods research offered in-depth, contextualized, and natural—but more time-consuming—insights of qualitative research (Patton, 1990), coupled with the more efficient and broad-based quantitative research for summary findings and *a priori* congruence with contemporary literature evidence.

In Phase 1, the focus of the quantitative and qualitative methods employed was on SDL and CL respectively, as these two were specifically covered through the quantitative questionnaire (for SDL) and the qualitative open-ended questions (for CL), of the SDLRS-A® Survey. The SDLRS-A® questionnaire gathered quantitative information to assess the current SDL skills, values, and attitudes of all 30 Senior Design students targeted in an ET program at M University. It was determined that the overall mean score of the students was nearly 7% *higher* than that of the adult population mean SDLRS-A® questionnaire scores of the population at large. This may suggest that the ET students were adequately prepared in SDL skills through their scholastic (and possible internship/work experiences).

The three open-ended questions on change leadership and change processes attracted textual responses from nearly all the 30 students. Many valuable ideas were garnered through the written responses of the students—including the need to be proactive and resolute in tackling changes in the project, to communicate clearly, and to resolve conflicts speedily. It was also deemed necessary to maintain sufficient momentum and resolve to overcome possible resistance, and to execute changes cooperatively and collaboratively.

The key statistical and demographic findings were that the internal reliability of the sample was high at 0.920 (comparing favorably within the *a priori* range of 0.79 to 0.96), The student sample was reasonably representative of the campus-wide population—except for low female representation. This is reflective of the current national trend of only around 25% female representation among engineers in the US. It also points to the need to encourage STEM education among female learners at high school and college levels.

The study conformed to the *a priori* SDL factors of Self-Management of Learning (SM), Desire for Learning (DL), and Self-Control in Learning (SC). Components of these three factors were clearly manifest in positive SDL experiences, skills, and attitudes of the ET students in the Senior Design course.

The Phase 1 qualitative research findings from the three open-ended questions confirmed that a strong foundation in Term 1 of the three-term Senior Design course was imperative for the students to sustain momentum in their PBL experience, and thus succeed in timely delivery of an innovative and working prototype. It was clear that change is inevitable and is iterative in nature through the planning, design, and construction phases. The pooling of knowledge and experience with the advisor and external experts and peers (see Chapter 2, Figure 7, p. 29) was necessary to ensure significant learning, hands-on expertise, and actionable knowledge that can be built upon for life-long learning.

The qualitative research of Phase 2 findings provided rich data on SDL, PM, CL, and PBL from the responses of both student leaders and faculty advisors. Proactive planning, designing, and resource management were deemed to be necessary to enhance control of changes and cost-and-time overruns. The expertise of external stakeholders such as the project sponsors, industry experts, and consultants cannot be underestimated; indeed, these entities can be sources of needed funding, technical expertise, well-equipped workspace, and time-saving innovations.

Frequent face-to-face meetings enabled more transparent and fluid communications, minimized conflicts, and enhanced problem-solving skills. A major benefit of PBL is the sharing of valuable knowledge and experience with peers, experts, and educators. All of these efficiencies, knowledge transfers, and proactive leadership can contribute significantly to acceleration of the capstone project with efficiency, economy, and momentum. In view of these reflections and findings, the results of the study are presented as follows:

Result #1: *SDL skills are essential to PBL as it motivates autonomous performance, desire for learning, self-efficacy, and interdependencies in a project team.*

Result #2: *PM efficiencies are needed in PBL for optimal cost, time, and quality management to minimize cost overruns, to avoid delays, and to enhance quality.*

Result #3: *CL effectiveness enables tackling of inevitable and necessary changes proactively, collaboratively, and resolutely.*

Result #4: *Best practices in PBL require strong leadership, coupled with holistic competence in SDL, PM, and CL.*

Result #5: *Acceleration of PBL optimizes SDL skills, maximizes PM efficiencies, and enhances CL effectiveness to enable competitive and relatively stress-free outcomes.*

Overall, Chapter 4 presented these results of the empirical analysis in depth, and substantially provided theoretical and empirical support to prepare the ground to convincingly address the three research questions. The overall results of the Phase 1 SDLRS-A® Survey were presented using: Microsoft Excel 2016 for the demographics; SPSS 24.0 for the quantitative component; and, NVivo 11 for the qualitative analyses. The results of the semi-structured interviews in Phase 2 were analyzed using textual software Leximancer 4.5 for the qualitative analysis. These focused and succinct exercises enabled completion of the findings, themes, results, and interpretations in the study of SDL, PM, CL, and PBL. These in turn comprised a solid basis for presenting cogent conclusions of this study, as well as thoughtful recommendations for current and future practice and research in higher education technological environments.

Chapter 5 thus presents the conclusions of the research and offers cogent recommendations arising from the study. Solutions to the research problem have also been rendered by addressing the three research questions systematically. The discussion includes final deliberations as they relate to the literature reviewed for this study in Chapter 2, aided by the multi-methods research approach crafted in Chapter 3, and the multi-pronged analysis and interpretations of Chapter 4. Chapter 5 thus proposes an accelerated model of PBL as mooted at the outset in Chapters 1 and 2.

The key contributions of this study, and recommendations for actionable solutions to the research problem and for future research, are also presented in Chapter 5. Thus, the findings, results, and interpretations of Chapter 4 provided a concrete basis for offering cogent conclusions and making actionable recommendations for application. in the foreseeable future.

Chapter 5: Conclusions and Recommendations

Introduction

This study of project-based learning (PBL) sought to present a promising and pragmatic page from the evolving 21st century vision of expanding educational opportunities, technologies, and methodologies on a global scale. Specifically, as one among several inquiry-based approaches to learning today, PBL is a departure from traditional *transfer* of knowledge, as in the historical art of Grecian pedagogy, to a *transformation* of knowledge. To this end, PBL is fuelled by a learner-centric approach that compels autonomy, demands self-motivation, and promises the joy of discovery.

Ideally, the learner would seek to render the learning experience acceptable, actionable, and even accelerated. The learning outcomes are targeted to impress a spectrum of stakeholders, not the least being potential employers. Like most popular socially-constructed phenomena, PBL as an inquiry-based learning method deserves to be examined. Indeed, its practice in a competitive, technology-infused and information-intensive environment also needs to be optimized to harness its full potential.

Although PBL is becoming a methodology of choice in educational institutions at various levels, it seems to thrive best at the volatile interface between education and employment. It is lamentable that industry is unable to absorb graduates from educational institutions on an as-needed basis (ILO, 2010). This is apparently due to incompatibility with job requirements in a fiercely competitive and innovation-driven environment of constant change (Fullan, 2011). Particularly poignant in this turbulent scenario is the turnover of technology in a spectrum of industries. It is understandable that educational institutions are straining to keep pace with the dynamic needs of a tech-savvy and sophisticated industrial environment. Clearly, there is a call for learning approaches that enhance employability and strive to close the employment gap—and the *employability* gap—as two sides of the same coin (ILO, 2010; O'Kane, 2010).

Despite the growing popularity of PBL, there does not seem to be a formal model of this industry-relevant learning methodology in educational institutions. This is probably because of the combination of diverse skills, values, and interdisciplinary approaches in the makeup of PBL that makes it a conceptual challenge.

The mixed-methods study embarked upon in this research delved deep into the literature, and parsimoniously extracted four interdisciplinary concepts as foundational to a robust PBL model. These are: Self-directed Learning (SDL), Project Management (PM), Change Leadership (CL), and, Project-based Learning (PBL). It is contended that enhanced SDL skills, streamlined PM efficiencies, and dynamic CL effectiveness would render such a robust PBL model widely applicable for actionable, employment-ready outcomes for the Senior Design capstone project participants.

To empirically examine the concept and methodology of PBL, a year-long Senior Design course was targeted for its application of an informal framework of PBL. The Engineering Technology (ET) program at M University was chosen for this study due to its mission to apply engineering and technology in a scientific manner to solve real-world problems (Mills & Treagust, 2003).

The study sample was relatively small (30 ET undergraduate senior students), but there was 100% participation with all the 30 students responding to the survey voluntarily (see Appendix I, p. 201, for the permission letter from the ET department head to pursue the research). Subsequently, one-on-one interviews were conducted with six student leaders from among the eight capstone projects, and six faculty advisors who advised from one to three of these capstone projects (see Appendix R, p. 210, for a sample interview transcript). The final-year undergraduate students in the ET program were also required to pass the Senior Design course, culminating in a working, innovative, and real-life-relevant prototype for successful graduation in Spring 2016.

A crucial factor was the intermediation of cooperative capstone project advisors as ‘honest brokers’ between the researcher and the students. The consequently high level of participation by the students in the research proved to be a testimony to this fact. The intermediated trust-building with the participants; persistence of the researcher; and, the layer of anonymity by numbering the SDLRS-A® instrument from #S1 to #S30 (thus de-identifying the students)—all of these factors played significant roles in this achievement.

Conclusions

The purpose of this study was to examine an existing framework of PBL in an Engineering Technology (ET) program, and propose a literature-based model of PBL that synthesizes SDL, PM, and CL as key enablers and accelerators of innovative technology diffusion through PBL.

This research has been empirically accomplished by studying the implementation of eight capstone projects by small groups of three-to-four final-year ET students applying PBL to implement these projects as a requirement for successful graduation. Drawing from the wellspring of supporting evidence that was presented in Chapter 4, these conclusions have been succinctly derived and consolidated in the context of responses to the three research questions initially posed in Chapter 1.

Research Questions

This study commenced with a statement of the research problem and the crafting of three research questions in Chapter 1 (p. 16). The research questions were aligned with focusing the literature review of Chapter 2 on four research streams (SDL, PM, CL, and PBL) that directly undergirded the three research questions. Based on this theoretical foundation in Chapter 2, a suitable mixed methodology was devised for the primary research in two contiguous phases in Chapter 3. By applying the quantitative and qualitative methods in the mixed-methods research, complex analyses were conducted in Chapter 4 towards a cogent resolution of the overall research problem by succinctly addressing the three research questions. These three interrelated research questions are reiterated from Chapter 1 (p. 16) as follows:

Research Question #1. What is the extent to which self-directed learning skills are applied by final-year Engineering Technology students in project-based learning, as determined quantitatively through the Self-Directed Learning Readiness Scale (SDLRS-A®)?

Research Question #2. How are self-directed learning skills, project management efficiencies, and change leadership effectiveness applied in the implementation of Engineering Technology capstone projects?

Research Question #3. What are the best practices to accelerate project-based learning by employing self-directed learning skills, project management efficiencies, and change leadership effectiveness?

In Table 20 (p. 146), these three research questions have been broken down into abbreviated versions of the five themes presented in Chapter 4 (see Figure 17, p. 129). These five themes were abstracted from the quantitative and qualitative research findings in Chapter 4, and supported by relevant literature. Table 20 (p. 146) depicts the plan of resolution of the research questions, and shows the correspondence among the following: the three Research Questions posed in Chapter 1; the four (4) Research Streams discussed in Chapter 2; and, operationalization of the mixed-methods research design of Chapter 3—to yield 11 Findings, five (5) Themes, and five Results that emerged from the detailed analysis in Chapter 4. This concluding chapter (Chapter 5) is the logical culmination of these earlier, progressively constructive and consolidated chapters—Chapters 1 to 4.

Resolution of the research questions.

The results and interpretations in Chapter 4 of the mixed-methods study confirmed that SDL, PM, and CL contributed to a robust PBL model as proposed in this chapter. This model was designed to be formalized for best practices, and also accelerated for economy, speed, and opportunity. Conclusions of this multi-pronged study are presented here in Chapter 5 from the findings, results, and interpretations of the empirical outcomes of Chapter 4, and from the literature evidence of Chapter 2. Also, recommendations are made subsequent to resolving the research questions herein. Subsequently, further development of the learner-centric PBL model, and the crafting of a validated PBL instrument can be expected in the foreseeable future. This study is thus geared to formalizing the use of PBL in a proactive, pragmatic, and productive manner.

It is hoped that the incorporation of PM efficiencies, SDL skills, and CL effectiveness will render PBL an outstanding tool to foster deep learning. With its hands-on approach, it should also enhance employability, and thus minimize the employment gap. This is poignant in technology-intensive settings that are characterized today by high technological turnovers that are fuelled and punctuated by disruptive innovations. Table 20 presents the plan of resolution of the three research questions, linking them to the research streams, themes, methodology, instruments, and, analytic technology.

Table 20

Plan of Resolution of the Research Questions

RQs	**Abbreviated Themes**	**Research Streams**	**Methodology**	**Instrument**	**Technology**
RQ#1	**Theme #1:** Use of Self-Directed Learning Skills	SDL	*Quantitative* (Phase 1)	SDLRS-A®	SPSS 24.0
			Qualitative (Phase 2)	One-on-one PBL Interviews	Leximancer 4.5
RQ#2 RQ#3	**Theme #2:** Effectiveness of Change Leadership	CL	*Qualitative* (Phase 1)	Open-ended CL Questions	NVivo 11
			Qualitative (Phase 2)	One-on-one PBL Interviews	Leximancer 4.5
RQ#2 RQ#3	**Theme #3:** Application of Project Management Efficiencies	PM	*Qualitative* Phase 2)	One-on-one PBL Interviews	
RQ#2 RQ#3	**Theme #4:** Best Practices in PBL	PBL	*Qualitative* (Phase 2)	One-on-one PBL Interviews	
RQ#3	**Theme #5:** Acceleration of PBL				

Table 20 (p. 146) revisits the parallel association of the three research questions introduced in Chapter 1, with the four research streams and the two phases introduced in Chapters 2 and 3 respectively. The in-depth literature review of Chapter 2 enabled examination of the four literature streams: SDL, PM, CL, and PBL (see Table 21). The literature streams were chosen for deeper understanding of these four key constructs underpinning the three research questions. The empirical research from Chapter 4 operationalized the applicability of SDL, PM, CL, and PBL—thus serving to resolve the research questions to support the construction of a robust model of PBL.

Table 21

Resolution of the Research Questions through Research Streams

Research Questions (Abbreviated)	**Research Streams**			
	SDL	**PM**	**CL**	**PBL**
	Study Phases			
	1 & 2	**2**	**1 & 2**	**2**
1. Were SDL skills *personally* applied in PBL?	☑			
2. Were SDL, PM, CL concepts *applied* to projects?	☑	☑	☑	
3. Was PBL *accelerated* through SDL, PM, and CL?	☑	☑	☑	☑

Through the study Phase 1 and Phase 2, the three research questions delve into practical aspects of the four research streams: SDL, PM, CL, and PBL. To accomplish this in breadth and depth, a mixed-methods approach was deliberately applied in the two contiguous phases, drawing from the convenience sample of 30 ET students, and six faculty advisors for their Senior Design capstone projects.

In Phase 1, the quantitative, 58-item SDLRS-A® questionnaire examined the familiarity of the 30 students with the concept and practice of SDL. In the qualitative part of the Phase 1 study, students' hand-written responses regarding how CL was applied in their capstone projects through each of the three terms of the Academic Year 2015-2016 were analyzed. Specifically, their understanding of change leadership and change processes was examined. Interestingly, these reflections by the students did not strictly confine themselves entirely to CL: they inevitably touched upon the other three literature streams (SDL, PM, and CL) to varying extents. This spontaneous spillover and overlap of these cognate literature streams undergirding PBL proved the pragmatic interlinks among them from the theoretical evidences (see Chapter 2, Figure 7, p. 29).

Similarly, the Phase 2 qualitative research of their respective capstone projects by six student leaders, as well as the six faculty advisors, encompassed the application of the four literature streams undergirding PBL practice. This has been amply demonstrated in Chapter 4, and has also been succinctly captured in Table 21 (p. 147). Drawing from the findings, themes, results, and interpretations of Chapter 4, the three research questions guiding this study have been addressed in the following discussion.

Research Question #1: Were SDL skills personally applied in PBL?

It can be seen from Table 20 (p. 146) that the SDLRS-A® Survey in Phase 1 of the study focused on SDL, and answered Research Question #1 as to whether SDL skills were personally applied to PBL. From the Phase 1 results of the SDLRS-A® questionnaire, it was seen that the students were reasonably familiar with SDL skills and attitudes as compared to the adult population mean in the academic community at large. The originators of the globally tested SDLRS-A® instrument have asserted that SDL skills are not innate, but can be improved with self-motivation and training.

Therefore, the proportion of students who had average (6 out of 30 students = 20%) and below average (5 out of 30 students=17%) scores on the SDLRS-A® Survey have ample scope for enhancing their SDL skills. With 50% of students having a cumulative GPA of above 3.00 it is evident that they entered their final year with above-average scholastic preparation for undertaking the challenging Senior Design course involving the innovative technology-based capstone projects.

The necessity to have academic and technical competence prior to embarking on PBL is critical for application of SDL skills which requires considerable autonomy and self-motivation, as well as sufficient technical competence. It is also crucial to have a solid foundation in STEM education in order to harvest the benefits of innovation. Therefore, students with cumulative GPAs below 3.0 out of 4.0 could avail of opportunities to strengthen their technical background with training and experience. According to one of the Phase 2 interviews (by student leader SL6), it was seen that a *quest for excellence* and encouragement by others could serve as dynamic motivators for SDL. Also, the *altruistic motive* of service to the community helped in focusing SDL towards this exercise of citizenship, which was also an inspiring revelation.

It was theorized by Knowles (1975) that SDL skills are necessary for students entering academic programs as adult learners; otherwise they are likely to become frustrated, anxious, and afraid of failure in a fast-paced, competitive, and complex academic environment. This will also be a challenge for educators, as students with low SDL skills could fall behind those who do have a modicum of these skills in order to undertake PBL competently.

According to theoretical expectations, the SDLRS-A® Survey results reflected the three *a priori* SDL factors/constructs (see Appendix P, p. 208) that were convincingly evident in the sample of 30 students surveyed:

[a] Self-management of learning (SM) [b] Desire for learning (DL); and, [c] Self-control in learning (SC). Without a keen desire for learning and knowledge-seeking, it is difficult for the learner to pursue PBL, as learner initiative and autonomy are critical to PBL.

Also, the self-efficacy, self-confidence, and self-control of the learner can give the necessary boost to achievement springing from self-motivation (Pajares, 2002). When working without direct supervision by autonomous learning and knowledge-seeking, self-management of learning and time management become essential SDL/PBL skills.

The demographic profile of the undergraduate senior student sample indicated an imbalance in the representation of female students in the ET capstone project, as they comprised only 10% of the sample. This was not reflective of the general 50-50 gender split in the student population of M university from which the sample was drawn. However, it was closer to the approximately 20% representation on average, of female students pursuing various engineering and technology studies at M University. Though not generalizable for ET from the small sample of 30 students, it would still be encouraging to see more female participation in the Senior Design project.

Unfortunately, the national evidence on female participation in engineering and technology is suboptimal, as only 25% of the engineering workforce in the US is female. Orientation to STEM (Science, Technology, Engineering, and Mathematics) education by female students early in their scholastic career may serve to achieve this goal. This is because there is evidence that STEM-trained students are more likely to enter and succeed in technology-intensive programs such as ET (Camera, 2015).

In the personal application of SDL skills by students, it was interesting to note from the findings of Chapter 4 that a ‘competitive spirit’ was a motivator for SDL—

even though there was no indication of this in the SDLRS-A® instrument. Having a competitive spirit does seem to be a plausible harbinger of SDL, as it can enhance self-motivation, drive, and focus towards goal achievement in relation to potential or actual competitors in the higher education arena.

Similarly, empirical evidence from this research suggests that *interdependence*—as distinct from the independence inherent in autonomous learning—is a valuable trait in the socially constructive setting of a capstone project. Team members need each other in PBL. Finally, profession of an *altruistic* motive in SDL—as opposed to a self-seeking motive—was a laudable outcome of the empirical research. Interdependence and altruism are not traits included in the SDLRS-A® instrument, but they do provide food for thought. Clearly, 'self-directed learning' is not quite synonymous with 'self-seeking learning'! This study has shown that SDL in practice has a strong social constructivist element, seeking interdependence, competition, and self-motivation toward goal-attainment—rather than a focus on self.

Research Question #2: Were SDL, PM, and CL concepts applied to projects?

Houle (1961) identified three possible, related categories of adult learners: (a) *goal-orientated,* whereby the learner is focused on a specific goal; (b) *activity-oriented,* wherein intrinsic satisfaction is derived from the physical or mental activity and the social impact thereof; and, (c) *learning-oriented,* wherein the learning experience is of paramount importance. Guglielmino et al. (2004) contended that it is the third group (learning-oriented) that can be associated with SDL.

