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Faculty Perceptions of Online Learning in Engineering Education

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Faculty Perceptions of Online Learning in Engineering Education

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Dedication

I dedicate my dissertation work to my wonderful wife, Tanya, and my amazing children, Riggen and Charlotte. They have supported me through the all ups and downs, the crazy conversations, and the endless years I've been working on this. They didn't sign up for this hazardous duty, but they've supported me, encouraged me, and been there with loving words and a big hug when it was most needed. As it turns out, my children have never known a day of their lives that their father was not in school – so yes, daddy is finally done with his homework.

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Faculty Perceptions of Online Learning in Engineering Education

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Abstract: Research indicates there is a gap in the implementation of online courses and programs in engineering education compared to other academic disciplines (Allen & Seaman, 2008, 2011, 2013). Using a mixed methods approach, this study collected both quantitative survey and qualitative interview data to identify which factors engineering faculty members perceived influence the implementation of online engineering courses. The survey items, based on the Technology Acceptance Model (TAM) and Unified Theory of Acceptance and Use of Technology Model (UTAUT) (Davis, 1989; Venkatesh, Morris, Davis, & Davis, 2003), included important factors specific to engineering education as indicated the literature. The interview instrument was developed based on the significant results of the survey portion of the study. The initial survey was sent to every engineering faculty member at all 31 institutions and 125 ABET accredited engineering programs in the state of Texas, with a final response population of *n*=266. The findings identified three major factors that influenced the implementation of online engineering courses: online teaching experience, course development issues, and implementation of technical aspects particular to engineering in an online format. The results are discussed within the

context of the literature and recommendations to address the identified factors and barriers to implementation of online engineering are provided.

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CHAPTER 1: INTRODUCTION

The implementation of online learning in higher education has been rapidly expanding, with a predominance of institutions offering online courses or fully online programs. During 2013, over 7.1 million students took at least one course online (Allen & Seaman, 2014). The implementation of online programs is approximately equal for most major discipline areas such as business, liberal arts, education, etc.; however, the literature indicates that engineering programs have a significantly lower implementation rate and there has been little growth in online engineering programs (Allen & Seaman, 2008, 2011, 2013). This research intends to identify factors and characteristics of online engineering education that contribute to this gap in implementation.

To provide background and context for this research, this chapter begins with the significance of the study. Next, the chapter provides a statement of the problem and the research question. The chapter concludes with key definitions and an overview of the remaining chapters of this study.

Significance of the Study

A recent report by the President's Council of Advisors on Science and Technology (2012) indicated that the United States needs to produce more graduates from Science, Technology, Engineering, and Mathematics programs, including at the university level, and the National Research Council (2004) in the *Engineer of 2020* called for an increase in engineering graduates specifically. One way to expand engineering programs and program availability is by offering courses and programs online. However, research indicates there is a gap in the implementation of online courses and programs in engineering education compared to other academic disciplines. While there is a considerable body of literature available concerning both online education and engineering education, research exploring potential explanations, barriers, and underlying causes for the gap in implementation of online learning in engineering courses and programs is fragmented and limited.

The literature on online learning identifies faculty members as a key constituency in implementing online courses and programs (Bolliger & Wasilik, 2009), and their perceptions of advantages of online learning and barriers to implementation can influence the adoption of online technologies. The literature also provides a research base to explore perceptions of users such as faculty members regarding the implementation and use of new technology such as online education (Davis, 1989; Venkatesh & Davis, 2000; Venkatesh, Morris, Davis, & Davis, 2003). A critical construct in determining a user's intent to implement a technology is the perception of usefulness of the technology in a particular application.

Engineering is a complex field and the literature describes many aspects and characteristics that are important for successful online courses and engineering programs such as engineering design, active learning experiences, engineering labs, and communications and teamwork. Engineering faculty perceptions of the effectiveness of online technologies in addressing these aspects and characteristics in engineering courses, along with other concerns such as learning outcomes, representing mathematics and engineering design graphics, and the ability to reach out to non-traditional learners are critical to the ultimate adoption of the technology for engineering education.

The results of this research contribute to the body of knowledge regarding online engineering education by identifying potential reasons for the gap in adoption and implementation of online engineering courses and programs. It provides information for academic administrators, engineering faculty, learning technologists, and researchers regarding areas of focus to remove these barriers, optimize affordances, and improve online engineering education.

Statement of the Problem

As the implementation of online courses and programs continues to grow in most areas of higher education, research indicates that implementation of online learning in engineering education lags behind other academic disciplines. There is no comprehensive research at present to examine the reasons behind the lag in implementation in online engineering education. This study focuses on engineering faculty perceptions regarding online learning and provides insight into issues and barriers to implementation in engineering education and therefore potential reasons behind the gap in implementation.

Research Question

To explore the perceptions of engineering faculty toward various factors and characteristics of online engineering education and to identify reasons for the gap in implementation of online engineering courses and programs, this research addresses the following question:

> What factors do engineering faculty members perceive influence the implementation of online engineering courses and why?

To address the research question, this study employed a two-phase explanatory mixed methods design including both quantitative and qualitative data to explore and compare various factors identified in the literature related to the adoption of technology and online learning, as well as the unique characteristics of engineering education, to attempt to identify the reasons behind this lag in implementation of online learning in engineering education. The study consisted of two parts: first, survey data were collected and analyzed from a broad sample of engineering faculty members; and then a subset of engineering faculty members were interviewed to expand upon and provide a richer understanding of important factors uncovered during the survey phase.

Definition of Terms

ABET: Organization responsible for standard setting, review, and accreditation of engineering programs in the United States. Formerly known as the Accreditation Board for Engineering and Technology (ABET, 2013a).

Asynchronous Online Course: Course in which materials and communications are delivered online to students at a distance without regard to a singular meeting time. The online course materials and presentations are not in conjunction with the meeting of a face-to-face course. Simultaneous communications are not possible in this scenario. Examples would include recorded video posted to be watched at any time or a bulletin board where questions can be posted for later review and response.

Blended Course: A course that mixes online and face-to-face delivery. A substantial proportion of the content is delivered online, typically using online discussions, and typically having a reduced number of face-to-face meetings (Allen & Seaman, 2013).

Distance Education: Any course that is delivered to students who are not present in the same room, regardless of technology used (Tallent-Runnels et al., 2006).

Engineering Discipline: A specific unique area of engineering practice, such as civil engineering, structural engineering, electrical engineering, etc. See ABET EAC (2012) for a complete list of disciplines.

Face-to-Face (F2F): A course in which at least two-thirds of the class content is delivered in person in a classroom, with less than a third of the content delivered online. This category includes both traditionally delivered and web facilitated courses (Allen & Seaman, 2013; Tallent-Runnels et al., 2006).

Online Course: A course where most or all of the content is delivered online. A fully online course typically has no face-to-face meetings (Allen & Seaman, 2013; iNACOL, 2011).

Online Program: An engineering program where all courses are available 100% online (ABET, 2013b).

Synchronous Online Course: Course in which materials and communications are delivered online to students at a distance at the same time. The online course may occur solely online or may occur in conjunction with a face-to-face course. Examples would be simulcast video lectures or real-time online chats.

Dissertation Structure

This research study is presented in five chapters. Chapter 1 consists of the background, purpose of the study, research questions, significance of the study, and a definition of the terms. Chapter 2 is a review of pertinent literature related to the online engineering implementation gap, technology acceptance frameworks, and various important factors in online engineering education. Chapter 3 describes the methodology, methods, and design used in the study. Chapter 4 describes the results of each phase of the explanatory mixed methods study. Chapter 5 provides a summary and conclusions.

CHAPTER 2: REVIEW OF LITERATURE

Introduction

Even as online courses and programs become more prevalent at the graduate and undergraduate level, the implementation of these courses and programs in engineering has lagged that of other academic and professional disciplines (Allen & Seaman, 2008). But why? The literature concerning online education in engineering indicates the importance of faculty perceptions of certain key factors related to adoption of technology, providing and implementing online courses, and key characteristics of engineering education. These factors provide a background and a foundation for this proposed research to explore the reasons for the gap in the implementation of engineering courses online.

