TEACHING CREATIVITY AND INNOVATION IN HIGHER EDUCATION

Rebecca Martha C. Wyke

A DISSERTATION

in

Higher Education Management

Presented to the Faculties of the University of Pennsylvania

in Partial Fulfillment of the Requirements for the

Degree of Doctor of Education

2013

Supervisor of Dissertation:

____

J. Matthew Hartley, Associate Professor of Education

Dean, Graduate School of Education:

____

Andrew C. Porter, Dean and Professor

Dissertation Committee:

J. Matthew Hartley, Associate Professor of Education
Mary-Linda Armacost, Adjunct Professor of Education
Theodora J. Kalikow, President, University of Southern Maine

TEACHING CREATIVITY AND INNOVATION IN HIGHER EDUCATION

DEDICATION

For my mother, Rosa,

who set the example

and for my husband, Joe,

who always encouraged me.

ABSTRACT

TEACHING CREATIVITY AND INNOVATION IN HIGHER EDUCATION

Rebecca M. Wyke

J. Matthew Hartley

A principal goal of higher education is to prepare students for the real-world challenges they will encounter upon graduation in their everyday life, in their work and in society. While discipline specific content knowledge is an important component of a college education, a 2010 survey of employers conducted for the Association of American Colleges and Universities reflected the changing expectations of employers for recent college graduates. Approximately ninety percent of employers surveyed said college graduates entering the workplace need a broader set of skills than in the past in order to meet increasingly complex workplace challenges. Among the top four workplace skills in demand are creativity and innovation.

This study employs a qualitative phenomenological approach to examine a particular curricular program designed to impart creativity and to promote the generation of new ideas that lead to innovation. Through the use of student surveys and in-depth interviews with students and faculty who have participated in the program, the study offers a synthesized description of the student experience of the curriculum and the pedagogies used in the program. The study identifies the key benefits of the program for students; offers guidance on what kind of pedagogical

approaches are necessary for faculty to successfully implement this kind of program; and addresses the challenges involved in advancing a curriculum for creativity and innovation that utilizes unconventional pedagogies.

What seems clear from the student experience is that the curricular program is effective in imparting the knowledge and skills to practice creativity and innovation. Also evident is that the constructivist learning environment and the pedagogies employed in teaching the program, including hands-on and collective learning, critical thinking and problem-based learning, and formative assessment, contribute to a feeling of confidence in the mastery of the skills and results in deep learning by the students. Through the experience, students are empowered with a creative capacity and an ability to innovate, as well as with skills in communication, collaboration, critical thinking and problem-solving. These are abilities that will prepare students for the complexities of rapidly changing world.

TABLE OF CONTENTS

List of Tables

CHAPTER 1: INTRODUCTION

A 2006 report by the National Center on Education and the Economy assessing the educational and skills preparation of the American workforce states that global economic leadership is dependent upon a workforce that represents "a deep vein of creativity that is constantly renewing itself," and notes that American education must produce graduates that are creative and innovative, as well as knowledgeable (p. 6). In additional research, employers who hired recent college graduates confirm that critical-thinking and problem-solving, which employ the cognitive functions of associating, analyzing, and reasoning are desired skills in need of improvement in those recently graduated from college (Association of American Colleges and Universities, 2008; New Jersey Commission on Higher Education, 2005). In his new book, *Creating Innovators: The Making of Young People Who Will Change the World*, Tony Wagner argues that the goal of education should be that every student should graduate college "innovation ready," prepared to add value to whatever they do (Wagner, 2012). In a 2013 interview, Wagner elaborated on what he meant by this to *The New York Times* columnist and best-selling author, Thomas L. Friedman: "Today, because knowledge is available on every Internet-connected device, what you know matters far less than what you can do with what you know. The capacity to innovate -- the ability to solve problems creatively or bring new possibilities to life – and skills like critical thinking, communication and collaboration are far more important than academic knowledge" (Friedman, 2013).

Because there is a need for creative and innovative college graduates who can employ critical thinking and problem-solving skills, curricula that develop cognitive abilities for idea generation and utilize a pedagogy that fosters critical thinking and problem-solving can provide students with the skills needed to successfully address challenges and seize opportunities in the real world (Behar-Horenstein & Niu, 2011; Tsui, 2002). Action-oriented approaches to learning creativity and innovation that simulate real world challenges encourage experimentation and risk-taking (Nieuwenhuizen & Groenewald, 2006; Noyes & Brush, 2011). Because experimentation encompasses learning by doing and trial and error, it engages the cognitive abilities needed for critical thinking, problem-solving and discovery -- imitating challenges students will face in the real world (Collins, Smith & Hannon, 2006). The best way to determine if an idea will work and to generate data on how to improve upon the idea and construct new knowledge is through experimentation (Dyer, Gregerson & Christensen, 2011). For this reason, problem-based learning, in which students learn by focusing on complex, ill-structured, real-world problems with no single correct answer, is particularly beneficial for enhancing the cognitive processes involved in learning. Problem-based learning provides students with the opportunity to experiment, take risks and learn from their mistakes (Hmelo-Silver, 2004).

A principal goal of higher education is to prepare students for the real-world challenges they will encounter upon graduation in their everyday life, in their work and in society (Tsui, 2002). While discipline-specific content knowledge is an important component of a college education, so too is learning that focuses on enhancing the cognitive processes that contribute to creativity and innovation, such as critical thinking and problem-solving (Behar-Horenstein & Niu, 2011). The development of cognitive skills provides students with the ability to translate their education into a life-long journey of learning, enabling them to adapt quickly to changes in the labor market and challenges in their personal lives (National Center on Education and the Economy, 2006).

Study Overview

The purpose of this study is to examine a particular curricular program designed to impart creativity and to promote the generation of new ideas that lead to innovation. The study focuses on the Innovation Engineering program offered through the Foster Center for Student Innovation at the University of Maine. The Center is home to the Innovation Engineering curriculum and provides a forum for University faculty and staff to work with students to develop the knowledge and skills necessary to transform the students' innovative ideas into real products and services.

The curriculum of the Innovation Engineering program provides students with a systematic approach to innovating, generating and communicating ideas, as well as managing the risk associated with experimentation and with bringing an idea to fruition. The desired curricular outcome is for students to gain the confidence to create their own opportunities and to lead change in their respective fields of expertise. Offered as a minor or graduate certificate, the program enhances any major or field of study. The minor consists of a minimum of eighteen (18) credit hours, including the three core courses of the curriculum - *INV180 Innovation Engineering I: Create*; *INV282 Innovation Engineering II: Communicate*; and *INV392 Innovation Engineering III: Commercialize*. Each of the core courses in the curriculum builds upon the concepts introduced in the prior course. Combined, they represent the continuum of the process of innovation.

Through the Innovation Engineering curriculum, students gain a process for innovation. The Innovation Engineering system represents the entire pipeline of innovation, from generating the idea to testing it out to effectively communicating the idea to the intended beneficiary. Through the pedagogic method known as applied learning, students come to master the tools and techniques taught in the program to engage in brainstorming activities that expand their thinking and let their ideas go without restraint. These methods work to multiply the amount of stimuli available to the imagination and engage students in a process of associative thinking to make new connections between thoughts and ideas.

Students also learn how to break down problems connected with an idea and to identify the issues that must be overcome to turn the idea into a successful innovation. This is accomplished through rapid cycles of learning, or small experiments, to control risk. Part of the experience for students is learning to control the fear associated with failure and with being judged by others. To combat this fear, a safe, judgment-free environment is created to encourage students to express their ideas, request help when needed, and learn from their mistakes. A critical part of this process is assessment and reflection. Students come to understand that the analysis and consideration of why something did not work often leads to a new and better idea.

Students learn to identify solutions that both solve the problem and do so in a novel fashion. This concept is known in the program as a *Meaningfully Unique* idea. Further, the curriculum assists students in effectively communicating their idea to the intended beneficiary by teaching students how to demonstrate a keen understanding of the problem, communicate the benefit promised by the innovation, and prove that the solution works. In the program this communications model is known as *Problem-Promise-Proof*.

The pedagogic methods used to teach creativity and innovation in the Innovation Engineering curriculum include employing a constructivist learning environment in which students actively participate in the construction of new knowledge, rather than simply receiving knowledge through formal instruction. Supported by an interactive learning community, teachers and students form a mentor and apprentice relationship. Through focused facilitated knowledge construction aided by the teacher and student peers, students learn to engage their cognitive abilities and to employ critical thinking and problem-solving skills.

Other pedagogies employed in the program include: problem-based learning, in which students are given complex, ill-structured problems for which there is no one right answer; applied learning, in which students learn program concepts through hands-on trial and error; collective learning, whereby students learn through collaboration and teamwork with their peers; and formative assessment, in which students learn from multiple interactive and iterative cycles of learning, assessment, feedback, and reflection. These pedagogic methods will be discussed in more detail in the literature reviewed in *Chapter 2*.

For the students, the benefit of the Innovation Engineering curriculum and the pedagogy by which it is taught is the confidence gained by the mastery of the tools and techniques employed by the program and the sense of empowerment in their own ability to create and innovate. The results realized from the pedagogic methods employed by the program raise real questions for faculty and institutions of higher education about the relative effectiveness of traditional methods of instruction and how those methods serve to develop the real-world skills needed for success in career and in life.

To establish the context for this study, *Chapter 2* provides an overview of the relevant literature. Beginning with an appraisal of how well colleges and universities prepare college graduates in creativity, innovation and other related workplace skills required for employment, the chapter explores the concepts of creativity, innovation and critical thinking and explains how researchers define and associate these similar concepts. The chapter also investigates the research on idea generation and the enhancement of cognitive processes and the role of experimentation in innovation. The chapter concludes with an examination of a constructivist learning environment for the promotion of creativity and innovation.

Chapter 3 outlines the research methodology – a qualitative analysis using a phenomenological approach – and includes a description of the site selection and access, the concept map for the study, the research design, the sampling strategy, and a description of the interview participants.

Chapter 4 presents a detailed description of the Innovation Engineering curriculum and lays out the research findings from the student survey and from in-depth interviews with students and faculty engaged in the program. The findings fall into four thematic categories. *Engineering a Process for Innovation* relays the findings on idea generation and the enhancement of cognitive processes. *Fail Fast, Fail Cheap Design Cycles* provide the findings related to learning cycles and experimentation. *Constructivist Learning Environment* conveys the findings on how the pedagogies employed in a constructivist learning environment contribute to the learning of creativity and innovation. Finally, *Learning to be Agile* explores the findings related to the sense of empowerment and creative strength enjoyed by those who embrace the curricular experience and discusses the participant experiences of educational and organizational reticence that sometimes occurs in response to the methods of teaching and the concepts of the program.

Drawing from the research findings in *Chapter 4* and the literature in *Chapter 2*, *Chapter 5* presents an analysis of the key findings derived from the study in three parts. The first part addresses what students consider the key benefits of the program; what they will take with them from the experience. The second part addresses what others in academia can learn from the research in this study and what kind of pedagogical approaches are necessary for faculty to successfully implement this kind of program. The third part addresses the challenges involved in advancing a curriculum for creativity and innovation that employs unconventional pedagogies.

Chapter 6 draws the major conclusions from the study and suggests how faculty and institutions can employ the research. This chapter also raises questions about applying the pedagogy used in a constructivist learning environment to other parts of the university curriculum. The chapter concludes with the limitations of the research and advice for future researchers.

CHAPTER 2: REVIEW OF THE LITERATURE

Demand for a Different Set of Workplace Skills

A 2010 survey of employers conducted for the Association of American Colleges and Universities reflected the changing expectations of employers for recent college graduates. Approximately ninety percent of employers say employees need a broader set of skills than in the past, with higher levels of learning and knowledge in order to meet increasingly complex workplace challenges. The survey also noted that only twenty-eight percent of employers believe higher education is doing a good job preparing students for work after college, while sixty-eight percent say there is room for improvement (Association of American Colleges and Universities, 2010).

One reason that college graduates may not be meeting employer expectations is that the economy has evolved. Hisham Ghassib, in his 2010 article *Where Does Creativity Fit into a Productivist Industrial Model of Knowledge Production?*, notes that "unlike pre-modern economies that were geared towards satisfying basic needs, the modern economy is geared towards creating new needs, including illusory needs (p. 14)." As the economy has shifted, so have the traits prized by employers. Daniel Pink, in a video-taped talk entitled, *A Whole New Mind with Daniel Pink*, suggests that in this modern economy, creative individuals with "right brain" qualities -- those who are artistic, empathic and able to understand synthesis and context -- will be in high demand. Conversely, the work of those individuals with "left brain" qualities -- those who are logical, linear, sequential and analytical -- will be automated by technology or off-shored to less expensive labor overseas (Hodge & Lear, 2011; Ahy, 2009).

The shift in traits sought by employers may explain the gap between faculty and student perceptions of desired skills and the real needs of employers. Hodge and Lear (2011) explored this issue through a quantitative survey to determine what skills faculty members and students perceive to be the most important to employers. Faculty identified the top four skills as interpersonal abilities, critical thinking, problem-solving and teamwork. Students identified the top four skills as management, interpersonal abilities, teamwork and time management.

The researchers then compared these results to a major business survey on workplace skills important for employment conducted by the American Management Association in 2010 (se). The results demonstrated a mismatch between the work skills employers say are important and those that faculty and students believe employers want. Faculty properly identified critical thinking and problem-solving, and teamwork among the most important skills, but failed to identify the number one desired skill of communications. Faculty likewise failed to identify the need for skills in creativity and innovation. Students were only able to identify one of the top skills, teamwork, and rated communications, critical thinking and problem-solving, and creativity and innovation much lower than did the employers. The results suggest that faculty may not adequately appreciate or understand the newly evolving workplace skills employers expect or, if they do, that they are not adequately conveying the need or the skills to students (Hodge & Lear, 2011).

Table 1
Surveys of Top Workplace Skills

AMA Survey	Faculty Survey	Student survey
Communications	Interpersonal	Management
Collaboration/Teamwork	Critical thinking	Interpersonal
Critical Thinking/Problem Solving	Problem Solving	Teamwork
Creativity/Innovation	Teamwork	Time Management

Many, if not all, colleges and universities offer some form of curricular experiences that work to close the skills gap for those students who take advantage of the opportunities. These offerings include experiential education such as internships, service learning and community-based projects, courses in oral and written communication, liberal arts curriculum that foster critical thinking and problem-solving, and curricular programs in innovation and entrepreneurship (Association of American Colleges and Universities, 2010; Shillace, 2012). However, despite curricular pockets where students can learn desired workplace skills including creativity and innovation, the educational system in the United States principally teaches a curriculum of content (Perkins, 2002; Sisk, 2010).

Beginning with K-12 education, there is an emphasis on a standards-driven curriculum that focuses on skills for memory and logic that represent the aptitudes measured by national and state tests (Sisk, 2010). By the time students get to college they are programmed to focus on right answers, not "novelty and nuance" (Ahy, 2009). What is missing is an intentional focus on infusing the skills of communications, collaboration and teamwork, critical thinking and problem-solving, and creativity and innovation into the entire curriculum (Perkins, 2002; Sisk, 2010).

Creativity, Innovation and Critical Thinking

The purpose of this section is to explore the concepts of creativity, innovation and critical thinking and to explain how researchers define and associate these similar concepts. Creativity is the use of imagination to form an original idea (Nieuwenhuizen & Groenewald, 2006). Innovation differs from creativity in the sense that creativity spawns the idea, while the activity of obtaining value from that idea is innovation (Bruton, 2010; Nieuwenhuizen & Groenewald, 2006; Norton & Hale, 2011).

Understanding how creativity and innovation occur and by what means these abilities can be enhanced offers a foundation for developing curricula to teach innovation. It is possible that creative and innovative people, individuals who come up with unique ideas and set them to work successfully, are simply born with a gift (Dyer, Gregerson & Christensen, 2011; Sisk, 2010) or that new ideas reveal themselves and the innovators who discover them are just lucky (Bruton, 2010; Norton & Hale, 2011). However, evidence explored through the literature suggests that there are ways to instruct people in how to be creative and how to innovate (Berglund & Wennberg, 2006; Bruton, 2010; Tsui, 2002).

Creativity most often occurs when different knowledge and perspectives collide through a process of associative thinking. Associative thinking is the discovery of connections among seemingly unconnected ideas in order to create a new idea (Dyer, Gregerson & Christensen, 2011). Bruton (2010) examined the impact of a course in creative thinking for undergraduates in an effort to understand whether there are ways to improve creativity in students of various disciplines. The study found that creativity, as measured by the fluency of idea generation, tolerance of ambiguity, originality of ideas and ability to elaborate with detail, was significantly improved in students through a curriculum that employed a mix of individual and group projects to explore creative problem-solving techniques.

The concepts of critical thinking and problem-solving are closely associated with both creativity and innovation (Behar-Horenstein & Niu, 2011; Gordon, 2011; Saiz & Rivas, 2011). Critical thinking is the use of reasoning skills to decipher available knowledge about a problem or opportunity, discriminate between various options and arrive at a decision point or plan of action (Behar-Horenstein & Niu, 2011; Facione & Facione, 2007; Gordon, 2011; Saiz & Rivas, 2011). In problem-based learning, students solve complex, ill-structured problems for which there is no one correct answer (Hmelo-Silver, 2004).

Through the use of problem-based learning students employ meta-knowledge -- knowledge discovered or learned through meaning construction, reflection, assessment, and comparison -- to arrive at a particular decision (Karakas, 2011; Saiz & Rivas, 2011). Saiz and Rivas (2011) studied an intervention program designed to enhance critical-thinking skills in students. In the program, students worked to resolve problems from everyday life. Using the skills of reasoning, problem-solving and decision-making, students demonstrated marked improvement in critical thinking.

Joining individuals of varying disciplines with different experiences and unique perspectives results in a combining of creative strengths that can lead to innovation. The collision of different approaches results in creative abrasion, a process by which individuals learn from the diverse contributions of each other and produce a variety of ideas to exploit an opportunity or find a solution to a problem (Leonard & Strauss, 1997). Effectively, students participate in their own education when immersed in an environment that promotes engagement with others and fosters the transformation of experience into knowledge (Nordstrom & Korpelainen, 2011). Student feedback evaluated in a study by Nordstrom and Korpelainen (2011) determined that student engagement in group work and in the preparation of portfolios with unorthodox materials, such as Legos, movies, music, modeling clay and drawings to demonstrate learning, enhanced critical thinking. The objective was for students to focus collectively on the learning process, rather than trying to achieve a correct outcome. The research demonstrated that the unconventional pedagogical approach employing student engagement in groups resulted in innovative thinking and behavior.

Idea Generation - Enhancing Cognitive Processes for Associative Thinking

Creative ideas that can lead to innovation are born from cognitive processes that combine the ability to make associations with behaviors such as observation, questioning and risk-taking (Dyer, Gregerson & Christensen, 2011). Cognitive ability is the emergent process of constructing meaning from information (Karakas, 2011). Through a process of associative thinking, innovators use cognitive ability to construct meaning by making connections between ideas, problems, and disciplines that others deem unrelated. There are a variety of techniques that enhance cognitive ability to improve associative thinking and to generate more ideas.

Brainstorming techniques assist in stimulating cognitive processes to make associations that might not otherwise occur and generate ideas. For example, the technique of free association encourages the individual to consider whatever stray thought comes to mind even if seemingly unrelated, while the technique of forced association utilizes a series of random words, forced into association with a particular subject. Paired thoughts produced by free or forced association yield new creative possibilities. Another method of brainstorming is mind mapping. A mind map is an actual diagram at the center of which is a central idea, or starting point, with threads of associated ideas networked out from the core. Through this process, mind mapping functions as a thinking tool to generate new ideas and to structure the results for analysis (Hall, 2001; Innovation Engineering Leadership Institute, 2011). A sample mind map appears in *Appendix* D.

A stimulus is an essential component that aids the cognitive processes of associative thinking. Whether a stimulus is related to the problem or opportunity at hand or unrelated, the stimulus contributes to the generation of ideas that feed associative thinking. Stretching the mind by providing new experiences exercises the mind and opens it to new concepts. Selecting books and music not ordinarily favored, learning a new craft or skill, traveling to a new place – all serve to generate new thoughts that can lead to new ideas. The more ideas generated, the more likely that one of those ideas will address the task or problem at hand (Hall, 2001). Ideas can come from anyone, anywhere, and at any time. Something observed, an answer given in response to a question, an association made, or something learned from a failed experiment all serve as stimuli that lead to an idea.

More notably, leveraging the thinking that occurs in groups enhances cognitive processes for associative thinking (Fletcher, 2011; Karakas, 2011). Group work results in more profound learning, as collaboration with other students stimulates the processes of cognitive thinking, affecting the construction of knowledge (Nordstrom & Korpelainen, 2011). "Left brain" thinkers utilize a logical, sequential and rational approach in addressing problems while "right brain" thinkers adopt a more holistic and intuitive approach. "Whole brain" teams leverage the diversity of thinking in groups, bringing left brain and right brain views together and using creative abrasion, a collision of differing points of view, to produce associations and form new ideas (Gordon, 2011; Leonard & Straus, 1997).

Ideas generated through a process called systematic search enhance associative thinking grounded in a particular knowledge base. Building on the individual or team's knowledge of a particular discipline or domain, systematic search and discovery utilizes a series of interrelated activities to search out ideas to address a particular problem or latent demand in the marketplace. Bounding the search protocols constrains the search to specific domains in which specific knowledge is possessed. The protocols used for systematic search exhibit success more than unstructured searches, also known as alertness methods. (Norton & Hale, 2011). In a research project designed to test whether the systematic search approach to discovery was more effective than alertness or plain luck, fully ninety-two percent of the experimental group utilized specific knowledge or experience to detect an idea versus only eight percent of the control group who depended on alertness methods (Fiet & Patel, 2008).

Experimentation and Risk-taking

Second only to creativity and critical thinking, risk-taking and experimentation are closely associated with innovation and entrepreneurial thinking (Nieuwenhuizen & Groenewald, 2006). Traits held by successful innovators and entrepreneurs include vision, creativity, intuitive decision-making, creative problem-solving, risk-taking and the ability to learn from their mistakes (Collins, Smith & Hannon, 2006). Creative, action-oriented approaches to innovation and entrepreneurship encourage experimentation with available resources (Noyes & Brush, 2011). Risk-taking encompasses learning by doing, which includes the activities of experimentation, or trial and error, as well as problem-solving and discovery (Collins, Smith & Hannon, 2006). Experimentation is the best method for ascertaining the viability of a possible solution and for producing information on what might work in the future (Dyer, Gregerson & Christensen, 2011).

Competent innovators have the capability to improve and reflect upon their experience with experimentation, including failures. In doing so, they develop a longer-term perspective that leads to improvement over time (Man, 2006). When grounded in self-reflection, failure can facilitate learning and resilience, increasing the level of preparation for pursuing new entrepreneurial ventures. However, the strong emotional and financial impacts of failure when a significant investment of time and resources are involved can hamper future efforts at innovation, underscoring the utility of small scale experimentation (Cope, 2011). Research shows that risk managed through limited experimentation requiring small investments reduces losses (Noyes & Brush, 2011).

Although experimentation enhances learning and advances innovation through the construction of new knowledge resulting from trial and error, avoiding the pitfalls that can occur from tendencies to filter out negative information due to biases in decision-making or the illusion of control is vital. Research demonstrates that the use of experience-based techniques for problem-solving, learning and discovery, known as heuristics, may be beneficial to innovation, but may cause individuals to prematurely arrive at a decision point or solution (le Roux, Pretorius & Millard, 2006). Further, the experimentation involved in innovation can bring significant stress. When stress is present in a situation, individuals are more likely to neglect the exploration of all available options, resulting in deficient decision-making (Keinan, 1987).