However, this research has demonstrated that for the Senior Design project using innovative technology, all three approaches to learning are required, thus expanding the scope of SDL—and spilling over to the goal-and-activity-oriented realm of PBL. This is because the students have to be *goal-oriented* to complete their capstone project as a condition for graduation; intensive group dynamics and change processes in the projectized environment require high *activity-orientation;* and, the academic goal of earning the undergraduate ET degree through PBL requires a strong *learning-orientation.* Such a desire for learning is needed for complex theoretical study (evidenced by cumulative GPAs—see Chapter 4, Table 5, p. 81) from the very inception of the ET program. This *triangulation* of SDL components (Learning-oriented→←Activity-oriented→←Goal-oriented) for innovative technology projects deserves due consideration for buttressing a robust model of PBL.

From the analysis of the textual, qualitative component of the Phase 1 study through three open-ended questions on change leadership (CL) and change processes, there was consensus that *change is inevitable in a project* (Sohmen, 1990). This was because of the high levels of uncertainty, risk, and unpredictability inherent in events, resources, logistics, and human performance during the project lifespan. Primarily in the construction phase of the project, the prototype had to be re-designed, re-built, re-tested, and refined for presentation at the end of the Academic Year 2015-2016. These activities involved significant changes and iterations (see Chapter 2, Figure 6, p. 27).

Therefore, key conclusions of the open-ended responses revolved around the need to be *proactive, collaborative*, and *resourceful* regarding inevitable changes in the project. There was also the need to seek and share knowledge, experience, and expertise with peers, advisors, lecturers, sponsors, and consultants. Furthermore, it was important to do *thorough front-end planning* and early project controls towards a successful project outcome. Waiting for disaster to strike—and then to react—would be unwise: the unexpected can be damaging or devastating to the project and its stakeholders without the critical front-end planning and preparation.

The above-average scores by a majority of the ET students in the SDLRS-A® Survey (see Table 7, p. 84, and Table 9, p. 88) coupled with student leaders' confirmation of SDL practice indicated that SDL was indeed applied by a significant number of students. In Chapter 4, Table 10 (p. 89) reflective and objective evidence is presented of the majority of the students applying SDL to their capstone projects.

Results of the 12 interviews suggested that a *competitive spirit* was a motivator for SDL, which translates into enhanced self-motivation by the engaged learner in a competitive environment. Such a competitive spirit helps in teamwork for within-teams as well as between-teams competition. This in turn can accelerate learning in the capstone project. Another finding from this empirical study is that SDL can engender an *altruistic motive* with the laudable goal of service to others in a spirit of citizenship and social responsibility. The application of SDL within PBL could thus provide a strong incentive for hands-on service initiatives towards good citizenship.

PM was not formally incorporated in the Senior Design course—though supporting concepts extracted by the Leximancer software in Phase 2 of the study, such as 'prototype', 'time', 'team' and 'skills' gave evidence of its practice. It was clear from Phase 1 and Phase 2 of the study that early planning, preparation, designing, prototyping, advising, and PM during the Fall 2015 term laid a solid foundation for successful completion of the capstone projects in the ensuing Winter 2016 and Spring 2016 terms.

It was also clear that iterative changes to the capstone project were inevitable through the three terms, and exchange of ideas drawn from the knowledge and experience among students, faculty advisors, sponsors, lecturers, and consultants was necessary for problem-solving and sustained progress (see Figure 7, p. 29). In fact, more than one-third (36%) of all jobs across all industries worldwide are expected to involve complex problem-solving as one of the core skills needed for success (World Economic Forum, 2016). This skill would be critical to navigate bottlenecks in a dynamic project, as due to high uncertainty, unexpected problems are inevitable, especially early in the project.

From the Phase 2 interviews, project team leadership was proven to be critical. Predetermined milestones and the final deadline for project completion in Spring 2016 were the real drivers to stay on schedule, under budget, and with acceptable quality (see Chapter 2, Figure 9, p. 34—The Dynamic Triple Constraints of Project Management). Under such circumstances of extrinsic motivation, the tendency was to be reactive in PM, rather than proactive, rooted in the self-motivation intrinsic to SDL. Obviously, a proactive, rather than a reactive stance puts the project participants in a stronger position.

Indeed, there are many benefits to adopting a robust PBL model: students will become well-prepared for project work when they secure employment; they will have learned the practical routines of companies; and, they will be able to communicate better with customers and users (Gjengedal, 2000). A student leader (SL4) rued and highlighted the lack of a formal PBL model in the ET program at M University by stating that, “the PBL model was not strictly clarified; rather, it was assumed to be inherently understood.” This was echoed by a faculty advisor (FA2) who confessed that he was “unaware of the existence of a ‘PBL framework’ until late in the third and final (Spring) term”.

However, there were indications of informal practice of PBL with planning, designing, teamwork, and learning. Advisors helped to shorten the students' 'learning curve' by sharing their expertise in innovative technology.

The conclusions of the Phase 1 SDLRS-A® Survey and Phase 2 interviews of six student leaders and six faculty advisors enabled a grassroots-level understanding of the challenges of the capstone project work. Specifically, Research Question #2 asked if SDL, PM, and CL were *applied* to the projects (hence, to PBL). The short answer to the question based on participants' responses was that they were indeed applied to various extents**—**but "unevenly" through the project phases, according to faculty advisor FA5. The candid reflections of the student leaders and faculty advisors highlighted some of the challenges and promises involved in applying SDL, PM, and CL to the projects.

For instance, there was no formal integration of the PBL framework through the three terms of the Senior Design Course, but there were indications of *informal* practice of PBL employing planning, designing, learning, and teamwork, with the help of advisors. Consequently, as observed by student leader SL3, plans had to be modified according to "each team member's skills, strengths, and expertise". A faculty advisor (FA5) pointed out that as the phases were "uneven", the activities were sometimes unpredictable. It was apparent that there was a lack of formal SDL, PM, and CL in the projects. However, varying levels of project success were evidenced in the research.

It was good to have the perspectives of both advisors and student leaders. Several faculty advisors (FA1, FA3, FA4, and FA5) made a few suggestions for best PBL competencies. These suggestions based on their PBL experience, included the following:

1. **Proactive conflict management** by helping the team to resolve any disagreement quickly and efficiently through discussion and voting;
2. **Strong team leadership** by appointing or approving a competent leader and motivating the team to exceed their own expectations;
3. **Better stakeholder management** by early identification, engagement, and communication with stakeholders throughout the project life;
4. **Clear goals** and agreement amongst the team members, advisors, and other faculty;
5. **Timely feedback** from the advisor(s) that would be both constructive and actionable;
6. **Project controls** to avoid unplanned and undue extension of the original scope—commonly known as 'scope creep'; and,
7. **Proactive logistics management** with detailed guidance on specifications, deliveries, and deliverables as early as possible in a timely and cost-effective manner.

Students usually work more and get better results from project-oriented work, rather than through classroom lectures (Guy, 2009). Teamwork is also applied in this process, and team-building improves the social life of students (Bass, 1985; Bell, 2010). Better communication, team dynamics, and problem-solving can be realized through application of SDL, PM, and CL in PBL. It was interesting to note from the study that students actually *applied* all these four concepts in their capstone projects, without formal knowledge of the four literature streams: SDL, PM, CL, and PBL (see Table 21, p. 147).

Research Question #3: Was PBL accelerated using SDL, PM, and CL through best practices?

Technology can be infused to enhance PBL competencies as acceleration is facilitated by use of modern learning technologies such as Chromebooks, tablets, Cloud computing, and 'smart' devices—as well as audiovisual software, platforms, and websites (Parr, 2015). It would therefore be necessary to make suitable use of technology that facilitates acceleration of PBL, both onsite and remotely (Howard, 2002; Parr, 2015). To increase project efficiency, one faculty advisor (FA1) suggested more use of *modular components,* as this would increase speed, lower costs, and even improve quality. The lecturers and advisors helped with efficient design of the projects, whereas willing and available sponsors assisted with financing and cost-cutting measures. As student leader SL4 suggested, an incentive for cost-efficiency was to strive to make the prototype product available at the *lowest possible cost, consistent with competitive quality*. *Telecommuting* also helped with controlling the schedule whenever possible by utilizing commuting time towards scheduled offsite project activity to move the project forward.

Nonetheless, to accelerate the project, it was deemed necessary for the team members to have *face-to-face meetings* frequently—for example, twice a week. In the Senior Design projects, according to student leader SL4 and faculty advisor FA5, such judicious use of face-to-face meetings contributed to project acceleration through transparent communication, speedy conflict resolution, and onsite team reaction to unexpected changes.

A working relationship with enhanced team dynamics was thus established with team members. Allocating work according to the skills and strengths of team members enabled acceleration through astute division of labor. This injected efficiencies in executing the prototype through PBL through the planning-design-implementation phases. These regular, face-to-face meetings could also expedite problem-solving and decision-making through methods such as brainstorming for creative solutions.

Economic use of time was also necessary through motivation and team dynamics, including prioritization of selected elements of the project work. For this, faculty advisor FA3 suggested that maintaining a tight schedule with some slack for contingencies, and to “stick to the schedule” would be crucial to ensure an accelerated PBL. According to faculty advisor FA3, the project schedule needed to be “locked down” rather than be allowed to “float”. For this, formal planning, goal-setting, collaboration, control, and scheduling/rescheduling were critical. Pronounced SDL skills would be useful for PBL efficiency and acceleration, as it relates to the desire for learning and taking the initiative to learn. Thus, inducting team members with genuine interest in the project and essential understanding of its complexity would be necessary for acceleration.

Thorough front-end research for feasibility and contingencies, as well as marshaling optimal human and material resources before start of the project, would therefore enable project acceleration, hence PBL. Adequate human resource support was considered essential by both student leaders and faculty advisors for acceleration of PBL. Thus, assigning *clear roles for each person* and setting performance standards and accountability through meetings could help to keep the project on target with minimal wastage of time, funds, and tangible resources.

Networking with outside sources of assistance such as the project sponsors, experts, and consultants throughout the project life could save much time by minimizing trial-and-error in the design and construction of the prototype. According to student leaders SL1 and SL4, *sponsored* projects generally moved forward faster, as sponsors' advanced facilities were made available for more efficient and speedier work.

Also, proactively *meeting with experts prior to the project* for their advice enabled accelerated progress with PBL. In this context, prior acquisition of foundational and specialized knowledge by the project leader and project team members could speed up PBL by obviating the need to learn relevant material anew during the project phases.

Quality of work, processes, and product are important considerations for acceleration of PBL. Poor quality results in rework and waste of time, manpower, and resources. A synergistic combination of *accelerated* SDL, PM, and CL also impacts quality of the product in terms of reduced time, creative idea-generation, and lower costs. The quality of the prototype, product, or service is considerably (and rapidly) enhanced with highly focused human resources, processes, equipment, and material.

In sum, both student leaders and faculty advisors of the capstone projects conceded that acceleration of PBL was quite possible with *hard work, discipline, prior preparation, control of changes, and, biweekly face-to-face meetings*—as well as a relentless focus on time management. It can be seen that an accelerated approach to SDL, PM, and CL contributes intuitively and constructively to accelerated PBL.

A Synthesis of the Research Questions

In synthesizing the research questions, both theoretical and practical aspects of applying PBL need to be taken into account. Research indicates that a wide range of occupations will require a higher degree of cognitive abilities than were required in the past—such as creativity, logical reasoning, and problem sensitivity—as part of the core set of skills required of employees (World Economic Forum, 2016). The pragmatism inherent here is illustrated in the following observation by the International Labour Organization (ILO, 2010, p. 2):

> To keep training relevant, institutional and financial arrangements must build solid bridges between the world of learning and the world of work. Bringing together business and labour, as well as the government and training providers at the local, industry, and national levels, is an effective means of securing the relevance of training to the changing needs of enterprises and labour markets.

Change is inevitable in a dynamic ecosystem that is a rich medium for the diffusion of innovation. It is ideally orchestrated in a robust PBL model that is buttressed by best practices in SDL, PM, CL, and PBL. In the process, the demonstrated interplay among these four constructs become clear. In this context, various literature-based attributes of SDL, PM, CL, and PBL had emerged in Chapter 2, and were supported in the empirical results of Chapter 4 through their persistent occurrences. From the literature and empirical evidence, these attributes have been grouped in Table 22 (p. 162) under the descriptors of *accelerators, facilitators,* and *self-actualizers*.

At the First Tier in Table 22 (p. 162), it was seen that a few attributes were common to all four of these literature streams of SDL, PM, CL, and PBL. Thus, the following seven (7) attributes serve as core competencies and *accelerators* of a robust PBL model: Planning, Pragmatism, Time Management, Innovation, Knowledge Transfer, Change Management, and, Technology Diffusion. This suggests further that an infusion of SDL, PM, CL, and PBL should enable the crafting of a robust model of PBL. Necessary acceleration can therefore be realized by synergizing SDL skills, PM efficiencies, and CL effectiveness as essential elements to best practices in PBL.

At the Second Tier, the following eight activities and attributes were predominantly common for at least three of the four streams of: PM, CL, and PBL (thus excluding SDL). These eight (8) activities serve as *facilitators* of a robust PBL model: Communication, Cost Management, Employability, Group Collaboration, Leadership, Quality Management, Change Management, and, Risk Management.

In this context, it is noteworthy that many formerly technical occupations are expected to become more innovative and interpersonal in nature in the future (ILO, 2010); therefore, innovative technology projects such as the Senior Design project in ET will require significant interpersonal skills (see under the 'Cross-functional Skills' column in Chapter 1, Table 1, p. 14)—for persuasion, conflict management, and motivating followers as seen in Phase 2 of this study (World Economic Forum, 2016). These attributes can therefore be seen as *facilitators*, as they help to facilitate and consolidate PBL.

Finally, at the Third Tier, the following five (5) attributes were evident in at least two of the four streams of literature (SDL and PBL): Autonomy, Inquiry-based Learning, Life-long Learning, Self-discipline, and, self-motivation (see also the themes under SDL in Chapter 4, Figure 17, p. 129). These are *self-actualization* attributes of a robust PBL model, reminiscent of Abraham Maslow's Hierarchy of Needs (Maslow, 1943). Such intrinsic factors provide the deep inner motivation for the learner to be future-orientated (Scharmer, 2009). Also, PBL is inherently autonomous, informally drawing from the self-development aspects of SDL, PM, and CL (Gibbons, 2002; Stewart, 2007; Thomas, 2000).

Despite some subjectivity, plausible layers can be seen in the ranking and categorization of the largely literature-based activities and attributes identified in Table 22

(p. 162). It is encouraging to note from primary research, as well as *a priori* support that SDL skills can be enhanced through training, self-motivation, and self-reflection (Gibbs, 1988; Guglielmino et al., 2004; Merriam et al., 2007). As discussed earlier, these SDL skills were evident from the primary research also as necessary ingredients for best practices in orchestrating PBL.

Table 22

Grouping of Common Attributes: PBL, SDL, PM, and CL

No.	Attribute/Skill/Behavior	PBL	SDL	PM	CL	Common	Group
1	Planning	√	√	√	√	**4**	ACCELERATION
2	Pragmatism	√	√	√	√	**4**	
3	Time Management	√	√	√	√	**4**	
4	Innovation	√	√	√	√	**4**	
5	Knowledge Transfer	√	√	√	√	**4**	
6	Change Management	√	√	√	√	**4**	
7	Technology Diffusion	√	√	√	√	**4**	
8	Communication	√	-	√	√	3	FACILITATION
9	Cost Management	√	-	√	√	3	
10	Employability	√	√	√	-	3	
11	Group Collaboration	√	-	√	√	3	
12	Leadership	√	-	√	√	3	
13	Quality Management	√	-	√	√	3	
14	Change Management	√	-	√	√	3	
15	Risk Management	√	-	√	√	3	
16	Autonomy	√	√	-	-	2	SELF-ACTUALIZATION
17	Inquiry-based Learning	√	√	-	-	2	
18	Life-long Learning	√	√	-	-	2	
19	Self-discipline	√	√	-	-	2	
20	Self-motivation	√	√	-	-	2	

Change is inevitable in a dynamic ecosystem—such as in evident in a projectized environment—that is a rich medium for the diffusion of innovation (Sohmen, 1990). Such change is ideally orchestrated in a robust PBL model that is buttressed by best practices in SDL, PM, CL, and PBL. In the process, the demonstrated interplay among these four constructs becomes clear. Thus, various literature-based attributes of SDL, PM, CL, and PBL had emerged in the study, and were supported by the empirical results through their persistent occurrences.

A study by Kennedy (2013) has reinforced the dire need for more sensitivity and caution—consistent with urgency—regarding change processes in higher education settings. Faculty, students, and administrators tend to approach change from different standpoints, though these internal stakeholder groups generally agree on the need for constructive change. In a technology-infused ecosystem, it is incumbent upon learners—students, faculty, and administrators—to embrace new technologies. Clearly, PM efficiencies through controlling cost, time, and quality parameters (see Chapter 2, Figure 9, p. 34) are ideal to economically transfer innovative technology.

Simultaneously, there is indisputable evidence of resistance to change despite the obvious need for change—thus confirming the significant literature evidence to this systemic phenomenon (Kennedy, 2013; Kotter, 1995; Senge et al., 2012). In view of these facts, the importance of a *collaborative* approach to technology diffusion through such vehicles of transformative education as the capstone projects in the ET program cannot be underestimated. Such diffusion can be seen as part and parcel of CL effectiveness.

CL requires personal qualities and attitudes on the part of both leaders and followers for successful outcomes. The enlightening concepts of Theory U Leadership as propounded by Otto Scharmer (2009) urges change leaders to suspend superficiality, judgmental attitudes, and preconceptions in order to introspectively delve deep into the self and unravel the ‘blind spot.’ Thus, the true source of the inner self of the inquisitive learner is revealed. Thus, SDL, PM, CL, and PBL can work in concert to impel the inner self to overcome resistance and actuate self-motivation (Candy, 1991; Stewart, 2007).

This self-motivation can also be accomplished by deep and empathic listening with an open mind, open heart, and open will to ‘presence’ (presence + sense) the emerging future even as it occurs (Scharmer, 2009). This calls for deep introspection and reflection. Therefore, the change leader has to be inclusive, collaborative, and constructive in order to have optimal impact in the ecosystem—and ultimately even beyond, into the global arena. Thus, Fullan (2011), Kotter (1995), and Scharmer (2009) emphasize the need for group collaboration to effect meaningful change through effective CL.

Acceleration has become necessary due to the changing needs, as well as the competitiveness and progress of enterprises. There is also a necessity to craft practical strategies to accelerate diffusion of innovation in an academic setting (Lew, 2002; Parr, 2015). Indeed, the need for a *collaborative and cooperative approach* in an environment of efficient learning is imperative (Wurm, 2005). For the capstone projects of the ET program, such collaboration would combine the self-motivation and autonomy needed for SDL, with the systemic, systematic, and synergistic effectiveness of CL to incorporate necessary changes. Unproductive iterations of the project phases of the capstone project can thus be minimized to promote the acceleration of SDL, PM, and CL, and PBL.

Innovative leaders will consequently need to gravitate toward speed. To illustrate this, Figure 19 (p. 165) shows 360 results for 57,113 leaders who were rated on their speed of execution and their ability to innovate (Zenger, 2015). Slow-moving leaders with a propensity to inaction or extreme caution were, on average, at the 12th percentile on their ability to innovate; whereas, those who were high on acceleration were at the top 89th percentile, as depicted in Figure 19 (p. 165).

In a competitive environment therefore, it is not enough to merely harness technological innovation in 21st century higher education: it needs to be leveraged productively for *acceleration*. Such leveraging can be accomplished through: the efficiencies of PM principles, tools, and methodologies; self-motivated learning in SDL; and, overcoming possible resistance to acceleration, through CL. This synergistic acceleration of PBL thus becomes possible through a speedy, critical path of strategic and goal-oriented initiatives (Sohmen, 2007, 2010; Turner & Müller, 2005). Therefore, in a competitive, resource-constrained, and dynamic higher education environment, PM, SDL, and CL are needed in concert to construct an *accelerated* PBL model that can overcome resource constraints, inertia, and resistance to achieving measurable progress.