This chapter is arranged to present a background and basis for the proposed research study of faculty perceptions of online learning in engineering education. The chapter begins with a discussion of the background and gap in implementation of online learning in engineering courses and programs and provides a review of research from prior studies. The implementation of any technology, including online learning, is influenced by various factors, and this chapter next reviews several relevant theories and models of technology acceptance and the importance of perceptions of users relating to the usefulness and effectiveness of these factors. In this research, the engineering faculty members are considered to be the technology users, so their perceptions of important characteristics of online learning and engineering education are critical to the success of implementation of a new technology such as online learning. Therefore, the next section reviews individual characteristics of engineering education, such as engineering design, active learning experiences, engineering labs, and communications and teamwork requirements. The chapter concludes with a summary, a discussion of the gaps in the literature, and the implications of this research.

The Online Engineering Gap

In order to fully explore the issue of adoption of online educational methods in engineering programs, it is important to first understand the problem itself and research regarding the various indicators of this problem. While engineering enrollment continues to grow in the United States, reports indicate that more students and graduates are needed in STEM fields and engineering (National Research Council, 2004; President's Council of Advisors on Science and Technology, 2012; Yoder, 2012). As more and more institutions offer online courses and programs (Allen & Seaman, 2013), it will be important to provide students options for online engineering courses and programs to help address this need.

A study by Bourne, Harris, and Mayadas (2005), which summarized efforts to improve implementation and quality of online education and the future of online engineering programs, indicated adoption of online learning in engineering has lagged other academic disciplines. A 2007 survey of over 2,500 programs in the United States (Allen & Seaman, 2008) supports this contention and shows that the penetration of online programs is generally equal for most major academic discipline areas such as business, liberal arts and sciences, health professions, education, psychology, social sciences, and computer and information sciences; however, engineering programs have a significantly lower implementation rate for online programs and lag other academic disciplines. Recent follow-up studies show little growth in online engineering programs, with enrollment in online programs in all areas increasing except for engineering which declined in 2010 (Allen & Seaman, 2010, 2011). These studies explore various trends and perceptions of academic officers in online engineering programs in a general sense, but they do not attempt to address the engineering implementation gap other than to simply report that it exists. Outside of these reports, there is little published research concerning the gap in online engineering education.

While additional comparison research is not available, other information can assist in providing a background for understanding the current state of online engineering education. Engineering programs are currently offered predominantly at the graduate level (Bourne et al., 2005). An analysis by Reynolds and Huisman (2011) found 163 online engineering Master's degrees offered at 54 institutions. U.S. News and World Report (2015) described a survey of 296 graduate engineering programs in which 27% of the respondents reported they were offering at least one fully online master's level engineering program for the 2014-2015 year. Of these programs, a review of information regarding accredited engineering programs in the U.S. shows there are 13 fully online engineering programs accredited by ABET (formerly known as the Accreditation Board for Engineering and Technology).

While online graduate engineering programs exist, online undergraduate engineering programs are rare and online undergraduate engineering education is mainly limited to individual courses and hybrid/blended delivery formats (Reynolds & Huisman, 2011). Summary data on the total number of undergraduate engineering programs with some online course offerings is not readily available. However, a review of almost any major engineering department website will show that many engineering programs have some sort of distance or online capabilities with at least some courses in a few engineering departments offered in an online format. Of those programs that do offer engineering courses, a review of their offerings indicate limitations in course types and availability across engineering disciplines. For example, Arizona State offers various electrical engineering courses online (Arizona State University, n.d.), Southern Methodist University (SMU) offers undergraduate civil and environmental engineering courses (Southern Methodist University, n.d.), and the University of North Dakota offers undergraduate programs in chemical, civil, electrical, mechanical, and petroleum engineering with most courses online (University of North Dakota, 2014a).

While a substantial amount of research has been done pertaining to online and distance education as well as to engineering education, research regarding implementing engineering education online is limited. The research that has been done specifically concerning online engineering education primarily consists of small scale case studies of particular implementations or developments at a particular institution or in a certain course. Large scale or broad ranging studies on online engineering education are rare (Corter, Esche, Chassapis, Ma, & Nickerson, 2011).

In consideration of the research question and the described gap in online engineering education versus other academic areas, it is important to understand what influences the implementation and acceptance of a particular technology such as online learning and how it might apply to engineering education.

Technology Acceptance

This research seeks to understand possible reasons for the lag in implementation of online methods in engineering programs. Several frameworks and models, such as the Technology Acceptance Model (TAM) and the Unified Theory of Acceptance and Use of Technology (UTAUT), have been developed to describe the acceptance and adoption of new technologies. These models identify key determinants that influence decisions to implement technology such as offering courses online (Davis, 1989; Venkatesh et al., 2003).

LEARNING THEORIES

Research and debate concerning the effectiveness of different media and technology in education have been going on for years. The exchanges between Richard Clark and Robert Kozma expanded this discussion from comparisons of the impact of individual media and technologies in education to include a discussion of whether any medium could be shown to have a unique advantage in providing instruction (Clark, 1983, 1994; Kozma, 1991, 1994).

The position taken by Clark (1983, 1994) states that technology itself is merely a vehicle to deliver instruction, that the methodology and pedagogy employed with any particular educational technology have the most influence on learning, and that media comparison studies tend to show no significant difference in outcomes. Therefore, it was proposed that the media did not influence learning and can be considered to be interchangeable. Given the equal outcomes, the only reason to select or employ a particular learning technology is for practical reasons such as efficiency or expense.

Kozma (1991, 1994) reframed the discussion, moving from the consideration of individual media or technologies and their surface features to focus on the interaction of the learner and the technology and how meaning is created from a constructivist and social constructivist perspective. The importance and effectiveness of online education is the interaction between the technology, the pedagogy employed, and the learner. From this aspect, determining what is important to the instructor and learner and how well these tools are used in an authentic educational context is crucial. It comes down to the individuals using the system and their perceptions of its utility and effectiveness.

A pragmatic combination of these two perspectives provides a foundation for this study. Investigating the unique aspects of a given technology and its applicability and efficiency to the task at hand, such as teaching engineering online, as well as the perceptions of the users, such as engineering faculty members, regarding the utility and effectiveness of a particular learning technology in a given educational context, allows for a broad range of inputs to be explored to help identify drivers for the gap in implementation of online learning in engineering.

TECHNOLOGY ACCEPTANCE MODELS

Several frameworks and models have been developed to help understand factors that influence the adoption of new technologies. In order to develop methods to measure and predict user acceptance of computers, the Technology Acceptance Model (TAM) was developed by Davis (1989). Figure 1 provides a visualization of the TAM. The TAM research surveyed computer professionals and identified and validated two primary constructs, perceived usefulness and perceived ease of use, which influence technology adoption. The TAM model was further modified, expanded, and refined as the TAM2 (Venkatesh & Davis, 2000), which reinforced the findings that user perceptions of utility and ease of use are important factors in predicting technology adoption behavior.

Perceived usefulness is defined in the TAM models as "the extent to which a person believes that using the system will enhance his or her job performance" and perceived ease of use is "the extent to which a person believes that using the system will be free of effort" (Venkatesh & Davis, 2000).

The TAM models show that these user perceptions can account for a substantial proportion of the variance in determining an individual's intent to use a particular technology. Of the two primary constructs, perceived usefulness has been shown to correlate strongly with usage behavior and ease of use is a significant secondary determinant (Davis, 1989; Venkatesh & Davis, 2000). Essentially, this means that if users of a system do not perceive it as useful, they are unlikely to use it. In addition, even if they perceive the system as useful, they may believe the system is too difficult to use and will therefore be less likely to use it. It is important to note that all of these constructs are perceptions and not measures of an objective reality. These are the opinions of the user, however they are developed, and not reflections of the actual functionality or applicability of a system to a given task.