Constructivist Learning Environment and Pedagogy

Cognitive abilities that promote creativity and innovation are cultivated in constructivist learning environments. The responsibility for learning shifts from teacher to student in a constructivist learning environment, requiring the student to employ cognitive processes and to actively participate in the construction of new knowledge by integrating new information with prior learning and experience (Kumar & Kogut, 2006). In this way, constructivism employs experiential learning methods, transforming experience into knowledge (Kolb, 1984). In contrast, traditional classrooms feature lecture-style instruction focused on the dissemination of information and employ conventional reward systems for academic performance that tend to favor single correct answers. Such passive forms of learning, where students receive information transferred to them by the teacher, do not afford students an opportunity to develop the capacity to engage in critical thinking that fosters innovation (Michel, Cater & Varella 2009).

Researchers have found that constructivist approaches promote capabilities such as critical thinking, adaptability, problem-solving, communication and interpersonal skills. These are achieved through the active engagement of students in learning activities facilitated by interaction with the teacher and peer students (Kember & Leung, 2005a). Students are also better able to grasp and learn new information when they participate in dialogue with others, allowing them to process, rather than just record information (Tsui, 2002). Research suggests that students exposed to non-lecture learning activities and real-life situations have higher perceptions of their development of these capabilities (Kember & Leung, 2005b). Additionally, researchers have found that pedagogical strategies that employ formative assessment, or multiple interactive and iterative cycles of learning, assessment, feedback and reflection, aid in the development of cognitive abilities that enhance a student's capacity to assess his or her own judgment and to improve learning outcomes (Asghar, 2012; Clark, 2012; Crossouard & Pryor, 2012). The literature points to key pedagogical strategies for achieving improved cognitive outcomes through problem-based learning.

Problem-based learning is a form of constructivism in which students learn through facilitated problem-solving. Students focus on complex, ill-structured problems that often require multi-disciplinary solutions and reflect either real-world or simulated real-world problems for which more than one answer can be formulated (Hmelo-Silver, 2004). The goal of problem-based learning is not to attain the correct answer, but instead to emphasize the learning process itself (Nordstrom & Korpelainen, 2011). Through the use of real world intelligence, students learn how to adapt to the unexpected and how to shape their interactions with the environment (Tan, 2007).

A major feature of the problem-based approach is the shift of responsibility for learning from the teacher to the student and the learning community (Kumar & Kogut, 2006). The teacher acts as a facilitator rather than the source of knowledge, modeling good thinking and learning strategies (Hmelo-Silver, 2004). Students become engaged in self-directed learning supported by the facilitator and the learning environment (Dochy, Segers, Bossche & Struyven, 2005; Downing, Kwong, Chan, Lam & Downing, 2009; and Hmelo-Silver, 2004). Learning is absorbed more deeply when students discover concepts themselves rather than receiving knowledge through formal instruction (Nordstrom & Korpelainen, 2011). Research shows that in addition to subject-specific skills, students are more likely to develop generic metacognitive skills when engaged in problem-based learning than they are in traditional classrooms (Hmelo-Silver, 2004), and that students find value in the self-regulated learning environment and in the process of constructing new knowledge (Dochy, Segers, Bossche & Struyven, 2005; Kumar & Kogut, 2006).

Knowledge construction improves when students engage in active learning collectively. In problem-based learning, collaborative groups generate an important source of cognitive development (Downing, Kwong, Chan, Lam & Downing, 2009), as interaction with other students yields deeper learning (Nordstrom & Korpelainen, 2011). Learning becomes a social act involving discussion, negotiation, interpretation and shared understanding (Kumar & Kogut, 2006) as knowledge is constructed using a multi-disciplinary approach integrating information and experience from diverse disciplines (Tan, 2007). Working collaboratively, students identify the need for new knowledge to solve the problem and share the responsibility for learning (Hmelo-Silver, 2004).

One of the advantages of collective learning is that it demonstrates how different students bring prior knowledge and diverse disciplines together to form new knowledge in addressing a problem (Tan, 2007). Information is first absorbed and processed before being used to address the problem, a process known as metacognition (Downing, Kwong, Chan, Lam & Downing, 2009). Students employ critical reflection to assess their own learning and that of other group members through an iterative cycle of action and reflection (Kumar & Kogut, 2006). Such a process promotes both content-specific and generic thinking strategies that develop into life-long learning skills (Hmelo-Silver, 2004).

Although problem-based learning affords many advantages for enhancing critical thinking and cognitive ability that can lead to innovation, research demonstrates some limitations of the approach and acknowledges that the same learning environment can cause differing student reactions (Struyven, Dochy & Janssens, 2008). Students used to traditional lecture-style instruction can find the student-centered learning environment uncomfortable, while the role of the teacher-as-facilitator can cause some students to believe the teacher is not contributing to their learning (Dochy, Segers, Bossche & Struyven, 2005; Kumar & Kogut, 2006). Research shows that group conflicts, weak facilitation, poorly constructed problems and perceived subjectivity of learning assessment can also detract from the student experience in problem-based learning (Kumar & Kogut, 2006).

A well-constructed problem-based learning approach is particularly conducive to teaching creativity and innovation in its ability to simulate the challenges encountered by innovators and entrepreneurs in the real world. Employing a combination of practical application of problem-solving methods and research-based scholarship provides the best framework for learning innovative and entrepreneurial behavior (Fiet, 2000). Research suggests that traditional courses in innovation and entrepreneurship focused on the identification of opportunities, the planning and financing of new ventures, and market development do not adequately cover the actual activities in which nascent entrepreneurs engage (Edelman, Manolova & Brush, 2008). Rather, activities that contribute to learning closely associated with the successful adoption of an innovation or with persistence in a start-up firm contribute relevance to the curriculum. These activities are action-oriented and have a focus on making the innovation or business opportunity tangible to the student and to others (Edelman, Manolova & Brush, 2008).

Conclusions

The ability to innovate, to continually produce new ideas, and to bring them to realization drives economic success. America needs college graduates who will occupy the workforce capable of generating new ideas to solve consumer, business, and social problems (Behar-Horenstein & Niu, 2011; National Center on Education and the Economy, 2006). While some innovators may be born (Dyer, Gregerson & Christensen, 2011) and others may be lucky (Norton & Hale, 2011), strong evidence suggests that there are ways to instruct the rest of us on how to generate or search out more ideas (Bruton, 2010). We can enhance our cognitive abilities for critical thinking and problem-solving to distinguish between those ideas that add value and those that do not (Behar-Horenstein & Niu, 2011). We can learn how to mitigate risks associated with experimentation and how to discover new knowledge from our mistakes (Collins, Smith & Hannon, 2006). In effect, we can learn how to innovate (Berglund & Wennberg, 2006; Bruton, 2010; Tsui, 2002).

Creating a learning environment for students that fosters cognitive processes that can help to stimulate creativity and innovation is vital for those abilities to flourish (Kember & Leung, 2005a). Such settings require students' active participation in the construction of new knowledge through the integration of new information with prior learning and experience (Kumar & Kogut, 2006). Problem-based pedagogy focuses on the learning process by shifting responsibility for learning from the teacher to the student and engages the student in self-directed learning that is enhanced through interaction with the teacher-as-facilitator and through collaboration with other students (Hmelo-Silver, 2004). Pedagogy that employs problem-based learning and that encourages students to take charge of their own education is essential to empower the creativity, critical thinking, and innovation that will ensure the preparation of college graduates for the complexity of a rapidly changing world (Bruton, 2011; Fiet, 2000; Nordstrom & Korpelainen, 2011; Pappas & Pappas, 2003).

CHAPTER 3: METHODOLOGY

This study focused on the Innovation Engineering program offered through the Foster Center for Student Innovation at the University of Maine. The Foster Center for Student Innovation opened its doors in 2006 with a generous gift of $1.5 million from Bion and Dorian Foster; its mission is to provide dedicated support for innovation programming (University of Maine System Board of Trustees, 2008). The center provides a forum for University faculty and staff to work with students to develop the knowledge and skills necessary to transform the students' innovative ideas into real products and services. The forum also provides modern office space and equipment to support students in their projects. Through a grant from the Blackstone Charitable Foundation, the Foster Center provides internship opportunities for students to work under the guidance of a mentor on projects with Maine entrepreneurs leading start-up and existing companies (Foster Center for Student Innovation, n.d.).

The study of the Innovation Engineering program examined the experiences of students who had completed at least a portion of the core curriculum, including their perceptions about their ability to think creatively and to innovate. The goal of the Innovation Engineering program is to provide students with a systematic approach to innovation: generating and communicating ideas, managing the risk associated with experimentation, and bringing an idea to fruition. The desired outcome of the curriculum is for students to gain the confidence to create their own opportunities and to initiate change in their respective fields of expertise (Foster

Center for Student Innovation, n.d.). A more detailed description of the curriculum appears in *Chapter 4: Research Findings*.

Specifically, the purpose of this study was to understand the perceptions of students after participating in a curriculum designed to impart innovative thinking, and to determine the extent to which the students believed the experience enhanced their ability to think creatively and innovatively. The main research question for the study was, "What are the perceptions of students who have participated in one or more of the core courses of the Innovation Engineering program and to what extent do they see the experience as enhancing their ability to think creatively and innovatively?" Other questions explored in this study included, "Do the students believe they are able to create more ideas, experiment without fear of failure and manage risk effectively?" and "Do the students perceive the pedagogy employed as contributing to their learning?"

Role of the Researcher

In my role as Vice Chancellor for Finance and Administration and Treasurer to the Board of Trustees for the University of Maine System, I function as the administrator of a grant award to the Innovation Engineering program from the System's Strategic Investment Fund. As administrator of the grant award, I have no role in the program, nor do I have a vested interest in determining the effectiveness of the program or its expansion.

Site Selection & Access

The Foster Center for Student Innovation at the University of Maine was the selected site for the research. The Foster Center is the home of the Innovation Engineering program and the curriculum that is the subject of this study. The co-directors of the Foster Center welcomed the research study as an opportunity for learning that contributes to continual improvement of the program. The co-directors approved the scope of the study and access to students and faculty members associated with the program.

Concept Map

Based on the literature explored in *Chapter 2: Review of the Literature*, I anticipated that the experience of the students might reveal that creativity and innovation are strengthened by the use of tools and techniques for generating ideas, the group diversity of thinking styles and disciplines, and the problem-based learning approaches that employ critical thinking. Further, I anticipated that the experience of the students might show that a pedagogy supporting a constructivist learning environment, rather than information processing and analysis, is most conducive to promoting creativity. Finally, I expected to demonstrate that small and frequent experimentation that embraces failure as a learning opportunity can reduce the risk of innovation.

The literature helped to inform the development of the following initial concept map upon which the study was structured:

- Creativity and Innovation
    - Critical thinking and problem-solving
    - Problem-based learning approaches (real life problem-solving)
- Idea Generation
    - Cognitive Processes
    - Techniques for generating ideas: e.g., stimulus, observation, questioning, brainstorming, free and forced association, mind mapping, systematic search, group think.
    - Associative thinking
- Experimentation and Risk-taking
    - Experimentation
    - Risk propensity
    - Interpretation of failure – loss versus learning opportunity
    - Systematic approach to risk mitigation through experimentation
- Pedagogy and learning environment
    - Nontraditional teaching approach: student has primary responsibility for his/her own learning
    - Focus on cognitive processes (learning) v. information processing/analysis (correct answer)
    - Student engagement and experiential learning
    - Diversity of thought, teamwork, individual empowerment and experimentation (learning from failure)

This initial concept map evolved during the coding of the interview transcripts into a more detailed concept map of interrelated ideas represented as thematic categories and sub-themes in *Chapter 4: Research Findings* and shown in *Appendix C: Matrix of Findings by Thematic Category and Sub-theme.*

Research Methods

A qualitative analysis using a phenomenological approach was the preferred methodology for this research. A phenomenological study accumulates information from individuals who have experienced the phenomena in order to develop an understanding of the lived experience (Cresswell, 2007; Grbich, 2007; Patton, 2002). This approach is best used "when the rich detail of the essence of people's experiences of a phenomenon is to be explored, described, communicated and possibly interpreted" (Grbich, 2007, p. 84). The resulting outcome of a phenomenological study is a synthesized description of the core essence of the experience shared by the individual participants (Cresswell, 2007; Grbich, 2007). Further, in-depth interviews are an effective qualitative method for gaining an understanding of the experiences and beliefs of participants in relation to a phenomenon (Knox & Burkard, 2009). In their review of forty-two research studies published between 1994 and 2009 on the teaching of critical thinking skills in postsecondary education, Behar-Horenstein and Niu (2011) found that "qualitative data can inform researchers about intervention effects that are not easily detected by quantitative instruments" (p. 25). This finding reinforced the use of a qualitative phenomenological approach to this research using in-depth interviews with participants who had experienced the phenomena.

In-depth Interviews

A qualitative, phenomenological approach explored the research questions through in-depth interviews with students who had completed one or more of the core courses of the Innovation Engineering curriculum at the University of Maine. The three courses making up the core are *INV180 Innovation Engineering I: Create*; *INV282 Innovation Engineering II: Communicate*; and *INV392 Innovation Engineering III: Commercialize*. At the time of the study, approximately one hundred and fifty to two hundred students had completed one or more of the core courses of the curriculum. Therefore, a sample of fifteen to twenty participants comprised approximately ten percent (10%) of the total population. However, the size of the sample remained flexible, evolving as the study progressed, until a point of redundancy in the themes from the interviews emerged (Marshall, 1996; Mason, 2010). The identity of the participants remained confidential to ensure their privacy, except where permission was expressly granted.

A semi-structured interview protocol allowed for flexibility in the interview to facilitate a fuller understanding of the participants' experience (Knox & Burkard, 2009; Turner, 2010). Open-ended questions required explanation in order to draw out each participant's experience of the phenomena (Behar-Horenstein & Niu, 2011; Grbich, 2007; Patton, 2002). The review of the literature in *Chapter 2* informed the questions for the in-depth interviews which focused on the study's central purpose: to understand whether students who had completed one or more courses of the core curriculum of the Innovation Engineering program believed that they were able to think more creatively and to turn their ideas into successful innovations.

The interview questions explored the students' experience of the course, their ability to generate ideas, and their preferred techniques and methods for enhancing idea generation. The interviews investigated students' aptitude for critical thinking and problem-solving, their propensity for risk-taking and experimentation, their view of failure, and their confidence in innovating. Students were also queried about the learning environment and the pedagogy used in the course, including nontraditional teaching approaches that empowered students to take primary responsibility for their own learning, hands-on problem-solving and experimentation, group work, and the use of unconventional methods to stimulate creativity. Further detail on the interview protocol appears in *Appendix A*.

In addition to the primary student participants, I interviewed three faculty members. As with the student participants, a semi-structured interview protocol employed similarly focused open-ended questions tailored to a faculty perspective. Expanding the study to include the faculty interviews enhanced my understanding of whether students who had completed one or more courses of the core curriculum of the Innovation Engineering program believed that they are able to think more creatively and to turn their ideas into successful innovations.

Sampling Strategy. Criterion sampling ensured that each student participating in the in-depth interviews and completing the survey instrument had enrolled in or completed one or more of the three core courses of the Innovation Engineering program and that at least some of the participants had completed all three of the core courses of the curriculum (Cresswell, 2007). Criterion sampling also ensured that each of the faculty members who volunteered for the in-depth interviews taught at least one or more of the core courses in the Innovation Engineering curriculum. Students enrolled in each of the three core courses of the Innovation Engineering program in fall 2012 completed the survey instrument.

Description of the Interview Participants. Fifteen (15) students volunteered for the study interviews to examine the perception of students who had completed a portion of the core curriculum on their ability to think creatively and to innovate. Of those students, one had completed the minor in Innovation Engineering and was graduated from the university with a degree in Political Science. Another student had completed the graduate certificate in Innovation Engineering, graduating with a Master's degree in English. At the time of the interview, this particular student was working for the Foster Center for Student Innovation as an Innovation Engineering Outreach Coordinator, as well as teaching and coaching students enrolled in the program. Of the other thirteen (13) students interviewed, all were upperclassmen, junior or senior equivalent. Six (6) of the students were pursuing Engineering degrees, including Electrical, Mechanical and Civil Engineering, and three (3) were pursuing Business degrees. The remaining students were majoring in English (2), Political Science (1) and Music (1).

Of those students who were enrolled at the time, ten (10) were working to complete the minor in Innovation Engineering. The minor consists of eighteen credit hours, twelve of which must include the core curriculum: *INV180 Innovation Engineering I: Create*; *INV282 Innovation Engineering II: Communicate*; *INV392 Innovation Engineering III: Commercialize;* and *INV401 Innovation Engineering: Experience*. All of the students interviewed had taken the *INV180 Innovation Engineering I: Create* and *INV282 Innovation Engineering II: Communicate* courses or the graduate course equivalent. Five (5) of the students had taken *INV392 Innovation Engineering III: Commercialize* previously and four (4) of them were taking the course at the time of their interview. Six (6) of the students had taken *INV401 Innovation Engineering: Experience* and one student was taking the course at the time of the interview. In addition, ten (10) of the students had taken other Innovation Engineering courses including *INV405 Innovation Engineering: Proposal* and *INV406 Innovation Engineering: Project* courses, as well as internships and independent study courses in Innovation Engineering.

Three (3) faculty members volunteered for the study interviews to enhance understanding of whether students who had completed one or more courses of the core curriculum of the Innovation Engineering program believed they were able to think more creatively and turn their ideas into successful innovations. The following faculty were interviewed for the study: the Director of Academic Programs in Innovation Engineering, who is also an associate professor of English with tenure at the University of Maine and who teaches all of the core curriculum courses: *INV180 Innovation Engineering I: Create*; *INV282 Innovation Engineering II: Communicate*; *INV392 Innovation Engineering III: Commercialize;* and *INV401 Innovation Engineering: Experience*; A Ph.D. in Chemical Engineering and the Innovation Engineer at the Foster Center for Student Innovation who teaches *INV392 Innovation Engineering III: Commercialize* and who also assists with other classes, in addition to practicing the innovation principles of the program on university technologies and research; and finally, a tenured professor of English, who also serves on the faculty of the Honors College, works with the Franco-American Centre as its faculty associate, and teaches *INV180 Innovation Engineering I: Create* and *INV282 Innovation Engineering II: Communicate*.

Coding of the Interviews. All interviews were first recorded and transcribed, then coded using *QSR NVivo version 9*. I then analyzed the information gleaned from the transcripts for "significant statements, sentences or quotes" (Cresswell, 2007) as compared to the initial concept map described earlier in this chapter. I then used these identified statements to develop a more detailed concept map of interrelated ideas represented as thematic categories and sub-themes and used the revised concept map to draft a detailed description of the participants' experience of the phenomena in *Chapter 4: Research Findings* (Grbich, 2007).

Creativity and Confidence Survey

In order to gain a broader understanding of the phenomena experienced by students who participate in one or more courses of the Innovation Engineering program, I used a survey instrument to reach a wider sample of participants. The survey was conducted during the fall 2012 semester on the first day of class, the mid-semester point, and on the last day of class for the three core courses of the Innovation Engineering curriculum and was executed during class time to ensure maximum participation. Administering the survey at multiple points during the course provided a deeper understanding of the phenomena at different stages in the process. The survey was brief, consisting of a mix of closed-and open-ended questions similar to those questions asked in the in-depth interviews. Closed-ended questions were used at all three survey points during the semester to convey an understanding of basic information about the participants, such as gender, grade in school, major, and level of confidence in creating ideas and communicating those ideas in response to a problem or opportunity. I added strategically worded open-ended questions for the mid-semester and end-of-semester survey points to allow participants to develop their own ideas in relation to the phenomena (Behar-Horenstein & Niu, 2011; Grbich, 2007; Maxwell, 1996). I then coded the data from the surveys against the revised concept map to determine what, if any, patterns emerged as students advanced through the course curriculum.

Survey Sample. The study consisted of four sections of the fall 2012 *INV180 Innovation Engineering I: Create* course, and one section each of the fall 2012 *INV282 Innovation Engineering II: Communicate* and *INV392 Innovation Engineering III: Commercialize* courses. Participants completed a total of eighty-nine (89) surveys on the first day of the course at the start of the semester, a total of seventy-seven (77) surveys at the mid-point of the semester, and a total of seventy-one (71) surveys at the conclusion of the course. Starting class sizes for each section ranged from eleven (11) to twenty-eight (28) students.

Coding of the Survey Responses. I first compiled the survey instruments using an Excel spreadsheet for the following fields: major, year in school, gender, and confidence level in creating and communicating ideas (at the beginning of the course, the mid-point of the semester, and at the conclusion of the semester). I then coded answers to open-ended questions for key words or phrases. The open-ended questions focused on: the aspect of the course that was the most/least useful in enhancing creative ability, the influence of group work, the evolution of the student's approach to problem-solving, the evolution of the student's perception of risk-taking and experimentation, and the contribution of the learning environment to creativity. The survey also included an open-ended question to allow for any additional comments.

Trustworthiness

Triangulated information from multiple sources including student interviews, student surveys and faculty interviews enhanced the trustworthiness of the study (Cresswell, 2007; Maxwell, 1996). A reasonable sample size of ten percent (10%) of the students who had completed one or more of the three core courses of the Innovation Engineering curriculum participated in the in-depth interviews to ensure adequate representation of the population of current students (Cresswell, 2007). Additionally, I employed member checking by providing participants with an opportunity to review and to question or validate their interview transcripts as consistent with their experience of the phenomena (Cresswell, 2007; Patton, 2002). In addition to the student interviews, three (3) faculty members volunteered for interviews to further the comprehension of the phenomena from the perspective of those teaching the Innovation Engineering curriculum to the students.

Eighty-nine (89) students, all of whom were enrolled in at least one of the three core courses of the curriculum as of the fall of 2012, participated in the survey instrument. The instrument, administered during class time on the first day of the course, at the mid-point of the semester, and on the last day of the course, was distributed in order to triangulate the information gathered during the research and to validate key findings from the interviews (Cresswell, 2007; Patton, 2002).

Through the in-depth interviews and the *Confidence and Creativity Survey* discussed in *Chapter 4: Research Findings*, I pursued disconfirming evidence indicating that all or a portion of the Innovation Engineering curriculum was not effective in teaching innovation (Maxwell, 1996; Patton, 2002). For example, I asked interview participants which of the tools and techniques used in the program they found least useful and whether group work hindered their creativity or their desire to take risks. I also specifically asked participants if they encountered students or others who just did not get the concepts or the curriculum. Additionally, I asked student survey participants to rate their level of confidence in creating and communicating ideas in response to a problem or opportunity and to describe the aspects of the course they deemed least useful to enhancing their creative ability.

CHAPTER 4: RESEARCH FINDINGS

Description of the Curriculum

The purpose of the Innovation Engineering program is to provide students with a systematic approach to innovation: generating and communicating ideas, managing the risk associated with experimentation, and bringing an idea to fruition. The desired outcome of the curriculum is for students to gain the confidence to create their own opportunities and to lead change in their respective fields of expertise. Offered as a minor or graduate certificate, the program can enhance any major or field of study. The minor consists of a minimum of eighteen (18) credit hours, including the three core courses of the curriculum - *INV180 Innovation Engineering I: Create*; *INV282 Innovation Engineering II: Communicate*; and *INV392 Innovation Engineering III: Commercialize*. Each of the core courses in the curriculum builds on the concepts introduced in the prior course. Combined, they represent the continuum of the process of innovation. The remaining credit hours are taken in the *INV401 Innovation Engineering IV: Experience* course, a proposal and project sequence, internship or independent study. Following is an introduction to the curriculum, including the three core courses, based on the course syllabi and other institutional documents.

Faculty representing diverse disciplines in the colleges of Liberal Arts & Sciences, Engineering, Business Public Policy and Health, Education, Natural Sciences Forestry and Agriculture, and the Division of Lifelong Learning developed the curriculum for the Innovation Engineering program (Foster Center for Student

Innovation at the University of Maine, n.d.). The faculty based the curriculum on the research conducted by Eureka! Ranch, whose research is informed by the work of Genrich Altshuller, Edward DeBono, Alex Osborn, George M. Prince and Arthur VanGundy, among others. Eureka! Ranch is a corporate innovation and research center led by CEO and University of Maine alumnus Doug Hall, who serves as an adjunct faculty member for the program (Innovation Engineering Leadership Institute, 2011).