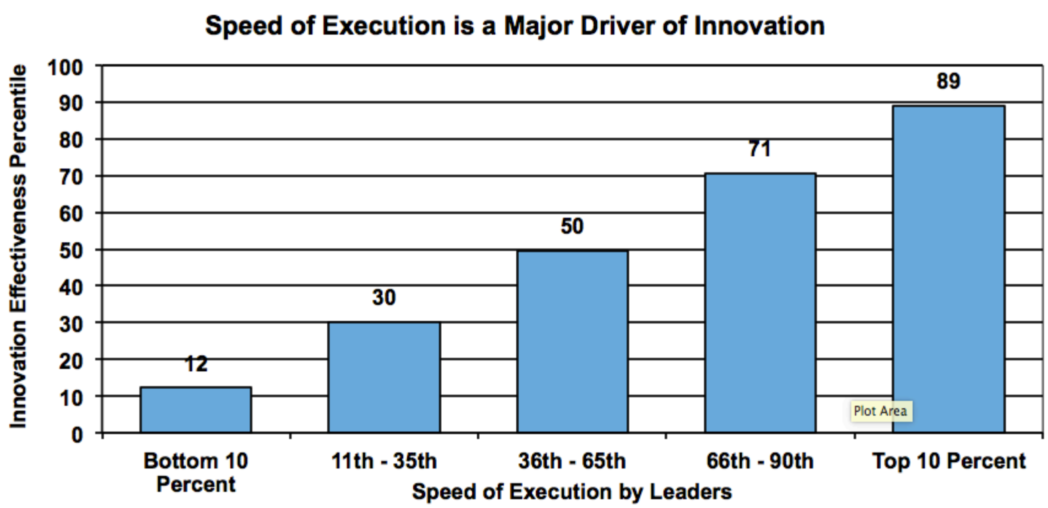

Figure 19. Relationship between speed of execution and innovation

Reprinted from: "Nine behaviors that drive innovation," by J. Zenger, 2015, *Forbes*.

Furthermore, *accelerated* progress has become necessary today due to increasing resource constraints, competition, and rising costs with relentless acceleration of innovation (Liebowitz & Frank, 2016; Zenger, 2015). There is thus a critical need for successful learning outcomes within compressed timeframes. This will enhance employability, while simultaneously decreasing the globally persistent employment gap (Bureau of Labor Statistics, 2016; Merriam et al., 2007; O'Kane, 2010; Parr, 2015).

In seeking best practices, an Australian study of engineering undergraduates comparing PBL and SDL deemed PBL to be strengthened by infusion of SDL (Stewart, 2007). This supports the idea that PBL is inherently autonomous, drawing from elements of SDL, PM, and CL (Gibbons, 2002; Stewart, 2007; Thomas, 2000). Therefore, effective PBL infused with SDL, PM, and CL should enable streamlined and purposeful diffusion of innovative technology in higher education.

This study examined the relative roles of SDL, PM, and CL within PBL as key drivers and accelerators of PBL. Thus, the three research questions posited have been addressed persuasively through adequate theoretical and empirical support (Machi & McEvoy, 2012). Armed with this support, a few suggestions have been made to enhance best practices in the acceleration of PBL:

- ***Leadership.*** Strong leadership is necessary for best practices in PBL. *Individuals with both technical skills and people skills are likely to make the best project leaders in the Senior Design projects.* Therefore, emotional intelligence (EQ) would be essential for the project leader (Turner & Müller, 2005). Individuals who also have context-relevant expertise are most appropriate for taking a leadership role in the capstone project.
- ***Team.*** Team members should be trained thoroughly in theoretical foundations and hands-on experience in technology *prior* to joining the project, and must be provided with clear roles and responsibilities. A healthy mixture of various

backgrounds and functional expertise would be beneficial in fostering creativity, collaboration, autonomy, and project acceleration.

- ***Innovation*****.** An innovative spirit should be encouraged in every aspect of PBL, as it fuels new learning, and seeks creative solutions (Gates, 2016; Zenger, 2015). SDL, PM, CL, and PBL in concert can enable continual and sustained innovation through necessary creative changes during the project.
- ***Change*****.** Every obstacle to change that moves the project forward expeditiously should be proactively, collaboratively, and persistently removed (Kotter, 1995).
- ***Transformational learning*****.** Rather than 'transferring information', learning should result in transformation to become *transformational learning* that goes beyond the learner's expectations (Bass, 1985). High-quality training outcomes depend on maintaining high quality of training contents, methods, facilities and materials. For best results, apprenticeships, internships, and work-studies provide a balanced combination of classroom-based and work-based training that promotes SDL, PM, CL, and PBL competencies.
- ***Competence*****.** Theoretical, technical, and experiential competencies are needed in PBL to undertake SDL, PM, and CL successfully in innovative technology projects. Experience, eagerness to learn, and self-reflection are critical for the learning process (Gibbs, 1988). These ingredients are thus crucial in PBL.
- ***STEM training*****.** There is an urgent need to train potential participants with necessary aptitude to undertake STEM training to facilitate entry into technology-infused programs. This is especially true of female and minority students, starting

as early as during their high school years through their formative years in a higher education institution (Bidwell, 2015; Camera, 2015).

- ***Sponsors and experts*.** It is important to cultivate and network with sponsors and experts in the field in order to transfer both tacit and explicit knowledge. This will enable acceleration by avoiding untested methods and actions that could cause problems, changes, and delays—and consequent loss of project momentum.

In sum, in resolving the three research questions, the succinct review of the four inter-related streams of literature—SDL, PM, CL, and PBL—demonstrated that best practices in PBL, as well as acceleration of PBL, can be accomplished through construction of a rich and robust model of accelerated PBL, infused with *accelerated* SDL, PM, and CL (see Figure 20, p. 170).

Proposed Model of Accelerated PBL

Models represent reality in a purposeful manner. They are theory-based, yet simplify theory by making intangible concepts more tangible, visual, and pragmatic. Models can combine compatible theories as in this study, bringing into convergence the diverse yet cognate constructs of SDL, CL, and PBL. The proposed model of accelerated PBL depicted in Figure 20 (p. 170) was targeted early in the study in its rudiments (see Figure 2, p. 9), as evidenced from the literature—and subsequently informed by a complex mixed-methods research approach and operationalized by empirical support. The model has been developed here in light of the earlier discussion of themes, subthemes, findings, results, interpretations, and conclusions. These progressive developments and reflections have resulted in developing the Model of Accelerated Project-Based Learning (PBL) presented in Figure 20 (p. 170).

The quantitative and qualitative analyses of the primary data resulted in identification of essential themes (see Chapter 4, Figure 17, p. 129) of an accelerated PBL model—through *enhanced* SDL skills, *streamlined* PM efficiencies, and, *dynamic* CL effectiveness. Accelerated PBL is thus represented in Figure 20 (p. 170) as a synergistic combination of 'Accelerated SDL', 'Accelerated PM', and 'Accelerated CL'.

Again, these three components are rooted in the literature evidence of Chapter 2, guided by the research methodology of Chapter 3, and enriched by the empirical findings and interpretations of Chapter 4. The requirements for each of these three accelerated components—of a consequently accelerated PBL—are admittedly complex. Nonetheless, these intrinsic and dynamic components of PBL (SDL, PM, and CL) with their subcomponents are encapsulated in Figure 20 (p. 170), and succinctly discussed.

PBL, with its related and overlapping components of SDL, PM, and CL (see Chapter 1, Figure 1, p. 6) studied in this theoretical and empirical research has clearly demonstrated the strong, logical linkages among these four multidisciplinary components (see also Chapter 1, Figure 5, p. 20).

First of all, in considering *Accelerated* **SDL** in Figure 20 (p. 170), the *passionate desire to learn* has to be genuine. Confidence in the learner's ability to learn will enhance self-efficacy. Also, self-motivation, self-management, and autonomy of the learner are key skills for the acceleration of SDL.

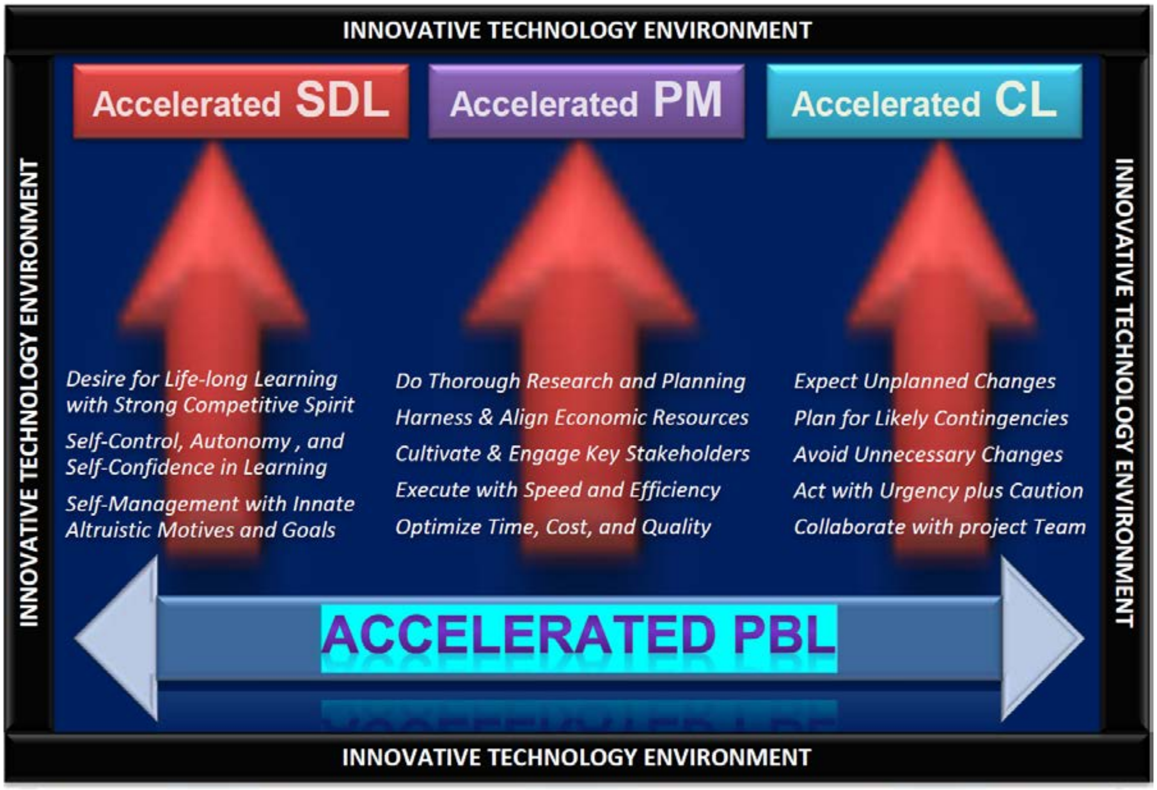

Figure 20. Model of Accelerated Project-Based Learning

Secondly, *Accelerated* **PM** involves thorough front-end research and planning, early harnessing of economic resources—and, the identification, engagement, and cultivation of stakeholders—even from the very outset of the project. Accelerated PM also requires speedy and efficient project execution through optimization of the Triple Constraints of time, cost, and quality (Sohmen, 2007). Thus, the potentially iterative loop of planning-design-construction can be relentlessly reduced by adequate forethought and early marshalling of resources in a systematic and systemic manner.

Thirdly, *Accelerated* **CL** proactively minimizes inevitable changes, and fosters the imperative need to control them persistently and resolutely. This requires early risk assessments and precise plans for expected and unforeseen risk and contingencies, and the avoidance of needless changes. As the term suggests, *accelerated* CL calls for swift, focused actions with a sense of urgency towards project success. Additionally, collaboration with the project team through effective communication and cooperation would be critical for accelerated CL.

Finally, *accelerated* **PBL** is a *synergistic combination of accelerated SDL, accelerated PM, and accelerated CL*. The resultant accelerated PBL model is geared to yielding optimal outcomes with minimal loss of time in rapidly evolving, 21st century higher education environments. Thus, costs are minimized, resources optimized, and quality enhanced. This study concludes that an accelerated PBL model can also work towards: minimizing the employment gap; fueling students' self-motivation; enabling rapid skill-building; and, instilling a deep commitment to life-long learning—in a technology-infused, information-intensive, and competitive global arena.

Key Contributions of this Study

By design and serendipity, this study has yielded a few contributions to academia, practice, and to the literature. These contributions need to be tested under a variety of situations to confirm, modify, or refute them, based on objective evidence and usefulness.

1. **Proposal of a new, literature-based model of a robust PBL.** A diligent search of the literature did not yield any literature-based model or validated instrument to operationalize PBL. A meta-review of PBL (Thomas, 2000) and cognate literature revealed that PBL is a complex and interdisciplinary social phenomenon, incorporating inquiry-based learning, leadership, and project management. Employing distillation and parsimony, three streams of literature (SDL, PM, and CL, in addition to PBL) were identified as being the most appropriate to compose a proposed theoretical model of PBL.

This preliminary PBL model (see Chapter 1, Figure 2, p. 9) was subjected to rigorous empirical testing in Chapter 4 using a mixed-methods approach to identify evidences of incorporation and overlaps of SDL, PM, and CL to garner best practices of PBL. Based on both theoretical and empirical evidence, an enhanced model of *accelerated* PBL has been proposed in this research (see Figure 20, p. 170).

2. **Introduction of an iterative model of project phases.** The *iterative* model of project management phases depicted in this research (see Chapter 2, Figure 6, p. 27) is a unique variation of the conventional waterfall model (see Chapter 3, Figure 11, p. 57). Unlike the typical industrial project with such stair-step fashioned 'waterfall' configuration and overlapping phases, the Senior Design project is a *learning* project. Learning is "an iterative process of questioning, data collection, reflection, and action" (Argyris & Schön, 1978, p. 50). The projectization of PBL naturally requires an iterative loop of planning-design-construction, with each of these phases linked to an overarching task of controlling/monitoring the project. Imbued with creativity, these iterations are also impelled by expected and unexpected changes in the planning, design, and construction of the prototype in an innovative technology project.
3. **Simultaneous use of two competitive textual analysis tools.** For the qualitative analysis of the study, NVivo 11 (see sample output in Appendices T and U, pp. 212-213), and Leximancer 4.5 (see sample outputs in Appendix BB, p. 220) have been employed for Phase 1 and Phase 2 of the study respectively. These have been briefly compared and contrasted.

Typically, only one textual analysis software is employed in a study of this nature. This comparison of two industry-leading textual analytic tools serves as an exemplar to inform researchers of the nature and quality of diverse, sophisticated graphical and tabular outputs that can be expected and utilized. In this research, Leximancer 4.5 and NVivo 11 have served a complementary function to promote both breadth and depth of the findings.

4. **Design of a projectized model of accelerated interview design.** As the window of qualitative research in the form of semi-structured interviews was limited to a few weeks at the end of Spring 2016 before the students graduated, the interviews had to be completed in a relatively short period. To accelerate the qualitative research, a projectized, time-compressed interview program in three (3) stages and three (3) weeks was designed for rich textual data collection (see Chapter 3: Figure 11, p. 57; and, Table 2, p. 59).

   Figure 10 (p. 53) and Table 2 (p. 59) respectively in Chapter 3 provide an overview of the time-table and project phases of this data-gathering project reflecting the 'waterfall' model. Two face-to-face interview sessions (First Interview→Follow-up Interview) were conducted for each of the 12 interviewees (see Chapter 4, Table 17, p. 108).

   This accelerated model of qualitative research allowed for an alternative by employing the Skype or phone interview methods for the second (follow-up) interview in case of inability of the interviewee to attend the follow-up interview in person. In all, 168 individual responses to questions were recorded and transcribed within three weeks.

Recommendations

Recommendations are offered for the following two purposes: (a) Actionable solutions to the research problem; and, (b) Future research. These recommendations draw from various aspects of the study, including the literature review, empirical research of Phase 1 and Phase 2, and, the researcher's reflections.

Actionable solutions to the research problem look at how the accelerated PBL model (see Figure 20, p. 170) proposed in this study can guide best practices and streamline the PBL experience for learners of innovative technology in a higher education setting. A few recommendations for future research are also made to overcome some of the limitations of this study as outlined in Chapter 3, and to serve the wider research and academic communities of practice.

For Actionable Solutions to the Research Problem

This study investigated the overarching research problem of how diffusion of technological innovations through innovative technology projects in a competitive higher education environment can be accomplished by employment of SDL, PM, and CL as key components of PBL. The following actions are recommended for competence in SDL, PM, CL, and PBL towards resolving the research problem.

1. **Apply the Accelerated PBL Model diligently for capstone projects.** Most innovative technology programs seem to either use PBL with inadequate structure, or employ it with lack of understanding of the constituents of self-directed learning (SDL), project management (PM), and change leadership (CL) as implicit or explicit ingredients for PBL competence. In the case of the ET program, there was a loose, working framework of PBL in place, with students and faculty advisors practicing PBL with various levels of understanding.

It is recommended that the Accelerated PBL Model be applied formally, diligently, and proactively by technology programs seeking to apply PBL for their capstone projects. Application of PBL requires strong commitment and support from the program leadership, with adequate instruction, training, and written operational guidelines.

Best practices can be applied when the use of PBL is formal, and exercised in a structured manner in order to yield rich dividends. It should also foster student competence and propensity towards lifelong learning. Acceleration of PBL can be a distinct reality by building continually on individual and team competence, as well as speed in each of the three areas: SDL, PM, and CL.

2. **Develop strong SDL skills among learners through the academic year.**

It was seen from the literature review and the SDLRS-A® Survey results that SDL skills are not optional in the 21^{st} century educational environment: they are critical to self-management, self-efficacy, and a genuine desire for learning. These attributes need to be *consciously developed* among the students to enhance their prior preparation for the Senior Design project. Indeed, this study has demonstrated that SDL skills are necessary for personal competence, interdependence, and self-motivation that will enable best practices as well as acceleration of the PBL experience.

It is also worthwhile to consider that SDL skills can enhance altruistic service motives towards responsible and productive citizenship. Additionally, SDL skills can foster a competitive spirit between learners and between project teams to further aid acceleration of PBL.

3. **Provide essential PM training for the students early in the curriculum.** PM training would involve a keen understanding of how the Triple Constraint of time, cost, and quality are dynamically managed (Sohmen, 2007). This training needs to be provided *prior* to embarking on PBL, as front-end planning and control mechanisms need to be in place in advance for best practices and results.

    This was underscored and concurred with by both faculty advisors and students during interviews in Phase 2 of this study. Scheduling with Gantt charts, costing and quality control techniques, and, the Work Breakdown Structure (WBS) are some of the basic tools of PM using Microsoft Project 2016 (free downloads of this program are available). Also, Massive Open Online Courses (MOOCs) in Project Management are freely available through open-source training sites such as EdX for self-study by the motivated learner.

4. **Give students opportunities to hone CL efficiencies.** The capstone project typically has shared leadership through referent power (French & Raven, 1959), as evidenced from the interview responses (see the comments of faculty advisor FA6 in Chapter 4, p. 120, who also stressed the need for communication skills).

    It is important for student leaders to be apprised of how to factor for risk management, as well as change management on a project. They need to be trained to develop their competencies to minimize changes, and to combat unexpected changes vigorously through risk analysis tools. Clear communication, speedy conflict resolution, and collaborative leadership skills are some of the soft skills needed for effective CL contributing to best practices and acceleration of PBL.

5. **Build strong stakeholder networks.** This study demonstrated the importance of sponsors, consultants, experts, advisors, and instructors as key stakeholders to train students through the capstone projects (see Chapter 1, Figure 4, p. 11). It was confirmed during the one-on-one interviews by both student leaders and faculty advisors that cost and time can be saved, and quality significantly enhanced, through the expertise of these key stakeholders.

   Use of the sponsor's facilities, funding, and other resources enabled many student teams in the ET program to finish their prototypes early—even during the second term (Winter 2016) of their final year. This was accomplished at a fraction of the cost due to assistance from sponsors. For project success, it is therefore important to *proactively* maintain external communication with the stakeholders, and to regularly seek their advice and practical assistance on the feasibility of the project and its economical resource requirements. This can be done even prior to start of the project, and can be continued through to project completion.

For Future Research

1. **Pilot-test the Accelerated PBL Model.** The Accelerated PBL Model (see Figure 20, p. 170) needs to be tested by developing a comprehensive, yet parsimonious PBL instrument (Booth et al., 2008) with up to 50 items incorporating the essence of SDL, PM, CL, and, PBL. The instrument will need to be expert-tested by 3-5 experts in the field; pre-tested by 5-10 typical respondents; and, pilot-tested by a random sample of 30-50 participants with a diversity of demographic features (Creswell, 2003). This will aid in fine-tuning of the instrument for face, content, and construct validity of the PBL survey. Systematic validity-testing can be done

through focus groups, interviews, and surveys before wider dissemination of the instrument to a larger population for analysis (Booth et al., 2008).

2. **Promote interdisciplinary research among SDL, PM, CL, and, PBL.** Research on SDL, PM, CL, and, PBL is currently conducted individually with very little evidence of crossovers among these streams of literature. There is some evidence of PBL and SDL research being conducted together (Stewart, 2007), and of PM and PBL being conducted in the same study (Gratch, 2012), but CL does not seem to feature in any of the inquiry-based learning studies.

   More interdisciplinary research (Casey, 2009; Jones, Rasmussen, & Moffitt, 1997; Machi & McEvoy, 2012) will enable these four streams of literature to inform one another—and thereby derive synergies, viable frameworks, and testing instruments. These in turn will generate multidisciplinary models of PBL incorporating diverse perspectives.