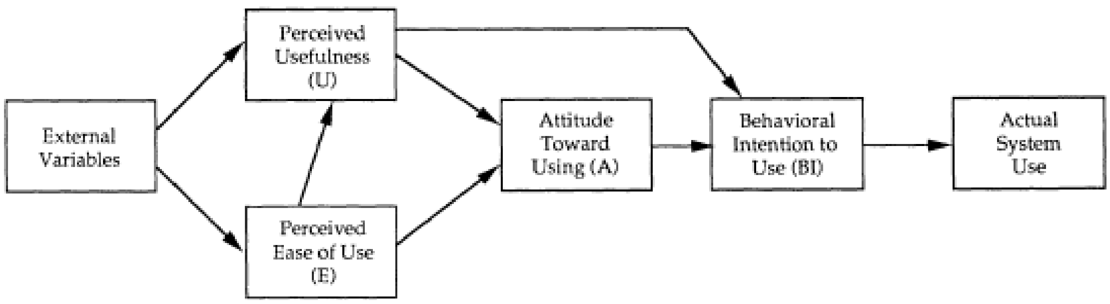

Figure 1 – Technology Acceptance Model (TAM). Adapted from "User Acceptance of Computer Technology: A Comparison of Two Theoretical Models. Management Science," by Davis, F. D., Bagozzi, R. P., and Warshaw, P. R. (1989). *Management Science*, 35(8), p. 985. Copyright © 1989, the Institute for Operations Research and the Management Sciences, 5521 Research Park Drive, Suite 200, Catonsville, Maryland 21228 USA. Used with permission.

The TAM and TAM2 research was primarily done with computer professionals, and studies in a wide variety of technology fields, including computer languages, information systems, and communication technologies have all been supportive of the TAM models and the influence of perceived usefulness and ease of use in the acceptance of technology (Davis, 1989). Additional research broadened the scope beyond the IT world and has tied these models to educational technology implementations.

Lee, Cho, Gay, Davidson, and Ingraffea (2003) explored the TAM model and social networking in a distance education engineering course for aerospace design. The results of the case study supported the primary constructs of the TAM and TAM2 model and that these attitudes will affect the user satisfaction with the technology. Drennan, Kennedy, and Pisarski (2005) studied a group of first-year management students and examined factors impacting student satisfaction with an online learning environment. The research found support for the TAM and perceived ease of use and utility and that student satisfaction is influenced by positive perceptions toward technology and an autonomous learning environment. Landry, Griffeth, and Hartman (2006) looked at student perceptions of the Blackboard learning management system and found that the TAM model was appropriate for use in an academic setting and was a useful instrument for measuring student reactions to the Blackboard system. Technology acceptance by pre-service teachers was studied using the TAM model with results supporting the primary constructs of perceived ease of use and usefulness as influencers of technology adoption, and noting that adequate technical and personal support also had an impact on user perceptions (Teo, 2009).

To further expand and refine technology acceptance models, Venkatesh et al. (2003) compared eight of the most common frameworks and models (including TAM and TAM2) and formulated the Unified Theory of Acceptance and use of Technology (UTAUT) model based on the pertinent factors. The model has been validated empirically and helps further explain the drivers of technology acceptance (Kidd & Davis, 2012; Venkatesh et al., 2003).

The UTAUT model sets forth four primary factors with significant roles as determinants of usage behavior, along with four moderators of individual behavior influencing technology adoption. The primary factors are performance expectancy, effort expectancy, social influence, and facilitating conditions. The first three factors – performance expectancy, effort expectancy, and social influence, are direct determinants of behavioral intention. Facilitating conditions and behavioral intention are determinants of ultimate use behavior. The four moderators of these various constructs are gender, age, experience, and voluntariness of use (Venkatesh et al., 2003). Figure 2 provides a visualization of the model.

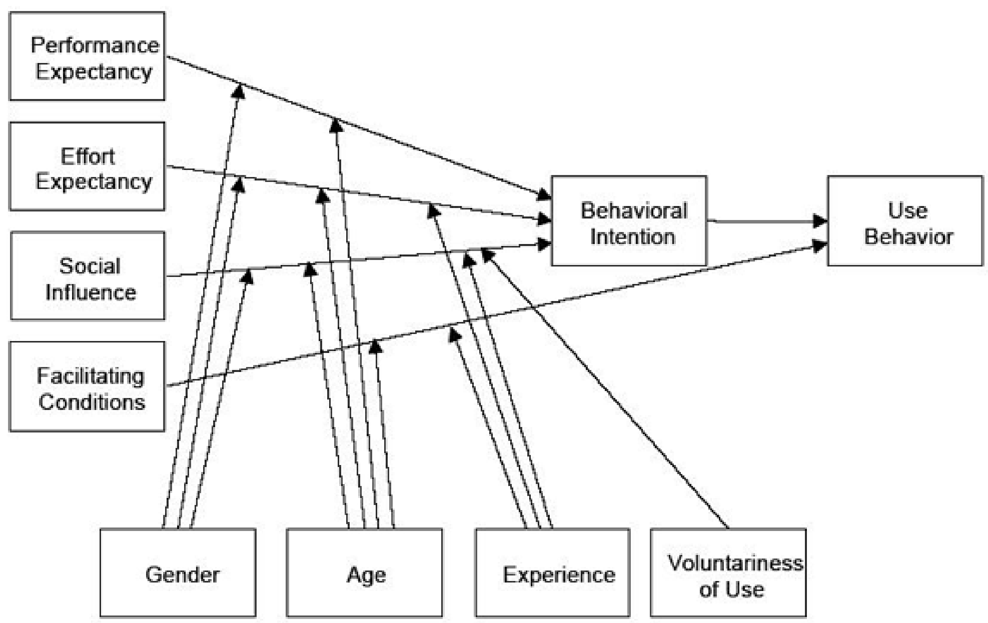

Figure 2 - Unified Theory of Acceptance and use of Technology (UTAUT) Model adapted from "User Acceptance of Information Technology: Toward a Unified View," V. Venkatesh, M. G. Morris, G. B. Davis, and F. D. Davis. (2003). *MIS Quarterly*, 27 (3), pg. 447. Copyright © 2003, Regents of the University of Minnesota. Used with permission.

Performance expectancy is the degree to which an individual believes that using the system will help attain gains in job performance. This construct is tied to perceived usefulness from the TAM and TAM2 models, and is the strongest predictor of intention, in both voluntary and mandatory implementation situations (Venkatesh et al., 2003).

Effort expectancy is the degree of ease associated with the use of the system and includes the perceived ease of use from the TAM/TAM2 model. This construct is significant during the first time period of the use of a technology, but becomes non-significant with periods of sustained usage. Social influence is the degree to which an individual perceives that important others believe a new system should be used. Research in the TAM model indicates this construct is not significant in a voluntary context but only when a particular technology use is mandated. Finally, facilitating conditions are the degree to which an individual believes than an organizational and technological infrastructure exists to support the system. This construct is not a direct driver of behavioral intention, but does play a role in influencing use behavior for a particular technology (Venkatesh et al., 2003).

Similarly to the TAM models, the UTAUT has been employed to evaluate user attitudes and adoption of technology in various scenarios, including an e-Learning system utilizing synchronous and asynchronous delivery of materials and communication methods for teaching and learning. The study determined that technological expectancy, in conjunction with educational compatibility, were important determinants of technology acceptance. Educational compatibility is related to the learning expectations of the student (Chen, 2011).

Kidd and Davis (2012) applied the UTAUT model to online teaching and factors that influence technology acceptance among faculty members. This model looked at the primary constructs of UTAUT through the lens of individual past experiences and perceptions and how it shapes current perceptions (Dewey, 1938). The study identified time, organizational support including instructional design and teaching support, faculty development and support to develop online content, and ease of use and reliability of technology tools as essential factors related to faculty acceptance of technology.