Innovation Engineering I: Create

The first course in the curriculum series is *INV180 Innovation Engineering I: Create*, a course intended to provide students with a systematic approach to creating ideas. Some of the critical elements of the course experience include: an understanding of the theory behind the use of stimulus as a means of generating ideas, the application and mastery of tools to enhance the amount of stimulus available, participation in generating ideas in response to problems or opportunities identified in the case studies of real-world organizations, group and individual work, and maintenance of a journal of ideas. During the *Create* class, students discover the concept of innovation as something that is *Meaningfully Unique* in that it offers the best possible solution to a problem. Students learn to understand the concept of creative abrasion, a process by which individuals learn from the diverse contributions of each other, through the diversity of thinking style preferences represented by the Herman Brain Dominance Instrument – analytical, organizational, personal and strategic. Students also learn a variety of tools and methods for producing stimulus to generate ideas. Some of the tools used in the course to produce stimulus include stimulus mining, searching websites and magazines to stimulate ideas; a product improvement check list (PICL), a list of adjectives to apply to a concept to generate a new take on an idea; free writing, a stream of consciousness exercise following exposure to stimulus; and mind mapping, a diagram resembling a web of connected ideas and thoughts networked out from a central idea (Foster Center for Student Innovation at the University of Maine, n.d.; Innovation Engineering Leadership Institute, 2011).

Innovation Engineering II: Communicate

The second course in the curriculum series is *INV282 Innovation Engineering II: Communicate*. The course combines "the clarity of professional writing, the precision of technical writing, and the expressiveness of creative writing" to provide students with the fundamentals needed to communicate effectively. Students learn to "communicate the benefit, the uniqueness, and the credibility of a concept" to a target audience through the use of *Problem-Promise-Proof*. The concept of *Problem-Promise-Proof* is broken down as follows: first, the *Customer Problem* is expressed as "the voice of the customer" and is clearly defined by an understanding of both *who* the customer is and *what* problem the innovation is intended to solve; second, the *Promise* answers the question, "*Why should I care*?" and consists of a unequivocal guarantee to *solve* the problem for the customer; and third, the *Proof* answers the question, "*Why should I believe you*?" and is the evidence offered that backs up the promise. An example of *Problem-Promise-Proof* used in the course is

"Kitchen Logic" where the problem is defined as "fruit lovers want more fruit flavor in their muffins," the promise is "more blueberry flavor than any muffin in town," and the proof is "that's because we add twice as many blueberries." Through the methods taught in the course, students learn to appreciate the communicative value of visual imagery and text, use writing as a method of prototyping a product or service, and translate the benefits of technical and specialized ideas to a target audience (Foster Center for Student Innovation at the University of Maine, n.d.; Innovation Engineering Leadership Institute, 2011).

Innovation Engineering III: Commercialize

In the third course in the curriculum series, *INV392 Innovation Engineering III: Commercialize*, students discover the concept *Fail Fast, Fail Cheap*. Students learn to turn an idea into a prototype, to test whether or not it will work, and to identify design flaws while minimizing financial and other risks. Students learn how to drive the fear of failure out of the process of innovation by employing methods for taking strategic, calculated risks based on the scientific method for solving a problem, known as *Plan-Do-Study-Act*. Students also learn to identify and address a *Death Threat* -- an issue that can kill an idea if it can't be overcome -- early in the experimentation process so that these issues can be dealt with first in order to minimize the overall risk associated with experimentation. The curriculum also introduces students to the basic elements of market research, sales forecasting techniques, open source technology, and searching and writing patents (Foster

Center for Student Innovation at the University of Maine, n.d.; Innovation Engineering Leadership Institute, 2011).

Findings from the Student Creativity and Confidence Survey

The responses of the eighty-nine (89) students who participated in the creativity and confidence survey introduce an understanding of the phenomena. Students took the survey during the fall 2012 semester on the first day of class, the mid-semester point, and on the last day of class for the three core courses in the Innovation Engineering curriculum. Four sections of *INV180 Innovation Engineering I: Create*, and one section each of *INV282 Innovation Engineering II: Communicate* and *INV392 Innovation Engineering III: Commercialize* completed the survey.

Responses to Standardized Questions

Students declared majors in a variety of disciplines including Engineering, Business, New Media, the Sciences and Liberal Arts. Students in all grades participated in the survey. About thirty percent (30%) of the students were freshmen, but the majority of students participating in the Innovation Engineering courses were upperclassmen (53%). The student population was predominantly male with a ratio of 3:1 (76%).

Confidence Creating and Communicating Ideas. For the start of the semester surveys in the *INV180 Innovation Engineering I: Create* class, forty percent (40%) of the sixty-eight (68) students responding to the survey stated that they felt "confident" or "very confident" that they could create ideas in response to a problem or opportunity. By the mid-semester point, sixty-eight percent (68%) of the sixty (60) students responding to the survey expressed this level of confidence. At the conclusion of the course, fully eighty-nine percent (89%) of the fifty-five (55) students responding to the survey stated that they felt “confident” or “very confident” that they could create ideas in response to a problem or opportunity. When asked about their ability to communicate *Meaningfully Unique* ideas in response to a problem or opportunity, twenty-five percent (25%) of the students in the course indicated they felt “confident” or “very confident” at the start of the course. By the mid-semester point in the course, fifty-seven percent (57%) of the students expressed this level of confidence. At the conclusion of the course, the percentage of students expressing that they were “confident” or “very confident” in their ability to communicate *Meaningfully Unique* ideas grew to seventy-three percent (73%).

The sample size for the *INV282 Innovation Engineering II: Communicate* class was significantly smaller. At the start of the semester, sixty percent (60%) of the ten (10) students responding to the survey stated they felt “confident” or “very confident” that they could create ideas in response to a problem or opportunity. At the conclusion of the course, the percentage of students expressing this level of confidence increased to one hundred percent (100%) of the eight (8) students participating in the survey. When asked about their ability to communicate *Meaningfully Unique* ideas in response to a problem or opportunity, forty percent (40%) of the students in the course indicated they felt “confident” or “very confident" at the start of the course. At the conclusion of the course, the percentage of students expressing that they were "confident" or "very confident" in their ability to communicate *Meaningfully Unique* ideas grew to seventy-five percent (75%).

The sample size for the *INV392 Innovation Engineering III: Commercialize* class was also smaller than the *INV180 Innovation Engineering I: Create* course. At the start of the semester, one hundred percent (100%) of the eleven (11) students responding to the survey stated they felt "confident" or "very confident" that they could create ideas in response to a problem or opportunity. At the conclusion of the course, the percentage of students expressing this level of confidence remained the same for the eight (8) students participating in the survey. When asked about their ability to communicate *Meaningfully Unique* ideas in response to a problem or opportunity, ninety-one percent (91%) of the students in the course indicated they felt "confident" or "very confident" at the start of the course. However, at the conclusion of the course, the percentage of students expressing that they were "confident" or "very confident" in their ability to communicate *Meaningfully Unique* ideas dropped to seventy-five percent (75%).

Coding of Open-Ended Questions

Most/Least Useful. The coding of the open-ended questions for the mid-point and end-of-semester surveys for all six (6) class sections revealed a number of themes. When asked, "*What aspect of this course has been the most/least useful for enhancing your creative ability?*" students aligned their "most useful" responses into three categories. The most predominant theme was student appreciation for the course tools and techniques intended to expand creativity through the generation of ideas and to aid innovation by driving out risk. The most mentioned tool was mind mapping (23). Individual references to tools, techniques and procedures totaled sixty-three (63) for all of the surveys. Students also cited various aspects of the pedagogy for teaching the program, noting the online video lectures, the instructor interaction and the instant feedback loop. Group work and class discussion was most frequently mentioned (27). Individual references to pedagogic aspects of the program as the most useful to enhancing student creativity totaled fifty-two (52). Finally, students cited the substance of the curriculum, thinking outside the box to create ideas to solve problems, as the most useful for enhancing their creative ability. Individual references to creating ideas, thinking outside the box, and problem-solving totaled twenty-seven (27). Students aligned their "least useful" responses into two categories. Individual references to the lack of organization in the course, conflicting teaching styles, and insufficient time for feedback during classwork totaled eleven (11), while references to the volume or tediousness of work assignments totaled six (6).

Influence of Group Work. When responding to the question, "*When engaged in group work, how did the influence of group members impact your opinions?*" at the mid-point of the semester, seventy-eight percent (78%) of the students responded that group work aided the creative process, while twelve percent (12%) said it was somewhat helpful. By the end of the semester the percentage of those citing group work as aiding the process grew to eighty-four percent (84%) with six percent (6%) noting it as somewhat helpful. Students observed that group work provided stimulus for ideas, using phrases such as "multiplied our ideas tenfold," "ideas from the group members worked as stimulus," and "made me see more possibilities." Diversity of thought was also prevalent as a theme in student comments, which noted "different points of view," "made me think in a different way," and "others help see things that one person may not." Finally, students cited the value of group work in analyzing problems, saying "[it] showed aspects of problems I would not have noticed on my own," "working in a group helps [me to] see multiple sides of the problem," and "it helped me open up different doors to better solutions." Students that did not find the group work aided the creative process noted they found it "challenging" and difficult to "stay on task."

Approach to Problem-solving. At the mid-point of the semester, eighty-nine percent (89%) of students responding to the question, "*How has your approach to problem-solving changed during your work in this course?*" articulated that the curriculum improved their problem-solving abilities, while three percent (3%) said it was somewhat helpful. By the end of the semester the percentage of those who cited improvement grew to ninety-six (96%) with one percent (1%) saying it was somewhat helpful. Student responses to this question included references to a "more structured" or "more logical" approach to problem-solving: "I think differently now in a more organized and structured way." Strategies for problem-solving were also prominent: "I feel like I have many pathways to use on the process of innovation now" and "I now have different strategies to tackle problems."

Students also referenced breaking problems down into more manageable issues: "Now I break down problems more" and "Breaking things down makes coming to a solution easier." Multiple students also noted they look "outside the box" for solutions, stating, "[I] look at problems from multiple perspectives," "I am able to free my mind and think more outside the box to solve problems," and "I have a more open mind and am able to move through a greater number of possible solutions in less time."

Perception on Risk-taking and Experimentation. When asked, "*How has your view on risk-taking and experimentation evolved during your work in this course?*," eighty-three percent (83%) of students in the mid-semester survey said that it was easier to take risks or that they were more confident doing so, while three percent (3%) indicated it was somewhat easier. By the end of the semester the percentage of students that expressed improvement increased to eighty-six percent (86%) with three percent (3%) somewhat improved. Overcoming fear was voiced by many of the students in response to this question: "This class has taught me to overcome a lot of fears," "I'm not afraid to take risks anymore," and "[I'm] far more willing and courageous." Students also expressed a newfound appreciation for failure as an opportunity to learn: "I have learned that experimentation as well as failure is part of the process"; "It is now easier for me to take risks and allow myself to get things wrong in order to learn"; and "Failing is not a bad thing, it's the knowledge that you get from failing that will help one succeed in the future." Learning new techniques to minimize risk was also noted: "I feel less afraid to take risks as I [now] know techniques and ways to *Fail Fast, Fail Cheap*"; "You can reduce risk with what [the program] has taught me"; "I've developed a more detailed method to weigh risks"; and "[The program] is almost a way to hedge against risk."

Contribution of Learning Environment. When asked, "*How did the learning environment for the course contribute to your creativity?,"* eighty-six percent (86%) of students who responded to the mid-semester survey indicated that the learning environment positively impacted their creativity. By the end of the semester, this percentage decreased to eighty-one percent (81%); however, nine percent (9%) now acknowledged it was somewhat helpful, for a total of ninety percent (90%) of students indicating that the learning environment contributed or somewhat contributed to their creativity. Students described the classroom environment as "free," "open," "laid back," "relaxed," "supportive," and "accepting" and noted a lack of "fear" and "stress." Students mentioned the group work: "I loved the open environment and group work, it let the creativity flow"; "It's an open environment where people throw out thoughts and you can build off what you hear and create new ideas"; and "People seemed engaged and eager to work together." Students also frequently referred to the hands-on nature of the work: "I like no lecture and more hands-on"; "It's much easier to learn when you have… no pressure, hands-on work"; and "Working hands-on with material." Some students found the lack of structure in the learning environment challenging, saying, "It somewhat hindered my learning, would have been much more constructive if we'd had a class, guided us through and then let us loose" and "Class was a little unstructured, which hurt." One student also mentioned that, "The amount of work stifled [creativity] at the end."

Other Comments. When students were asked, "*Are there any other comments they would like to add?"*, most talked about the enjoyment of the course using phrases such as, "It's fun" "I enjoy this class" and "great course." A few were more specific: "[An] enjoyable class, have learned a lot"; "I enjoyed this class and would recommend it to a friend"; "This class changed my life"; "[I'm] very grateful for the opportunity"; and "I can't wait to start INV282 [the Communicate course] next semester!" Some students offered suggestions for improvement: "better organization of books and homework," "make assignment rubrics more clear," "some graders are inconsistent," and "too many assignments."

An Unhappy Experience. Although the vast majority of student responses to the survey were positive about the elements of the curriculum, the pedagogy, and the learning environment, one student in the mid-semester survey for the *INV392 Innovation Engineering III: Commercialize* class expressed extreme frustration with the class. Responding to the question on level of confidence in creating ideas in response to a problem or opportunity, he rated himself as "not at all." He used the same rating to describe his level of confidence in his ability to communicate *Meaningfully Unique* ideas in response to a problem or opportunity. In response to the question on the evolution of his approach to problem-solving he stated, "Every attempt I've made to solve a problem has failed, since everything I've seen as a problem [has] actually been a feature. I've lost my ability to problem-solve." When asked about his perception of risk-taking and experimentation, he relayed, "It's devolved. Any leap I've attempted to make, a new idea has been cut down before I've had time to finish explaining it." On the contributions of the learning environment to creativity, he responded, "Said environment kept changing from day to day. Each teacher graded an assignment differently and it's nearly impossible to know what I'm asked to do, when five teachers are giving me different requirements for the same assignments, it confused me."

Findings from the In-depth Interviews with Students and Faculty

Engineering a Process for Innovation

The interview dialogue with the study participants who agreed to share their experience of the Innovation Engineering curriculum, conveys both insight and understanding about the phenomena. The analysis of the coded transcripts as described in the research methods in *Chapter 3: Methodology* yielded twenty-eight (28) separate findings assembled into fourteen (14) sub-themes that are then organized under four (4) thematic categories: Engineering a Process for Innovation; *Fail Fast, Fail Cheap* Design Cycles; Constructivist Learning Environment; and Learning to be Agile. This section begins with the first thematic category, Engineering a Process for Innovation.

Applying a System for Solving Problems

When asked about the meaning behind the name of the program, participants convey a deep understanding of the core phenomena as illustrated by their perceptions of the term "innovation engineering." The observations of the student and faculty participants on the objectives of the curriculum emerge in this section and provide a basis for comprehending the phenomena. These findings purposefully lead the section to deliver an introduction to the shared experience.

A Process for Innovation. Group participants describe the Innovation Engineering curriculum as a "process," "system," "structure," or "framework" for generating ideas in response to a problem or opportunity and for bringing those ideas with promise to culmination as an innovation. A Mechanical Engineering major in his senior year, who is also pursuing a minor in Innovation Engineering, described it as a "systematic approach to innovation," stating, "The first three courses [Create, Communicate and Commercialize] really break down the whole…pipeline of innovation engineering. It's almost like a conveyor belt of tools that they teach you to create *Meaningfully Unique* ideas." A faculty member for the Innovation Engineering program with a Ph.D. in Chemical Engineering, who also serves as the Foster Center's Innovation Engineer, depicts the curriculum as "applying a system to innovation." When asked about what the word "engineering" means in reference to this program, he stated, "When you look at engineering, it's applied science. For all intents and purposes, it's applying all of these [engineering] theories into innovative parameters."

Participants asked to describe the curriculum to a fellow student offered descriptions such as "a system of thinking" and "a structure to think more critically," or "a way to make you think differently," and said that in the program, students are “encouraged to think outside of the box.” A junior in Mechanical Engineering Technology said he would explain the curriculum to a friend this way:

> I’ll tell them that in the first course they are going to think it’s crazy and that there’s no way this could possibly work, but I would also tell them that it was a system of thinking that allows you to -- in an effective structured way -- look at a problem, and in a different light, and to use resources in order to kind of open up the world of solutions, because it’s … really a system of thinking … an approach to problems.

Applied Learning. The shared experiences of the participants reveal the curriculum as teaching a system for thinking, a process for innovating, employed to address any problem or to create an opportunity. In this way, the Innovation Engineering curriculum as applied learning emerged as a finding for this section. Both students and faculty used phrases such as, “applying it,” “doing something with it,” and “doing things rather than just learning things.” The Director of Academic Programs in Innovation Engineering, who also serves as an associate professor of English with tenure at the University, stated the reason that the term “engineering” is included in the title of the program is because, “it implies that we are applying these tools, we are going to … learn how to use them and then use them.” A senior Music major put it this way:

> You can just call it “innovation,” but then it just kind of sounds like you’re going to sit there and listen to teachers talk about how people think and how people create, whereas the term “engineering” kind of really makes you feel like you’re going to be doing something with it.

Another student participant, a junior in Mechanical Engineering with a minor in Innovation Engineering, described his concept of the program like this:

> When I first came into Innovation Engineering, I was expecting engineering because [there was] "engineering" in the title, but when you get into it you realize it's not the classical engineering in that sense of the word. I mean there's an Art professor teaching Innovation Engineering and that kind of threw me for a little bit at first, but I realized they definitely have their place, because engineering is not just math and science, engineering is the process of creating and building and solving problems. They definitely do that here.

The Center's Innovation Engineer illustrated it as "taking the scientific method [and] applying it not to the product R & D, but to the R & D system":

> Formulate your hypothesis, test it, make a decision and then move on and … just keep running that cycle as quickly as possible. It's what you learned in seventh and eighth grade, the scientific method to solve a problem.

Cultivating Creative Thinking

Students describe the experience of the curriculum as imparting a different way of thinking, a process or system for innovating taught through applied learning. An important initial step in this process is enabling students to think expansively, to push boundaries through a system of stimulating ideas through associative thinking.

No Boundaries. About a third of the participants talked about the curriculum as imparting a sense of having no boundaries. The feeling of freedom allowed participants to remove their cognitive restraints and imagine ideas that they described as "crazy" and "out in left field." In describing the freedom fostered in association with creativity in the curriculum, the junior in Mechanical Engineering Technology stated, "There's something to be said for just … coming up with crazy ideas and … verbalizing [them] that frees your mind to think." A junior majoring in Business Management with a minor in Innovation Engineering described the curriculum as making "you think in ways you have never thought before." Defining the experience, a senior English major with a minor in Innovation Engineering stated, "Usually, when I do mind maps … I will do kind of a conservative mind map that can go from topics that are connected … to topics that are just completely right out in left field. … I think that's where I come up with my best ideas." A junior in Mechanical Engineering with minors in Math and Innovation Engineering, depicted the phenomena this way:

> One of the tools is actually to come up with … a crazy idea that would never happen and then you make it a little more believable or doable, and then … a little more doable, and then you come up with your final idea. So you can take pretty much any crazy idea and turn it into something that's doable.

In describing his experience of learning to generate ideas, the junior majoring in Mechanical Engineering with a minor in Innovation Engineering examined his propensity to search for the single true idea as opposed to just brainstorming, which led him to kill a thought before it got a chance, "I'd just shoot them down … I'm a very analytical person, so [I'd] think of an idea and [I'd] go, that's not possible." He went on to say:

> I feel fluent in creating now. Once you get the hang of it and you just buy into the process and don't try to resist it, just go with it, you can really create. Bring out idea, after idea, after idea very quick[ly]. They may not all be winning ideas, but you get ideas and through those ideas you can take out some winners.

A System for Creating Ideas. In discussing how the Innovation Engineering program helps to create ideas, a second senior majoring in English with a minor in Innovation Engineering declared, "[The] Innovation 180: Create [class] is the imagination expansion class. … It's a perfect introduction to the program, because it says, ‘so you like to create ideas, well here are a couple of tools that will allow you to create ideas one thousand percent more efficiently’.” The senior Mechanical Engineering major stated, “I really like … taking the randomness out of creativity and making it more systematic. I can … turn one decent idea into four hundred ideas and out of those four hundred ideas, there might be twenty [that are] gold mines.” He went on to relate his experience with the program:

> I was … blown away. I was really, really impressed that there is … a systematic way to pump out tons of ideas … I like explaining to people that you don’t have to be born a creative person … Even if you consider yourself a very uncreative person, with Innovation Engineering you could almost force yourself to be creative.

The first senior English major described himself, saying, “I have never considered myself a creative person.” He went on to recount his realization that the curriculum could change this:

> I actually remember the first day I had class … so I said … ‘I don’t know how adept I am going to be at this, is this for anybody or do I really have to be creative to do this?’ and in a very short time I realized … how easy it was. [If] I had been exposed before … it could have changed my whole collegiate experience. It could have been a lot easier had I just learned how to be creative [earlier].

A number of the student participants detailed their experience in using the system of tools to generate more ideas. In discussing his first assignment for the Create course, the junior in Mechanical Engineering with a minor in Innovation Engineering described his experience as follows:

> The first assignment is to create fifty *Meaningfully Unique* … ideas for a new candy. And I remember everyone who did that, especially me, that was the most painstaking process. Fifty ideas for candy, it took me probably two or three hours. [Now] I could probably do it in ten minutes just through mind

> mapping. It's just realizing that you can't be unique right away. … Anything that pops in your mind, just put it on paper, write them all down. They may be crazy and stupid … but you can work from these ideas and create something that's actually meaningful.

The Foster Center's Innovation Engineering Outreach Coordinator, who completed the graduate certificate in the curriculum as part of her Master's Degree in English and who also teaches in the program, related a real-life example in which she applied the program's tools for creating ideas from her time as a graduate student:

> Thinking back … I had to take the comp exams for the English Department, which is like the most miserable time of the year. And you've got forty-eight hours to write four essays and they are usually poorly written and very painful [to read]. And what I ended up doing was … I used these tools to come up with ideas for these papers [so] that [these papers] would not be generic and boring to write or read.

Pay Attention to Stimulus: Associative Thinking. Many of the participants described the value of stimulus to help them to make associations between thoughts and to capture ideas. A junior in Mass Communications explained what used to block her sense of creativity, "I always thought of creativity as something that just … comes from your mind and your mind alone." Noting that she since came to understand that it is permissible to use the ideas of other people to build on, she stated, "My idea of creativity has kind of expanded as far as it doesn't necessarily have to just be somehow developed in your own mind. You can use others' ideas as stimulus." Building on this theme, the junior in Mechanical Engineering Technology said that:

> Sometimes I'll just share stuff. … I'm not sharing it because I think it is good, I'm sharing it because I'm hoping that it will trigger something in your mind. … There's something to be said for just talking, for just coming up with crazy

> ideas. And there's something about verbalizing [them] that then frees your mind.

A tenured professor of English who teaches for the program, who also serves as the faculty associate for the Franco-American Centre and is on the faculty of the Honors College, described that what the program imparts to students "… is a sense of how to sort of find one's own creativity and ability." Calling it "practical creativity," he went on to say that the program gives students "the tools that encourage people to pay attention to ideas that come up in their heads." A writer and teacher of poetry, the professor also drew a parallel to that form of expression, "Poetry is a lot about noticing what you are thinking, what's occurring to you, and then seeing where it takes you." Noting that Steve Jobs "has done a very good job of vocalizing that creativity is not just a thing that happens, it's a connection of ideas and thoughts," a graduate of the university with a bachelor's degree in Political Science and a minor in Innovation Engineering put it this way:

> What Innovation Engineering has done for me, it's given me a way to get to those connections, to manage those connections. So inherently, you can kind of understand that creativity is connecting things, it's not some … aroma-based moment of inspiration … Nobody intuitively knows how to make … [an] iPhone until you have actually tried and done it.