3. **Follow-up with larger mixed-methods study samples.** As the sample in this study was small (30 students), employment of significantly larger samples with 100 to 1,000 participants would enable generalization. The samples could be drawn from a variety of universities, multiple ET programs, across STEM disciplines, or, transnationally across cultures.

   Comparisons can then be made of diverse sample groups for testing using MANOVA, Cluster Analyses, and Structural Equation Modeling. These would provide diversity in samples, tests, applications, and instrument constructions. Generalizability would thus be significantly strengthened. Reliability and validity testing can also be carried out through both cross-sectional and longitudinal studies and analyses. Through these processes, the PBL Model proposed in this study could be developed further, modified, or refined.

4. **Conduct a meta-review of PBL literature.** The last meta-review of PBL literature was conducted over 15 years back by Thomas (2000). Such a meta-review selects and analyzes available research on a topic conducted within a time period. The meta-review thus seeks to review a number of articles on a subject such as PBL, condense the available evidence into groups or subtopics, compare and contrast them, and provide a condensed overall review for the guidance of future researchers. In the case of PBL, no follow-up meta-reviews seem to have been undertaken since the cogent meta-review by Thomas (2000).

   It is therefore recommended that a thorough meta-review for the contiguous 15-year period from 2001 to 2016 be carried out. This will not only bring forward the research on PBL by a couple of decades, but will also enable best practices in PBL to be extracted through greater depth and breadth of research. As a sequel to this meta-review, an edited volume on best practices in PBL could be produced for the benefit of educators, researchers, and trainers.

5. **Recommend update of the SDLRS-A® instrument.** The SDLRS-A® Survey was produced in 1978 by Lucy Guglielmino from her Ed. D. dissertation. It has proven to be reliable and valid across a range of educational and industrial environments globally (Guglielmino, 1997). In reviewing the items in the SDLRS-A® Survey, several of them seem to have nearly identical meanings or are ambiguously worded (for example, “I love learning”/“Learning is fun” can be treated as

identical by Millennials). Also, subtle cultural changes and linguistic tweaks have occurred over the nearly 50 years since the instrument was launched.

Global respondents may therefore find some of the language to be quaint. Further, having to reverse the scores of the 17 negative items is tedious. It is recommended that a thorough face, content, and construct validity analysis be carried out for the SDLRS-A® instrument, and the 17 negatively-worded items be rendered positive to minimize complexity for both participants and researchers.

Summary and Conclusion

Higher education in the 21st century is faced with challenges precipitated by accelerating innovative technology diffusion, flexibility of learning models, and gravitation from pedagogy to andragogy. This research is therefore focused on how a robust model of project-based learning (PBL), buttressed by a combination of self-directed learning (SDL), project management (PM), and change leadership (CL) can facilitate systematic technology diffusion in a higher education environment. It is argued that such a model can also enable acceleration of PBL through self-motivation, learner-centered efficiencies, and collaborative effort to overcome systemic resistance.

The quantitative and qualitative analyses of this mixed-methods research involved multi-pronged research instruments (including the globally employed SDLRS-A® instrument), open-ended written responses, and in-depth interviews. The analytical software deployed included Microsoft Excel 2016, SPSS 24.0, NVivo 11, and Leximancer 4.5. The sophisticated, multi-faceted analysis thus resulted in identification of essential elements of an accelerated PBL model. This *Accelerated PBL Model* comprised enhanced SDL skills, streamlined PM efficiencies, and, dynamic CL effectiveness. The model is geared to yielding optimal outcomes with minimal loss of time or wastage of resources in rapidly evolving 21st century higher education settings.

In a typical Engineering Technology (ET) program, students are oriented to solving practical problems in the real world, and hands-on experience is critical to this pragmatic philosophy. Therefore, ET graduates need to be applications-oriented and well-equipped with a solid foundation in quantitative skills, science, business, economics, engineering, and, technology. They should then be able to produce practical results to include: service and maintenance of industrial equipment and systems; installation and operation of technical systems; development and production of innovative products; and, the management of sophisticated production processes.

The accelerated PBL model proposed in this paper can be gainfully applied as a dynamic tool for the development of an array of hands-on skills demonstrated through formative and summative assessments of students pursuing PBL. This study concluded that the accelerated PBL model developed can also work towards fueling students' self-motivation, skill-building, and life-long learning commitment to minimize the employment gap.

Overall, the accelerated PBL model would instill a deep commitment to life-long learning in a technology-infused, information-intensive, and competitive global arena. In a nutshell, against the broad canvas of 21st century technological innovations in higher education, this research on Project-Based Learning (PBL) promises to be fruitfully poised at the confluence of *enhanced* Self-directed Learning (SDL), *streamlined* Project Management (PM), and, *dynamic* Change Leadership (CL).

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Appendix A

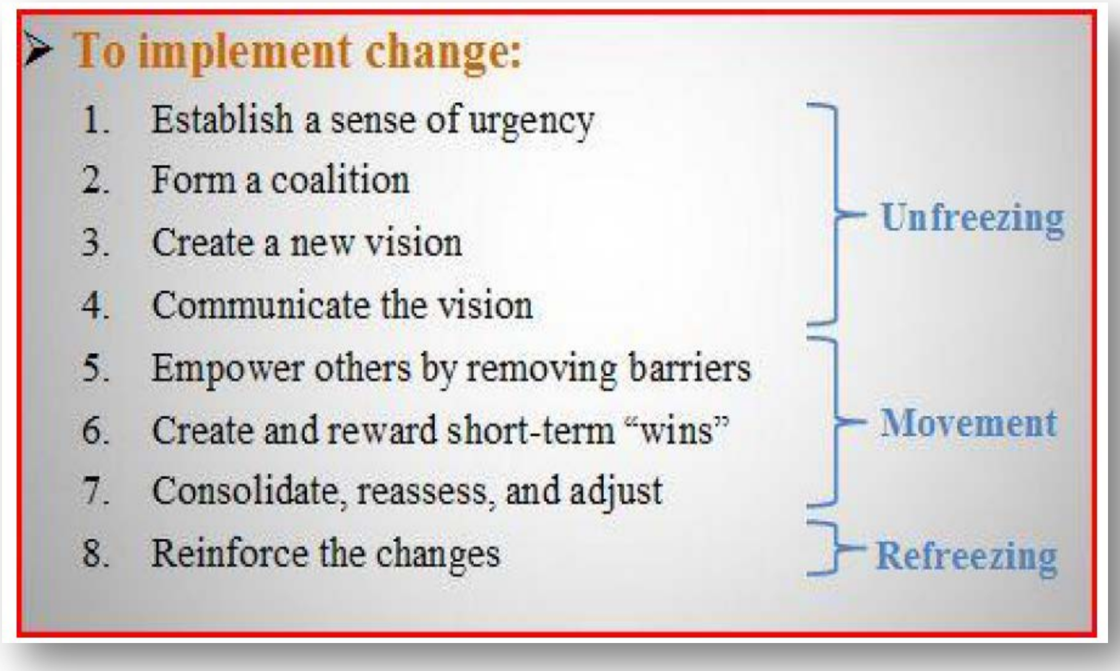
Five Orientations to Learning

Aspect	Behaviorist	Humanist	Cognitivist	Social Cognitive	Constructivist
Learning theorists	Guthrie, Hull, Pavlov, Skinner, Thorndike, Tolman, Watson	Maslow, Rogers	Ausubel, Bruner, Gagne, Koffka, Kohler, Lewin, Piaget	Bandura, Rotter	Candy, Dewey, Lave, Piaget, Rogoff, von Glaserfeld, Vygotsky
View of the learning process	Change in behavior	A personal act to fulfill development	Information processing (including insight, memory, perception, metacognition	Interaction with and observation of others in a social context	Construction of meaning from experience
Locus of learning	Stimuli in external environment	Affective and developmental needs	Internal cognitive structure	Interaction of person, behavior, environment	Individual and social construction of knowledge
Purpose of learning	To produce behavioral change in desired direction	To become self-actualized, mature, autonomous	To develop capacity and skills to learn better	To learn new roles and behaviors	To construct knowledge
Instructor's role	Arrange environment to elicit desired response	Facilitate development of whole person	Structure content of learning activity	Model and guide new roles and behaviors	Facilitate and negotiate meaning-making with learner
Manifestations in adult learning	• Behavioral objectives • Accountability • Performance improvement • Skill development • HRD and training	• Andragogy • Self-directed learning • Cognitive development • Transformational learning	• Learning how to learn • Social role acquisition • Intelligence, learning, and memory as related to age	• Socialization • Self-directed learning • Locus of control • Mentoring	• Experiential learning • Transformational learning • Reflective practice • Communities of practice • Situated learning

Source*:* Merriam, S. B., Caffarella, R. S., & Baumgartner, L. M. (2007). *Learning in adulthood: A comprehensive guide*. San Francisco, CA: Wiley & Sons.

Appendix B

Kotter's 8-Steps Change Model



Source: Kotter, J. P. (1995). Leading change: Why transformation efforts fail. *Harvard Business Review*, *73*(2), 59-67.

Appendix C

Senior Design Capstone Projects

M University
(Department of Engineering Technology)
Senior Design Capstone Projects:
Fall 2015, Winter 2016, Spring 2016

Project #	**Student Last Name**	**Student First Name**	**Capstone Project Title**	**Faculty Advisors**
#1 (3 Students)	**SL1**		A-H-P-M	**F1** ***F6***
	B___	B___		
	C___	C___		
#2 (4 Students)	**D___**	**D___**	l-A	
	E___	E___		
	F___	F___		
	G___	G___		
#3 (4 Students)	**SL2**		C-L-P-M-S	**F2** ***F6***
	I___	I___		
	J___	J___		
	K___	K___		
#4 (4 Students)	**L___**	**L___**	C-E-W-O-B	
	M___	M___		
	N___	N___		
	O___	O___		
#5 (4 Students)	**SL3**		M-H-I-V-V-L	**F3** **F4** ***F6*** UU
	A___	B___		
	C___	D___		
	E___	F___		
#6 (3 Students)	**SL4**		N-C-I-D-T-I-S	**F3** ***F6*** VV
	I___	J___		
	K___	L___		
7 (4 Students)	**SL5**		H-E-H-P-E-S	**F3** **F4** ***F6*** VV
	O___	P___		
	M___	N___		
	S___	T____		
8 (4 Students)	**SL6**		P-I-M	**F5** ***F6*** VV
	W___	X___		
	Y___	Z___		
	U___	V___		

Faculty Advisors:

F1: **1** project; **F2**: **1** project; **F3**: **3** projects;
F4: **2** projects; **F5: 1** project
F6: *Economic Advisor for all projects*

Student Project Leaders:

SL1, SL2, SL3, SL4, SL5, SL6

Appendix D

Definitions of Key Terms

Capstone Project: A long-term, multifaceted, investigative project that culminates in a final product and presentation, typically during the final year of an academic program

Change Leadership (CL): Describes leadership that concerns vision, driving forces, and processes that fuel change and transformation in an organization (Kotter, 1995)

Diffusion of Innovation (DOI): Occurs when an innovative product spreads through an environment in successive, overlapping waves (Business Dictionary, 2014)

Engineering Technology: Emphasizes the application of existing scientific and engineering skills and techniques to real-life issues and problems

Innovative Technology: New technology that can be incremental, radical, or disruptive

Project-Based Learning (PBL): Refers to any programmatic or instructional approach utilizing multifaceted projects as a central organizing strategy for educating students; an inquiry-based teaching method in which students execute a project to investigate a real-life, complex problem (Glossary of Educational Reform, 2013)

Project Management (PM): A methodical approach to execute a project within time, cost, and quality constraints through the phases of initiation, planning and design, execution, commissioning, and, closing (Turner & Müller, 2005)

Self-Directed Learning (SDL): Learning characterized by personal autonomy, management of self-learning, and, viewing problems as challenges; a self-disciplined approach with a high degree of curiosity, diagnosis, and, self-confidence; and, having a strong desire to learn, evaluate the learning, and make necessary changes (Candy, 1991; Guglielmino, 1978; Knowles, 1975)

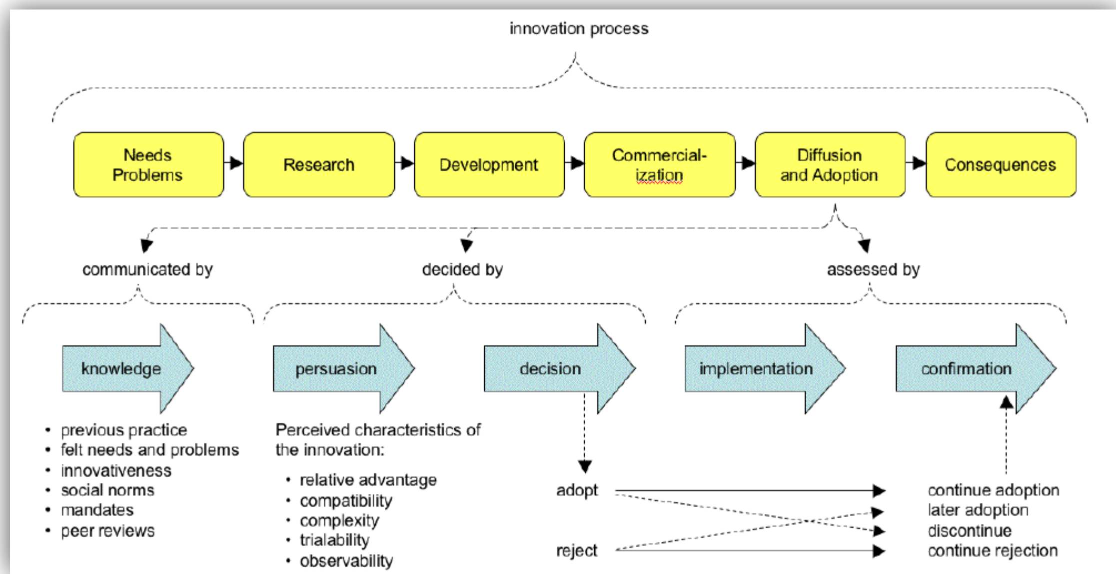
Appendix E

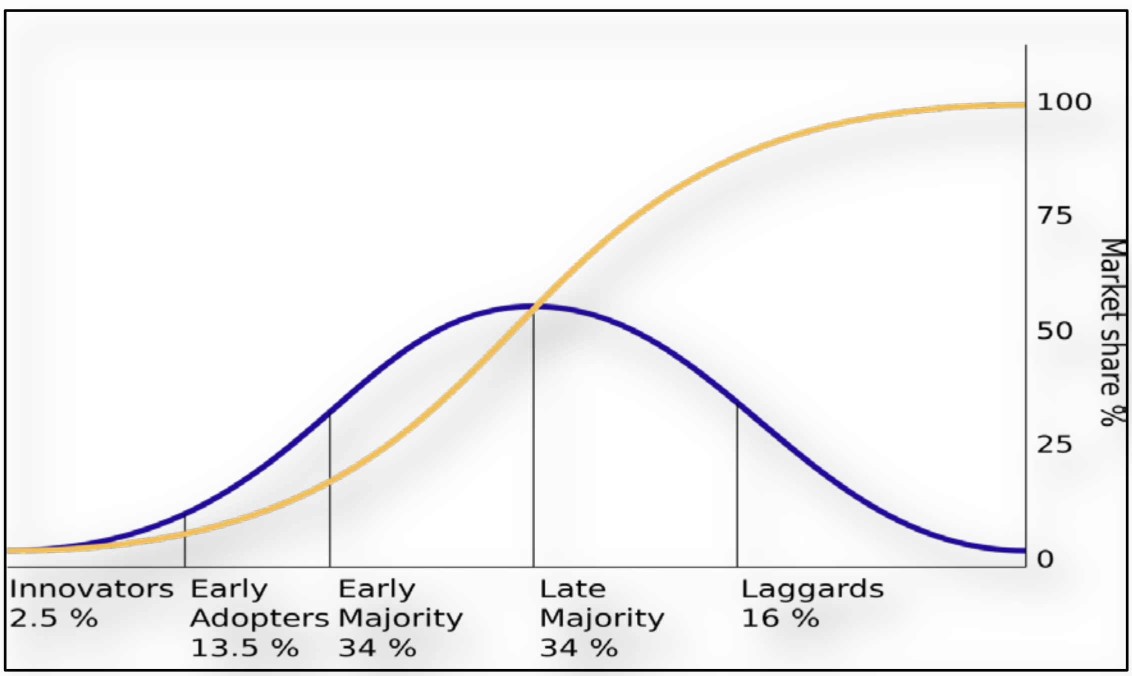
List of Abbreviations

BME	Bio-medical Engineering
CL	Change Leadership
DOI[1]	Diffusion of Innovation
DOI[2]	Digital Object Identifier (for published documents)
EE	Electrical Engineering
EFA	Exploratory Factor Analysis
ET	Engineering Technology
EQ	Emotional Intelligence/Emotional Quotient
ICT	Information and Communication Technology
IRB	Internal Review Board
IWNC	Industry Workforce Needs Council
LPA®	Learning Preference Assessment (alternate for SDLRS-A®)
ME	Mechanical Engineering
MOOC	Massive Open Online Course
PBL	Project-Based Learning
PCA	Principal Components Analysis
PM	Project Management
PMBOK	Project Management Book of Knowledge
SDL	Self-Directed Learning
SDLRS-A®	Self-Directed Learning Readiness Scale (for Adults)
SPSS	Statistical Package for the Social Sciences
STEM	Science, Technology, Engineering, and Mathematics

Appendix F

Rogers' (2003) Model of Diffusion of Innovation (DOI)





Source*:* Rogers, E.M. (2003). *Diffusion of innovations (*5th ed.). New York, NY: Free Press.

Appendix G
CITI Certification by Researcher

COLLABORATIVE INSTITUTIONAL TRAINING INITIATIVE (CITI PROGRAM)
COURSEWORK REQUIREMENTS REPORT*

* NOTE: Scores on this Requirements Report reflect quiz completions at the time all requirements for the course were met. See list below for details. See separate Transcript Report for more recent quiz scores, including those on optional (supplemental) course elements.

- **Name:** VICTOR SOHMEN (ID: 4760233)
- **Email:** VSOHMEN@DREXEL.EDU
- **Institution Affiliation:** Drexel University (ID: 1857)
- **Institution Unit:** School of Education
- **Phone:** 2674417007

- **Curriculum Group:** Social, Behavioral and Educational Research Investigators
- **Course Learner Group:** Same as Curriculum Group
- **Stage:** Stage 1 - Basic Course

- **Report ID:** 15658305
- **Completion Date:** 06/06/2015
- **Expiration Date:** 06/05/2018
- **Minimum Passing:** 80
- **Reported Score*:** 100

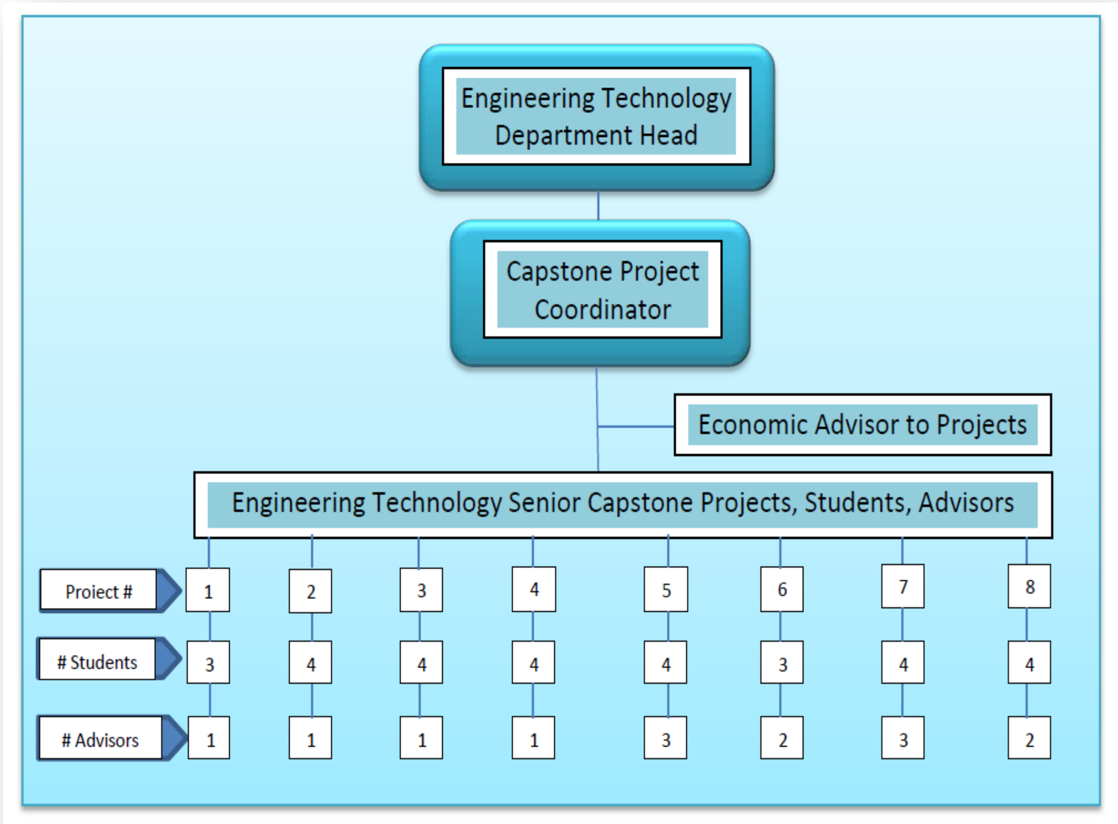
REQUIRED AND ELECTIVE MODULES ONLY	DATE COMPLETED	SCORE
Belmont Report and CITI Course Introduction (ID:1127)	06/03/15	3/3 (100%)
Students in Research (ID:1321)	06/03/15	10/10 (100%)
History and Ethical Principles - SBE (ID:490)	06/03/15	5/5 (100%)
Defining Research with Human Subjects - SBE (ID:491)	06/04/15	5/5 (100%)
The Federal Regulations - SBE (ID:502)	06/04/15	5/5 (100%)
Assessing Risk - SBE (ID:503)	06/04/15	5/5 (100%)
Informed Consent - SBE (ID:504)	06/04/15	5/5 (100%)
Privacy and Confidentiality - SBE (ID:505)	06/04/15	5/5 (100%)
Research with Children - SBE (ID:507)	06/05/15	5/5 (100%)
Internet-Based Research - SBE (ID:510)	06/06/15	5/5 (100%)
Research and HIPAA Privacy Protections (ID:14)	06/06/15	5/5 (100%)
Conflicts of Interest in Research Involving Human Subjects (ID:488)	06/06/15	5/5 (100%)
Drexel University College of Medicine Courses (ID:14085)	06/06/15	No Quiz

For this Report to be valid, the learner identified above must have had a valid affiliation with the CITI Program subscribing institution identified above or have been a paid Independent Learner.