These studies point to common significant and supporting constructs in the TAM, TAM2, and UTAUT models. While there are a number of constructs involved, the significance of perceived usefulness / performance expectancy is the most consistent and influential and will therefore be the focus of the current study. Other factors such as technology support and training and compatibility with learning expectations, along with gender, age, and experiential factors, may influence user acceptance of technology and the ultimate implementation or use of that technology.

From a practical theoretical perspective, this proposed study takes a similar approach to the issues of adoption and implementation of online education as those implicit in the TAM and UTAUT frameworks. While the creators of these models make no specific claim to theoretical perspective (Davis, 1989; Venkatesh & Davis, 2000; Venkatesh et al., 2003), it is clear that the models take an interpretivist perspective in that they explore how users interpret their prior experiences and what meaning they attribute to these experiences, with the ultimate goal of understanding how people make sense of these experiences and make choices based upon them (Merriam, 2002).

Given the interpretivist perspective, it can be seen that constructivist and social constructivist perspectives permeate these models. Certain factors (performance expectancy, effort expectancy) are based on learning that builds upon prior experiences (constructivism), while other factors (social influence, and facilitating conditions) are related to social influences that are constructed through interactions with others (Dewey, 1902; Vygotsky, 1978).

In summary, the TAM and UTAUT models, as well as research into their applicability in educational technology and other areas, point to several relevant factors that are the focus of this research. The strongest predictor of intention to use a particular technology, such as online education, is the perception of usefulness and technological applicability to a task, summarized in the models as performance expectancy.

The TAM and UTAUT models look at the perceptions of users to determine intentions to adopt a particular technology. The key constituency for any successful implementation of educational technology is the faculty members required to use these systems (Allen & Seaman, 2008; Kidd & Davis, 2012; Tabata & Johnsrud, 2008). Bolliger and Wasilik (2009) state that faculty satisfaction is an important factor in online education. In the context of the technology acceptance models, the faculty members are a considered a primary user group and therefore their perceptions can be drivers of the ultimate implementation and use of a particular technology.

Demographic factors such as gender, age, and experience are shown in the TAM and UTAUT models to be moderators of use and are therefore included in this study to explore their influence on perceptions of faculty. Additionally, facilitating conditions such as organizational and technological support, as well barriers to implementation have also been shown to influence use behaviors and are therefore also be explored in this study.

Comparing faculty perceptions of different aspects and characteristics of engineering education as related to performance expectancy will provide an opportunity to identify which factors are important and may influence the reported implementation gap in online engineering education.

Characteristics of Engineering Education

To further explore the research problem of the gap in implantation of online learning in engineering education, it is important to review and explore important aspects and characteristics that are particular to engineering education and may provide opportunities or barriers to the implementation of engineering courses online. This section provides a review of the literature related to engineering education in general and research related to implementations online learning in engineering in particular, such as engineering design and engineering labs.

Engineering is a complex academic discipline covering many different areas of practice, from traditional fields such as civil, structural, electrical, and mechanical engineering to the specialized fields of petroleum, control systems, and software engineering (ABET EAC, 2012). ABET (formerly known as the Accreditation Board for Engineering and Technology), the organization that accredits engineering programs in the United States, provides a set of nationally recognized criteria that summarizes the key factors in any high quality engineering program, and by extension, the key factors in engineering education. These include an ability to apply knowledge of mathematics, science, and technology to an engineering context, to design and conduct experiments, to analyze and interpret data, to design a system, component, or process to meet desired needs within realistic constraints, to function on teams, and to effectively communicate (ABET EAC, 2012).

DESIGN

Design is a critical and complex component of engineering education. Wankat and Oreovicz state that many engineers believe that "designing is the heart of engineering" (1993, p. 168). The National Research Council (2009) released a report pointing out that four threads run through engineering – math, science, technology, and design. Mathematics, science, and technology represent foundational domain knowledge for the fourth area - engineering design. Engineering design encompasses attributes the such as analysis, constraints, modeling, optimization, and systems (p.77). Mathematics, science, and technology are a common part of most engineering curricula and are also taught as stand-alone courses and academic disciplines. Science and mathematics are self-explanatory; technology in this context can be thought of as a domain that runs alongside science and mathematics, focusing detailed learning about specific technologies, such as mechanical systems, digital electronics, digital communication and information technologies, automation, computer-aided design, and computer-aided manufacturing (p. 82). Technology also has clear incarnations in courses and laboratory experiences relating to these specific technologies.

Design, however, is not generally a stand-alone academic discipline. Design is emphasized as a central activity that permeates engineering knowledge and practice and engineering design is considered a "strong, thick thread" in engineering education (National Research Council, 2009, p. 83). In the Standards for Technological Literacy, the International Technology Education Association (ITEA, 2007) state that the design process is the main approach that engineers use to create solutions to problems, and it is generally accepted that design is the central and distinguishing activity in engineering (Brophy, Klein, Portsmore, & Rogers, 2008; Dym, Agogino, Eris, Frey, & Leifer, 2005) . Engineering is also defined by Katehi, Pearson, and Feder (2009), as "the process for designing the human made world" and engineers "provide plans and directions for how the artifacts are to be constructed" (p.27). The design process that engineers use is iterative, uses knowledge and skills from a variety of fields, includes problem definition and specification, is open-ended, optimizes competing needs and constraints, and uses modeling and analysis.

The National Research Council (2011), added to the definition of engineering design, stating that it is both iterative and systematic in that each new version of a design is tested and potentially modified based on what has been learned to that point. The design process includes steps such as: identifying the problem; defining specifications and constraints; generating ideas for how to solve the problem, including research and teamwork; testing potential solutions by building and testing models and prototypes; analyzing data from various solutions to meet the given specifications; and finally evaluating what is needed to improve the best design.

Undergraduate engineering student understanding of the design process changes as they migrate from novice to more experienced learners. Comparing first year to senior year students, the importance and focus on fundamental activities such as visualization and building give way to more the more abstract but expert level concepts such as modeling, iteration, and identifying constraints (Atman et al., 2010).

The complex and critical nature of design in the practice of engineering make it an important focus of engineering curricula and translating teaching design to an online format could be a key concern of faculty in engineering education. Faculty perceptions of the importance of design in engineering courses and the effectiveness of teaching design in an online format is therefore a factor that will be explored in this research.

EXPERIENTIAL LEARNING

In contrast to science education, engineering is primarily focused on design and evaluation in a real-world context. Therefore, engineering education contains a significant component of real-world experiences (Katehi, Pearson, & Feder, 2009) and could be considered an embodiment of constructivist learning (Dewey, 1902). Providing this type of active educational experience is critical and could be seen by faculty as a potential concern in teaching engineering online.

Active learning, problem based learning, and project-based learning are all important parts of engineering curricula, providing students direct interaction with the physical world and built environment, as well as the project-centered framework that exemplifies engineering practice (Ambrose, 2013; Dewey, 1902; Mills & Treagust, 2003). The focus of active learning in engineering educational practice is based in the experiential and constructivist frameworks as described and exemplified by John Dewey and others (Dewey, 1902; Dewey, 1938). Dewey (1902) opined that the best way to learn was through experience and that past experience interacts with the present situation. He felt that education should be like real life and have real life relevancy. He advocated for active learning - that students learn best by being active participants. In their text on engineering teaching, Wankat and Oreovicz (1993) emphasize the constructivist nature of teaching and learning engineering and the need for engaging and relevant activities to support and exemplify the topic of study.

Litzinger, Lattuca, Hadgraft, and Newstetter, (2011) state that engineering education should encompass a set of learning experiences that allow students to construct deep conceptual knowledge, to develop the ability to apply key technical and professional skills fluently, and to engage in a number of authentic engineering projects. Effective learning experiences are those that support the development of deep understanding organized around key concepts and general principles, the development of skills, both technical and professional, and the application of knowledge and skills to problems that are representative of those faced by practicing engineers. Atman et al. (2010) have shown that even two design experiences do not improve students' ability to consider broader context in their design process, and therefore students would benefit from a greater number of opportunities to address authentic problems.