Tools and Techniques for Thinking Creatively

Participants relate an important part of allowing creativity to flourish is a sense of having no boundaries to their thoughts. This can occur using a system of stimulating ideas through associative thinking. Students use tools, techniques and other elements of the Innovation Engineering program to augment available stimulus and to advance creative thinking.

A Systematic Approach: A Common Language. All of the student and faculty participants discussed the use of the tools, techniques and other elements of the curriculum designed to generate creative thinking. Although some participants preferred certain tools more than others, or found some tools not to be useful, universally there was recognition that the core of idea generation was boosting the amount of stimulus in order to generate more ideas. Moreover, the participants understood that the more ideas generated, the more likely one or two would prove useful in leading to an innovation. Acknowledging that most of the tools were pretty simple to use, the Director of Academic Programs in Innovation Engineering talked about their value in developing creativity in students from diverse disciplines:

> This simple set of tools … becomes a common language between the English student, the History student, the Business student, the Engineering student … and gets them around the same table with their various kinds of [disciplines] and their varying thinking styles.

She went on to discuss how the tools help to reduce fear and build confidence:

> The tools really do help reduce fear. One of the reasons … is that you have the confidence that if something is not working, you can fiddle with it and ideate on it and do research about [it] … fast and cheap, [and not have to] put all your eggs in one basket.

When asked if students prefer some tools over others, the Foster Center's Innovation Engineering Outreach Coordinator discussed the influence of learning styles on preference:

> It really depends on the thinking and learning styles of the student. Some really prefer certain kinds of tools, so they are really split up into ones that are typically preferred by people who are left brain and those who are right brain. So the people who are traditionally left brain, they are kind of logical and they go step by step and they have a lot of checklists. For the folks who are not really about checklists… they just want to come up with ideas from … different types of … stimulus, they seem to like those tools that push them a little further.

Expanding on the influence of thinking styles, the university graduate with a degree in Political Science offered the following:

> My observation has been … certain tools simply work better with certain people's minds. However, the most effective tools are often the tools that push people the furthest. I found that … by using a tool that doesn't match your brain waves … but goes against your natural mental process, you are forced to think differently. And, Innovation Engineering as a system is [designed] to force you to consider all angles and get you to the … endpoint without leaving you out in the open.

He went on to discuss the role of the instructor and coaches in the classroom in working with students to master the tools, saying:

> The coach really has to get them to the point of using [the tool] effectively, that's something the tools don't do automatically. But it's … empowering because you know it reinforces that this is a system for humans, you know this is just not a system you can let go and it's just automated. We need … human brains to operate it.

When asked if he found any of the tools more difficult to use than the others, the junior Business major said, "Practice makes perfect and the more that you go and use the tools the easier it is to get. You can get more out of them if you have more practice with them, so it's really about repetition."

Mind Mapping. Student participants cited a number of different tools used for generating stimulus to create ideas, including free-writing, meditation, lateral thinking and various forms of stimulus mining. However, when asked if they have a favorite tool for creating ideas, students selected mind mapping most often. The review of the literature defines a mind map as an actual diagram at the center of which is a central idea, or starting point, with threads of associated ideas networked out from the core (Hall, 2001; Innovation Engineering Leadership Institute, 2011). The junior in Mechanical Engineering with a minor in Innovation Engineering described mind mapping as "an elaborate brainstorming on what [you] learned from kindergarten, or first grade. That really is the essential part of the Create [class] that all the tools branch off of." Saying, "I'm a huge fan of mind mapping," a junior Business major with minors in Pre-Law and Innovation Engineering went on to say, "the simple mind maps can draw together ideas that you would never correlate." A junior majoring in Electrical Engineering with minors in Music and Innovation Engineering said this about mind maps:

> It's one of those tools that doesn't take a lot. It's really diverse. I can use it in many different ways. You can just start with four stimul[i] that … have nothing to do with anything, just branch off of them and it just gives you something to look at, something to get your creative mind moving. I'd say mind mapping is definitely … my favorite tool. It's probably the one that I use the most.

The first senior English major it this way: "I think [my favorite tool is] my mind map, especially when I just take… farfetched ideas and put them on paper. I just love what I come up with." He went on to describe the experience further:

> I used to think of it like … this kind of familiar circle that comes around it and everything you hit is just kind of in that circle. When I start[ed] mind mapping and just putting crazy things in the mind map and branching out from there, I was finding … all the things outside the circle that wouldn't

> work, and there is no way possible that it could work. But I started outside the circle, so then it was kind of dialing it down in reach of the outer edge [of the circle] to come up with something new. I think that's where I come up with my best ideas.

Finally, the university graduate with a bachelor's in Political Science described the experience of mastering the mind map:

> Mind mapping … to boil it down, it's just a piece of paper. But the visualization of putting the idea or the concept or the goal in the center of the paper and the branching out from there … visualizing the way your mind … literally works … connections that lead back to this core function. Essentially it becomes like muscle memory. There is a tipping point, when you graduate from the minor, the goal is that you don't need a mind mapping piece of paper. You just need a surface and you naturally write like that. I find myself on white boards occasionally … designing my notes like that as I'm talking.

Developing Meaningfully Unique Ideas

Participants describe tools, techniques and other elements of the curriculum used by students to augment available stimulus and to advance creative thinking. Ideas that address problems or create opportunities in ways that are unique can lead to desirable innovations, because such ideas provide a meaningful opportunity or solution that may be accomplished in a novel way. Part of the experience students undergo in the curriculum is learning to identify ideas that are *Meaningfully Unique* and to communicate the benefit of such an idea to an intended audience.

Ideas that are Meaningful and Unique. Offering his definition of one of the program elements, *Meaningfully Unique* ideas that lead to an innovation, the junior Business major stated:

> There are two ends of the spectrum, alright. A really meaningful idea is something that's very practical, that you use every day, for instance a garage door opener. A unique idea is like anything and everything, but it may not serve a purpose. A *Meaningfully Unique* idea kind of joins the two and meets it halfway, where it's something that you would use every day, [but] that hasn't been thought of in the past. It's a unique offering that's important to daily life.

The Foster Center's Innovation Engineer described *Meaningfully Unique* as follows, "It's meaningful to somebody. It solves the problem for somebody … and it's unique because it does it in a way that nobody has done before." The professor of English who teaches for the Innovation Engineering program expanded on this definition, "A lot of critical thinking comes into deciding whether the unique is meaningful. And I do like the idea of working a little more loosely towards the unique before one determines whether it's meaningful, because I think people may get a few interesting results."

Problem-Promise-Proof. The Innovation Engineering program's tool for conveying an innovation's meaningful uniqueness is the *Problem-Promise-Proof* element, which utilizes a template to draw out the important aspects of an innovation. A number of the student participants identified this tool as their favorite from the program's Communicate class. The junior majoring in Mechanical Engineering Technology describes the element as follows:

> It's a list of different questions that you can go through and different approaches you can take when you are looking at a problem. So if you are going to try and communicate to a certain customer audience, or you're going to use it to write a proposal … you would go through this guide … and answer the questions in it. Those questions … help draw out the important parts.

Saying, “I really like the *Problem-Promise-Proof*,” the senior Mechanical Engineering major described it as, “A really good way to go about pitching any idea to anybody about anything.” The junior Mechanical Engineering major with a minor in Innovation Engineering also identified this tool as a favorite from the Communicate class, “you plug your idea through this concept card, and you just answer the questions that it prompts you to answer. It takes maybe five minutes. By the time you’re done, you have a whole pitch that can be targeted towards any audience.”

While the student participants recognized *Problem-Promise-Proof* as an easy and effective tool for getting their ideas across, the faculty participants expanded on the value of this element of the program as it relates to student learning. The professor of English noted its importance in aiding students’ listening, as well as communication skills: “The way we do ‘voice of the customer’ is very useful, because it gets people to listen to each other, write down precisely what other people are saying and then try to see what, in what they are saying, will give an insight.” He went on to describe how the tool helps students who have difficulty expressing their thoughts, “What it particularly does is that it encourages students who are not very strong and interconnected at communicating with each other.”

The Director of Academic Programs for Innovation Engineering, also an associate professor of English, talked about how she now uses the *Problem-Promise-Proof* tool with her English students:

> You are going to give people a course in British literature … Native American literature … or T.S. Eliot, what’s the benefit of that? That’s one of the questions that we ask in the Communicate course … who is my audience, …

> what problem does this course solve, what's the promise that this course delivers, and what's the proof that it's going to deliver on that promise?
>
> I always say [to my students], always think of an audience for your work besides me, you know too many papers in English courses get written for the professor. And the professor writes comments on them and the student doesn't pick them up, so how much waste of effort on both sides is in that picture. So … this paper needs to do something for somebody. Maybe it's your mom you are going to share it with, maybe you are going to publish in the local newspaper. ... Think of an audience for it and then think of what benefit it's going to get that audience … and then the proof.

Pointing out that generating ideas is only a part of the innovation process, the Foster Center's Innovation Engineer stated:

> You've got to do that free thinking, but you're going to need to communicate to the guy that wants to put you in that box. How do you build a message that allows you to communicate with the guy that doesn't care, that's been running IBM [since] the 1970s? How do you formulate your thoughts to that individual? It's going to be numbers, it's going to be results. … Simply by looking at *Problem-Promise-Proof*. What did I solve, what did I promise and how did I get to there.

The student participants also described the significance of the learning centered on the 'voice of the customer' through the *Problem-Promise-Proof* tool. A senior Civil Engineering major with minors in Math and Innovation Engineering expressed its value as, "it gives you the skills to be more persuasive." Describing how the Communicate class helped him with his writing skills, he went on to say, "The writing class has helped me a lot where I'm doing capstone proposals … where I don't know how to start, [it's helped] with who you're writing to, what you're writing about and solving the problem, and really keeping it focused and centered." The junior in Mechanical Engineering Technology described how developing mastery of the Communicate tools felt:

> Eventually you internalize those methods so … you don't need to have the tools anymore, because … it just becomes a part of how you write … part of how you think. What's the opportunity in your problem I'm trying to address … what's important to them, what do they need to get out of it in order to create an action.
>
> What I gained is the ability to write effectively and to communicate effectively with people and I think that is probably … the number one piece that I'll bring away, is effective communication. Because that's important wherever you go, whether you're a professor of philosophy or whether you're an engineer.

Fail Fast, Fail Cheap Design Cycles

As the experiences of the students suggest, the curriculum imparts a different way of thinking, a process or system for innovating that is taught through applied learning. An important part of this process is enabling students to think expansively without boundaries. This can occur through a system of stimulating ideas with tools and techniques that advance associative thinking. Participants who experience the curriculum learn that ideas that address problems or create opportunities in ways that are unique can lead to desirable innovations, because such ideas provide a meaningful opportunity or solution and do so in a novel way.

The curriculum experienced by the participants helps them to determine whether an idea can result in a workable innovation by identifying the issues to overcome to make the idea viable, then running little experiments or learning cycles to break down and resolve those issues. These learning cycles are known as *Fail Fast, Fail Cheap* in the curriculum. Controlled experimentation helps to dissolve financial and other risks associated with innovation, but requires a certain level of strategic risk-taking by the innovator. Helping students to overcome their fear of failure and to learn from their mistakes facilitates this process.

Design Cycles and Death Threats

The Foster Center's Innovation Engineer discusses the use of design cycles to identify and resolve obstacles to overcome in order to solve a problem, which are referred to as *Death Threats* in the curriculum:

> Students really like *Death Threats*, because they like to point out other people's *Death Threats*. But it's identifying what do you have to overcome with your *Fail Fast, Fail Cheap* ... In my 392 [Commercialize] class, I've have a section of [that] class I call "King of the Hill". ... Everybody has a concept, an idea that they've written out using all the skills they have so far. ... Somebody gets in front of the class and starts to pitch their idea. All the other students at any point can raise their hand, stop the speaker and point out a threat or an issue for that idea.
>
> At that point it's not your point to defend it or to fix it, [but] to sit down and work on it, so run a [design] cycle, right. The student who has found the fault then gets to go up and pitch and then you keep going on with that. So you know, at the end, hopefully, finally, you pitch an idea that nobody shoots down. But the students really like trying to find the holes in the ideas, because they've realized that if I can find holes in somebody else's idea, then I can create the same benefit of assessment for a thought that I have. ... And that's the cycle that students learn rapidly, not just to try to fix their ideas, but to quickly assess where are the issues that need to be worked on.

He went on to say, "If you break it down into small enough pieces, there'd be no risk left. So if you look at the *Death Threats*, you break down the threats into manageable bites and then you can move that forward quite rapidly." The junior in Mechanical Engineering with a minor in Innovation Engineering described his process:

> The immediate thing that I go through and do is just check the *Death Threats*: Will [the idea] actually work? How much does it cost? If it's going to cost a

million dollars to solve a hundred thousand dollar problem, kick it out. If it doesn't even solve the problem, automatically kick it out. And I look at the criteria of the problem, what they actually want. … What resources they have to solve this problem and I kind of weave through [the issues].

Rapid Cycles of Learning. The junior in Mechanical Engineering Technology put it this way:

> *Fail Fast, Fail Cheap* allows you to take small steps without being totally committed to something to manage risk. … It's just a way to do little cycles of learning and small tests that can help you figure out … how big of a risk is this really? … Is this manageable or is this something that is going … to flatten us. Being able to look at [the problem] and decide, what is the biggest risk? Because you need to deal with that first. … Otherwise you're wasting time and you're wasting money.

He went on to relate a real life experience confronting *Death Threats* from his internship with the program:

> There is that one day [a local company] came in and had us work on some problems for them and I'll never forget one of the head guys … big burly kind of push people around kind of guy … he was exactly like the worst kind of customer that you want to innovate for. … Any idea that you come up with [he's] "no, no, no … we can't do this, we can't do that." What I realized is, working on the process with someone like that … he was in fact becoming part of the process that we learned called … *Death Threats*.
>
> He is voicing all of those *Death Threats* and for me, I loved it. I would almost rather work with someone like that because he was coming up with all the problems that I needed to overcome to make the ideas work for him.

Conquering the Fear of Failure

Virtually all of the student and faculty participants expressed recognition that fear inhibits creativity and innovation and used phrases such as, "fear of failing," "fear driven," "biggest fears," and "fear plays a huge role." The participants also recognized that the Innovation Engineering program offers methods to "reduce fear," "drive out fear," and that the program embodies the concept that "failure is a great way to learn." The English professor who teaches for the program noted, "I have been concerned over a number of years about how you decrease the level of fear in a classroom and… increase the stimulus to empower diversity [of thinking]." He goes on to explain that he tells his students at the beginning of each course:

> If they find themselves in an environment which has very little stimulus, very little diversity in terms of ways of thinking about something and a lot of fear, they shouldn't be surprised if a lot of *Meaningfully Unique* ideas don't start occurring to them. But what they can do, rather than just give in to that, is figure out how to find their own stimulus, their own … ways of thinking and counter that … fear.

Discussing the impact of fear on innovation, the junior Electrical Engineering major shared:

> I found that even I've battled with anxiety too. … Sometimes I get nervous and it's all fear driven and [driving out] fear really… is a major… component of Innovation [Engineering]. … Even bigger than being creative is driving out fear, because if that fear becomes unmanageable, you'd find yourself coming up with ideas and not even putting them down on paper because you've already thought … 'Oh, no, that's stupid' or 'Nobody will like that.'

Speaking of how the program helps him to recognize his own fears, the senior Civil Engineering major said about the curriculum, "It definitely does something. It makes you see the risks and the fears more for sure. It's helped me to take more risks. The fear and stuff is still there, [but] I can recognize it now." The second senior majoring in English put it this way: "What that boils down to is fear and that fear is what stops good ideas. It's an idea killer."

Creating a Safe Environment. Students described the experience of being in "a safe place" where "you're not afraid that people are going to judge you." The junior in Mechanical Engineering Technology stated, “You’re encouraged to take the restraints off. You’re in a safe place in the sense that, you know, nobody criticizes you. In fact, that’s one of the rules of the class. We don’t tell people … ‘no, it’s not a good idea.’” The senior in Mechanical Engineering put it this way: “I really like … being part of the classroom and being able to interject freely without feeling … I’m antagonizing the entire experience for the students around me.” Similar sentiments were echoed by a junior in Business Management with a minor in Innovation Engineering, “I definitely felt like more of an individual in a community. … Because within a big group of people you don’t know, you are afraid to say things, you are afraid that people are going to judge you.” The importance of creating a safe place, free of judgment, was underscored by the Director of Academic Programs in Innovation Engineering:

> The opportunity to fail is also the opportunity to fail creatively, to fail constructively. The opportunity to work on, what would happen if you let your ideas… really go. That’s a big aspect of freedom. And so often … in the disciplines … without even meaning to, we communicate boundaries and that’s a sad thing.

In order to create a safe environment for expressing ideas, the program lays out ground rules as described by the Foster Center’s Innovation Engineering Outreach Coordinator:

> In the first class it can be a really challenging thing because the students will come in and they are so used to an environment where they are … afraid to speak up because somebody will say ‘that’s a stupid idea’ … so they are afraid to put themselves out there, so we lay down ground rules. First, you don’t kill the new ideas, because a really crappy little seedling of an idea may lead to something great. Second, you have to have fun, because if it’s painful then you are probably not coming up with good ideas. So they know when they

> walk in the door that it's a safe zone. So we have to combat fear… it's a judgment free zone, we are not going to laugh at the idea.

The second Senior English major related, "In our first few classes [we] had to learn ways to not control fear, but to eliminate it, to kill it, to get it out, so that way we had no problems submitting ideas." The senior majoring in Business Management and Finance shared his experience of confronting his fears in the program:

> I've had a lot of fears, like in the back of my head, like this big cloud, it's like I couldn't recognize what it was… but it was there. They didn't ask us to talk about it in class, but to talk about it … with a partner. And honestly that was a life changing experience. Right now I know why I'm afraid and what I'm afraid of and what that causes me to do. That one week changed my life. … I never would have learned that in any other class.

"The only way you can get over the fear of failing and to be able to understand that you've got something wrong, but you need to learn from it is to provide a safe environment," stated the Foster Center's Innovation Engineer. "So the space, the classroom space is completely different. The faculty are … much more relaxed and it's a much more open conversation in class and we demonstrate that it's okay to express ideas … The expressing of ideas and asking of questions is safe in this classroom, which is an experience that you don't get very often in other classes." The Director of Academic Programs in Innovation Engineering described the learning environment for the curriculum:

> We also tell them that we want you to get As, but the way you get As is by failing, please fail and learn from your failure, do not be afraid to fail, and if you get a red X it means, 'yes, I am getting my money's worth'. … The whole notion that failure is a path to learning contradicts a lot of what they just get from the culture and it's like [failure] is a bad thing.

The student participants also described the experience of overcoming their fears and learning from failure. The junior Mechanical Engineering Technology major said one of the things he learned was how to request help: "You need to know how to say 'I don't know' and you need to know how to ask for help. I think that addresses fear in a huge way." The junior majoring in Mechanical Engineering with a minor in Innovation Engineering talked about the concept of failure in traditional education versus this curriculum:

> I think it's ingrained in our educational system that failure is just not acceptable. I know growing up in high school and elementary school, failure is not acceptable. You need good grades, which I believe is true, but you can be constrained by that fear of failure and [they] definitely break that mold here. … They encourage you to just express your ideas without fear of failure, because they are not going to fail you as long as you do the work and practice the process and get the … quantity of ideas.

He went on to say, "I could be kind of constricted by my own analytical thinking, [so] that I'm killing my ideas before they get off the ground. … Now, I'm more confident. … I have confidence in myself that I can solve almost any problem." The senior majoring in Mechanical Engineering put it this way: "One of the things in Innovation Engineering that [they] push on you is that failure is a great way to learn." He went on to share his experience with risking failure:

> It's definitely hard to accept that, [but] I think it's definitely helped me push. I am not afraid to call somebody up if I need to get an answer. I'm not afraid to just make something and see how it works. It's kind of a balance of taking a risk without wasting too much time. … It's fun to take quick little risks.

Describing his experience with conquering the fear of failure, the university graduate with a bachelor's degree in Political Science said, "A failure sounds like and it feels like … something you should be ashamed of, but it's not. … It's another tool to get to the end. [The curriculum] takes the shame out of it … transforms it into something empowering." A senior Business Management and Finance major with a minor in Psychology and in Innovation Engineering shared one of his takeaways from the curriculum:

> One of the best things I learned is that there is variance in everything. That if I [have] three apples, it's not just three apples. There will be different weights, there'll be different sweetness. Nothing is the same so I should stop pretending there is a right answer. And for me, I don't know if I would say that's enlightening or comforting, but it's definitely taken the pressure off.

Experimentation

Participants in the Innovation Engineering curriculum describe how their perceptions on experimentation and risk-taking have evolved as a result of what they have learned in the program and how they experienced the curriculum as helping them learn to manage risk through experimentation. "I think risk taking is a given here," explained the English professor who teaches for the program, "Of course what you are trying to do is make risk a little less risky." He went on to describe the classroom environment:

> I think as people discover more that there is receptivity [for] what they are saying, that there may be a critical discussion of it, but it's not wrong, that encourages more and more … [and] make[s] it safer to take risks. I think as they begin to experience what it's like to take a risk and for it to work, it builds courage … to take a risk, but a sensible risk, a strategic risk. And we are teaching students how to take strategic risks, not foolish risks.

In discussing how the program's curriculum takes on risk, the senior Business Management and Finance major said:

> When I think of risk-taking, I think of actually risking something. I think the best thing about Innovation Engineering is it shows you all the ways that there is very little risk … in getting you to do things when the risk is small instead of when the risk is big. Like working on a project a half an hour every day instead of trying to get it all done in an hour before it's due.

The junior majoring in Business Management shared:

> If you are not doing new things and trying new things you are not going to get anywhere. You are just going to keep doing the same thing over and over. So [the program] has definitely helped me out … just being able to … go out and do things and failing and [to] just be okay with it, because you can always just do it again in a different way.

Relaying that "it's not a risk, it's a learning opportunity and that's a big mindset change," the Foster Center's Innovation Engineer stated, "When you look at it, when you pull back from it, you can take that risk…and if you break it down into small enough pieces, there'd be no risk left." The Foster Center's Innovation Engineering Outreach Coordinator described it this way:

> What we talk about is small risks versus … giant leap innovation risks. And a lot of people are afraid of innovation because it is that giant leap, 'we are going to try something new and we are going to put it all on the line and we are going to see what happens' and that is not what we are teaching. What we are teaching [is] if you break it down into very small steps of risk, then you can do a quick cycle and you can learn from it and if you fail that's okay because it was a very small risk that you were taking. And the experimentation is part of dissolving that risk. … Experiments are really the way to just get rid of the risk or learn from it and move forward, you can't move forward without trying it.

Noting one of the limitations of the program, the senior Civil Engineering major acknowledged, "Because it's such a safe environment where we don't get the chance to experience [real risk] … no one out there [in the class is] spending money, [therefore] you can't get that risk and fear as much."