CITI Program
Email: citisupport@miami.edu
Phone: 305-243-7970
Web: https://www.citiprogram.org

Appendix H

Organization Chart of the ET Senior Design Capstone Projects



Appendix I

Permission for Research from Participants' Department Head

April 26, 2016

Dear Victor:

<u>Sub</u>: Permission letter for research purposes – Victor Sohmen

This letter is to inform you that as the Head of Department of Engineering Technology, [redacted] I support your Ed. D. dissertation research entitled: "Towards an Accelerated Model of Project-Based Learning in Innovative Technology Projects". It is my understanding that the actual empirical research will be conducted during May-June, 2016.

Upon IRB approval, you will have my permission to contact the instructors and senior undergraduate students in the Engineering Technology Department if they are willing to be a part of the study. I understand that this study will enhance our understanding of best practices in Project-Based Learning (PBL) in a technology-infused environment. I grant you access to the research participants upon approval of your proposal by the IRB [redacted]

If you have any questions, please contact me at: Email: [redacted] or phone: [redacted]

Sincerely,

[redacted]

Department Head, Professor

(Note: All identities, except that of the researcher, have been expunged for anonymity)

Appendix J

Permission Letter from Original Author of SDLRS-A® Survey

Guglielmino & Associates
7339 Reserve Creek Drive
Port St. Lucie, FL 34986
772 429-2425
www.lpasdlrs.com
lguglielmino@rocketmail.com

May 4, 2016

Mr.Victor Sohmen
Email: vsohmen@gmail.com
3001 Market Street, Suite 100,
One Drexel Plaza
Philadelphia, PA 19104
Telephone : 215-886-6007
Organization or Educational Institution: Drexel University

Dear Mr. Sohmen:

This correspondence certifies that you have my permission to use the *Self-Directed Learning Readiness Scale (Learning Preference Assessment)* in your dissertation research for the number of uses that you have purchased (30 copies of the English version of the SDLRS-A).

Lucy M. Guglielmino

Lucy M. Guglielmino, Ed. D.
lguglielmino@rocketmail.com
(772) 429-2425
website: http://www.lpasdlrs.com

Appendix K

PBL Research Participant Consent Letter

Consent Letter

Dear Student:

I request your assistance with my dissertation study, which seeks to assess the Self-Directed Learning (SDL) skills of Engineering Technology students in their final year and required capstone project, using the Self-Directed Learning Readiness Scale (SDLRS). You were selected to participate in this study because you are completing your capstone project involving SDL. Participation in the study is voluntary and your decision to participate or not to participate will in no way be prejudicial to you, and will have no impact whatsoever on your grades. Your identity will be anonymous: a code will be used as your ID, rather than your actual name.

Your informed consent to participate in the study is assumed by your completing the survey and submitting it to the capstone project coordinator on the researcher's behalf. Do not complete the survey if you do not understand or agree to these conditions.

If you have questions or concerns about this study, please send them by email to the capstone projects' coordinator,

Purpose of the Study:

The purpose of this study is to examine the Project-Based Learning (PBL) framework used in supporting capstone projects by undergraduate students in an engineering technology program, and to propose an accelerated model of PBL.

Survey Description:

The survey will take approximately 30 minutes to complete, during weeks 8-10 of your course. The survey includes questions about your Self-Directed Learning (SDL) skills. I will also ask for some demographic information (e.g., age, race, major, education level, GPA) so that I can accurately categorize the general traits of the group of students who participate in the study. This personal information will be strictly anonymous. You have the option of choosing not to reply if you do not want to share this information

Interview Description:

Students who complete the survey are also invited to participate in a semi-structured interview that will allow you to describe your experience in Project-Based Learning (PBL) as part of your capstone project. No personal information will be obtained. No personally identifying information will be gathered. The interview will take approximately 30 minutes. If you would like to you would like to participate in the semi-structured interviews, please sign the interview consent that is located on page 3 of this consent letter.

APPROVED
Human Research Protection
Protocol # 1605004510
Approval Date: 5/11/16
Expiration Date: 5/10/17

(Note: All identifying information has been expunged for confidentiality)

Appendix L

IRB Approval to Conduct Human Subjects' Research

Office of Research

APPROVAL OF PROTOCOL

May 11, 2016

On May 11, 2016 the IRB reviewed the following protocol:

Type of Review:	Initial
Title:	Towards a Model of Accelerated Project-Based Learning (PBL) for Innovative Technology Projects
Investigator:	
IRB ID:	1605004510
Funding:	Internal
Grant Title:	None
Grant ID:	None
IND, IDE or HDE:	None
Documents Reviewed:	HRP 211 Application Form, HRP 201 Contact Forms, Conflict of Interest Forms, HRP-503 Template Protocol, HRP-502 consent, Recruitment Letters, Self-Directed Learning Readiness Survey (SDLRS), Data Collection Tools, SDLRS Permission Use Letter,

According to 45 CFR 46, 110, this study is Approved Expedited Category 7. This study will enroll 45 subjects recruited from to complete surveys and participate in interviews.

The IRB approved the protocol from May 11, 2016 to May 10, 2017 inclusive.

Before March 27, 2017 which is 45 days prior to study closure, you are to submit a completed "FORM: Continuing Review Progress Report (HRP-212)" and required attachments to request continuing approval or closure.

(Note: All identifying information has been expunged for confidentiality)

Appendix M

Demographic and Open-Ended Responses by Student #S28

S28

THIS IS AN ANONYMOUS SURVEY: DO NOT WRITE YOUR NAME ANYWHERE

DEMOGRAPHICS:

Gender: Male ☐ Female ☑

Ethnicity:

☐ Asian/ Pacific Islander ☐ Hispanic/Latino ☐ African-American ☐ Native American
☑ Caucasian ☐ Other: _______________.

What is your age group?

☐17-19 years ☐20-22 years ☑23-25 years ☐26-28 years ☐ 29-30years ☐ 31-35 years
☐ 36-40 years ☐ 41-45 years ☐ 46-50 years ☐ 51-60 years ☐ 61-70 years

Major: ENGINEERING TECHNOLOGY **Cumulative GPA:** 2.75

Academic year: ☐Freshman ☐Sophomore ☐Junior ☑Senior

How many Capstone Projects have you completed so far? ☑ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5+

COMMENTS:

Please share about your experience in making changes to the Senior Design project during the year:

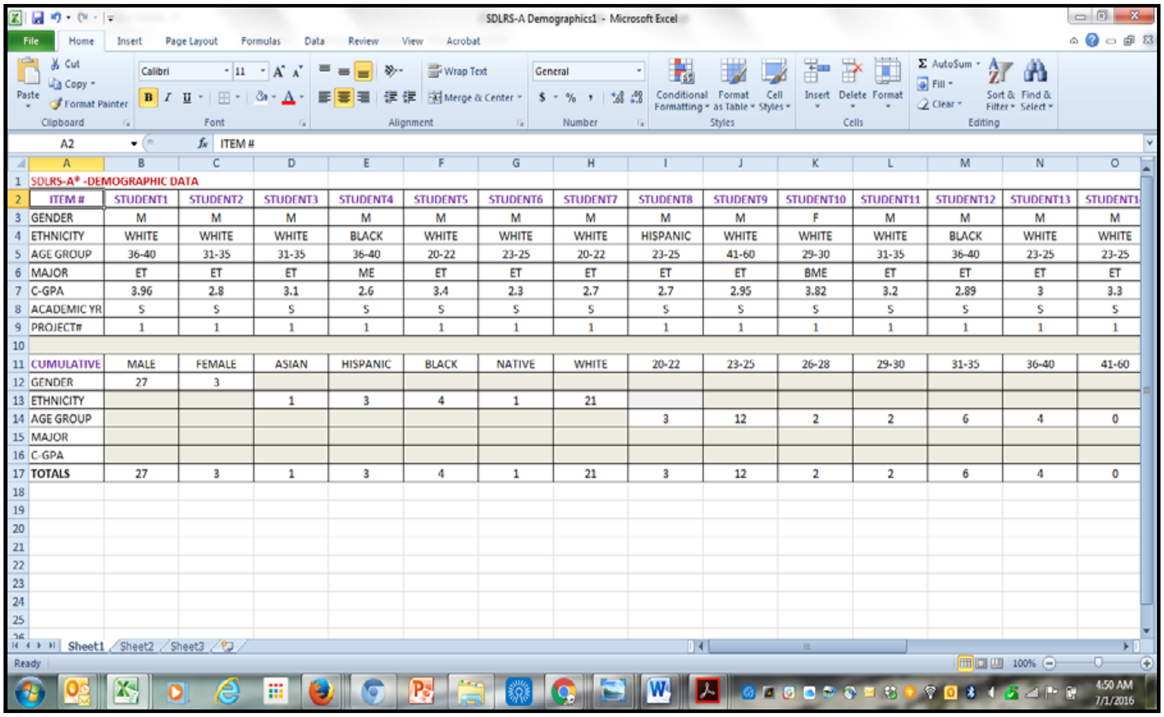
Experience through MET421 (Fall Quarter) 2015:
THE MOST TIME SPENT ON THE PROJECT WAS UP FRONT DURING THE FALL QUARTER. DURING THIS TIME PERIOD WE WORKED HARD DOING ALL THE RESEARCH NECESSARY TO COME UP WITH OUR INITIAL DESIGN AND TO SEE IF THE PROJECT WAS FEASIBLE. THIS WAS BY FAR THE MOST WORK INTENSIVE QUARTER FOR SENIOR DESIGN.

Experience through MET422: (Winter 2016):
DURING THE WINTER QUARTER WE SPENT IT FINALIZING OUR DESIGNS AND BUILDING OUR PROTOTYPE. IT WAS FUN SEEING OUR DESIGN COME TO LIFE. I DID NOT LIKE THE FACT WE HAD TO DO A PRESENTATION DURING THIS QUARTER BECAUSE IT FELT LIKE THINGS WERE BEING RUSHED MORE THAN NECESSARY.

Experience through MET 423 (Spring 2016):
THE SPRING QUARTER WAS BY FAR THE EASIEST FOR OUR GROUP. BY THIS POINT WE HAD ALREADY HAD OUR PROTOTYPE BUILT, SO WE JUST HAD TO GET IT IN WORKING ORDER. ONCE IT WAS WORKING, WE THEN WENT INTO THE TESTING PHASE WHICH WAS THE MOST FUN FOR US.

Appendix N

Excel Spreadsheet of SDLRS-A® Demographic Data



SDLRS-A® -DEMOGRAPHIC DATA

ITEM #	STUDENT1	STUDENT2	STUDENT3	STUDENT4	STUDENT5	STUDENT6	STUDENT7	STUDENT8	STUDENT9	STUDENT10	STUDENT11	STUDENT12	STUDENT13	STUDENT1
GENDER	M	M	M	M	M	M	M	M	M	F	M	M	M	M
ETHNICITY	WHITE	WHITE	WHITE	BLACK	WHITE	WHITE	WHITE	HISPANIC	WHITE	WHITE	WHITE	BLACK	WHITE	WHITE
AGE GROUP	36-40	31-35	31-35	36-40	20-22	23-25	20-22	23-25	41-60	29-30	31-35	36-40	23-25	23-25
MAJOR	ET	ET	ET	ME	ET	ET	ET	ET	ET	BME	ET	ET	ET	ET
C-GPA	3.96	2.8	3.1	2.6	3.4	2.3	2.7	2.7	2.95	3.82	3.2	2.89	3	3.3
ACADEMIC YR	S	S	S	S	S	S	S	S	S	S	S	S	S	S
PROJECT#	1	1	1	1	1	1	1	1	1	1	1	1	1	1
CUMULATIVE	MALE	FEMALE	ASIAN	HISPANIC	BLACK	NATIVE	WHITE	20-22	23-25	26-28	29-30	31-35	36-40	41-60
GENDER	27	3												
ETHNICITY			1	3	4	1	21							
AGE GROUP								3	12	2	2	6	4	0
MAJOR														
C-GPA														
TOTALS	27	3	1	3	4	1	21	3	12	2	2	6	4	0

Appendix O

Page from a Completed SDLRS-A® Survey by Student #S7

SDLRS-A

S7

LEARNING PREFERENCE ASSESSMENT

Instructions This is a questionnaire designed to gather data on learning preferences and attitudes towards learning. After reading each item, please indicate the degree to which you feel that statement is true of you. Please read each choice carefully and circle the number of the response which best expresses your feeling.

There is no time limit for the questionnaire. Try not to spend too much time on any one item, however. Your first reaction to the question will usually be the most accurate.

RESPONSES

ITEMS:	Almost never true of me; I hardly ever feel this way.	Not often true of me; I feel this way less than half the time	Sometimes true of me; I feel this way about half the time.	Usually true of me; I feel this way more than half the time.	Almost always true of me; there are very few times when I don't feel this way.
I'm looking forward to learning as long as I'm living.	1	2	3	4	**5**
2. I know what I want to learn.	1	2	3	4	**5**
3. When I see something that I don't understand, I stay away from it.	1	2	**3**	4	5
4. If there is something I want to learn, I can figure out a way to learn it.	1	2	3	**4**	5
5. I love to learn.	1	2	3	4	**5**
6. It takes me a while to get started on new projects.	1	**2**	3	4	5
7. In a classroom. I expect the teacher to tell all class members exactly what to do at all times.	1	2	**3**	4	5
8. I believe that thinking about who you are, where you are, and where you are going should be a major part of every person's education.	1	2	**3**	4	5
9. I don't work very well on my own.	**1**	2	3	4	5

Appendix P
SDLRS-A® Survey: Three *A Priori* Factors

SDLRS-A*	Items*	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
SM	***Self-management***					
SM1	I manage my time well.					
SM2	I am self-disciplined.					
SM3	I am organized.					
SM4	I set strict timeframes.					
SM5	I have good management skills.					
SM6	I am methodical.					
SM7	I am systematic in my learning.					
SM8	I set specific times for my Phase.					
SM9	I solve problems using a plan.					
SM10	I prioritize my work.					
SM11	I can be trusted to pursue my own learning.					
SM12	I prefer to plan my own learning.					
SM13	I am confident in my ability to search out information.					
DL	***Desire for learning***					
DL1	I want to learn new information.					
DL2	I enjoy learning new information.					
DL3	I have a need to learn.					
DL4	I enjoy a challenge.					
DL5	I enjoy studying.					
DL6	I critically evaluate new ideas.					
DL7	I like to gather facts before a decision.					
DL8	I like to evaluate what I do.					
DL9	I am open to new ideas.					
DL10	I learn from my mistakes.					
DL11	I need to know why.					
DL12	When presented with a problem I cannot resolve I will ask for assistance.					
SC	***Self-Control***					
SC1	I prefer to set my own goals.					
SC2	I like to make decisions for myself.					
SC3	I am responsible for my own decisions/actions.					
SC4	I am in control of my life.					
SC5	I have high personal standards.					
SC6	I prefer to set my own learning goals.					
SC7	I evaluate my own performance.					
SC8	I am logical.					
SC9	I am responsible.					
SC10	I have high personal expectations.					
SC11	I am able to focus on a problem.					
SC12	I am aware of my limitations.					
SC13	I can find out information for myself.					
SC14	I have high beliefs in my abilities.					
SC15	I prefer to set my own criteria on which to evaluate my performance.					

*This is a partial document with three *a priori* factors of the 41 positively-worded items of the 58-item

Appendix Q
Semi-structured PBL Interview Questions

This interview is intended for us to gain an understanding of Project-Based Learning (PBL), Self-Directed Learning (SDL), Project Management (PM), and Change Leadership (CL), based on your learning, background, and experience in implementing/advising ET capstone projects. Key terms have been defined for clarity of these four concepts. Please respond to the following questions concerning your project experience and participation in the Engineering Technology Senior Design course in as much detail as possible.

1. **The Project-Based Learning (PBL)** ***framework*** in the ET program has the following elements: 1) identify a design problem of technological and/or entrepreneurial value; 2) write a proposal and evaluate, analyze, and innovate a project design; 3) develop and test a workable prototype; 4) research and accommodate the societal and environmental impact of the product/process; and, 5) present a detailed capstone project report of the finished product/process/service.

a. Could you explain in your own words how the **Project-Based Learning (PBL)** ***framework*** has been integrated through the three terms of the Senior Design Course?

b. Given that the ***project phases*** include initiation, planning & scheduling, construction, prototyping, and completion, could you describe how the **PBL framework** was applied through the various **project phases**?

2. **Self-Directed Learning (SDL)** ***skills*** include: 1) the desire for learning; 2) initiative to seek knowledge; and, 3) autonomy of effort: self-discipline, self-motivation, and continual learning with minimal supervision. Could you describe how **Self-directed Learning (SDL)** ***skills*** were applied in your capstone project(s)?

3**. Project Management (PM)** ***efficiencies*** include the control of cost, schedule, and quality of the project to optimize all resources, and to complete the capstone project successfully. What are the ways in which **Project Management (PM)** ***efficiencies*** were applied to your project(s)?

4. **Change Leadership (CL)** ***effectiveness*** is determined by vision, goal-setting, collaboration, motivation, dynamics, and resolute change through the project phases to successfully create an innovative product. How often, and under what circumstances, did you use **Change Leadership (CL)** ***effectively****?*

5. If you were to repeat the same project(s) for **best PBL competencies** with **PM efficiencies, SDL skills,** and **CL effectiveness**, how would you plan, organize, and accomplish it?

6. Looking back on your capstone project(s), what actions could you have taken to ***accelerate*** **PBL competencies** using **PM efficiencies, SDL skills,** and **CL effectiveness**?

Appendix R
Annotated Transcript Sample of Phase 2 Interview

1.a. Could you explain in your own words how the Project-Based Learning (PBL) *framework* has been integrated through the three terms of the Senior Design Course (Capstone Project)?

[SL1]

The first step was crucial: identify a design problem of technological and/or entrepreneurial value and write a proposal, those two steps are the most important for deciding the outcome of the project. The research and time spent on the early stage was immense and hard. Later steps were easy until we reached trial, and then came up with the problem of solving unexpected issues later.

Comment [S1]: Fall 2015 term was intensive.

Comment [S2]: Changes were needed.

[SL2]

PBL steps were exactly as given in the question. We chose the right project we were capable of doing, and then in the proposal, we lay out the **structure of the project.** After building the prototype, we took it for trial. In the trial, problems needed to be resolved through trouble-shooting. Actually, the prototype can change according to the problem.

Comment [S3]: Any problem with the prototype could initiate an iterative cycle of re-plan, redesign, and re-execute.