Project-based and problem-based learning are common methods of student centered learning used in engineering courses and are based on constructivist principles that have been used for teaching engineering design. Both methods have much in common, including an identified problem or goal, multiple phases, open ended solutions, observation and feedback, and team skills (Mills & Treagust, 2003; Perrenet, Bouhuijs, & Smits, 2000).

Problem-based learning is one approach that allows students to practice complex problem solving (Litzinger et al., 2011). Research into the effectiveness of problem-based approaches in engineering courses include qualitative evaluations using interviews or surveys, with results indicating that students are in favor of the method (Mills & Treagust, 2003). Prince and Felder (2006) report that a review of multiple studies supports the positive response of students and faculty, as well as improvements in retention, skills development, and application of material, with similar outcomes in academic achievement reported. Studies performed in engineering courses utilizing problem-based learning support this finding (Yadav, Subedi, Lundberg, & Bunting, 2011).

Project-based learning has similar outcomes to problem-based learning, but includes real-world linkages through the projects selected, is more focused on the application of knowledge than the acquisition of knowledge, may have a larger scope or longer timeframe, and involves more time and resource management (Mills & Treagust, 2003). Research of effectiveness of this approach reveals similar results to that for problem-based learning, including skills development, retention, teamwork, and understanding of real-world applications. However, understanding of fundamental principles can be less than through other methods (Prince and Felder, 2006).

Project-based learning is multi-disciplinary in nature, and can be divided into two main themes: design oriented (know how) practice problem solving and problem-oriented (know why) based on theoretical principles (Dym et al., 2005). Project-based learning addresses the transfer of knowledge from one domain or concept to another, an important aspect of learning in engineering (Dym et al, 2005).

The literature on engineering education shows that, unlike some other disciplines, many real-world engineering problems are ill-structured, often have incomplete data and competing constraints, and may have multiple solutions. These criteria challenge traditional engineering teaching methods, which are often deductive in nature; that is, normally instructors first state general principles and move toward application of a concept. Research shows that inductive learning, such as exposing students to theories as needed to find solutions to problems, can lead to deeper understanding (Carr, 2011; Jonassen, Strobel, & Lee, 2006; Mills & Treagust, 2003; Prince & Felder, 2006).

Engineering programs often use capstone courses to provide these real-world active learning experiences and technical challenges (Biney, 2007; Dixon & Kauffmann, 2010). ABET (2013c) defines a capstone course as, "a culminating course that allows students who are nearing graduation to 'put together' the knowledge and skills they have acquired in their program and apply it to a major project or assignment." The cornerstone (first year) and capstone (final year) courses often employ Project-Based Learning (Dym et al., 2005). Capstone courses provide opportunities for students to make connections across ideas, contexts, engineering disciplines, experiences, to synthesize and transfer their learning to new and complex situations, and to work together with others on teams (Ambrose, 2013). Due to the importance and complexity of capstone courses, perceptions of engineering faculty as to the usefulness and effectiveness of online teaching methods may impact their implementation in such courses.

Engineering Labs

One of the important ways that real-world active learning experiences are included in engineering education is through the engineering lab. The literature concerning engineering education contains numerous articles and case studies about engineering labs and their importance. Included in these studies is speculation by the authors that the difficulty of presenting engineering lab experiences in an online format is a key factor inhibiting engineering education from moving online (Bourne, Harris, & Mayadas, 2005; Corter et al., 2011; Grose, 2003; Lawton et al., 2012; Nickerson et al., 2007). There is a growing body of literature describing case studies of various implementations of online, remote, or virtual labs and evaluating their effectiveness. This disconnect between the speculation that labs are a reason for the gap in implementation and the actual development and use of online labs is worth exploring, and this research intends to address both faculty perceptions of the importance of engineering lab experiences in the overall engineering curriculum and the overall applicability and usefulness of online engineering labs.

The literature indicates that many researchers agree that a key aspect of engineering education is the inclusion of laboratory experiences (Balamuralithara & Woods, 2009; Bochicchio & Longo, 2009; Bourne, Harris, & Mayadas, 2005; Corter et al., 2011; Gomes & Bogosyan, 2009; Nickerson et al., 2007). ABET accreditation criteria require that adequate and appropriate laboratory facilities are available to each program and lists conducting laboratory experiments and analyzing data as critical skills to be included in each engineering curriculum (ABET EAC, 2012). However, engineering laboratories are particularly difficult to provide online (Bourne, Harris, and Mayadas, 2005).

The top three goals of an engineering lab are learning course concepts, teaching social and team skills, and teaching design of experiments and experimentation skills. Engineering labs are purely constructivist endeavors, focusing on active learning, problem-based, and project-based learning (Corter et al., 2011).

Laboratory and course structure can vary along with the purpose of the laboratory course, but common goals for labs include design, experimental skills, real world experiences, building objects, discovery, and learning to use equipment, along with non-technical objectives such as motivation, teamwork, networking, and communication. Labs can be part of a lecture course to reinforce theory and allow students to discover results as part of the scientific learning cycle or as a stand-alone course, possibly synthesizing several theory courses or to have students design and/or build something. Laboratory exercises can be individual or in teams (Wankat & Oreovicz, 1993).

Engineering labs provide engaging authentic learning experiences that tie theory to real world practice (Ambrose, 2013, Ma & Nickerson, 2006). An engineering design is developed using more than the application of fundamental scientific principles. It can require the use of empirical data and experimentation and engineering programs should include actual experimentation in laboratory or real-life situations so engineers can learn how to efficiently plan and execute experiments and analyze and understand the results (Dym et al., 2005).

In inquiry or problem-based laboratories, student engagement in deeper learning processes lead to conceptual understanding instead of simply following standard procedures. Students learn to design and conduct experiments to answer questions, thereby challenging them to apply their knowledge and skills to realistic problems, as well as regulate and control their own learning (Litzinger et al., 2011).

Engineering labs are not only for understanding and experimenting with the physical principles required to understand the built environment, but are used as environments to explore and reinforce the iterative engineering design process: identifying the problem and constraints, collecting ideas and selecting a solution, building and testing a prototype, evaluating and refining the design, and repeating until a suitable solution is found (Balamuralithara & Woods, 2009).

As noted previously, it has been proposed that engineering programs lag other academic disciplines in implementing online programs because engineering education requires extensive laboratory and hands-on activity; however, this has not been the case with other disciplines such as health professions, which also involve significant hands on activity and interactions but continue to experience growth in online programs (Allen & Seaman, 2011; Lawton et al., 2012). At the graduate level, there is less of an emphasis on engineering laboratory courses than at the undergraduate level, which has been hypothesized as a reason that the implementation of online engineering programs at the undergraduate level lags far behind the graduate level programs (Bourne, Harris, & Mayadas, 2005).

Concerns about engineering labs and online courses are more than just a theoretical problem or an area for research; it is a real-world issue with current online engineering programs. There are online engineering programs that provide almost all coursework completely online, except for the lab components. An example is the University of North Dakota which offers several ABET accredited undergraduate engineering programs with all recorded lectures, materials, and assignments provided online, except for the labs. All lab work is required to be performed on campus during a special summer term (University of North Dakota, 2014b).

This is not to say that there has not been research or progress in creating online engineering labs. There are a number of comparative studies in the literature that describe or summarize various options and technologies that could employed for online labs. A literature review by Ma and Nickerson (2006) provides a summary and comparison of research concerning hands-on labs and the two primary modes of online delivery for engineering laboratory experiences: remote labs and simulations. Remote labs are lab activities in which interaction with real world apparatus are made available via online methods, including remote control of the devices, video, and audio feedback. A simulated lab is a computer program that simulates the action of a real-world instrument or system and provides feedback based on algorithms or models of the activity in question. Ma and Nickerson (2006) show that, while some contend that hands-on labs focus on design aspects and online labs focus on conceptual understanding, the boundaries between hands-on and online labs is blurred since most modern engineering laboratory activities, including hands-on labs, are mediated by computers, and that the "psychology of presence may be as important as technology" (p. 1).