Experimentation Dissolves Risk. Student participants referred to experimentation as "taking baby steps," "one step at a time," and "small bites." The junior Mass Communications major stated: "If you fail once, you just try, try again. …I definitely take more risks now knowing that just because it hasn't happened yet, doesn't mean it won't." Student and faculty participants recognized the learning cycle, called *Fail Fast, Fail Cheap* in the program, as the Deming Cycle, otherwise known as *Plan-Do-Study-Act* and named for W. Edward Deming, who brought the scientific method to industry (The W. Edward Deming Institute, n.d.). The Foster Center's Innovation Engineer also likened it to John Boyd's *Observe-Orient-Decide-Act* (*OODA*) methodology (Hammonds, 2002). An Air Force pilot, Boyd used the *OODA* loop in warfare:

> Essentially, it's applying the scientific method to a dog fight. Well, if you pull back, if you consider your battle is with your competitors or with your market, well your goal is to observe the market as quickly as possible, orienting yourself with the new mission, decide the fashion that you're going and then make the action and then re-observe.
>
> It's just increasing the cycles of learning and forcing a decision to go for it from there. If you do that faster than anybody else, you become Toyota to Ford. You're able to launch the new model in four years. You are able to launch the hybrid and sell your first gen hybrid to Honda and still be ahead of the market. So, it's creating rapid cycles of thinking.

The student participants shared their experiences with using experimentation as a learning cycle, "I had a real innovation moment," stated the junior Electrical Engineering major. "I finally came up with the system that worked and then it was like, well, how can I make it better." The first senior English major shared one of his examples:

> We had a project that I had to replicate … a design, a format that was for a magazine [and] before I would have kind of tried to over analyze it. [This time] I just started … putting it together and I was like 'that's wrong' and I'd just scrap it off, but I didn't spend a lot of time with it. … So I was able to do that five or six times. And the fourth one, I actually… set it aside and so, the design is pretty good, it's close. I ended up coming back to it after the fifth and sixth one. I don't think I would have done that before.

The junior majoring in Business Management described it as, "focusing a lot on quick, maybe not tests, but quick ways of figuring out whether your idea or concept or whatever is good or bad." Elaborating, he said:

> So you know you can sit there and think about it and think about it, or you can just take your idea and go outside and ask five people 'what do you think about this, would you buy this'… It has helped me out a little bit in just figuring out quick ways of solving big decisions … instead of just sitting and thinking … about it, because you can only get so far without actually, physically doing something.

He went on to describe his experience teaching kite-boarding in Hawaii last year, "I always tell people I can sit here on the beach and talk to you about kite-boarding for three hours or I could put you out in the water for ten minutes, and you will learn way more out there doing it then you would by me sitting here talking to you about it." Another student participant also shared his experience. The junior majoring in Mechanical Engineering Technology talked about what he worked on during his internship with the Advanced Manufacturing Center at the University:

> The *Fail Fast, Fail Cheap* testing, we did some stuff like that for a few different clients at the [Advanced Manufacturing Center]. [We did] some quick testing to try and figure out how to mix a certain kind of granola that a certain company had. They were looking for a mixing machine and they had some special requirements. … So we took some of the product and ran it through some quick cycles to see … what happens if we run it … at such and such RPM, what happens if we run it a little faster, what happens if we … tilt it at this angle. So we were able to do some cycles of learning for them and we

> were able to come to a conclusion, what kind of machinery they needed. … That gave them direction, that gave them a structure to work in so they could figure out what the next step was in their process and that was going to help them automate a system so they didn't have people having to stuff by hand.

The aspects of assessment and reflection also emerged as important components of experimentation. Participants shared that the analysis and consideration of why something didn't work often leads to a new idea of something to try. In the early stages of learning to experiment, immediate assessment of student work and built-in opportunities for student reflection are important to help students understand how failure is a learning opportunity. The Director of Academic Programs in Innovation Engineering asserted:

> Failing is a path to learning if you stop, reflect and get why the first experiment didn't quite get there. *Plan-Do-Study-Act*, *Plan-Do-Study-Act*. And … students are always pretty shocked. … It is very hard to get people to really believe that failure is good. You really can't convince people that that's the truth, if you don't give them immediate feedback. … Assessment is proof, it's what you want to know. You have to find out the stuff that is working and isn't working. We can't just get positive feedback.

The Foster Center's Innovation Engineer who teaches for the program put it this way:

> I've seen the progression. I'd probably say eighty to ninety percent of the students come in with the view of 'I have always gotten A's and you keep telling me that we're going to fail and that is scary.' Later, eighty to ninety percent of the class understands that the failure is not what's important. It's the assessment of the failure. It's the study of what failed … [so you can] figure out what happened and how … [to] change it going forward. … So the important part was not to do it that way, but [to] try something different.

In describing his take on the value of assessment and reflection to the learning cycle, the university graduate in Political Science stated the following:

> It's like a foundation you can build on. You know that even if the house burns down, the concrete foundation will stand and that's the opportunity to build as many houses as you want, until you get it right. … [It] is a good comfort, because you have the freedom to fail.
>
> I can stand up and justify why I came to a conclusion and I can say my conclusion is wrong because I made an incorrect assumption here and here. I have no problem saying that, there is no shame in that.

Constructivist Learning Environment

Through their experiences, the participants share in determining whether an idea results in a workable innovation by identifying the issues to overcome to make the idea viable, then running design cycles to break down and resolve those issues. The student and faculty participants relate that controlled experimentation helps to dissolve financial and other risks associated with innovation, requiring a certain level of strategic risks taken by the innovator. For this reason, helping students to overcome their fear of failure and learn from their mistakes is a critical part of the curriculum. An effective method for teaching these components of creativity and innovation is a constructivist learning environment, in which students are required to employ cognitive processes and to participate actively in the construction of new knowledge by integrating new information with prior learning and experience.

Interactive Learning Community

In sharing their experiences, student participants describe an interactive learning community where teachers and students form a mentor and apprentice relationship and in which students engage in focused, facilitated knowledge construction aided by the teacher and student peers. Describing the Innovation

Engineering classroom environment, one student called it "the best learning experience I've had in the University" while another said "it helped me really take [the information] in and comprehend it." The junior Business Management major said, "Here I felt like we were all a group of people trying to learn and work together. [Here] you are an interactive member of the learning community." He went on to further describe the environment and his relationship to the instructors:

> I like this environment … sitting at … small tables and small groups of people and talking and interacting. The teacher is just walking around … and helping you out with the problem that you have. I think it allows you to learn a lot faster… as opposed to sitting in a desk and having a teacher lecture you. … Personally, I don't like that very much, feeling like there is a big separation between you and the teachers. … I want it to be a very close relationship, where I can ask you questions and you will help me out and you know who I am.

When asked about his experience in the classroom, the junior Mechanical Engineering major said, "It's very interactive. … It's almost a student run classroom." The junior majoring in Mechanical Engineering with a minor in Math described it as, "very, very casual. … It makes it … more accepting for idea generation." He went on to explain the difference from a traditional classroom:

> In a regular classroom setting … you have to raise your hand and wait to be called on every time you want to say something. It takes a really long time for ideas to come across; whereas, if the whole classroom is basically just one big discussion, it's really easy to get your ideas across.

The university graduate in Political Science put it this way: "The … environment is very much key … for any type of class, [but] especially one that relies on actual engagement of the students." The senior majoring in Mechanical Engineering depicted the program's classroom environment as enabling student contributions.

"In the Engineering lectures and in the Liberal Arts lectures … you're a spectator to the presentation of the content, so you're watching the play if you will. Whereas in Innovation Engineering, you might be a part of the play … and actually contribute a great deal to the content of the play."

Mentor and Apprenticeship Relationship. Student and faculty participants also related that the relationship of the instructor to the students is also integral to a constructivist learning environment. The senior Business Management and Finance major said he believed the job of the teacher is "to facilitate learning. I think that's what education is really about. It's about students learning on their own." The senior Civil Engineering major contrasted traditional education as "not focused enough on the students in getting them to learn the material." Relaying his experience in the Innovation Engineering program, the senior Music major stated, "I kind of see it more as a teacher in the Innovation program just kind of getting your foot in the door, and [then] they allow you to expand on that." "I could completely change the topic of the class with something that I brought up," the senior Mechanical Engineering major said about the program. "I mean definitely the deeper you get into the curriculum, the more the student brings to the table." When asked about the feeling of freedom in the classroom that some students expressed, the English professor who teaches for the program shared these thoughts:

> I hope that's a quality that happens in my other classes, because a feeling of freedom is I think one of my highest values. … The atmosphere in the classroom is one of significant respect between the teachers and the students. I think that's built into the [Innovation Engineering] curriculum. … So it becomes more of a mentor-apprenticeship relationship.

The junior Mass Communications major related the teacher's role in the Innovation Engineering classroom as follows: "They definitely are there to help guide us, but basically it's to help us teach ourselves these skills." She went on to say, "They put it out there for our interpretation, but ultimately it's up to us. … There is definitely direction there, but they're doing it ultimately to help us become more independent thinkers for our future careers [and] life goals."

The Goal is to Learn. Student and faculty participants conveyed the experience of metacognition that occurs in a constructivist learning environment. "The problem with learning [the traditional way] is I didn't retain that information as well," the second senior English major shared. He went on to talk about his experience with the Innovation Engineering classes: "[The] information is not only retained, but reinforced. We've had practice. [Then] after every tool that we learn, possibly one of the most important things that we get taught is [that] we need to write a reflection, what did you learn?" The university graduate in Political Science put it like this: "[I think] college is not there to teach you what … to learn; college is there to teach you how to learn. And Innovation Engineering is really the epitome of that. … By definition [it] gives you a system and a process for doing things and for applying [it to] whatever your passion is." The English professor who teaches for the program defined Innovation Engineering as "applying principles of innovation or creativity to get practical results." Noting that traditional summative assessment methods sort students by their scores on tests and exams, he stated, "The goal here is not to sort; the goal here is for everybody to learn this and to give everybody really the chance to learn it, to redo it, to rethink it and to care about what they think. … I think that sense of respect for the students is very strong." He went on to talk about how to produce this type of learning:

> Wouldn't you want to begin to find ways of having people work together more in groups, rather than as isolated individuals? Wouldn't you want to have a classroom that looked different and wouldn't you want people to be able to move around? Wouldn't you want to begin to think of how you could create whole brain groups with people with different talents and the group and really honor the different learning styles your students have by knowing about them? … You need to have that feel of mobility and freedom.

Critical Thinking and Problem-based Learning

Through their experiences participants describe an interactive learning community, where teachers and students form a mentor and apprentice relationship and in which students engage in focused facilitated learning aided by their peers. Some participants also shared that when information is first absorbed, then reinforced, and finally reflected upon, it enhances learning. Problem-based learning proves to be a valuable pedagogic method for teaching critical thinking, as it often utilizes real-world situations for which there is no single right answer.

Learning to Think Critically. The student participants discussed how the Innovation Engineering program expanded their critical thinking skills. The first senior majoring in English related, "I don't know if it helps me think more critically … I was always a very analytical person; thinking critically is never something I struggled with. I do think that [it] does push the boundaries of how I think." He went on to say, "I do think a little bit more outside of where I used to think. … I think way outside of the circle and try to bring it in, rather than working with what I have and sticking it in a very, kind of, tight space." "When it comes to Innovation Engineering courses you're definitely encouraged to think outside the box," said the junior Mechanical Engineering major. "It's like you're paving roads that have never been made before. In a sense you are given a framework to think within, but the framework applies to anything." The Electrical Engineering major said the program "gets you problem-solving without actually thinking about it as problem-solving... You end up deconstructing what you would call the problem and really the mindset becomes … don't look at it so much as problem- solving anymore, just being creative and coming up with new ideas." He went on to say this about the curriculum, "I would say that these classes, it's not like learning. It's not like giving someone a hammer. It's giving someone the skills to make the hammer. It's really problem-solving." The Foster Center's Innovation Engineering Outreach Coordinator described how the program also asks students to apply critical thinking to their own educational goals:

> In each class we kind of set up the level of problem-solving and critical thinking, but I would say the whole minor is focused around problem-solving. One of the first assignments we do in the Create [class], we have students look at their major … and compare it to other majors at other schools, other majors at this school, and say 'what are the things that I would like to see when I graduate.' With most of the students that take Create … they are kind of here because it's the next thing you do after high school, but not really a lot of focus. ... We will have a huge, one day discussion about everything they learned about their majors, themselves, and it's one of my favorite days, because they have really thought critically about 'why am I here' and 'what am I spending my money on,' 'what do I want to get from the university.'

Problem-based Learning. One of the findings that emerged related to the curriculum's use of problem-based learning to address sometimes hypothetical, but mostly real-world, problems or opportunities for which there is no single right answer. The junior majoring in Business Management differentiated this type of problem-based learning from problems sometimes presented in other courses:

> Unlike some classes where it's, you know, Suzie is running this business ... [where] you just have to think about the ways we just told you to do it and then figure out which one fits, [these classes say] here is a problem and there is really no [single] right answer, so come up with your own way of figuring it out and think, use your brain, and see if you think it is going to work. As opposed to just applying something that someone has already taught you and it's just like two pages in the back of the textbook.

The junior Business major with a minor in Pre-Law reflected on a class exercise to help an academy for bag-piping diversify its revenue opportunities:

> The approach to solving a problem like this, is you take the step back from the third party perspective and you look at all the aspects. You are trying all these things … and you are realizing that this process is pretty similar to, if you were … in the board room at a company and they are … looking to innovate on a specific product … and the more practice you have doing something like this, the better it is.

The Foster Center's Innovation Engineering Outreach Coordinator described the use of problem-based learning like this:

> Students would get a new business or a new case study and this business or non-profit would have a problem. Sometimes it was as simple as we need to do more fundraising … or it was we are going to need to completely revamp what we are doing or we are going to be out of business in six months. So there are these real problems that are happening to these companies in real time. [The students] really have to think critically about, is this an idea this company could pursue, is this feasible, is this something that aligns with their mission?

Real-world Situations. Many of the student participants recounted experiences in addressing real-world problems, or creating real-world opportunities, through their independent study and internship opportunities with the Innovation Engineering program and through their capstone projects, as well as through their own experiences outside of the university. In addition to the other examples described in this chapter, student participants shared their experiences using the Innovation Engineering tools to develop their own ideas for the following: a compressed natural gas system to run a snowmobile, gloves with sensors that make drum sounds, a high-tech rubber stamp for use on a smart phone, and a dual rate core set-up to filter water out of the fuel for a ferry boat.

In his independent study class, the junior Business Major with a minor in Pre-Law and his teammates developed a business opportunity for a protein shake smoothie bar at the University Rec Center. The smoothie bar was meant to address the lack of natural and organic alternatives for protein supplements available to students and other members of the Rec Center. The student explains:

> It ended up being very viable. … We decided that we wanted to move forward with this idea and we presented it to a few of the important people in the University, directors of the respective departments: auxiliary services, dining services … and the Vice President of … Financial Affairs. And we got permission to move forward and open this business as student run.

During his Innovation Engineering internship, the junior majoring in Electrical Engineering worked with a diagnostics company, "It's a large lab where they get anything from blood samples, urine tests … they get all kinds of specimens from all around. [The specimens] come here … and get processed." He went on to describe his work, which the company implemented:

> What they wanted … was a way to keep track of them … a tracking system for the specimens. It wasn't like they didn't have a system in place, it was just that they needed a better system. So, I kind of went ahead with almost like a UPS system where I came up with … a scanning system, something that would be fairly easy for them to implement. This way they could track the times that [the specimens] were actually picked up. … It was nice to see how it works in the real world and how you can apply what you've learned. … It's a different way of thinking and approaching problem-solving and you get the tools and you get the confidence from the program.

Describing how he applied his knowledge of Innovation Engineering to a real-world engineering problem for his Commercialize class final, the senior Civil Engineering major said:

> I specialize in geotechnical engineering, which is the foundation in soil engineering and the big problem they have is disturbance of samples from the field to the lab, which results in lower strength. So, you [can] have too much settlement in buildings because you predict one thing and [that isn't what happens]. So, it's a system to reduce the disturbance. I literally did it in a week. I created a prototype, I tested it, I proved the concept of it. I've [also] gotten in contact with people to see about changing the standards for [soil sample] transportation.

Hands-on Learning

Through their experiences, students relayed the curriculum's use of problem-based learning for teaching critical thinking skills. In their own words, several students recounted real-world situations in which they employed these skills to address complex problems and create opportunities. Another pedagogic method for building confidence and generating real-world mastery is a form of applied learning called "hands-on learning" or "learning by doing." In their interviews, students used phrases such as "for me, I really learn hands- on," "I am a very hands-on learner," "using the hands-on I think you remember it a lot better."

Learning by doing. The Director of Academic Programs in Innovation Engineering, in describing the pedagogy of the program, said, "We really care about application of the tools and learning to use the tools and … giving people a project is one attempt at assessing how they are doing." Relating his preference for this approach to learning, the junior Business Management major said, "If … I am physically doing something I will learn it a lot better and if I know how it's applicable and … why I am using this, I will learn it a lot better." He went on to contrast traditional courses with his Innovation Engineering classes:

> All of the other university classes are very cut and paste, like this is what you need to learn, this is what we are teaching, I am going to … give you a test to make sure you know this. With this class, it's like we are making sure that you learn this, but we are learning it in a very unconventional way. It's not cut and paste 'this is the good idea' … It's just you are coming with a system and then the result isn't quite as important as how you got there.
>
> Here, … they are looking at how did you come up with this idea, what did you use to come up with this idea, what was your stimulus, show me the drafts of your writing, how did you go back and revise your concept. As long as you are confident in your decision and it makes sense … that's what gives you a good grade.

The junior Mass Communications major put it this way: "Especially with gen eds, a lot of what I learned … my freshman year I don't remember any of it. I don't see how I would … apply it to anything in life or would have any way of remembering [it].

But I know with Innovation [Engineering] … the skills that I've learned have stuck with me." She continued to explain why she believes this is the case:

> I definitely think it's the application and I also think it's the fact that it could be applied to any aspect in your life, where you could use it every day. [Innovation Engineering] is something that could help [students] not only with their major, but also help them expand on it and I think that is one thing we all take away … just the fact that we have that application and experience and it applies to our life so it's important to us.

Also comparing traditional education to the pedagogy of the courses in Innovation Engineering, the Foster Center's Innovation Engineer offered the following analysis:

> Let's take math for example. If you take twelve years of K though 12 math, here's how you learn. Teacher reads what's in the beginning of the chapter, you do practice problems in class, you go home and you do the problems they give you and the answer is in there. There are word problems that are structured so you can pick out element A, B, C, D and no decision required. Plug it in the formula and you calculate.
>
> You do that through elementary, through middle school, you get Algebra, it's the same way. Geometry, Pre-Cal, Cal, you get to this point where then, you're taking Calculus 3, you're expecting the book to have the example. You have the problem that looks exactly like the example and by the time you get the exam, it's a little bit different to try and see if you've figured it out. There's no need for us to solve the problem. There's no abstract.
>
> And everything that we do outside of the classroom involves us applying that knowledge in a completely new way. We don't do that in the classrooms enough. Providing [the students] with 'how did you break down your analysis?' and discussing it, that is where all of the learning happens.

Discussing the value of learning by doing, the senior Business Management and Finance major portrayed the pedagogy as follows: "Innovation Engineering is a lot more hands-on." He went on to say about the teaching, "Here I really feel like I'm actually learning something. …[It] is asking me to think … asking me to do something, instead of absorb something, and I find that very valuable. … Because for me I really learn hands-on. … I learn reflectively." Talking about his experience in the program, the junior Electrical Engineering major said, "The goal is … to have educated people that go out into the world and do something. [In this program, you] … become part of the process, just pay attention, just go through the steps and they're going to prepare you." In describing the value of learning by doing, the associate professor of English and the Director of Academic Programs in Innovation Engineering communicated the importance of applying the learning:

> Liberal Arts has the opposite problem than say the community college. And that opposite problem is that you have all this depth and critical thinking skill … but you don't know how to make things or do things in a real world way. The process of learning to do was something that [for] many twentieth and twenty-first century students has sort of … been phased out of learning, especially for people in the Liberal Arts. [What is lost] is this essential idea that you gain a kind of confidence and mastery of the "real world" [by doing].

Collective Learning

The experience with hands-on learning shared by the students denotes a sense of real-world mastery or confidence in what they have learned. Similarly, collective learning, also sometimes called "group work" or "peer learning," can positively contribute to the enhancement and mastery of learning, as well as to the generation of ideas. All of the student and faculty participants touched on the importance of group work to the constructivist learning environment of the program. Two-thirds of the student participants focused on the value that differing perspectives added to the process of creativity, observing the benefits of diversity of thought, improved interpersonal skills and increased opportunities for peer learning.

Group Work and Peer Learning. Noting the interactive nature of the courses, the junior majoring in Mass Communications said, "It helps to hear others' ideas and also to get feedback on [your] ideas from others." The junior Mechanical Engineering major said that, "The strength of the group is being able to bounce your ideas off that person and get their spin on it and see their take, because everyone thinks differently." He went on to say:

> I think a lot of people can get focused on their idea and they see it in their mind and they have it – boom - laid out in front of them. And then you say it to someone else and they say, oh, well, what if you did this and … you realize, oh, I could do that and that opens this door. And they really expand off your idea and make it a much bigger idea, or it could be the opposite and they say, oh, what about this and you say, oh, I didn't think of that, I guess I won't go with that idea.

Emphasizing the different thinking styles of group members, the Foster Center's Innovation Engineering Outreach Coordinator stated that, "Group work is a big part of it … and it's really important because … everybody has a different way that they learn and they think, so having a group of four people, chances are you are going to get four different approaches to something." In discussing the diversity of the students in the minor, the Director of Academic Programs in Innovation Engineering made this observation:

> Students come into class and they are not going to see a cohort, they are not going to see the kids they saw in their 10 a.m. Chemistry class or … Statistics class … or lecture in American Lit. They are going to see kids from all different disciplines… and they will be working with them in various configurations.

Discussing the value of the group in providing stimulus for creativity, the junior Mechanical Engineering Technology major said, "I really respond well to the stimulus from other group members. … Just the fact that people are there conversing actually helps stimulate ideas for me." He went on to elaborate on how the diversity of a group can foster creativity:

> There's a lot of group work; one of the factors that they say helps come up with good ideas is diversity … how many people you have involved in the process, so if you have a group of two people you might come up with some good ideas you wouldn't have gotten otherwise, but if you had a group of five people, especially if those five people all tend to think differently … You get some awesome ideas when you put a group of different people together which is good because I think, especially in a work place, you end up with lots of different kinds of people. So if you can involve an entire work community together you can get some awesome ideas.

The junior Electrical Engineering major put it this way:

> It's a great tool working with the group, because … you get different ideas, bounce ideas off each other, you come up with new stimulus. …Working in a group has definite benefits and I think some of my best ideas have come from -- you get a great idea, you work with the group and then they have something to say and all of a sudden, your idea grows into something completely different, because of somebody else's view or somebody else's input and … everybody thinks in a different way, so it's a great way to get a different spin on what you're thinking of.

"I think the group work is much better [at] valuing [the] interpersonal stuff," stated the English professor who teaches for the program. The junior in Business Management also voiced the benefit of improved interpersonal skills:

> I think it adds to a lot in the fact that you have to want to learn how to work with other people. You have to be able to socialize and talk with people; [for] some people that's difficult. … You also get a lot of different perspectives… and we all think about things totally differently. … Just being able to have different perspectives on things helps because then you can start… to think in a different way.

Noting that, "there [are] no projects in real applications that you are truly working by yourself," the junior Business major with a minor in Pre-Law said, "Whether you are in construction, whether you are in business, whether you are in law, whether you are an engineer, you are never working alone. This program is effective to that end. … It lets you … bounce ideas off … people just [as] you would in a real application."

Remarking on the advantages of peer learning, the junior in Mass Communications observed, "We're able to help each other." She elaborated on the distinction between group work in Innovation Engineering and in other classes:

> The difference is in regular classes there is a structure to the group work and there is stimulus for our group work here, but there is not really a structure. We kind of take it and go with what we think it means or what we want to do with it, so it's kind of all left to us, like there is more responsibility for us and I think that helps us learn and grow better.