[SL3]

The PBL framework identified above was incorporated by **establishing a series of milestones. Item 1.4 research and accommodate the societal and environmental impact** of the product/process was implemented as a research topic and reported on in Item 1.2 write a proposal and evaluate, analyze, and **innovate** a project design.

Comment [S4]: Milestones are PM tools.

Comment [S5]: Research and Proposal

[SL4]

First term was proposal (Planning and research—tasking and task completion were difficult); Second term was the prototype (Research and experimentation); Third term was testing and completion with an improved prototype **(evaluation, reassessment, testing, and upgrade of the** prototype—in an **iterative** manner).

Comment [S6]: Evaluation, reassessment, testing, and upgrade of the prototype—conducted in an iterative manner.

[SL5]

The PBL framework has been integrated through finding alternative solutions to our project. Although the project presents a single problem, we are inclined to discover after evaluating the problem multiple solutions. Through a series of testing and implementation, we must learn and adapt to the most feasible solution to the project's problem. This process is the most time-consuming as **one must learn new skills in order to understand a problem enough to approach 23 it from various** angles.

Comment [S7]: A single problem can have multiple solutions.

Comment [S8]: Having at least a PBL framework helps to find multiple solutions to the problem.

Comment [S9]: Necessity to learn new skills

[SL6]

At the beginning (in fall 2015) there was no prior information regarding the project. We chose the project using my background in micro-fluids. Also, the resources were generally available. My advisor was helpful by sharing his expertise and was interested in the actual **project**. He had prior **project experience** in these topics and outside contacts, as well as prior published research papers. So we had a **good learning** curve. In the Winter 2016 term we had to find solutions to problems dealing with the actual design flaws. One issue was to approach the problem from different angles. This required consulting and collaborating with the group.

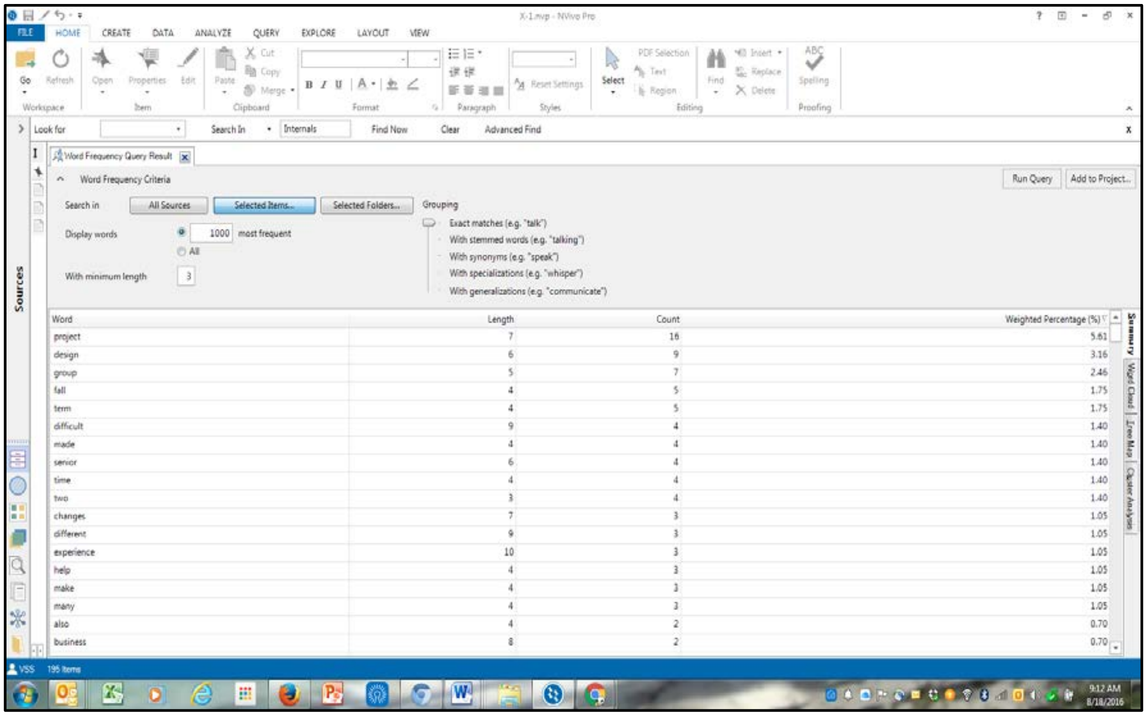
Comment [S10]: No prior, pre-set project information

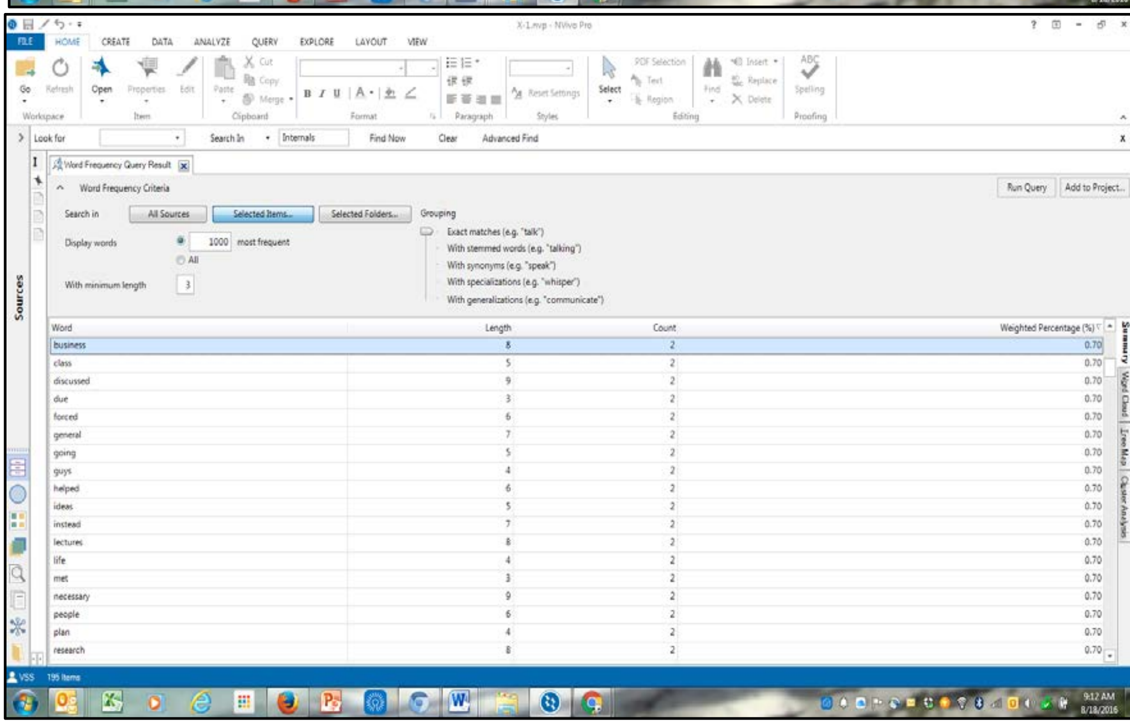
Comment [S11]: Advisor's role was helpful to impart expertise to the students using PBL.

Comment [S12]: Good learning curve because of the advisor's experience and expertise.

Appendix S

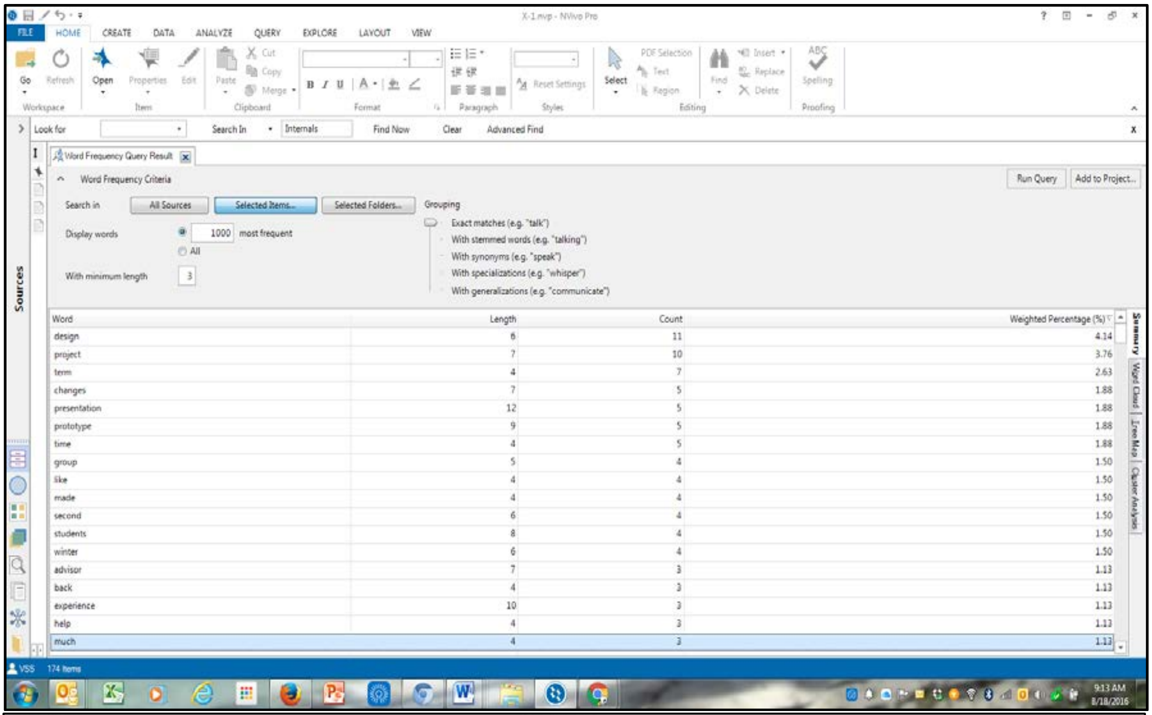
NVivo Word Frequency for Q. 1 on CL: Fall 2015



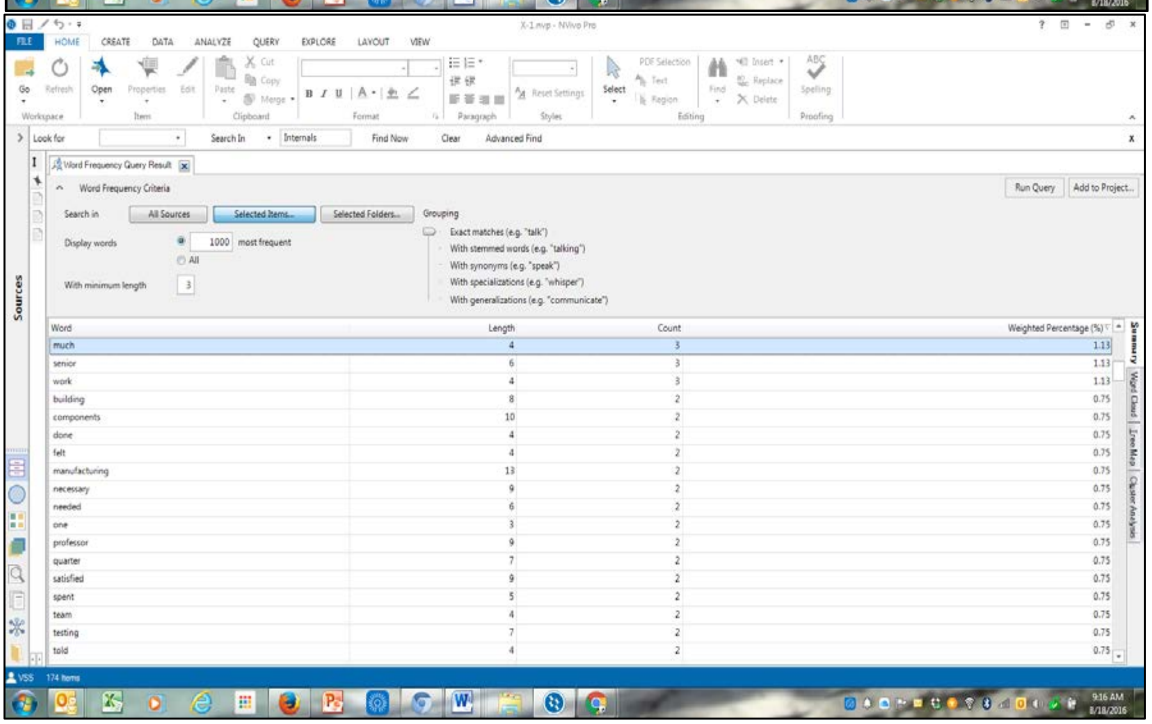


Appendix T

NVivo Word Frequency for Q. 2 on CL: Winter 2016



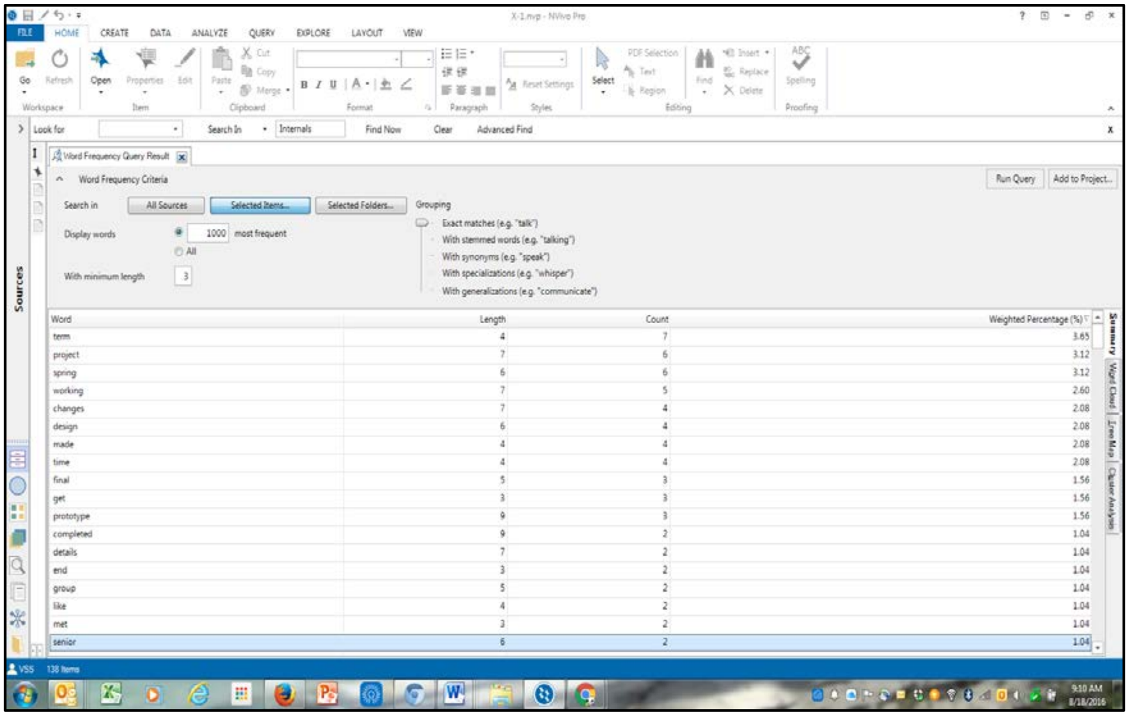
Word	Length	Count	Weighted Percentage (%)
design	6	11	4.14
project	7	10	3.76
term	4	7	2.63
changes	7	5	1.88
presentation	12	5	1.88
prototype	9	5	1.88
time	4	5	1.88
group	5	4	1.50
like	4	4	1.50
made	4	4	1.50
second	6	4	1.50
students	8	4	1.50
winter	6	4	1.50
advisor	7	3	1.13
back	4	3	1.13
experience	10	3	1.13
help	4	3	1.13
much	4	3	1.13



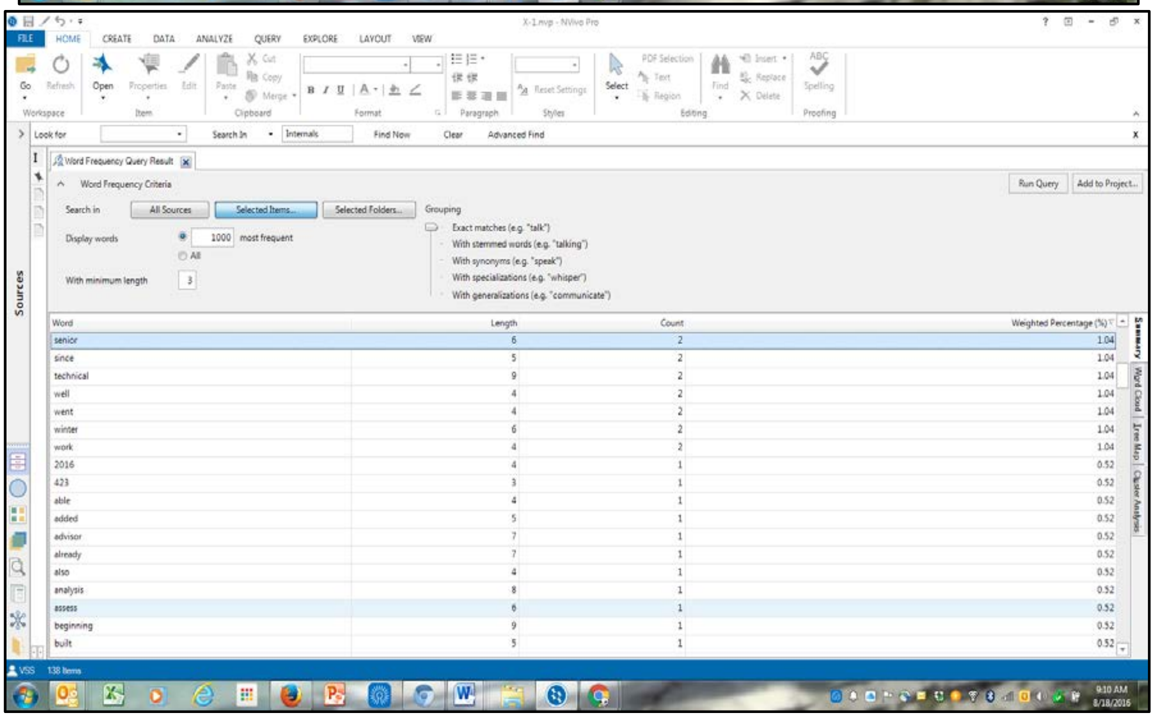
Word	Length	Count	Weighted Percentage (%)
much	4	3	1.13
senior	6	3	1.13
work	4	3	1.13
building	8	2	0.75
components	10	2	0.75
done	4	2	0.75
felt	4	2	0.75
manufacturing	13	2	0.75
necessary	9	2	0.75
needed	6	2	0.75
one	3	2	0.75
professor	9	2	0.75
quarter	7	2	0.75
satisfied	9	2	0.75
spent	5	2	0.75
team	4	2	0.75
testing	7	2	0.75
told	4	2	0.75

Appendix U

NVivo Word Frequency for Q. 3 on CL: Spring 2016



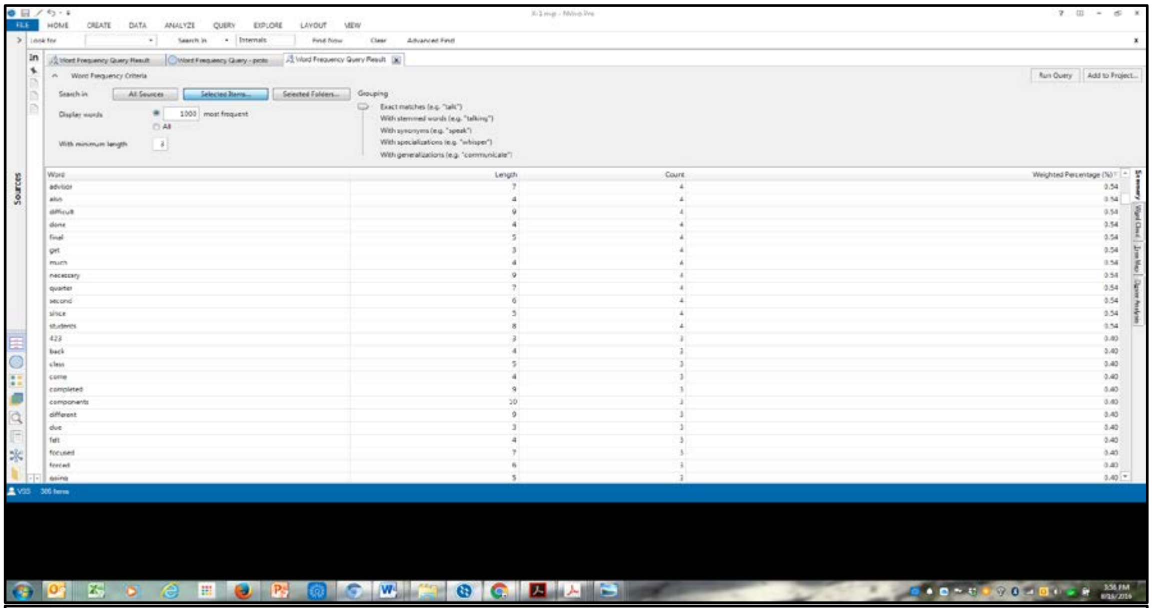
Word	Length	Count	Weighted Percentage (%)
term	4	7	3.65
project	7	6	3.12
spring	6	6	3.12
working	7	5	2.60
changes	7	4	2.08
design	6	4	2.08
made	4	4	2.08
time	4	4	2.08
final	5	3	1.56
get	3	3	1.56
prototype	9	3	1.56
completed	9	2	1.04
details	7	2	1.04
end	3	2	1.04
group	5	2	1.04
like	4	2	1.04
met	3	2	1.04
senior	6	2	1.04