The literature provides a description of remote labs and describes various advantages and disadvantages that may influence their implementation in online engineering programs. Remote labs are characterized by computer-mediated real-world experience in which students can manipulate an instrument or experimental setup, control the inputs, and collect data. This arrangement still requires instruments, lab space, consumable materials, and staff support, and there can be access and configuration issues (Bochicchio & Longo, 2009; Gomes & Bogosyan, 2009).

However, due to the nature of the system, a single setup can be shared by many students at geographically removed locations and accessed on a more continuous basis, thereby potentially reducing costs due to the amount of usage and access to more students

(Corter et al., 2011; Ma & Nickerson, 2006). While students do not get the advantage of physical proximity, unlike with a simulation they do get to remotely experience a real experiment and explore all of the intricacies of the physical phenomena in question. Like hands-on labs, and unlike virtual simulations, students observe and explore real phenomena and collect real data (Nickerson et al., 2007). There is also flexibility in scheduling lab activities and the ability to repeat experiments or collection additional data (Corter et al., 2011).

Similarly to remote labs, simulations and virtual labs have advantages and disadvantages that can influence implementation and adoption by engineering faculty and programs. Compared to hands-on or remote labs, simulated labs are computer mediated imitations of real experiments (Ma & Nickerson, 2006). Simulated labs can be provided at a lower cost since there is no actual lab space, instruments, consumable materials, or face-to-face lab staff (Corter et al., 2011); however, costs for software development, maintenance, networking, and computer infrastructure may off-set such savings. Due to the computer-mediated nature of simulations, processes, interactions, or other aspects of the labs can be stopped or slowed to observe hidden, complex, or even dangerous aspects of the process or activity in question, thus allowing the learners access to a learning experience that cannot be achieved in a hands-on or remote lab using real-world materials (Balamuralithara & Woods, 2009; de Jong, Linn, & Zacharia, 2013).

Issues with virtual or simulated engineering labs include a disconnect with the real world in that physical presence and interaction cannot be exactly simulated via computer. In a similar manner, the computer approximation or model of physical processes cannot completely imitate all real-world factors, such as gravity, friction, wind resistance, etc. While this allows for a clean experiment, it does not completely replicate a hands-on experience (Balamuralithara & Woods, 2009; Ma & Nickerson, 2006; Nickerson et al., 2007).

In addition to the active learning experience provided by engineering labs, Bochicchio and Longo (2009) noted that the collaborative and social learning aspects of lab experiences are crucial and must be included in online education laboratories. They emphasized that learners interact directly with other students, instructors, and the lab equipment, and that this interaction is key to understanding and construction of concepts.

Ultimately, an important factor that can influence adoption of a particular online engineering format is the usefulness of the technology in education, and a measure of this is learning outcomes. Corter et al. (2011) performed a large-scale experimental comparison of learning activities and outcomes and collection student perceptions of effectiveness for hands-on, remotely-operated, and simulation-based engineering laboratories in an undergraduate engineering course. In addition to comparing the three formats, they also compared individual and group data collection to examine the importance of social interactions in the lab experience. Analysis of learning outcomes showed that hands-on labs with group data collection performed best, reinforcing the standard engineering lab delivery model. The authors noted that it was unclear if this was due to educational superiority of this learning condition, the familiarity of the students with this lab method, or possibly that this arrangement creates more group interaction and more efficient sharing of knowledge resulting in better overall work. Challenging these hypotheses is the result that individual remote labs ranked a close second to hands-on group labs, and the authors had no explanation for this outcome.

Similar to the proposed study, the study by Corter et al. (2011) included a survey of participant perceptions of the labs. The analysis identified two major underlying components: perception of effectiveness and perception of convenience. For effectiveness, students rated hands-on labs as most effective, followed by simulated and then remote labs. For convenience, remote labs were rated higher than both of the other formats. The authors felt that simulation-based labs would be rated as very convenient, but explained that in this case the simulation software had to be installed as a first step in the lab setup and caused some problems for the students. For overall satisfaction, however, hands-on labs were rated highest. The authors hypothesize that familiarity and immersion are critical factors influencing overall satisfaction, and that interaction and physical context are important for effective learning from a constructivist perspective.

Complicating the evaluation of perceptions of usefulness in implementation of a learning technology such as online engineering labs, Corter et al. (2011) reported that the actual learning outcomes did not necessarily match student perceptions of effectiveness for a particular lab delivery scenario. For example, remote labs were rated as less effective than simulated labs, even when test scores showed the reverse was true. When combined with the model that perceptions of effectiveness influence adoption of a particular technology, this would indicate that students would be more inclined to engage with simulated labs than remote labs regardless of the actual learning outcomes.

In summary, engineering labs are a key component of engineering programs. The ability to provide adequate engineering lab experiences in an online environment is reported to be a key concern of faculty, even while research into possible solutions continues. Given the complex and controversial nature of the issue, this research explores faculty perceptions of engineering labs as a possible factor in the adoption of online learning in engineering.

Communication and Teamwork

A critical component of any course, whether face-to-face or online, is the ability to effectively communicate and interact between instructors and students, and between the students themselves. Faculty perceptions of the quality of communication available via online methods could influence their perceptions of usefulness and implantation of online engineering courses.

Anderson (2003) states that interaction serves a wide variety of functions in education, including allowing for learner control, allowing for different forms of participation, and can be both formal and informal. The online distance education course experience can be very different from a classic classroom environment. There is little or no face-to-face interaction, video or text-based information delivery can limit the richness of communication, and other methods of synchronous and asynchronous communication can limit student-instructor and student-student communication. In addition, technological issues can interfere with the learning process (Tanner, Noser, & Totaro, 2009).

In support of the critical nature of communication in engineering programs and communications as a skill engineering students need to achieve, ABET has included a requirement in their criteria for accreditation regarding the evaluation of student outcomes: "(g) an ability to communicate effectively" (ABET EAC, 2012, p.3).

A meta-analysis by Bernard et al. (2009) of 74 studies concerning distance educational methods verified that three critical types of communication in distance education as described by Moore (1989) - student-student, student-instructor, and student-content - were associated with increasing learning outcomes. It is interesting that the strongest interaction was between the students and the content, providing guidance to designers to provide strong associations with the online content. This research also analyzed the studies for any influence in distance course delivery method, whether synchronous, asynchronous, or blended, and results indicated a strong association between achievement and asynchronous courses.

Communication and interaction between student-instructor and student-student is a key part of social constructivist learning theory. As described by Vygotsky (1978), learning is a social, collaborative activity focused on the connections between people and the sociocultural context in which they act and interact through shared experiences.

Based on his observations and the literature, Anderson (2003) developed an equivalency theorem concerning the three methods of interaction:

> Deep and meaningful formal learning is supported as long as one of the three forms of interaction (student–teacher; student-student; student-content) is at a high level. The other two may be offered at minimal levels, or even eliminated, without degrading the educational experience. High levels of more than one of these three modes will likely provide a more satisfying educational experience, though these experiences may not be as cost or time effective as less interactive learning sequences. (p. 4)

Anderson (2003) expands upon this theorem to an online learning context, providing other implications concerning interactions. For example, student–teacher interaction is perceived as having the highest value amongst students, student–student interaction is critical for constructivist learning designs and collaborative tasks, student-instructor interaction is the least scalable and can be time and labor intensive for large courses. Some student–instructor interaction can be facilitated by videos, animations, etc., thereby changing from student–instructor to student-content interactions. The ability to provide these interactions adequately in an online environment, whether from a technology, development, training, or a support perspective, may influence faculty concerns and perceptions of the capabilities of online learning.