"One of the things you learn right away in Innovation classes is not to try to do it by yourself," said the junior in Mechanical Engineering with a minor in Math. "Always be talking with other people and networking; one of the biggest ways to find out whether or not an idea is good or not is to talk with other people about it and get their thoughts." Talking about some of the contributions group work brings to the curriculum, the senior Civil Engineering major stated:

> I think [group work] helps a lot because it gives the ability for [the] teachers to coach to the groups. So they can work off each other and really, if someone is stuck on something, the other person can help through it. Then it also gives us the ability to see what they're doing and to help them and maybe we can explain it well enough to one of them, but someone else in the group can explain it better, because we can't be at all the groups all the time.

The senior Mechanical Engineering major discussed the benefits of teamwork to innovation:

> You might have someone who is a great writer and you might have someone who is great at math. The person who's great at math might have a bunch of good ideas, but can't necessarily write them out in the way that they envision – or say it in the way they envision. The same way, the writer might not be able to envision the numbers and that's where the teamwork works really good in the different brain styles.

The Down-side of Group Work. However, the senior Mechanical Engineering major also acknowledged some of the drawbacks that accompany group work:

> One of the things that I've noticed with the group work is that everyone sort of has their own unique idea that it's hard to branch off from that once you're really into it. If you have conflicting feelings of passion about an idea, product, service, whatever it may be, that can hinder the group work.

Other participants also discussed some of the downside to working in groups. The senior Music major said, "Working in groups can be a big hindrance … [if] people just keep shooting down ideas or trying to add more detail than necessary, and it [can] slow down the group." Added the junior Business Management major, "When you have a project and you start divvying up [the work] and then someone just doesn't do what they are supposed to … that can be frustrating." Noting that he is an "individual thinker," the junior Mechanical Engineering major said, "I can feel hindered by other people being adamant on their ideas or [if I am expected] to cater to their ideas." The university graduate who majored in Political Science put it like this:

> Not everything benefits from group work … and knowing where those pieces fit into the system and in the process of learning to mastery is something the program has evolved … over the last four years. We know much more now about what's effective when than we did four years ago.

Formative Assessment

As indicated by the shared experience of the student participants, collective learning can positively contribute to the enhancement of and mastery of learning. In particular, students communicated the value added to the process of creativity and innovation when others share their perspectives, observing the benefits of diversity of thought, improved interpersonal skills and increased opportunities for peer learning. A process known as formative assessment also contributes to the constructivist learning environment.

Formative assessment consists of multiple interactive and iterative cycles of learning, assessment, feedback and reflection. During the fall of 2012, faculty for the Innovation Engineering program introduced a new format for teaching the curriculum in the Commercialize class. Referred to as a "flipped classroom" because the lecture on the theory is delivered to the students online and on the students' own time and the homework is completed in the classroom, the new format added formative assessment to the pedagogy for the curriculum. To a person, all of the student and faculty participants exposed to the new format found it improved learning outcomes.

Applying Learning Cycles in the Classroom. The Foster Center's Innovation Engineering Outreach Coordinator shared that:

> The new way that we are teaching, doing the flipped classroom with the rapid cycles of feedback, I think that the student is responsible for less of trying to figure out what they need to be learning and more for critical thinking and pushing themselves deeper. So the students watch the video,

they do some type of interactive exercise and they know, this is the key concept, now I just need to apply it.
[The teachers] are giving feedback every day, so we are hoping that with each piece of the content the students have that one-on-one conversation about what they did well and what they didn't do well, so that they are learning immediately, while it's still fresh.

Describing the new format, the Director of Academic Programs for the Innovation Engineering program described the experience:

> What we have done is we have put content as a relatively brief video or slides with audio over delivery that they watch before class and class time is lab and application. And that it's coached … in the class, which means the students are given tasks, the kind of tasks [that] would have ordinarily [been] given [to] them for homework.

Saying, "we're taking the learning and we're applying it to ourselves again," the Foster Center's Innovation Engineer provided an analysis of the new format and its use of formative assessment:

> So we're doing formative assessment in a flipped classroom. … First, there's an online component where the student gets essentially all the theory. Read this chapter. There's no lecture in the classroom. Then, the class is the assignment and you're coached through the assignment.
>
> So the goal is the student starts doing the work and they're going to get it wrong, 10 times out of 10, because they haven't been told how to do it. Here do it. You then evaluate, what did they understand? From that quick assessment you start grading in class, immediately. The goal is you grade it as many times as they can submit it in the class[time]. So then you're providing them with continuous feedback so they can do a [learning] cycle.
>
> So … you're providing formative assessment to the student so they get more cycles of learning. More iterations for them to determine where they got [it] wrong, more feedback to figure it out, give it another try and keep cycling. Essentially you're applying Innovation Engineering logic [of learning cycles] to a teaching system. The key is not to sit down and re-explain [the theory] because the student should be responsible for, needs the motivation, to at least read it once and to try it once and then be able to receive feedback that

> tells [him] what it is that [he's] not understanding and what is it that [he's] not applying correctly. Then have [him] try it again.

The students voiced their appreciation for the new learning method. "The way they're doing it now, it's excellent to come to class," stated the junior Electrical Engineering major:

> [We] have most of the lectures at home … online. You go and you watch two 5 to 10-minute videos and it gives you the information that you need for class [on Tuesday]. Then you come to class and we do group work where we apply what we just learned and the teachers are all there … so you can have their input. Then on the Thursday class, we come in and we'll usually have some kind of … real world experience. … You're using it. So, it feels more like [the] development of a physical skill rather than schooling. You've used it and you've implemented it. So, all of a sudden, it's kind of ingrained in your head and you didn't even notice it was happening.

The senior Civil Engineering major is helping to coach the new flipped classroom and relates his experience: "Instead of teaching, we're coaching the students, so it gives a much … greater ability for them to master the material … [when] they come to class and they're doing their assignments and we can be there next to them and see what they're doing. If they're going down the wrong track, we can push them more towards the right one." "You are getting instant feedback," said the junior majoring in Business with a minor in Pre-Law, "That's really the most important aspect of this process that I feel is hugely effective."

Advantages of the Flipped Classroom. Discussing the problem with the old format for teaching the Innovation Engineering courses before the flipped classroom, the junior majoring in Mechanical Engineering Technology said, "My one and only gripe, I would have to say, is that oftentimes the grading and the feedback

[had] not been really [timely], and so maybe sometimes you don't know whether you're on the right path or you don't get that feedback soon enough." In contrast, the new flipped classroom provides immediate feedback for the students and grading evolves with the assessment of each iterative cycle of learning. Two of the student participants had the opportunity to more directly compare and contrast the two teaching approaches. The first senior English major was taking two classes at the same time, one taught in the old format and the Commercialize class taught using the flipped classroom. The student stated, "The [flipped classroom] is so much better." He went on to explain:

> It really does feel like a mini lecture before you get into the class. So you show up and you understand what you are supposed to do and then you go use it and sometimes you misunderstand it, but that's why you do the group work, you get straightened up pretty quick.

Another student was repeating the Commercialize class, having taken it the prior year in the old construct. This student, the second senior English major, declared, "The new format is incredible." He then described the old construct, "For the most part, [it was] five to six classes of studying it and just pounding it into our heads. It's a very familiar way of learning. It was new material, but it was the old system of learning." Then he shared his experience with the flipped classroom:

> With this, it's a brand new different way of learning where we get told the information on our own time … it's a nice core chunk of time at your own convenience, so that way when you're ready to learn you're actually mentally prepared and you'd be surprised how much information you actually retain. [Then] you come to class and it's not that you're expected to know that information, you're expected to reinforce that information with group learning. You're figuring it out together and being able to learn on that level really reinforces things.

When asked how the students were assessed in the flipped classroom, the Director of Academic Programs in Innovation Engineering stated, "We are evaluating how well they apply the tool, [their] mastery of the tool. … She continued, "Every student works for mastery of each little piece and so as each piece gets mastered it adds more points to the final grade. It is up to them to keep applying themselves to do that. … In a way it's a sort of grown-up way to be self-motivated." Asked to describe how evaluation of student answers occurs in the new classroom format, the Foster Center's Innovation Engineer put it this way:

> It's not the answer that's important. Just thinking that what are the steps that you've taken to get there? What is your logic from point A to point B? So, you have to assess the system and the process. You can't assess the answer. That's where everything falls on because if you solely base your assessment on the answer, you're [just] doing quality control.
>
> It's the rate at which they apply the cycles. It's the depth of logic in applying those cycles and you can see it. They're very superficial the first few times and the more they get to practice, the deeper their reasoning gets. … And you can see the depth of the understanding of the student increase. So as the understanding increases you can actually see the process expand and then you can understand the student's running the [learning] cycles.

Describing how the pedagogy and the curriculum work together to help students achieve mastery of the tools for creativity and innovation, the graduate of the university with a major in Political Science shared his experience:

> It's really focused on achieving mastery by the end result. And mastery in this case is a mastery of a system for applying innovation. Because this class is trying to empower you to be different, to be innovative, to be *Meaningfully Unique* in what you do and the things you do and the byproduct of what you do.

Learning to be Agile

Through their experiences, the participants conveyed that an effective method for teaching creativity and innovation is with a constructivist learning environment, in which students are required to employ cognitive processes and to participate actively in the construction of new knowledge by integrating new information with prior learning and experience. The student participants describe an interactive learning community where teachers and students form a mentor and apprentice relationship and in which students engage in focused facilitated learning aided by their peers. Students also share that the use of pedagogic methods such as problem-based learning, hands-on learning, peer learning and formative assessment contribute to the constructivist learning environment and provide students with a sense of real-world mastery and confidence in what they have learned.

However, these different ways of learning and thinking can challenge the norms in education, as well as in business and other organizations. One of the experiences students encounter in this curriculum is that the inclusion of creativity in the curriculum and its mode of instruction is different from their other educational experiences. Similarly, the concepts of creativity and innovation taught in the curriculum, when employed in the real world, can test organizational inhibitions.

Not for Everyone

Unanimously, the student study participants expressed appreciation for the curriculum. They used phrases such as "it really allows anyone to express their creative side to the fullest," and "it's applicable in everyday life," in describing the program of study. Several participants noted that learning this system for thinking, this process for innovation, had "changed their lives." However, when asked if there are sometimes students or others who just do not get the concepts or the curriculum, the faculty and student participants described infrequent instances when this occurs.

I Don't Get It. The junior in Mechanical Engineering Technology described an experience from his internship, saying "people don't necessarily connect with this stuff. … It's a little bit disheartening … to know that there's just this resistance to anything new." The Innovation Engineer at the Foster Center admitted this happens sometimes with students:

> You have students that sometimes just don't get it. It'll either be – and it's so weird – there are some students it's just too abstract a concept for them. It's too far right brain for them to comprehend because they're in this box and they can be in that box forever. You really work hard to at least get them a little bit of that pie that they can understand. Then there are some other students, it is way too structured for them. It's way too left brain. Same concept and they look at you like you're a scientist, forget it. I don't want to hear about it. And then you work on that kid just so they can get it a little bit. It's being able to get that blend stuff.

The Center's Engineering Innovation Outreach Coordinator recalled a student from when she took the curriculum in graduate school, noting:

> He was an undergraduate student and … I think he was not getting it because he didn't want to get it. And we had to work together in a group … and there [are] all these deliverables you have to do, so you have to show your process, that's the most important thing. And he just did not get it, so it was like, "Well I don't use tools to come up with ideas" and I am like, "But you are in the fourth class, how can you not use tools?" It was so painful, but, yeah, he was the one who just did not get it.

Educational and Organizational Reticence

Participants describe a sort of reticence in relation to encouraging and trying new ideas in their educational and real world experiences. The first senior English major with a minor in Innovation Engineering said that coming out of high school, he loved language, but that he didn't think creativity was his strong suit: "It has more to do with the fact that I was so unprepared beforehand … in the creative aspect. I want to say the culture … I was never prepared to be creative in school." He went on to describe his experience further:

> When I went through high school it was … math, science and you answered questions and the creativity part was left out. … We never had any exposure to being creative, we were never told how to be creative. Actually, I had really assumed that it was either you were or you weren't.

The Foster Center's Innovation Engineer who practices the innovation principles of the program on university technologies and research noted that for education and business, "It's learning to be agile again. It's almost like we forgot how to think it." He went on to state:

> You can tell when you speak to employers, "We had an [Innovation Engineering] intern and it was amazing to have that guy in here and always fishing for fresh ideas and helping us analyze … all this stuff." And I say, well, you've been doing your job for thirty years and that's [what's] missing.

When asked what he would take from his experience with the curriculum, a senior majoring in Civil Engineering discussed the need for businesses to constantly adapt to a changing environment: "We have to change and that companies that are not willing to change … eventually will die. Because everyone has to change, you always have to be willing to change."

In discussing the need for our nation to reclaim its passion for innovation, the Center's Innovation Engineer observed the need for a change in educational and societal norms; a willingness to try new things and to embrace change:

> When you talk about culture change … it's not something you can just do in education, but it's the best chance at trying. … So you need to do it here, you need to do it at every university, you need to do it in every K through 12 in the country, and then you've got to do it in our businesses. Only then will you reap all of the benefits.
>
> When Deming showed up in Japan, they said, "We are broken, we are willing to change." They were willing to throw everything out …and to start over. That's a big reset. This is our best chance … as a country, to hit the big reset, because we felt like this two hundred years ago. We built this country from scratch.

In his depiction of the need for education and society to foster creativity and embrace new ideas, the first senior English major said it this way: "As a culture … we are not pushing the boundaries anymore." He went on to describe the Innovation Engineering program as being a catalyst for "creating that hunger … and drive to be different, to think different[ly]."

Empowerment

Through their experiences the participants shared that the curriculum of the Innovation Engineering program does not appeal to everyone and that its concepts can challenge educational and organizational resistance to change and trying new ideas. Nevertheless, participants who embrace the methods taught in the program find it a source of empowerment and creative strength.

Economic Justice. The faculty participants saw the curriculum as a form of "economic justice", of "empowering the little guy." The Director of Academic Programs in Innovation Engineering put it this way: "In the State of Maine we have a lot of economic disparity … so Maine is a major laboratory for this [curriculum]. The idea that students … at earlier stages could make something happen with Innovation Engineering, in my mind it's about economic justice." The professor of English who teaches for the program spoke of it as "cultural power," that he describes as more regularly instilled in the elite universities rather than in the public university system. Noting that cultural power should be a core value of all education, he stated, "I think that if that feeling of enablement and empowerment is good enough for the rich, it should be good enough for the rest of us." In describing the empowerment aspect of the curriculum, the Foster Center's Innovation Engineer asserted, "So in a lot of ways it's a revolution of empowering the little guy. I know that is way out there, but in a lot of ways it's what it is. You're giving everybody the same tools to play with on the same playing field."

Finding Your Voice. For many of the student and faculty participants, the curriculum provides a sense of empowerment in what they do. Some student participants described this in terms of having a "voice in the classroom" in the sense that they are contributing something, while some others articulated it as the simple knowledge that there is "no single right answer." When asked how the courses in Innovation Engineering differed from other courses she took, a junior Mass Communications major said, "I feel like I have more of a voice in this class. In other classes … your ideas are[n't] going to be put forth and used." She went on to describe an experience where a local company benefitted from class contributions:

> We did a couple of projects where our ideas are actually considered by a company and I know they are [using those ideas] now. That … makes you feel good because it's a class, but you're also contributing something to society. It feels good.

The Innovation Engineering Outreach Coordinator for the program defines the opportunity to address problems presented by real-world companies as a source of the empowerment and freedom expressed by the students:

> We say … here's the problem, here's the company … we need your ideas, what do you think is best. So as they are generating ideas, it's up to them to explain why they are really passionate about it and why it's an idea worth pursuing. Because if they can't explain why … [no one] will choose that idea. So … they feel a lot of ownership over it and they are really excited to present. I think that there is freedom in that respect.

Being able to admit what you do not know and to ask for help was also put forth as a form of empowerment by the junior in Mechanical Engineering Technology: "One of my biggest fears in the past has been to admit that I didn't know. But to realize that when you admit that you don't know and you do ask for help, that's power."

The experience of the participants also converged around the liberation connected with having "no single right answer" in how the curriculum is taught. Student participants described this as "no one is ever going to say you are wrong" and "it's an exhilarating feeling … knowing that there's not a [single] right answer."

The senior Civil Engineering major said it this way: "In other classes, you have to get to the right answer and there's one right answer. It's the professor's way or no way. In Innovation [Engineering], it's more of the student's way and the professor is giving you the ability to do it." The first senior English major described the feeling of empowerment as follows: "I feel like here I am much more in control of what I am learning."

An Accelerant for Any Major. While a couple of students said they wished they could major in Innovation Engineering, several of the other student participants and all three of the faculty found that the fact that the curriculum is offered as only a minor, and not as a major, was an important component of the curriculum's design. One student, a junior Electrical Engineering major minoring in both Music and Innovation Engineering, said, "It's meant to be an accelerant. … It's meant to drive your passion." The graduate of the university with a bachelor's degree in Political Science and a minor in Innovation Engineering described the curriculum as designed to "empower you in what you want to do." A senior Civil Engineering major pursuing a minor in both Math and Innovation Engineering expressed it this way:

> I would describe it as a way to supplement your major, a way to bring new ideas to what is currently being done and to make you think differently. Because your major is really to get you to think one way, but Innovation [Engineering] really makes you think laterally … about everything and outside of the box.

The Foster Center's Engineering Innovation Outreach Coordinator, who also teaches and coaches students in the program, stated:

> We are really teaching you how to create ideas and how to make them real, because it doesn't matter what you are going to do or where you are going to … work, you are going to have ideas and there are going to be certain things that you are passionate about that you want to work on. So you need to understand how to generate those ideas and convince your boss or convince your peers that it's something worth pursuing, and then how to make it real.

Creative Strength. Creative strength as a source of confidence-building leading to a feeling of empowerment was expressed by several of the faculty and student participants. The professor of English put it in the context of liberal education:

> I think liberal education in the American context is Emersonian, which means building a sense of cultural and personal self-reliance. What Innovation Engineering does is [provide] a mode of empowerment. And I think it does that practical thing that the liberal education does; it gives one a sense of creative strength in oneself.
>
> I also think the students coming out of 180 [Create] are beginning to feel they have a future. They may not know what it is, but they feel they have one.

Expanding on this theme, the Innovation Engineering Outreach Coordinator, who teaches for the program, described the Innovation Engineering curriculum as being "helpful because it allows the students to find something they are passionate about and pursue it." She went on to say:

> Being able to go into any organization and say, I am going to make my path, doing what I want whilst still serving the best interest of whatever company or non-profit organization that I'm working for. So that they are getting the best work and I am getting to wake up and go to work happy every day. I think that is a huge takeaway.

The student participants also verbalized this theme of creative strength contributing to one's happiness in work. "I believe that this minor will let me have a job that I love," articulated the senior majoring in Business Management and Finance. The junior in Electrical Engineering put it this way:

> The Blackstone internship [in Innovation Engineering], that was huge. It was my first chance to really … be able to work for a company where it was all on me and I kind of stepped into the leadership role and got to implement the kind of stuff that I have learned, got to help people.
>
> It was a real eye opener, because I had a job before working for BMW and it was one of those dream jobs that make a lot of money, but I didn't always love … what I was doing. [Whereas, this internship] was a chance to be creative, work for people who want you there, and do something that matters. I'll take that with me. The skills to be able to do that so you don't have to get stuck in those dead end jobs.

Conclusions from the Findings

In this chapter, through the interview dialogue with students and faculty members and the responses of the students who completed the Creativity and Confidence Survey, study participants shared their experiences of the Innovation Engineering curriculum. In particular, participants revealed their perceptions of how the program enhanced their ability to think creatively and innovatively. Following are the conclusions or major findings of the study.

Engineering a Process for Innovation

As the experiences of the students suggest, the curriculum imparts a different way of thinking, a process or system for innovating taught through applied learning. An important part of this process is enabling students to think expansively without boundaries. This can occur through a system of stimulating ideas with tools and techniques that advance associative thinking. Participants who experience the curriculum learn that ideas that address problems or create opportunities in ways that are unique can lead to desirable innovations, because such ideas both provide a meaningful opportunity or solution and do so in a way that has not been thought of before.

Fail Fast, Fail Cheap Design Cycles

Through their experiences, the participants shared that determining whether an idea can result in a workable innovation depends on identifying the issues to overcome to make the idea viable and then running design cycles to break down and resolve those issues. The student and faculty participants relate that controlled experimentation helps to dissolve financial and other risks associated with innovation, requiring a certain level of strategic risks be taken by the innovator. For this reason, helping students to overcome their fear of failure and to learn from their mistakes is a critical part of the curriculum.

Constructivist Learning Environment

Through their experiences, the participants conveyed that an effective method for teaching creativity and innovation is with a constructivist learning environment, in which students are required to employ cognitive processes and to participate actively in the construction of new knowledge by integrating new information with prior learning and experience. The student participants describe an interactive learning community where teachers and students form a mentor and apprentice relationship and in which students engage in focused facilitated learning aided by their peers. Students also shared that the use of pedagogic methods such as problem-based learning, hands-on learning, peer learning and formative assessment contribute to the constructivist learning environment and provide students with a sense of real-world mastery and confidence in what they have learned.

Learning to be Agile

However, different ways of learning and thinking can challenge institutional and societal norms. One of the experiences students encounter in this curriculum is that the mode of instruction is different from their other educational experiences. Likewise the system for innovation taught, when employed in the real world, can test organizational inhibitions. Nevertheless, participants who embrace the methods taught in the program find it a source of empowerment and creative strength.

CHAPTER 5: ANALYSIS OF THE FINDINGS

Drawing from the research findings in *Chapter 4* and the literature in *Chapter 2*, this chapter presents an analysis of the key findings derived from the study. This analysis is in three parts. The first part addresses what students consider the key benefits of the program, what they will take with them from the experience. The second part addresses what others in academia can learn from the research in this study and what kind of pedagogical approaches are necessary for faculty to successfully implement this kind of program. Finally, the third part addresses the challenges involved in advancing a curriculum for creativity and innovation that employs unconventional pedagogies.

The Tools to Make the Hammer: What Students Take From the Experience

One thing that the findings clearly demonstrate is that the experience of the Innovation Engineering program had a profound effect on the students who participated. The Innovation Engineering curriculum provides students with a complete system for solving problems and creating opportunities, from generating the idea and testing it out to effectively communicating the innovation to the intended beneficiary. The curricular outcome envisioned by the Innovation Engineering program is for students to gain the confidence to lead positive change in their respective fields of expertise. The senior Mechanical Engineering major described the program, "The first three courses [Create, Communicate and Commercialize] really break down the whole … pipeline of innovation engineering.

It's almost like a conveyor belt of tools that they teach you to create *Meaningfully Unique* ideas." Evidence explored through the literature supports that there are ways to instruct students in how to be creative and how to innovate (Berglund & Wennberg, 2006; Bruton, 2011; Tsui, 2002).

The Electrical Engineering major aptly described the curriculum, "I would say that these classes, it's not like learning [in the traditional sense]. It's not like giving someone a hammer. It's giving someone the skills to make the hammer." Students felt empowered by their mastery of the tools and techniques taught in the curriculum and felt certain of their capacity to generate ideas in response to a problem. The university graduate in Political Science echoed the Electrical Engineering major, contrasting the difference between content-driven instruction and the curriculum of the Innovation Engineering program: "[I think] college is not there to teach you what … to learn; college is there to teach you how to learn." Mastering this system, applying it and then learning from mistakes instilled in the students a confidence in their ability to learn, to teach themselves, and to create their own opportunities in their careers and in life.

Working with real companies and nonprofit organizations, on everyday challenges, as well as working on the students' own innovations, engendered meaning in the coursework. Students felt a sense of contributing something to the world, which is not typically found in traditional course assignments. In giving the work meaning, the experience became tangible for students and enhanced the learning process. The research explored in the literature showed that activities that contribute to learning -- in particular, those activities that are closely associated with real-world experience and that simulate the successful adoption of an innovation or persistence in a start-up firm -- contribute relevance to the curriculum. These activities are action-oriented and have a focus on making the innovation or business opportunity palpable to the student and to others (Edelman, Manolova & Brush, 2008).