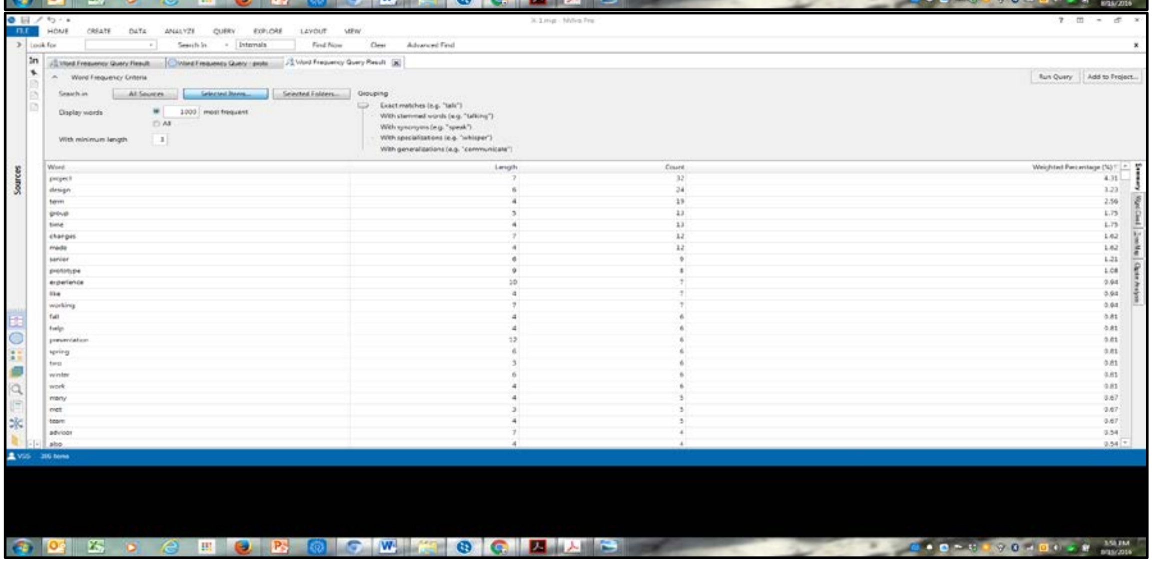


Word	Length	Count	Weighted Percentage (%)
senior	6	2	1.04
since	5	2	1.04
technical	9	2	1.04
well	4	2	1.04
went	4	2	1.04
winter	6	2	1.04
work	4	2	1.04
2016	4	1	0.52
423	3	1	0.52
able	4	1	0.52
added	5	1	0.52
advisor	7	1	0.52
already	7	1	0.52
also	4	1	0.52
analysis	8	1	0.52
assess	6	1	0.52
beginning	9	1	0.52
built	5	1	0.52

Appendix V

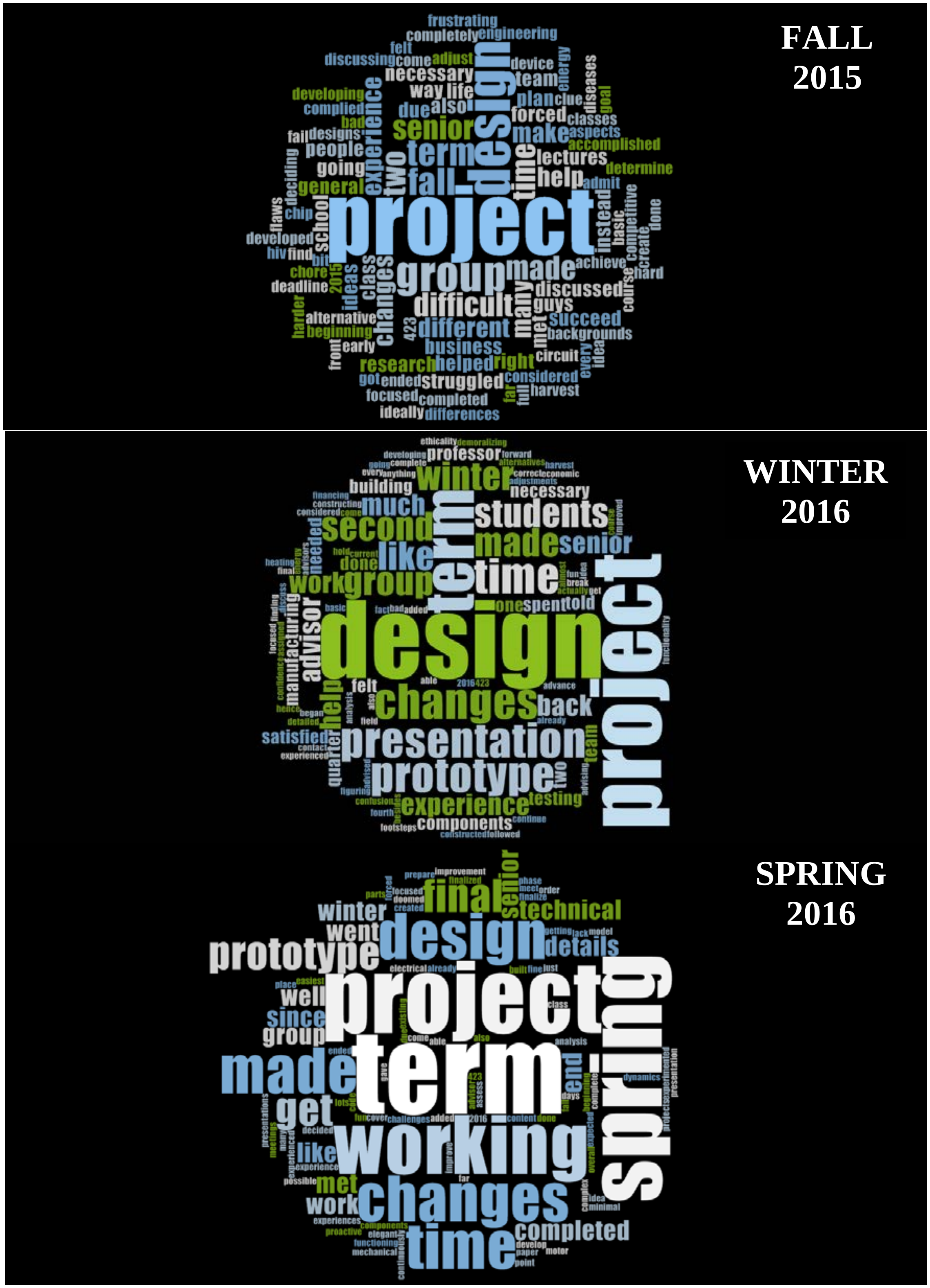
NVivo Word Frequency and Word Cloud for CL: AY 2015-2016





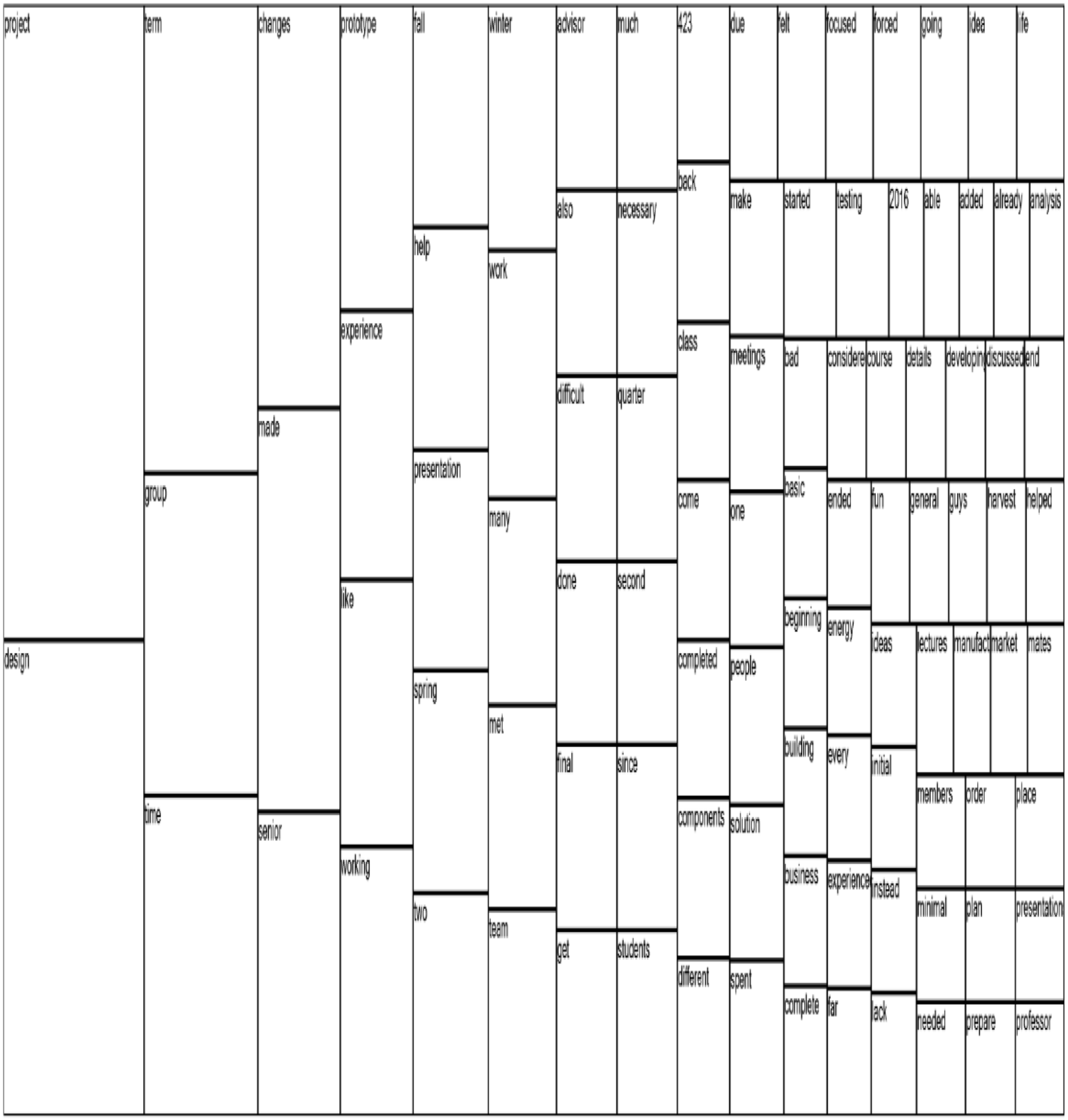
Appendix W

NVivo Word Clouds by Three Terms on CL: AY 2015-2016



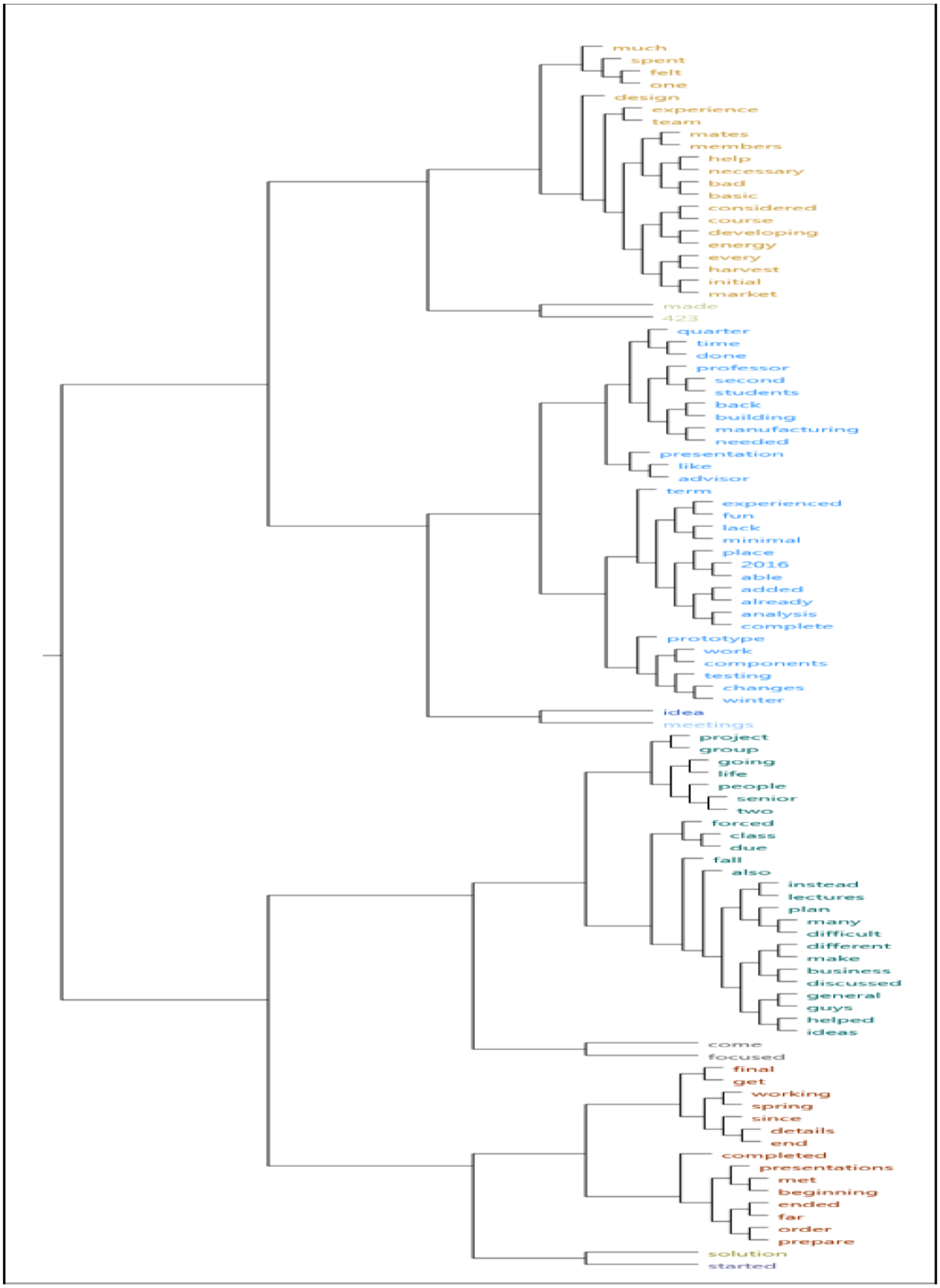
Appendix X

NVivo Tree Map of CL: AY 2015-2016



Appendix Y

NVivo Cluster Analysis of CL: AY 2015-2016



Appendix Z

Rank Order of SDLRS-A® Items by Mean Scores of 30 Students

ITEMS	**SDLRS-A® Item Description** (Abridged & Truncated)	Mean Score	% Positive (4-5) Responses
Q1	I look forward to lifelong learning.	4.67	90%
Q56	Learning makes a major difference in my life.	4.63	93%
Q49	I want to learn more to keep growing as a person.	4.60	90%
Q30	I am very curious about things.	4.47	93%
Q45	I have a strong desire to learn new things.	4.40	90%
Q55	I learn several new things each year.	4.37	87%
Q7	I am self-directed in a class setting.	4.33	87%
Q52	It is never too late to learn new things.	4.33	83%
Q6	I am a quick starter on new projects.	4.30	83%
Q14	Difficult study does not deter me if I am interested in it.	4.30	87%
Q23	I think libraries are exciting places.	4.30	83%
Q43	I enjoy discussing ideas.	4.27	87%
Q39	I think of problems as challenges, not as stop signs.	4.23	83%
Q16	I can tell whether I am learning something well or not.	4.23	83%
Q50	I take personal responsibility for my own learning.	4.20	83%
Q46	Learning makes the world exciting.	4.20	83%
Q37	I like to think about the future.	4.20	80%
Q26	I try to relate my learning to my long-term goals.	4.17	83%
Q4	If there is something I want to learn, I find a way to do it.	4.17	80%
Q47	Learning is fun.	4.13	77%
Q2	I know what I want to learn.	4.13	70%
Q51	Learning methods are important to me.	4.07	73%
Q34	I like to try new things, even if unsure of the outcome.	4.07	73%
Q17	There are so many things to learn, I wish for longer days.	4.07	70%
Q24	The people I admire are always learning new things.	4.03	70%
Q8	Goal setting and direction are important for education.	4.03	77%
Q15	I take personal responsibility for my own learning.	4.00	70%
Q54	Learning is a tool for life.	4.60	90%
Q9	I am an autonomous worker.	4.40	90%
Q5	I love to learn.	4.33	87%
Q21	I know when I need to learn more about something.	4.00	80%
Q20	I take personal responsibility for my own learning.	3.97	66%
Q44	I like learning situations that are challenging.	3.97	66%
Q36	I am good at thinking of unusual ways to do things.	3.93	70%
Q53	Constant learning is exciting.	3.93	70%
Q3	When I see something I do not understand I tackle it.	3.93	70%
Q10	If I need new information, I know how to go about getting it.	3.90	77%
Q41	I am happy about how I investigate problems.	3.90	70%
Q32	I am more interested in learning than some other people.	3.87	66%
Q42	I become a leader in group learning situations.	3.83	63%
Q28	I really enjoy tracking down the answer to a question.	3.83	66%
Q58	Learners are leaders.	3.80	63%
Q19	Understanding what I read is not a problem for me.	3.80	57%
Q25	I can think of many different ways to learn about a new topic.	3.77	53%
Q27	I am capable of self-learning almost anything I need to know.	3.73	66%
Q40	I can make myself do what I think I should.	3.73	60%
Q57	I am an effective learner in and out of class.	3.70	63%
Q11	I can learn things on my own better than most people can.	3.70	57%

Appendix AA

Exploratory Factor Analysis: Solution with Three *A Priori* Factors

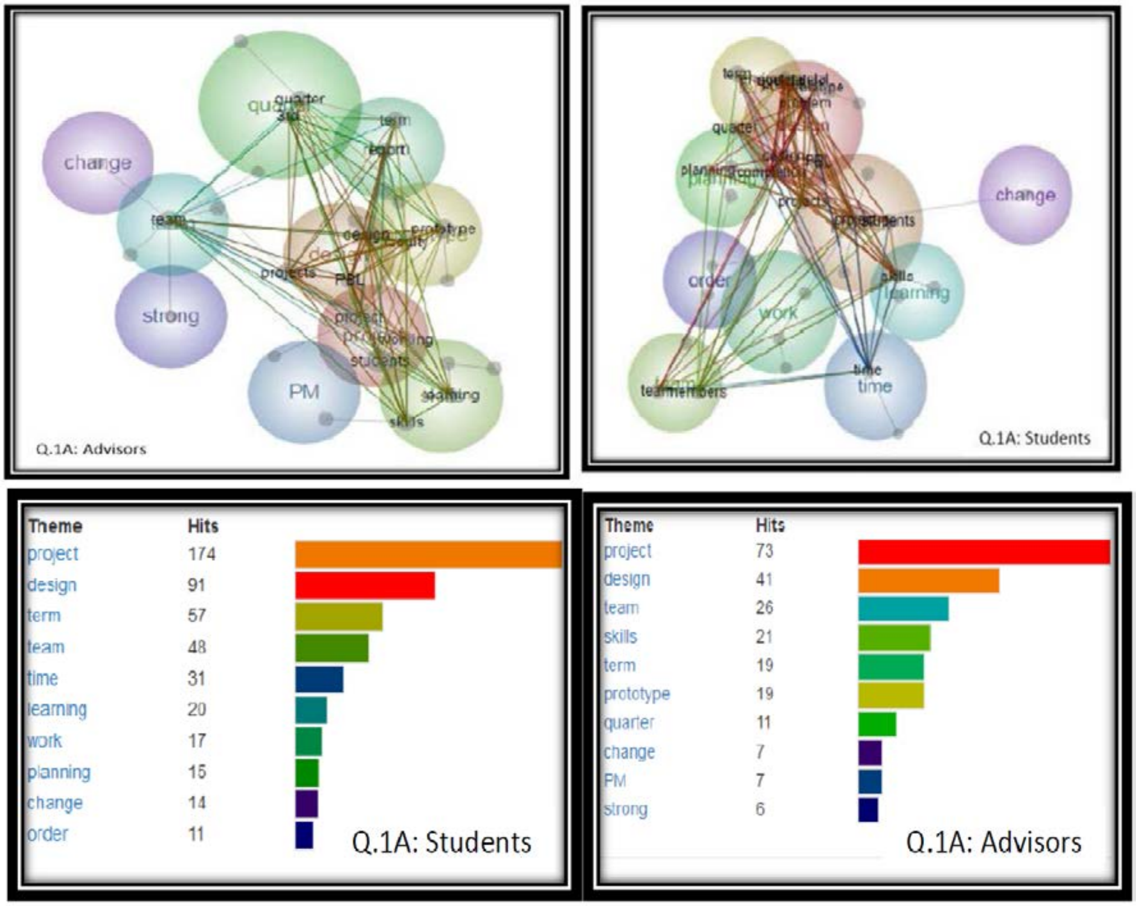
Rotated Component Matrix[a]