There are generally two major types of interaction in learning situations. Synchronous communication is a situation where student-student or student-instructor interaction is occurring simultaneously, such as in a face-to-face class or when multiple students are online at the same time. Asynchronous communication is the opposite; communication is isolated in time and one way, with some time gap between message and response. Additionally, asynchronous classes allow students to interact even if no one else is online at the same time.

In their review of online teaching research, Tallent-Runnels et al. (2006) noted that synchronous communications provided a direct, immediate environment for responses, while asynchronous methods provided for more focused and purposeful communications, reasoning that students in asynchronous discussions had more time to think and reflect on responses. Designing a learner-focused course and developing a community of learners by establishing connections, working groups, and modeling effective communications was critical for successful online courses. Moderation by an instructor of online communications is also critical to address misconceptions, guide students learning, and to encourage participation, and the online presence of the instructor requires a certain amount of work, even in an asynchronous course.

In research on perceptions of students and faculty in online social science courses, Osborne, Kreise, Tobey, and Johnson (2009) found that effective communication methods are critical for online courses. Faculty believed that interactions in online courses are less effective than in face-to-face course. A pilot study of engineering faculty and students based on the work by Osborne et al. (2009) showed similar results, with faculty and students agreeing that online courses have fewer opportunities for communication, less effective communication than face-to-face courses, and that it can be difficult to ask questions or clarify information in an online course (Kinney, Liu, and Thornton, 2012).

A case study by Abler and Wells (2005) describes an implementation of synchronous online communication, including audio, video, whiteboard, and application sharing, between students and engineering experts, allowing students to benefit from the knowledge and practical field experience of topic experts beyond the normal confines of a classroom or campus.

Another advantage of online education is distributed learning or remote access and sharing of resources across a number of campuses within a system or between institutions. AlRegib, Hayes, Moore, and Williams (2008) described the challenges of providing synchronous delivery of courses to an integrated system of campuses worldwide. The system utilized streaming video between campuses, and the authors identified three primary concerns in their design: minimizing constraints on teaching style, minimizing any sense of loss of remote student connectivity in that the student who is removed from the live classroom should not become detached or be neglected, and providing a rich set of technological and online tool choices for student participation and engagement to address limited engagement opportunities.

Building on the issue of communication is teamwork, a factor that is also important in modern engineering education. It is exemplified in team projects, team lab exercises, and in capstone course projects. The perception of faculty as to the ability for students to communicate with each other in a robust and meaningful as a team may be an important factor in evaluating the usefulness of online education.

To emphasize the importance of teamwork in engineering programs, ABET has included a requirement in their criteria for accreditation regarding the evaluation of student outcomes: “(d) an ability to function on multidisciplinary teams” (ABET EAC, 2012, p.3).

In research summarizing engineering design thinking in a team environment, Dym et al. (2005) stated:

> Constructivist theories of learning recognize that learning is a social activity, and both cornerstone and capstone project-based courses are seen as opportunities to improve students' ability to work in teams, as well as their communication skills. As a result, campuses now incorporate many of these dimensions in their design classes, ranging from cornerstone to capstone. (p. 107).

FACULTY CONCERNS

As noted previously, the perceptions of engineering faculty are critical to the implementation and acceptance of online engineering education, and are the focus of this study. The literature concerning faculty perceptions identifies additional concerns related to online education in general that may be relevant to the current study of the gap in online engineering. These concerns are explored as part of this study.

This research is informed by results of the Online Learning Consortiumresearch regarding faculty perceptions and factors that influence implementation of online programs. The Online Learning Consortium, formerly known as the Sloan Consortium (Online Learning Consortium, 2015a), a professional online learning society devoted to advancing quality online learning (Online Learning Consortium, 2015b), have produced a series of annual reports utilizing broad based survey research to evaluate several factors relating to adoption and implementation of online learning over time and across academic disciplines. This series of reports identifies and tracks trends in opinions on such items as perceptions of student outcomes, whether students require more discipline to complete online courses, student retention in online programs, faculty acceptance of online learning, faculty training and preparation, as areas of concern related to adoption of online learning technologies (Allen & Seaman, 2011, 2013, 2014).

In a survey of business faculty teaching online courses, Totaro, Tanner, Noser, Fitzgerald, and Birch (2005) reported that faculty members perceived that barriers to implementing online courses included the labor intensive nature of online courses, that the quality of online resources lag behind that of face-to-face courses, that additional technical and support systems are needed, difficulties with student-student and student-instructor interactions, and that there are challenges with teaching quantitative courses online. A subsequent study of business faculty and students by Tanner, Noser, and Totaro (2009) found similar results for faculty members and that in general, faculty opinions were significantly less favorable than students. This reinforces the proposition that faculty perceptions of online learning play a role in the gap in implementation in online engineering courses.

Research by Tabata and Johnsrud (2008) explored important factors in faculty implementation of online courses and found that faculty participation in distance education is influenced by their skill in using technology and their attitude toward technology and distance education. In a survey of factors important to faculty teaching online courses, Bolliger and Wasilik (2009) reported that reliable technology, workload, preparation, and compensation were concerns. In a survey comparing perceptions of online learning by students and faculty in social science courses, Osborne et al. (2009) found that faculty reported online courses take more time for students and that students who procrastinate should not take online courses.

While most research regarding faculty perceptions and factors in acceptance of online learning have been in non-engineering academic disciplines, there are a few studies specifically related to engineering. In their review of the state of online engineering education, Bourne, Harris, and Mayadas (2005), found that faculty satisfaction was one of several metrics that drive online education.

Institutional and administrative aspects were found to be important across studies, with faculty indicating that opportunities for training in different technologies, media, and course design were critical. In addition to training, technical support and a reliable infrastructure were important to delivering online courses effectively. Studies indicated that developing and delivering online courses generally took more time, and that faculty thought they should be paid for the development of such courses (Tallent-Runnels et al., 2006).

ADDITIONAL ISSUES

In addition to the foundational factors in engineering education such as design, experiential learning, and engineering labs, the literature contains studies exploring faculty perceptions of additional issues related to engineering education and online learning that may related to acceptance and adoption of online learning technologies. This research explores each in the context of the technology acceptance models and faculty perceptions of usefulness.

Learning Outcomes

A metric related to the faculty perception of usefulness of online learning is the comparison of learning outcomes to traditional course delivery methods. Given the differences between online and traditional teaching methods, it seems reasonable to question the effectiveness of online education methods. A number of studies in different disciplines have demonstrated that distance and online delivery methods are at least as or more effective than face-to-face methods in terms of student outcomes. However, educator perceptions do not always reflect this finding, with some faculty still reporting that online learning is not effective as face-to-face (Allen & Seaman, 2014).

In a review of research on online learning across various academic disciplines, Tallent-Runnels et al. (2006) reported that there are no significant differences in various measures of learning outcomes (test scores, course grades, performance ratings, etc.) across various areas of study (nursing, teachers, special needs), indicating from one perspective that online instruction is at least as effective as face-to-face or traditional teaching methods. This study also noted that, from the perspective of Clark (1983), the delivery media may not be the only variable in a comparison of online and face-to-face course delivery, as instructional methods also change relative to the medium, and evidence was found that students employed different learning strategies in online and face-to-face courses.

In a large scale quantitative study comparing student course grades across a number of academic disciplines (civil engineering, communications, computer science, management, nursing, psychology, etc.), Abdous & Yoshimura (2010) also found that there was no significant difference in learning outcomes between on-campus face-to-face courses and courses delivered remotely, either via live online video streaming or via satellite broadcast.

The literature in online engineering education provides similar results, reporting that test scores and measures of satisfaction were comparable in face-to-face and online courses (Bourne, Harris, & Mayadas, 2005).