Finding meaning in their work after college was also important to the student participants. They strongly believed that this curriculum would provide them with the creativity and the tools to help them drive their passions, whether in English, Engineering or some other field, and would permit them to pursue their own path in life. The senior Civil Engineering major described the curriculum as, "a way to supplement your major, a way to bring new ideas to what is currently being done." One of the reasons students might feel confident and empowered is that they are more likely to develop generic metacognitive skills when engaged in problem-based learning [Hmelo-Silver, 2004]. Additionally, the research suggests that students exposed to non-lecture learning activities and real-life situations have a higher perception of their own development of capabilities such as critical thinking and problem-solving [Kember & Leung, 2005b].

In the *Create* class, students came to understand that the act of creating, coming up with ideas, is a process of associative thinking. Creative ideas that can lead to innovation are born from cognitive processes that combine the ability to make associations with behaviors such as observation, questioning, and risk-taking (Dyer, Gregerson & Christensen, 2011). The English professor who teaches for the program says the curriculum gives students "the tools that encourage [them] to pay attention to ideas that come up in their heads."

An important initial step in this process is enabling students to think expansively, to push boundaries. Research explored in the literature illustrates that stretching the mind by providing new input and experiences exercises the mind and opens it to new concepts (Hall, 2001). The junior in Mass Communications explained what used to block her sense of creativity: "I always thought of creativity as something that just … comes from your mind and your mind alone." Noting that she since came to understand that it is okay to use associative thinking, building off of the ideas of other people, she stated, "My idea of creativity has kind of expanded as far as it doesn't necessarily have to just be somehow developed in your own mind. You can use others' ideas as stimulus."

Students also learned that stimulus is the accelerant for generating ideas and that there are ways to augment available stimulus and push the boundaries of your own thinking abilities so you never feel stuck (Hall, 2001). The ideas taught in the curriculum are basically techniques for brainstorming, techniques that assist in stimulating cognitive processes to make associations that might not otherwise occur and in generating ideas. The graduate of the university who majored in Political

Science discussed the role of the instructor and coaches in the classroom in working with students to master the tools, stating that:

> [The] coach really has to get them to the point of using [the tool] effectively, that's something the tools don't do automatically. But it's … empowering because you know it reinforces that this is a system for humans, you know this is just not a system you can let go and it's just automated. We need… human brains to operate it.

In describing his experience of learning to generate ideas, the junior majoring in Mechanical Engineering examined his propensity to search for the single true idea as opposed to just brainstorming, which led him to kill a thought before it had a chance: "I'd just shoot them down. … I'm a very analytical person, so [I'd] think of an idea and [I'd] go, that's not possible." He went on to say, "I feel fluent in creating now. Once you get the hang of it and you just buy into the process and don't try to resist it, just go with it, you can really create. Bring out idea after idea after idea very quick[ly]."

Students found mind mapping to be the most beneficial of the brainstorming tools, perhaps because a mind map readily demonstrates the associations between the ideas, leaving a trail of the creative process. "The simple mind map can draw together ideas that you would never correlate," said the junior Business major with a minor in Pre-Law. Other tools used by the students to brainstorm included: stimulus mining, searching websites and magazines to stimulate ideas; a product improvement check list (PICL), a list of adjectives to apply to a concept to generate a new take on an idea; and free writing, a stream of consciousness exercise following exposure to stimulus.

In the *Commercialize* course, students learned how to test the viability of their idea for an innovation by running little experiments or learning cycles to break down and resolve problems. The Foster Center's Innovation Engineer described the process: "If you break it down into small enough pieces, there'd be no risk left. So if you look at the *Death Threats* [to an idea], you break down the threats into manageable bites and then you can move that forward quite rapidly." Research explored in the literature supports creative, action-oriented approaches to innovation, which involves risk-taking, or learning by doing, and which include the activities of experimentation as well as of problem-solving and discovery (Collins, Smith & Hannon, 2006; Noyes & Brush, 2011). Research also shows that experimentation of this sort is the best method for ascertaining the viability of a possible solution and for producing information on what might work in the future (Dyer, Gregerson & Christensen, 2011).

Part of this process is identifying the issues to overcome, then tackling those issues that represent the greatest threat first. In this way, students learned to reduce the risk associated with experimentation. The junior in Mechanical Engineering Technology put it this way: "*Fail Fast, Fail Cheap* allows you to take small steps without being totally committed to something to manage risk. … It's just a way to do little cycles of learning and small tests that can help you figure out …

how big of a risk is this really. … Is this manageable or is this something that is going … to flatten us." The research discussed in the literature supports the notion that limited experimentation requiring small investments that represent affordable losses allows for risk to be managed effectively (Noyes & Brush, 2011).

One of the biggest challenges students face in the curriculum is overcoming their own fears -- fear of being judged by others and fear of failure. To aid this process, the curriculum calls for creating a safe environment in which students feel free to let their ideas go. The junior in Mechanical Engineering Technology describes one of the major ground rules of the curriculum: "You're encouraged to take the restraints off. You're in a safe place in the sense that … nobody criticizes you. In fact, that's one of the rules of the class. We don't tell people … 'no, it's not a good idea.'" Another of the ground rules is to learn from your mistakes. The senior majoring in Mechanical Engineering put it this way: "One of the things in Innovation Engineering that [they] push on you is that failure is a great way to learn." The junior Mechanical Engineering Technology major described the third key ground rule of the curriculum: "You need to know how to say 'I don't know' and you need to know how to ask for help. I think that addresses fear in a huge way."

Through immediate feedback from the faculty and through their own reflection on what they did wrong, students came to learn from their mistakes and to embrace failure as a learning opportunity. Research shows that competent innovators have the capability to reflect upon their experience and to improve even failures with experimentation (Collins, Smith & Hannon, 2006). When grounded in self-reflection, failure facilitates learning and resilience (Cope, 2011). Through reflection, innovators develop a longer-term perspective that leads to improvement over time (Man, 2006). Students embraced learning and using the tools for creativity and experimentation in an environment that was free of judgment and free from the fear of failure.

Assessment and reflection also emerged as important components of experimentation. Students learned that the analysis and consideration of why something didn't work often leads to a new idea of something to try. In the early stages of learning to experiment, immediate assessment of student work and built-in opportunities for student reflection were important to help students understand how failure is a learning opportunity. The Director of Academic Programs in Innovation Engineering described it as follows: "Failing is a path to learning if you stop, reflect and get why the first experiment didn't quite get there. … It is very hard to get people to really believe that failure is good. You really can't convince people that that's the truth, if you don't give them immediate feedback. … Assessment is proof." Research discussed in the literature shows that pedagogical strategies that employ formative assessment, or multiple interactive and iterative cycles of learning, assessment, feedback and reflection, aid in the development of cognitive abilities that enhance a student's capacity to assess his or her own judgment and to improve learning outcomes (Asghar, 2012; Clark, 2012; Crossouard & Pryor, 2012).

Through the curriculum, students learned to identify solutions that were meaningful and unique, in that the idea solves the problem better and more efficiently than other means. Without novelty, a product or service cannot rise above other possible choices and, thus, result in a true innovation (Polk, 2009). The Foster Center's Innovation Engineer described the element of *Meaningfully Unique* as follows: "It's meaningful to somebody. It solves the problem for somebody … and it's unique because it does it in a way that nobody has done before."

In the *Communicate* class, students learned ways to convey their ideas effectively to others. This process requires a keen understanding of who the beneficiary or customer is, what problem the innovation is intended to solve, what benefit is promised by the innovation, and what proof will be offered that the innovation works. Describing how the *Communicate* class helped him with his writing skills, the senior Civil Engineering major said, "The writing class has helped me a lot where I'm doing capstone proposals … where I don't know how to start, [it's helped] with who you're writing to, what you're writing about and solving the problem, and really keeping it focused and centered."

Students Have a Part in the Play: What the Academy can Learn

A constructivist learning environment is an effective method for teaching the components of creativity and innovation. Kumar and Kogut (2006) relate in their research findings how the responsibility for learning shifts from teacher to student in a constructivist learning environment, requiring students to employ cognitive processes and to participate actively in the construction of new knowledge, thus integrating new information with prior learning. The senior majoring in Mechanical Engineering depicted the program's classroom environment as enabling student contributions: "In the Engineering lectures and in the Liberal Arts lectures … you're a spectator to the presentation of the content, so you're watching the play if you will. Whereas in Innovation Engineering, you might be a part of the play … and actually contribute a great deal to the content of the play." The research explored in the literature supports that constructivist approaches foster capabilities such as critical thinking, adaptability, problem-solving, communication and interpersonal skills (Kember & Leung, 2005a).

Students responded positively to the pedagogies used to create an interactive learning community. Within the community, teachers and students formed a mentor and apprentice relationship and students benefitted from focused facilitated knowledge construction aided by the faculty and by their peers. The junior Business Management major described it like this: "Here I felt like we were all a group of people trying to learn and work together. [Here] you are an interactive member of the learning community." Tsui (2002) found that students are more apt to grasp and learn new information when they participate in dialogue with others, permitting them to process, rather than just record, information. In contrast, passive forms of learning, in which students receive information transferred to them by the teacher, do not afford students an opportunity to develop the capacity to engage in the critical thinking needed for innovation (Michel, Cater & Varela, 2009).

One of the pedagogies used in the program is problem-based learning. The benefit of engaging in problem-based learning to explore actual or simulated real-world situations for which there is no single right answer is that it allows students to hone their creativity, critical thinking, and problem-solving skills in ways that make the experience real to them. In this form of instruction, the teacher acts as facilitator rather than as the source of knowledge, modeling good thinking and learning strategies, while students become engaged in self-directed learning (Dochy, Segers, Van den Bossche & Struyven, 2005; Downing, Kwong, Chan, Lam & Downing, 2009; Hmelo-Silver, 2004). The goal of problem-based learning is not to attain the correct answer, but is, instead, to emphasize the learning process itself (Nordstrom & Korpelainen, 2011). Through the use of real world intelligence, students learn how to adapt to the unexpected and how to shape their interactions with the environment (Tan, 2007).

Problem-based learning was also reinforced in the *Commercialize* curriculum, in which students learn to turn their own idea into a prototype, test whether or not it works, and address design flaws while minimizing financial and other risks involved in the innovation process. Students found value in the self-regulated learning environment and in the construction of new knowledge (Dochy, Segers, Van den Bossche & Struyven, 2005; Kumar & Kogut, 2006). The junior Business major with a minor in Pre-Law described the effect:

> The approach to solving a problem like this, is you take the step back from the third party perspective and you look at all the aspects. You are trying all

> these things … and you are realizing that this process is pretty similar to, if you were … in the boardroom at a company and they are … looking to innovate on a specific product.

Through the use of problem-based learning students employ meta-knowledge -- knowledge discovered through meaning construction, reflection, assessment and comparison -- to arrive at a particular decision (Karakas, 2011; Saiz & Rivas, 2011). Learning activities such as these, which are closely associated with real-world challenges contribute to knowledge construction (Edelman, Manolova & Brush, 2008).

Students also benefitted from the use of the pedagogy for applied learning known as hands-on learning. Hands-on learning helped students to master skills and to build their confidence with the tools taught in the curriculum. The junior Business Management major said, "If … I am physically doing something I will learn it a lot better. And, if I know how it's applicable and … why I am using this, I will learn it a lot better." The literature suggests that learning is absorbed more deeply when students are given the opportunity to discover concepts rather than having to simply receive knowledge through formal instruction (Nordstrom & Korpelainen, 2011). The junior Mass Communications major contrasted hands-on learning with traditional instruction, "Especially with gen eds, a lot of what I learned … my freshman year I don't remember any of it. I don't see how I would … apply it to anything in life or would have any way of remembering [it]. But I know with Innovation [Engineering] … the skills that I've learned have stuck with me."

Collective learning by the students and their peers was also a critical component of the pedagogy in teaching creativity and innovation. Students learned to appreciate the different perspectives within the group and how that diversity enhanced the group's ability to generate ideas and to identify solutions to a problem. Evidence discussed in the literature shows that cognitive processes are enhanced through the leveraging of the diverse thinking that occurs in groups, resulting in more profound learning (Fletcher, 2011; Karakas, 2011). Collaboration with other students stimulates the processes of cognitive thinking that result in the construction of new knowledge (Nordstron & Korpelainen, 2011). Emphasizing the advantages offered by different thinking styles of group members, the Foster Center's Innovation Engineering Outreach Coordinator noted that, "Group work is a big part of it…and it's really important because … everybody has a different way that they learn and they think, so having a group of four people chances are you are going to get four different approaches to something." Researchers have found that joining individuals of varying disciplines and experiences results in a combining of creative strengths or a collision of different approaches resulting in creative abrasion, a process by which individuals learn from the diverse contributions of each other (Leonard & Strauss, 1997).

Students benefitted from the opportunity to exercise interpersonal skills in collaboration and teamwork and to learn from those experiences. The junior Business major with a minor in Pre-Law said, "Whether you are in construction, whether you are in business, whether you are in law, whether you are an engineer, you are never working alone. This program is effective to that end … it lets you … bounce ideas off … people just [as] you would in a real application." The research discussed in the literature supports that through group work, learning becomes a social act involving discussion, negotiation, interpretation and shared understanding that serve to enhance learning (Kumar & Kogut, 2006).

The addition of formative assessment in a flipped classroom to the pedagogies used to teach the curriculum improved learning outcomes. By putting the content online as a brief video or slide set to be viewed by the students prior to class, the new format opened up the class time for iterative cycles of learning in which the student was coached through the assignment. "You are getting instant feedback," said the junior majoring in Business with a minor in Pre-Law. "That's really the most important aspect of this process that I feel is hugely effective." Researchers have demonstrated that through pedagogies like formative assessment, the process of metacognition is aided when information is first absorbed and processed before it is employed (Downing, Kwong, Chan, Lam & Downing, 2009).

Through formative assessment, students explored multiple cycles of learning with immediate feedback from faculty, providing them with a greater opportunity to master the material. The senior Civil Engineering major who is helping to coach the new flipped classroom relates his experience:

> Instead of teaching, we're coaching the students, so it gives a much … greater ability for them to master the material. … [When] they come to class and they're doing their assignments and we can be there next to them and see

> what they're doing. If they're going down the wrong track, we can push them more towards the right one.

Research explored in the literature shows that pedagogical strategies that employ formative assessment, or iterative cycles of learning through assessment, feedback and reflection, aid in the development of cognitive abilities that enhance learning (Asghar, 2012; Clark, 2012; Croussouard & Pryor, 2012).

The rich experiences of the students with the curriculum of the Innovation Engineering program, and the pedagogy by which it is taught, raise real questions for faculty and institutions of higher education about the relative effectiveness of traditional methods of instruction. What the synthesized experiences of the students clearly demonstrate is that the constructivist learning environment enriches learning in students. The constructivist learning environment, combined with pedagogic methods for problem-based learning, hands-on learning, collective learning and formative assessment, also serves to develop the real-world skills needed for success in career and in life.

While the pedagogy used in a constructivist learning environment involves real risks for some faculty to come out from behind the safety of the podium and the prepared lecture, the benefit to students of genuine engagement with faculty and peers in the learning process cannot be ignored. Likewise, the use of messy ill-structured real-world problems with no single right answer may challenge the risk tolerance of some faculty, but the pedagogy's track record for engendering critical thinking and problem-solving skills in students is well documented in the research explored by the literature. While the curriculum's focus is on the teaching of creativity and innovation, the pedagogic methods used in the program also serve to develop the very skills employers say are needed for success in the workplace: communication, collaboration and teamwork, critical thinking and problem-solving, and creativity and innovation (Hodge & Lear, 2011).

Teaching and Learning Outside the Box: The Challenges Faced

One of the experiences students encountered in the curriculum was that the inclusion of creativity in the curriculum and the mode of instruction were different from their other educational experiences. The first senior English major with a minor in Innovation Engineering said that coming out of high school, he didn't think creativity was his strong suit: "It has more to do with the fact that I was so unprepared beforehand … in the creative aspect. I want to say the culture … I was never prepared to be creative in school." Regardless of their preparation in high school, the student participants embraced these differences. The senior Civil Engineering major said it this way, "In other classes, you have to get to the right answer and there's one right answer. It's the professor's way or no way. In Innovation [Engineering], it's more of the student's way and the professor is giving you the ability to do it."

Students benefitted from the tools they learned to generate ideas, the techniques for communicating effectively, and the use of iterative learning cycles to improve upon ideas. They applied these newly acquired skills to other coursework in their disciplines and in their own lives. The junior in Mass Communications said:

> It could be applied to any aspect in your life, where you could use it every day. [Innovation Engineering] is something that could help them not only with their major, but also help them expand on it and I think that is one thing we all take away … just the fact that we have that application and experience and it applies to our life, so it's important to us.

Students also preferred the constructivist learning environment and the pedagogies employed to teach the curriculum over traditional methods like lectures and exams. The senior Business Management and Finance major portrayed the pedagogy in ths way: "Innovation Engineering is a lot more hands-on. Here I really feel like I'm actually learning something. …[It] is asking me to think … asking me to do something, instead of absorb something, and I find that very valuable … because for me I really learn hands-on. … I learn reflectively."

However, it is important to note that not all students experience the curriculum in the same way. Although they represent the exception, some students resist the concepts taught in the curriculum and the pedagogy by which they are taught. These students find both the curriculum and the pedagogy too foreign to their experience of traditional educational delivery in which the teacher conveys the content through a formal lecture and through which there is often no room for more than one right answer. The Innovation Engineer at the Foster Center admitted this happens sometimes with students: "You have students that sometimes just don't get it. … There are some students it's just too abstract a concept for them. It's too far right brain for them to comprehend because they're in this box and they can be in that box forever." Research explored in the literature supports that some students feel uneasy in a nontraditional learning environment. Students used to traditional lecture-style instruction can find the student-centered learning environment uncomfortable, while the role of the teacher as facilitator can cause some students to believe the teacher is not contributing to their learning (Dochy, Segers, Van denBossche & Struyven, 2005; Kumar & Kogut, 2006). Additionally, the literature offers evidence that group conflicts, weak facilitation, poorly constructed problems and perceived subjectivity of learning assessment can also detract from student experience in problem-based learning (Kumar & Kogut, 2006). The one student with the unhappy experience who responded to the mid-semester survey in the *INV392 Innovation Engineering III: Commercialize* course reinforced this. Responding to a question about the contributions of the learning environment to creativity, he said, "[The] environment kept changing from day to day. Each teacher graded an assignment differently and it's nearly impossible to know what I'm asked to do, when five teachers are giving me different requirements for the same assignments, it confused me."

One of the people involved with the start-up of the Innovation Engineering program shared some of the challenges that arose and that persist with introducing an unconventional curriculum delivered through an unconventional pedagogy: "I have been grubbing away since 2005 and … trying to work my way around the kind of Byzantine aspects of 'If you don't report to a dean, how do you get courses approved and into the catalog?'" The individual went on to describe the prejudice some faculty colleagues directed at the program, "I felt embattled … There are too many people who don't understand and who think that this [program] is sucking away their resources or … not rigorous [enough academically] … and there is also suspicion that faculty governance was not entirely in play."

However, the individual went on to describe some bright spots for the future of the program: "With every [Innovation Engineering] Leadership Institute the door opens a little wider and a few more people walk through … or [maybe] their company may have done an extended [Innovation Engineering] Jumpstart coaching program. … We [also] had the first round of Blackstone funded internships … for small companies. So … [the program] is beginning to be well-known, at least in the State of Maine, [and] we have this culture beginning to grow around it."

CHAPTER 6: CONCLUSIONS

One of the benefits for students of the Innovation Engineering program is the faculty collaboration on the development of the curriculum to create a seamless continuum of the educational experience. Each of the core courses in the curriculum build on the concepts introduced in the prior course, reinforcing for students their prior learning and then introducing new concepts upon which to construct knowledge. Through the use of consistent pedagogies and the connection of the key concepts for creativity and innovation throughout the core courses in the minor, students are supported in developing their knowledge and in improving their confidence in the mastery of the skills over a period of time.

Another significant benefit of the program for students is the awakening of their desire to learn. Through their own words, students related the simple joy they experienced when they discovered their passion for learning. This passion is ignited when teaching involves active student engagement, is infused with best practices that facilitate empowered learning, and is open to student creativity and innovative thinking.

What seems clear from the student experience is that the Innovation Engineering curriculum is effective in imparting the knowledge and skills to practice the continuum of the process of innovation. Further, mastery of the skills engenders a sense of empowerment and creative strength in the participants. Also evident is that the constructivist learning environment and the pedagogies employed in teaching the program, including hands-on and collective learning, critical thinking and problem-based learning, and the use of formative assessment, contribute to this feeling of confidence in the mastery of the skills and result in deep learning by the students.

More than a quarter of a century ago, Chickering and Gamson (1987) published their findings based on fifty years of research on teaching and learning in college settings. The *Seven Principles for Good Practice in Undergraduate Education* outlines these best practices as a guide for faculty, administrators, and students. These best practices are infused in the constructivist learning environment and pedagogies employed to teach the curriculum of the Innovation Engineering program:

1. Encourages contact between students and faculty;
2. Develops reciprocity and cooperation among students;
3. Encourages active learning;
4. Gives prompt feedback;
5. Emphasizes time on task;
6. Communicates high expectations; and
7. Respects diverse talents and ways of learning (Chickering & Gamson 1987).

What is new and different about the Innovation Engineering program is the introduction of an emerging eighth best practice: *Encourages creativity and innovative thinking*. A recent article that appeared in *The Chronicle of Higher Education* highlighted this trend at universities and colleges across the country. The article noted that, "Today's student will need [creativity] to tackle the problems they stand to inherit. … Knowledge will need to be combined across disciplines, and juxtaposed in unorthodox ways (Barrett, 2013)."

The need for the integration of creativity and innovative thinking into the undergraduate curriculum is supported by the demands of the evolving modern economy, as described in *Chapter 2*. The modern economy is "geared towards creating new needs, including illusory needs" … as opposed to "the pre-modern economies that were geared towards satisfying basic needs" (Ghassib, 2010). Further, in the modern economy, individuals with "right brain" qualities -- those who are artistic, empathic and able to understand synthesis and context -- will be in high demand while the work of those individuals with "left brain" qualities -- those who are logical, linear, sequential and analytical -- will be automated by technology or off-shored to less expensive labor overseas (Hodge & Lear, 2011; Ahy, 2009).

The introduction of creativity and innovative thinking into the undergraduate curricula, through programs such as Innovation Engineering, responds to the increasing demand for the relevance of higher education to the complexities encountered in a rapidly changing world. Today's college graduates will be called upon to find solutions to the problems confronted in work, in society and in life. They will need the imagination to draw unique connections between the contributions of various disciplines in order to discover new ideas of how to address these problems. They will also need the confidence to test out and refine these ideas through trial and error, assessment, and reflection in order to achieve a solution.

Today's college graduates need to be "innovation ready" in a society where "what you know matters far less than what you can do with what you know" (Friedman, 2013; Wagner, 2012).

Through the synthesis of the experience with the curriculum and the pedagogy of the Innovation Engineering program, students are empowered with creative capacity and an ability to innovate and are endowed with skills in communication, collaboration, critical thinking and problem-solving. These are abilities that will serve them in their careers and in life. In order to meet the workplace demands of the modern economy, faculty and universities would do well to examine and employ similar curricula and pedagogies to help ensure that students are prepared for the real-world challenges they will face.

Limitations of the Study and Opportunities for Future Research

This study focused on the Innovation Engineering program offered at the University of Maine and therefore represents only a single approach to the teaching of creativity and innovation in higher education. Further study, including comparisons between other programs that teach creativity and innovation, could expand understanding of the most effective curricula and pedagogy for imparting this knowledge and the skills needed for success in the modern economy. Additionally, as this was an exploratory study, it might prove interesting to follow these students in a longitudinal study to see how the learning from their experience with the curriculum holds up over time.