Items	Component			Items	Component		
	1	2	3		1	2	3
Q1	.698	.121	-.031	Q30	.197	.636	.046
Q2	.378	.522	-.340	Q31	.576	-.121	.251
Q3	.382	.112	.410	Q32	.587	.267	.284
Q4	-.046	.299	-.156	Q33	.220	.058	-.478
Q5	.405	.442	-.099	Q34	.519	.067	.362
Q6	.240	.388	.133	Q35	.137	-.215	-.165
Q7	-.110	.058	.386	Q36	-.099	.649	.344
Q8	.552	.291	-.208	Q37	.511	.290	-.405
Q9	-.217	-.005	.031	Q38	.399	.651	-.139
Q10	-.093	.564	.029	Q39	.563	.544	-.144
Q11	.218	.499	.204	Q40	-.037	.329	-.080
Q12	.314	.023	.354	Q41	-.006	.701	-.118
Q13	-.033	.587	-.114	Q42	.406	.452	.279
Q14	.158	.148	-.131	Q43	.487	.531	-.286
Q15	.371	.113	.621	Q44	.378	.195	.037
Q16	.166	.322	.064	Q45	.662	.461	-.049
Q17	.679	.051	.011	Q46	.551	.315	.025
Q18	-.246	.395	.550	Q47	.715	.263	.079
Q19	.023	.101	-.214	Q48	.083	-.129	.602
Q20	.554	-.442	.149	Q49	.704	.223	-.067
Q21	.461	.434	-.003	Q50	.580	.170	.362
Q22	.142	-.316	.628	Q51	.738	-.093	-.071
Q23	.476	-.084	-.045	Q52	.646	.005	.043
Q24	.681	.199	-.167	Q53	.535	.132	.143
Q25	.180	.583	-.232	Q54	.808	.280	.110
Q26	.575	.212	-.039	Q55	.430	.627	.091
Q27	.202	.531	.053	Q56	.512	.291	.223
Q28	.249	.477	-.100	Q57	.518	.302	-.359
Q29	.389	-.106	-.129	Q58	.745	.043	-.334

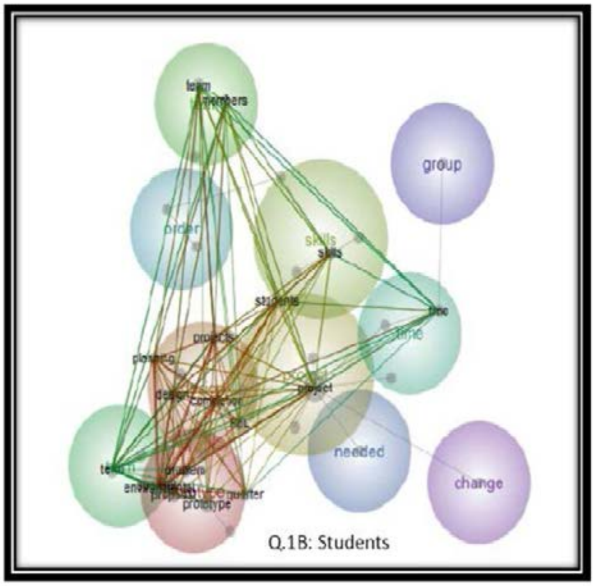
Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
a. Rotation converged in 5 iterations.

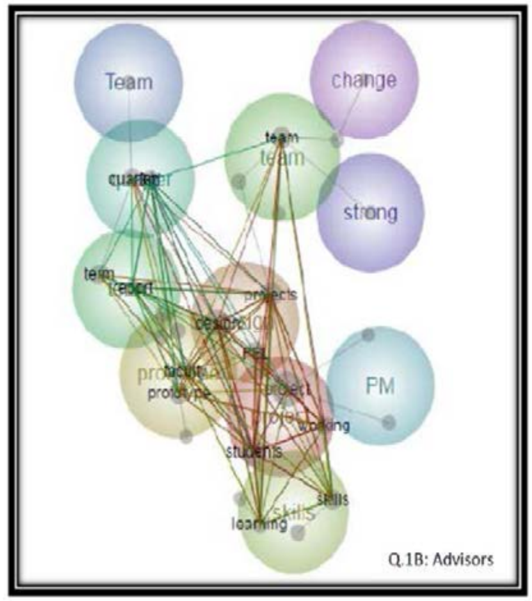
Appendix BB

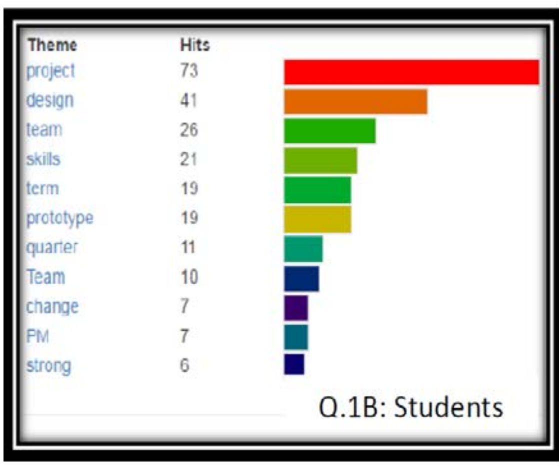
Q. 1A Concept Maps and Ranked Concepts



Appendix CC
Q. 1B Concept Maps and Ranked Concepts

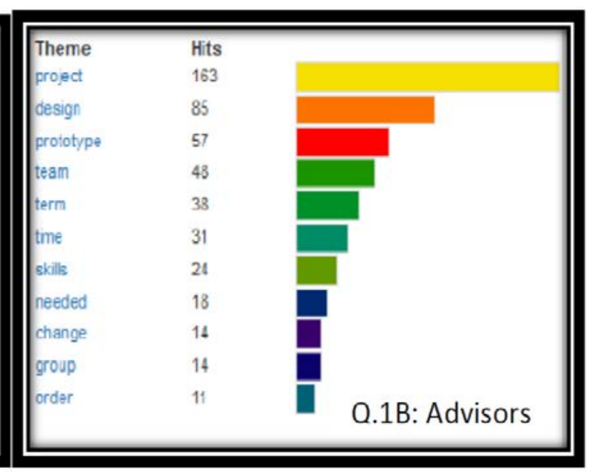






Theme	Hits
project	73
design	41
team	26
skills	21
term	19
prototype	19
quarter	11
Team	10
change	7
PM	7
strong	6

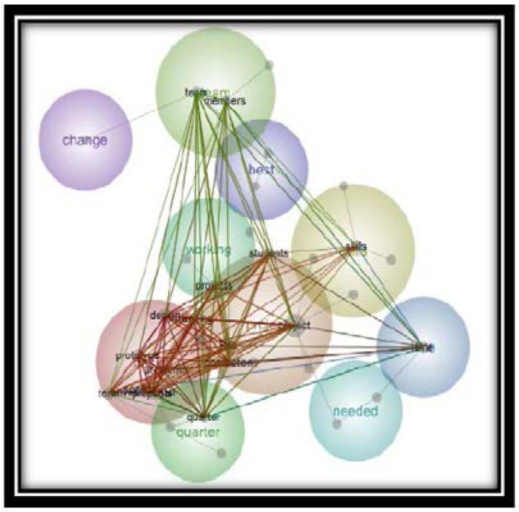
Q.1B: Students

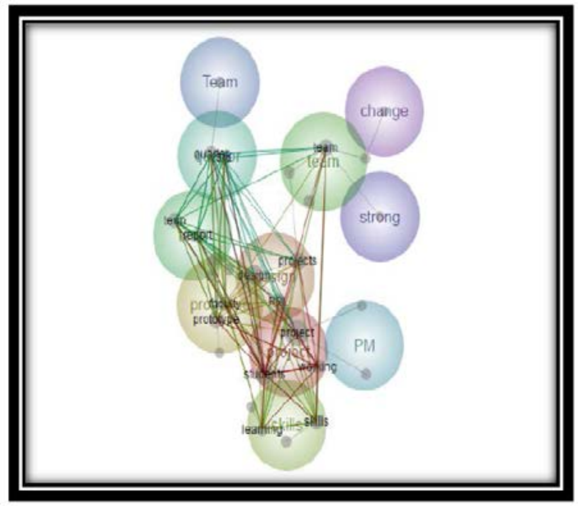


Theme	Hits
project	163
design	85
prototype	57
team	48
term	38
tme	31
skills	24
needed	18
change	14
group	14
order	11

Q.1B: Advisors

Appendix DD
Q. 2 Concept Maps and Ranked Concepts





Theme	Hits
project	168
design	100
team	48
time	31
skills	24
working	19
quarter	19
needed	18
change	14
best	13

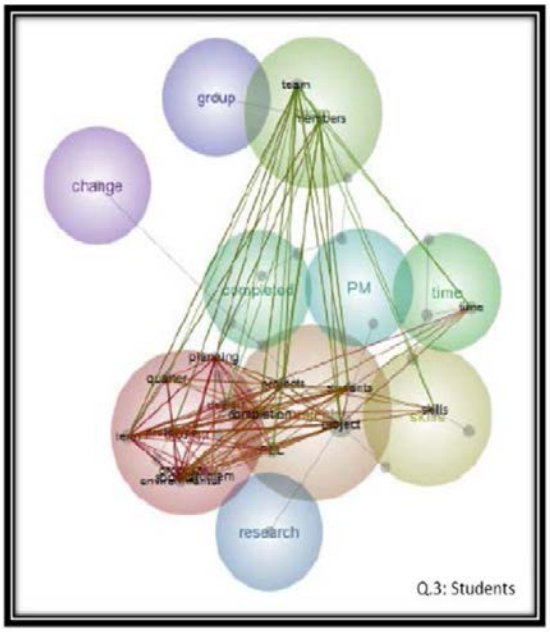
Q.2: Students

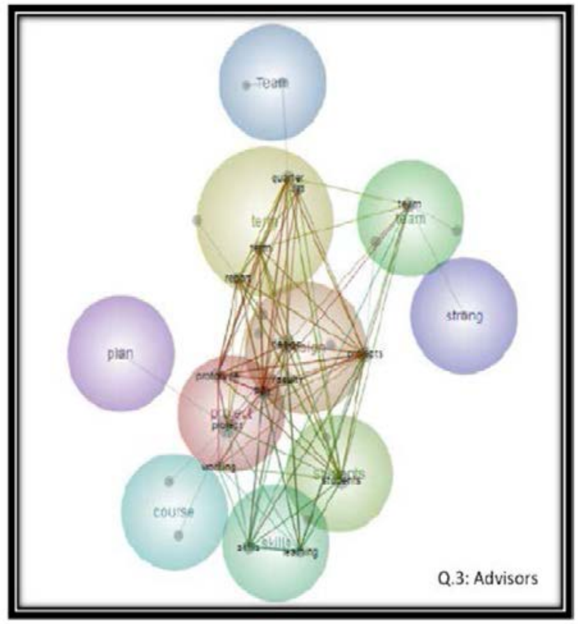
Theme	Hits
project	73
design	41
team	26
skills	21
term	19
prototype	19
quarter	11
Team	10
change	7
PM	7
strong	6

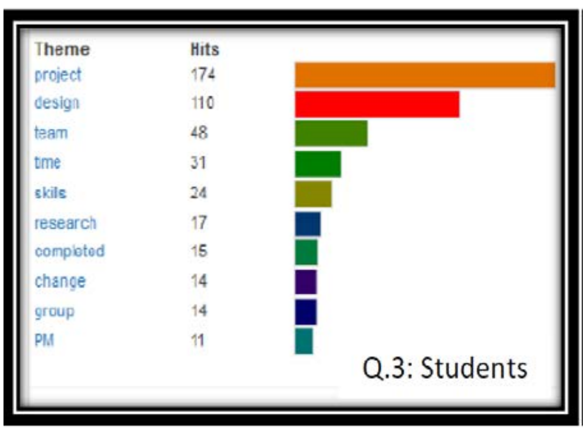
Q.2: Advisors

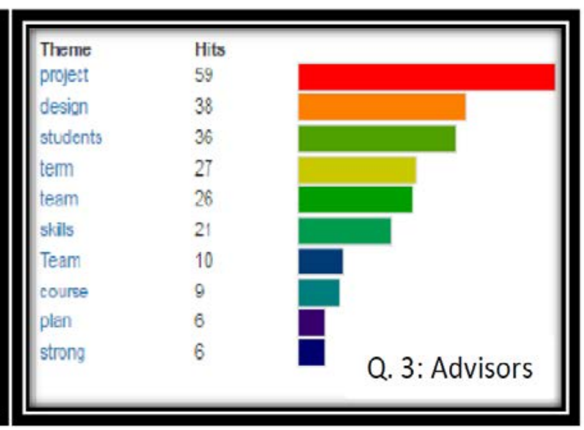
Appendix EE

Q. 3 Concept Maps and Ranked Concepts

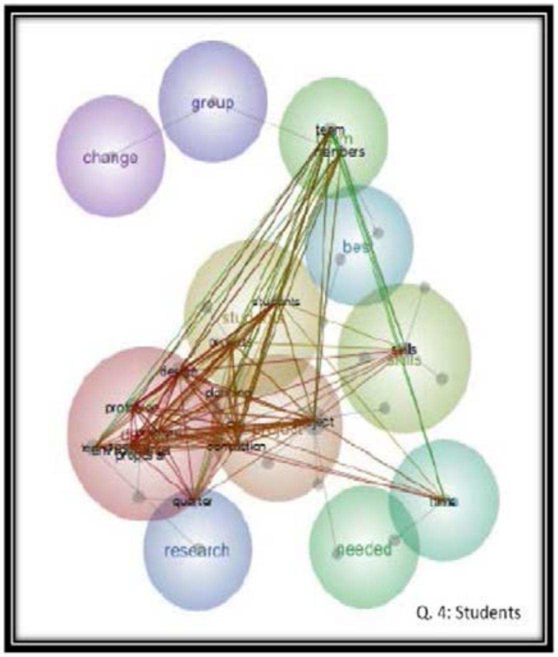


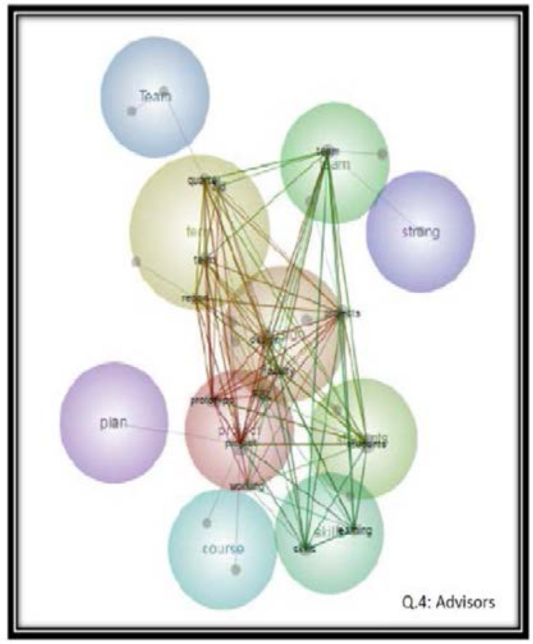


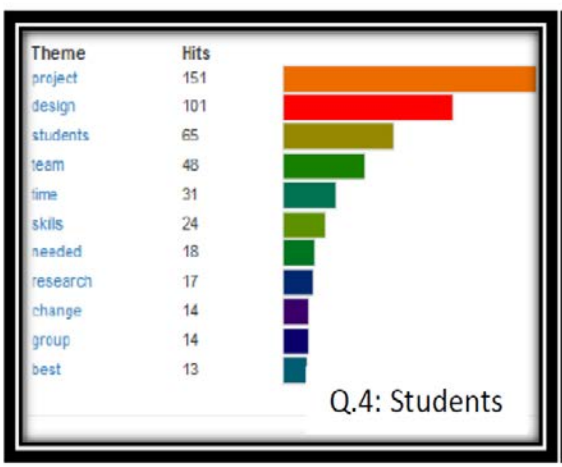


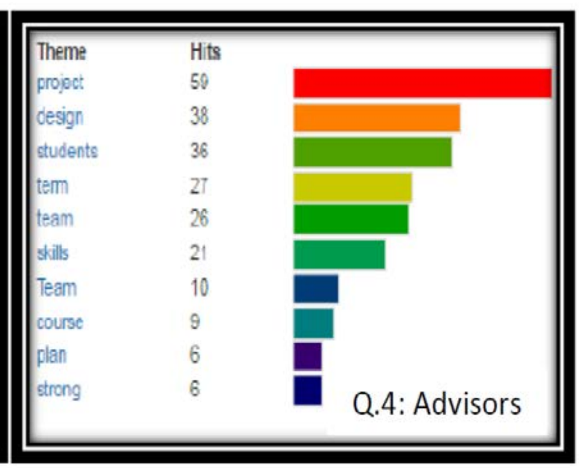


Appendix FF
Q. 4 Concept Maps and Ranked Concepts



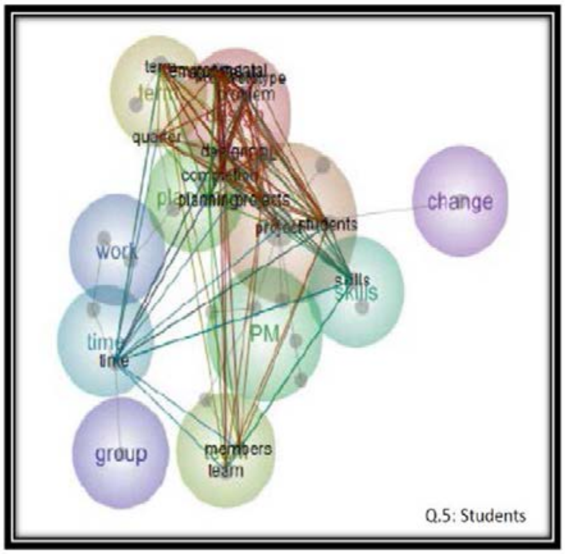




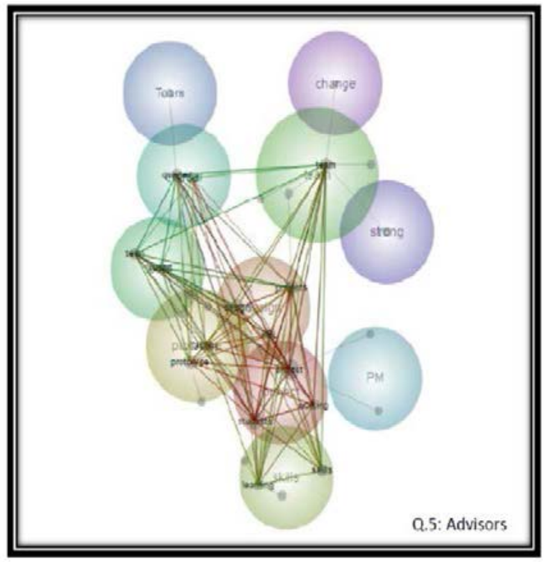


Appendix GG

Q. 5 Concept Maps and Ranked Concepts



Q.5: Students



Q.5: Advisors

Theme	Hits
project	170
design	91
term	55
team	48
time	31
skills	24
work	17
planning	15
change	14
group	14
PM	11

Q.5: Students

Theme	Hits
project	73
design	41
team	26
skills	21
term	19
prototype	19
quarter	11
Team	10
change	7
PM	7
strong	6

Q.5: Advisors

Appendix HH

Q. 6 Concept Maps and Ranked Concepts