While this study focused on student and faculty perceptions of the shared experience of a curriculum designed to impart creativity and innovative thinking, future research might benefit from more objective forms of data collection. One suggestion is to utilize an assessment tool for measuring improvement in creativity as the result of curricular interventions. Perhaps the best-known tool is the Torrance Test of Creative Thinking, which measures divergent thinking and other problem-solving skills as well as resistance to premature closure. This tool was first developed in the 1960s and has been updated several times (Torrance Center for Creativity & Talent Development, n.d.). Another more recent tool is the Next Generation Creativity Survey, an assessment tool that utilizes self-reporting, as well as ratings of original student work, to assess creativity (Centers for Research on Creativity, n.d.).

In this study, students talked about how valuable their experiences with the learning environment and the pedagogy were to their learning, but these methods are not exclusive to the learning of creativity and innovation. This raises questions about using a constructivist learning environment and the other employed pedagogical aspects in other parts of the university curricula across the disciplines. A better understanding of whether these pedagogies contribute to the enhancement of learning for any discipline merits further exploration.

Similarly, the literature on the evolving needs of the modern economy suggest that creativity and innovative thinking should not be confined to classes in creativity. Rather, creativity and innovative thinking should be integrated into the curricula across disciplines. A better understanding of whether *Encouraging creativity and innovative thinking* should emerge as an eighth principle for good practice in undergraduate education is deserving of attention.

The conclusions drawn from the synthesized description of the findings as experienced by the student and faculty participants in this study were substantially supported by the research in the literature with several notable exceptions. These exceptions provide an opportunity for further exploration in future research. First, the participants' perception of educational and organizational reticence to encouraging and trying new ideas was not fully supported in the literature. While the research included in the literature acknowledged that students used to traditional lecture-style instruction can find a student-centered learning environment uncomfortable, it did not adequately cover the inhibitions experienced by the participants. In the findings, the participants, through their own words, described this as a reluctance or averseness to change that is both institutional and societal, and noted a lack of preparation for creativity in conventional education and a loss of creative agility in business. Further exploration of the impact of institutional and societal norms on inhibiting creativity and innovation is warranted.

Second, the participants' sense of creative strength and empowerment was perhaps only partially explained by the literature. The research explored in the literature suggests that metacognitive skills are enhanced through problem-based learning and that students engaged in applied learning activities that use real-life situations have higher perceptions of their development in critical thinking and problem-solving. This research suggests the development of a sense of confidence in their own abilities for students engaged in problem-based learning, which supports the conclusion that participants feel a sense of creative strength and empowerment, but does not seem to adequately explain the fullness of their experience. Therefore, a better understanding of the participants' perception of their creative strength and empowerment is needed to fully understand the benefits of participating in the curriculum.

Finally, the finding that participants convey a sense of freedom in having no boundaries or restraints on their ideas and their experience that this sense of freedom is vital to allowing creativity to flourish is only partially addressed in the literature. That the mind can be expanded to accept new concepts through involvement in new experiences is supported in the research delineated in *Chapter 2*. However, the concept of freedom to express one's self as described by the participants and the environmental or pedagogical factors that contribute to this sense of having no boundaries is absent. Consequently, the participants' experience of removing the restraints on their thoughts and ideas and the factors that contributed to this phenomena would benefit from further understanding.

APPENDIX A: Student Interview Protocol

[The protocol was adjusted as appropriate for faculty participants]

Introduction.

1. How did you learn about the Innovation Engineering program and why did you decide to enroll in a course?
2. How would you describe the course experience to someone who was considering enrolling?
3. What do you believe you gained from the experience of the course that you will take with you and use again?

Techniques.

1. Discuss the basic tools and techniques employed in the course. Which techniques did you (students) find most/least useful in generating ideas and explain why?
2. Describe why you believe the tools helped you to generate ideas you would not have otherwise discovered?
3. Can you describe an occasion when you used one of the techniques to address a real life problem or opportunity?

Creativity.

1. How has your approach to creativity changed as a result of your work in the course?

2. Describe how would you go about generating ideas in response to a problem or opportunity?
3. How would go about communicating an idea to engender support for it?
4. What about your new approach is different than your previous approach?

Critical thinking and problem-solving.

1. How has your approach to problem-solving changed as a result of this course?
2. Can you describe a case study used in the course, or other circumstance, where you applied your new knowledge to generate solutions to a problem?
3. Describe and explain your comfort level with your ability to find a solution to a problem or to create an opportunity?
4. What process would you use for determining whether an idea can add value or not?
5. How has your thinking changed after taking this course?

Risk-taking and experimentation.

1. How did you view risk-taking prior to taking the course?
2. Explain the type of experimentation you engaged in as part of your coursework?
3. How did your view of risk-taking and experimentation evolve during the course?
4. Are you more or less likely to experiment with an idea after completing the course and explain why?
5. How has your view of failure evolved as a result of this experience?

Group work.

1. How did working in groups help/hinder your creativity, explain why?
2. How did working in groups help/hinder your desire to take risks and express your ideas, explain why?
3. How did the influence of group members impact your ideas?
4. Was your ability to create ideas stimulated more by others in the group who generally think like you and/or share similar backgrounds and experiences, or by those who think differently and/or have different backgrounds and experiences and explain why you believe that is the case?
5. Describe the most meaningful group project in which you engaged during the course?
6. If confronted with a real life problem or opportunity in the future, would you be inclined to assemble a group of people to help you address the issue and, if so, what qualities would you look for in the individuals you invite to join your group?

Pedagogy and learning environment.

1. Describe the classroom or learning environment for the course.
2. How did the learning environment contribute to your learning and/or creativity?
3. Describe the level of responsibility you believe you had for your own learning and how you believe this influenced your experience of this course.

APPENDIX B: Student Survey Protocol

Survey: Innovation Engineering INV_____

Your major: ___________________________________

Your year in school: FY SO JR SR

You are: Male or Female

At this point in the course, how confident are you in creating ideas in response to a problem or opportunity?

1 Not at all 2 Only a bit 3 Somewhat 4 Confident 5 Very confident

What aspect of this course has been the most/least useful for enhancing your creative ability?

When engaged in group work, how did the influence of group members impact your opinions?

How has your approach to problem-solving changed during your work in this course?

How has your view on risk-taking and experimentation evolved during your work in this course?

How did the learning environment for the course contribute to your creativity?

At this point in the course, how confident are you in your ability to communicate meaningfully unique ideas in response to a problem or opportunity?

1 Not at all 2 Only a bit 3 Somewhat 4 Confident 5 Very confident

Are there other comments you would like to add?

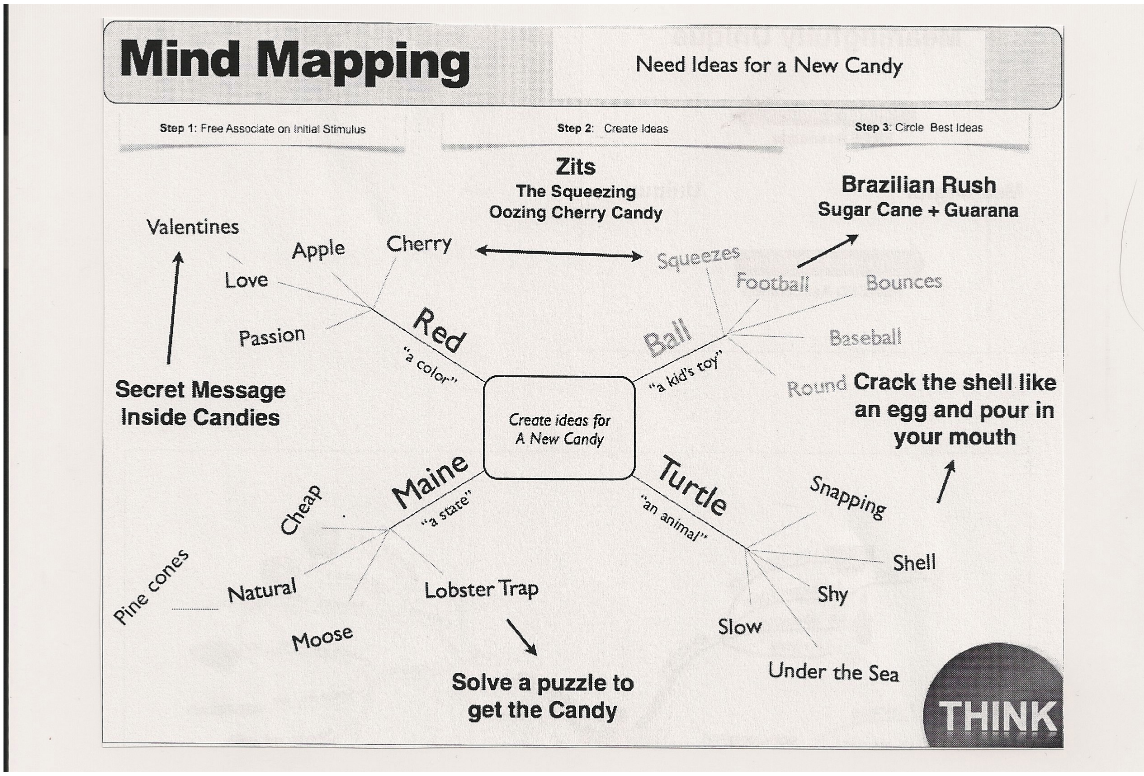
APPENDIX C: Matrix of Findings by Thematic Category and Sub-theme

Teaching Creativity and Innovation in Higher Education	
Thematic Categories & Sub-themes	**Findings Outline**
Engineering a Process for Innovation	
Applying a System for Solving Problems	A Process for Innovation ▪ A system for thinking differently
	Applied Learning ▪ Applying the system ▪ Applying the tools
Cultivating Creative Thinking	No Boundaries ▪ Let your ideas go
	A System for Creating Ideas ▪ Imagination Expansion
	Paying Attention to Stimulus: Associative Thinking ▪ Stimulus ▪ Associative Thinking
Tools & Techniques for Thinking Creatively	A Systematic Approach: A Common Language ▪ Influence of thinking preferences ▪ Practice and mastery of the tools
	Mind Mapping ▪ Definition of a mind map ▪ Favorite tool for creating ideas
Developing Meaningfully Unique Ideas	Ideas that are Meaningful and Unique ▪ Definition of the term
	Problem-Promise-Proof ▪ Description of the *Communicate* tool ▪ Communicating the benefit of the innovation: Understanding your audience
Fail Fast, Fail Cheap Design Cycles	
Design Cycle & Death Threats	Rapid Cycles of Learning ▪ Breaking down the problem ▪ Identifying what must be overcome
Conquering the Fear of Failure	Creating a Safe Environment ▪ Freedom from judgment ▪ Learning from failure ▪ Variation in everything ▪ It's okay to ask for help
Experimentation	Experimentation to dissolve risk ▪ Plan-Do-Study-Act ▪ Reflection and Assessment

Thematic Categories & Sub-themes	Findings Outline
Constructivist Learning Environment	
Interactive Learning Community	Mentor and Apprentice Relationship ▪ Student focused facilitated learning
	The Goal is To Learn ▪ Practice and Reflection
Critical Thinking & Problem-based Learning; Real-world Problems	Learning to Think Critically ▪ Pushing the boundaries
	Problem-based Learning ▪ Complex ill-structured problems with more than one solution
	Real-world Situations ▪ Independent study, internships, capstone & class projects
Hands-on Learning	Learning by Doing ▪ Application of the tools ▪ Assessment of the learning ▪ Doing something v. absorbing information ▪ Building confidence; Real-world mastery
Collective Learning	Group Work and Peer Learning ▪ Diversity of thought ▪ Interpersonal skill-building
	The Down-side of Group Work ▪ Conflict ▪ Not everyone does their part
Formative Assessment	Applying Learning Cycles in the Classroom ▪ Flipped classroom ▪ Rapid cycles of feedback
	Advantages of a Flipped Classroom ▪ Retention of information ▪ The goal is mastery

Thematic Categories & Sub-themes	Findings Outline
Learning to be Agile	
Educational and Organizational Reticence	Educational and Organizational Reticence ▪ No exposure to creativity ▪ Learning to be agile ▪ Willingness to change ▪ Pushing the boundaries
Not for Everyone	I Don't Get It ▪ Too abstract; too structured ▪ Resistance to change
Empowerment	Economic Justice ▪ Empowering the Little Guy
	Finding Your Voice ▪ Making a contribution ▪ No single right answer
	An Accelerant for Any Major ▪ The program offered only as a minor
	Creative Strength ▪ Building confidence ▪ Driving your passion

APPENDIX D: SAMPLE MIND MAP



Innovation Engineering Leadership Institute (2011, October).

References

Ahy, J. (Uploaded by). (2009). *A whole new mind with Daniel Pink*. Retrieved on March 17, 2013 from http://www.youtube.com/watch?v=pVFQ78HbJK0

Asghar, M. (2012). The lived experience of formative assessment practice in a British university. *Journal of Further and Higher Education*, 36(2), 205-223.

Association of American Colleges and Universities (2008). *How should colleges assess and improve student learning? Employers views on the accountability challenge*. Retrieved May 23, 2012 from http://www.aacu.org/leap/documents/2008_Business_Leader_Poll.pdf

Association of American Colleges and Universities (2010). *Raising the bar: Employers' views on college learning in the wake of the economic downturn*. Retrieved March 17, 2013 from http://www.aacu.org/leap/documents/2009_EmployerSurvey.pdf

Barrett, D. (2013, April 5). Creativity: A cure for the common curriculum. *The Chronicle of Higher Education*, p. A33.

Behar-Horenstein, L., Niu, L. (2011). Teaching critical thinking skills in higher education: A review of the literature*.* *Journal of College Teaching and Learning*, 8(2), 25-41.

Berglund, H., Wennberg, K. (2006). Creativity among entrepreneurship students: Comparing engineering and business education. *International Journal of Continuing Engineering Education and Lifelong Learning*, 16(5), 366–379.

Bruton, D. (2011). Learning creativity and design for innovation. *International Journal of Technology and Design Education*, 21(3), 321-333.

Centers for Research on Creativity. (n.d.) *The next generation creativity survey*. Retrieved on April 29, 2013 from www.croc-lab.org

Chickering, A. W., Gamson, Z. F. (1987). *Seven principles for good practice in undergraduate education*. Retrieved on April 29, 2013 from http://teaching.uncc.edu/sites/teaching.uncc.edu/files/media/files/file/InstructionalMethods/SevenPrinciples.pdf

Clark, I. (2012). Formative assessment: Assessment is for self-regulated learning. *Educational Psychology Review*, 24, 205-249.

Collins, L., Smith, A., Hannon, P. (2006). Discovering entrepreneurship: An exploration of a tripartite approach to developing entrepreneurial capacities. *Journal of European Industrial Training*, 30(3), 188-205.

Cope, J. (2011). Entrepreneurial learning from failure: An interpretive phenomenological analysis. *Journal of Business Venturing*, 26, 604-623.

Cresswell, J. (2007). *Qualitative inquiry & research design*. Thousand Oaks, CA: Sage Publications, Inc.

Crossouard, B., Pryor, J. (2012). How theory matters: Formative assessment theory and practices and their different relations to education. *Studies in Philosophy and Education*, 31, 251-263.

Dochy, F., Segers, M., Van den Bossche, P. and Struyven, K (2005). Students' perceptions of a problem-based learning environment. *Learning Environments Research*, 8, 41-66.

Downing, K., Kwong, T., Chan, S., Lam, T. and Downing, W. (2009). Problem-based learning and the development of metacognition. *Higher Education*, 57, 609-621.

Dyer, J., Gregerson, H., Christensen, C. (2011) *The innovator's DNA: Mastering the five skills of disruptive innovators*. Cambridge, MA: Harvard Business Review Press.

Edelman, L., Manolova, T., Brush, C. (2008). Entrepreneurship education: Correspondence between practices of nascent entrepreneurs and textbook prescriptions for success. *Academy of Management Learning & Education*, 7(1), 56-70.

Eickhoff, M. (2008). Entrepreneurial thinking and action: An educational responsibility for Europe. *European Journal of Vocational Training*, 45(3), 5-31.

Facione, P. A., Facione, N. C. (2007). Talking critical thinking. *Change*, 39(2), 38-44.

Fiet, J. (2000). The pedagogical side of entrepreneurship theory. *Journal of Business Venturing*, 16, 101-117.

Fiet, J., Patel, P. (2008). Entrepreneurial discovery as constrained, systematic search. *Small Business Economics*, 30, 215-229.

Fletcher, T. S. (2011). Creative thinking in schools: Finding the "Just Right" challenge for students. *Gifted Child Today*, 34(2), 37-42.

Foster Center for Student Innovation at the University of Maine (n.d.). *Innovation Engineering.* Retrieved on May 3, 2012 from: http://foster.target.maine.edu/

Friedman, T. L. (2013, March 30). Need a job? Invent it. *The New York Times*. Retrieved on April 6, 2013 from http://www.nytimes.com/2013/03/31/opinion/sunday/friedman-need-a-job-invent-it.html?_r=0

Ghassib, H. B. (2010). Where does creativity fit into a productivist industrial model of knowledge production? *Gifted and Talented International*, 25(1).

Gordon, D. (2011). Return to sender. *T.H.E. Journal*, 38(3), 30-32, 34-35.

Grbich, C. (2007). *Qualitative data analysis*. Thousand Oaks, CA: Sage Publications, Inc.

Hall, Doug (2001). *Jump start your business brain: Win more, lose less and make more money*. Cincinnati, OH: Brain Brew Books.

Hammonds, K. H. (2002). The strategy of the fighter pilot. *Fast Company*. Retrieved from: http://www.fastcompany.com/44983/strategy-figher-pilot

Hodge, K. A., Lear, J. L. (2011). Employment skills for 21st century workplace: The gap between faculty and student perceptions. *Journal of Career and Technical Education*, 26(2).

Hmelo-Silver, C. (2004). Problem-based learning: What and how do students learn? *Educational Psychology Review*, 16(3), 235-266.

Innovation Engineering Leadership Institute (2011, October). *The path to a profitable future: Confidence Building; Advanced Tools; Fundamentals* (conference workbooks). Cincinnati, OH: Eureka!Institute, Inc.

Karakas, F. (2011). Positive management education: Creating creative minds, passionate hearts, and kindred spirits. *Journal of Management Education*, 35(2) 198–226.

Keinan, G. (1987). Decision making under stress: Scanning of alternatives under controllable and uncontrollable threats. *Journal of Personality and Social Psychology*, 52(3), 639-644.

Kember, D., Leung, D. (2005a). The influence of the teaching and learning environment on the development of generic capabilities needed for a knowledge-based society. *Learning Environments Research*, 8, 245-266.

Kember, D., Leung, D. (2005b). The influence of active learning experiences on the development of graduate capabilities. *Studies in Higher Education*, 30(2), 155-170.

Knox, S., Burkard, A. (2009). Qualitative research interviews. *Psychotherapy Research*, 19(4-5).

Kolb, D. (1984). *Experiential learning: Experience as the source of learning and development*. Prentice-Hall, Inc., Englewood Cliffs, N.J. Retrieved from http://academic.regis.edu/ed205/Kolb.pdf

Kumar, M., Kogut, G. (2006). Students' perceptions of problem-based learning. *Teacher Development*, 10(1), 105-116.

Leonard, D., Straus, S. (1997). Putting your company's whole brain to work. *Harvard Business Review*, 75(4), 110-121.

le Roux, I., Pretorius, M., & Millard, S. (2006). The influence of risk perception, misconception, illusion of control and self-efficacy on the decision to exploit a venture opportunity. *Southern African Business Review*, 10(1), 51-69.

Man, T. (2006). Exploring the behavioral patterns of entrepreneurial learning: A competency approach. *Education and Training*, 48(5), 309-321.

Marshall, M. (1996). Sampling for qualitative research. *Family Practice*, 13(6), 522-525.

Mason, M. (2010). Sample size and saturation in Ph.D. studies using qualitative interviews. *Forum: Qualitative Social Research*, 11(3). Retrieved on May 30, 2011 from http://www.qualitative-research.net/index.php/fqs/article/view/1428/3027#g12

Maxwell, J. A. (1996). *Qualitative research design: An interactive approach*. Thousand Oaks, CA: Sage Publications, Inc.

Michel, N., Cater, J., Varela, O. (2009). Active versus passive teaching styles: An empirical study of student learning outcomes. *Small Business Institute National Proceedings*, 33(1), 55-67.

National Center on Education and the Economy (2006). *Tough choices or tough times: The report of the new commission on the skills of the American workforce -- Executive summary*. Retrieved on May 23, 2012 from http://www.otis.edu/creative economy/download/ToughChoices_EXECSUM.pdf

New Jersey Commission on Higher Education (2005). *Survey of New Jersey employers to assess the ability of higher education institutions to prepare students for employment*. Retrieved May 23, 2012 from http://www.nj.gov/highereducation/PDFs/CHEemployersurveyreport04 19 05.pdf

Nieuwenhuizen, C., Groenewald, D. (2006). Level of creativity and risk among successful entrepreneurs. *Southern African Business Review*, 10(1), 70-90.

Nordstrom, K., Korpelainen, P. (2011). Creativity and inspiration for problem solving in engineering education. *Teaching in Higher Education*, 16(4), 439-450.

Norton, W. I. Jr., Hale D. H. (2011). Protocols for teaching students how to search for, discover, and evaluate innovations. *Journal of Management Education*, 35(6) 808–835.

Noyes, E., Brush, C. (2011). Teaching entrepreneurial action: Application of creative logic. In Corbett, A. & Katz, J. (Eds.), *Entrepreneurial Action: Advances in Entrepreneurship, Firm Emergence and Growth,* pp TBD. In press.

Pappas, J., Pappas, E. (2003). *Creative thinking, creative problem-solving, and inventive design in the engineering curriculum: A review*. Presented at the 2003 American Society for Engineering Education Annual Conference & Exposition, Nashville, Tennessee.

Patton, M. (2002). *Qualitative research & evaluation methods* (3rd ed.). Thousand Oaks, CA: Sage Publications, Inc.

Perkins, D.N. (2002). Mindware and the metacurriculum. *Creating the Future: Perspectives on Educational Change*. Retrieved on March 9, 2013 from http://education.jhu.edu/PD/newhorizons/future/creating_the_future/crfut_perkins.cfm

Saiz, C., Rivas, S. (2011). Evaluation of the ARDESOS program: An initiative to improve critical thinking skills. *Journal of the Scholarship of Teaching and Learning*, 11(2), 34-51.

Shillace, B. (Winter/Spring 2012). Jumping the connection gap: Helping students build a bridge between major and career. *The CEA Forum*.

Sisk, D. A. (2010). Creativity an ultimate goal and challenge for education: A response to Ghassib's article. *Gifted and Talented International*, 25(1).

Struyven, K., Dochy, F., Janssens, S. (2008). Students' likes and dislikes regarding student-activating and lecture-based educational settings: Consequences for students' perceptions of the learning environment, student learning and performance. *European Journal of Psychology of Education*, 23(3), 295-317.

Tan, Oon-Seng (2007). Problem-based learning pedagogies: Psychological processes and enhancement of intelligences. *Education Research for Policy and Practice*, 6, 101-114.

The W. Edward Deming Institute. (n.d.). *The PDSA cycle*. Retrieved on June 15, 2013 from: https://www.deming.org/theman/theories/pdsacycle

Torrance Center for Creativity & Talent Development. (n.d.). *E. Paul Torrance*. Retrieved on April 29, 2013 from www.coe.uga.edu/torrance/.

Tsui, L. (2002). Fostering critical thinking through effective pedagogy: Evidence from four institutional case studies. *Journal of Higher Education*, 73(6), 740-763.

University of Maine System Board of Trustees (2008, February). Agenda item summary: Naming of the student innovation center.

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