A study by Barbour (2007) of online faculty and course developers of asynchronous courses identified a set of design factors that are important in delivering a successful online course, including: pre-planning; simple navigation; diverse media for content, including text, visuals, appropriate multimedia, and interactive elements;

personalization; summaries of content; clear instructions and expectations; and developing the overall course at the appropriate level for the target audience.

Non-Traditional Learners

The concept of teaching at a distance, or distance education, has a long history. Distance education has been described as the use of technology “to deliver instruction and learning freed from the geographical and time constraints associated with face-to-face instruction” (Tabata & Johnsrud, 2008, p. 626). Many different technologies have been employed in this manner over time, from printed books and educational materials sent through the mail, to radio and audio recordings, to live and recorded television, and now to the ‘fourth wave’ of distance education – computer and internet technology, the preferred mode of distance education (Lease & Brown, 2009).

As student demographics have changed, many colleges and universities have employed various distance education strategies to expand their offerings to ‘non-traditional’ markets, including students that are older, married or with families, or working part- or full-time. Due to these various demands, many of these students are not able to attend on-campus courses during regular course times. They require flexibility in time and place, and institutions are working to address these needs by offering courses online. A key advantage of online learning is that courses can be available when needed and accessible from anywhere by any number of learners. (Bourne, Harris, & Mayadas, 2005; Lease & Brown, 2009).

Engineering is no different. The ability for students to remotely access engineering courses and programs when they are not available at a local institution, or for a working student to be able to take a course or earn an engineering degree online without having to physically attend a class will help address the need to educate more engineers

(Bourne, Harris, & Mayadas, 2005; President's Council of Advisors on Science and Technology, 2012).

The Language of Engineering – Mathematics and Graphics

Mathematics has been referred to as the "language of engineering" (Dym et al., 2005, p.108). The critical component of engineering design also requires the ability to render drawings of the structures, items, or systems being designed. A practical matter that may influence the capability to implement online engineering courses is not only the ability to represent mathematics, graphics, and engineering design drawings easily in both course materials and the work of the students, but also faculty understanding and perceptions of this capability. While rendering images and generating mathematical equations for course materials has been made simpler via equation editors and graphic design tools, the ability to produce and communicate such critical work products is still more difficult than in a face-to-face, pencil-and-paper class (Bourne et al., 2005). Branoff and Totten (2006) they describe challenges engineering instructors face, such as finding appropriate ways to demonstrate design software, preparing graphic intensive materials, and determining adequate methods to evaluate student work.

Summary of the Literature and Gaps

SUMMARY

Research indicates there is a gap in the implementation of online courses and programs in engineering education compared to other academic disciplines. This research is focused on exploring and providing reasons for this gap. Engineering faculty play a key role in the implementation of online learning technologies. The literature provides a framework to explore perceptions of users such as faculty members in the implementation of a particular technology. A critical construct in determining a user's intent to implement a technology is the perception of usefulness of the technology in a particular application.

Engineering education is a complex area with many important characteristics. Exploring faculty perceptions of the effectiveness of online technologies in addressing these aspects, along with other concerns such as learning outcomes, representing mathematics and graphics, and how to best address non-traditional learners, is key to providing insight into opportunities or barriers to the implementation of online learning in engineering education.

GAPS

Outside of the surveys by the Sloan Consortium identifying the presence of a gap in implementation of online learning engineering programs, there is almost no research exploring the reasons for the gap. Research in online learning in engineering education is limited. Most of the literature on online engineering education speculates or hypothesizes about a few isolated factors and then provides case studies to explore a particular possible solution. Quantitative data is often limited to simple pre- and post-course comparisons of achievement or learning outcomes, and qualitative data consists of a student survey concerning the technology. Studies on faculty perceptions of online learning and online engineering education often focus only on one or two issues instead exploring the issue in a more holistic manner or in a broader context.

Much of the research focused on implementations of online learning and online engineering courses is performed by either instructors or researchers that are interested in the success of online learning itself. Survey data is generally from faculty and students that have taken or are teaching online courses. While these populations have valuable opinions and can provide insight comparing online and traditional face-to-face courses, the body of research does not also explore the opinions and perceptions of those that have limited or no experience in online learning.

IMPLICATIONS OF THIS RESEARCH STUDY

This research study addressed the gap in the literature by focusing on current perceptions of engineering educators with varying levels of experience, personal and institutional demographics, and from the perspective of importance and usefulness of various factors in online learning. Online programs continue to grow and be implemented in all academic disciplines, including engineering, and findings concerning possible issues or barriers to implementation that are specific to engineering will help inform future instructional designers, educators, and administrators as to areas of improvement or focus.

The literature showed that several factors are considered to be important to successful implementation of an online engineering program, including design, active learning experiences, earning effectiveness, communication and teamwork, and faculty satisfaction. Each has been studied in isolation or in limited combinations, and the field of online engineering education will benefit from a broad study that includes and compares multiple factors and asks a broad range of engineering faculty members for their opinions on each issue directly. In this research, these factors were explored together and the results provided guidance for future research and development in the area of online engineering education.

In summary, it is apparent that understanding faculty perceptions of effectiveness and utility of various features of online engineering courses and programs is vital to understanding the gap in implementation of online education in engineering.

CHAPTER 3: METHODOLOGY

Chapter 3 is organized to define and explain the methods and procedures involved in this study. The sections are as follows: Research Question, Summary of Pilot Study, Research Design, Participants and Demographics, Data Sources, and Procedures.

Research Question

The review of literature in Chapter 2 identified many factors and characteristics that are important in delivering a high quality engineering education. A key determinant in the implementation of online learning is the perception of faculty regarding the usefulness of online methods in delivering and addressing these various factors.

This study used a mixed methods approach incorporating survey and interview data to explore and understand faculty perceptions of online engineering education and to answer the following question:

> What factors do engineering faculty members perceive influence the implementation of online engineering courses and why?

Summary of Pilot Study

This study was informed by a mixed methods pilot study conducted to investigate both faculty and student perceptions of the effectiveness of online engineering courses and specific technologies used in online courses (Kinney, Liu, & Thornton, 2012). The research goals and methodology in the pilot study were similar to the current study but incorporated both faculty and student respondents, had a smaller set of questions, and had a significantly reduced number of participants. The work completed in the pilot study identified opportunities to improve and expand the survey, interview instrument, and analysis and provided several insights into potential areas of future study. This preliminary study forms the basis for the current research.

The pilot study also focused on the gap in adoption of online courses in engineering and non-engineering programs. However, a broader approach was taken to attempt to explore different possibilities and look for significant factors. The pilot study approached the issue from two directions and sampled two different groups: the perceptions of both faculty and students about online engineering courses and perceptions of particular online educational technologies and tools. The research questions in the pilot study were:

1. What are the perceptions of engineering faculty and students about online engineering courses?
2. What are the perceptions of engineering faculty and students about different technologies and educational methods employed in engineering courses delivered online?

The pilot study was conducted using a mixed methods design implemented in two phases. In the first phase, a two-part survey was developed to include items to address both research questions. The section of the survey to address the first research question was based on a survey developed by Osborne et al. (2009) to compare perceptions of online courses by faculty and students. The section of the survey focused on the second question was developed to explore faculty and student opinions of the efficacy and utility of certain online educational tools as used in online engineering courses. A convenience sample of faculty members and students from three graduate engineering programs at universities in Texas that had experience in teaching or attending online courses were contacted for the survey portion, and ultimately 17 faculty and 28 student responses were received and analyzed.

In the second phase, a semi-structured interview protocol was developed based on results of the survey data from the first phase. Questions for the interviews were generated to explore areas where the faculty and students opinions diverged concerning aspects of online engineering education or where both faculty and students indicated a significant issue might exist. A convenience sample of two faculty and three graduate students from a single graduate level engineering program were interviewed, the results of the recordings transcribed, and the transcriptions analyzed using open coding to find emergent themes.

The qualitative results of the second phase were then incorporated with the quantitative data from the first phase to develop a more complete picture of the perceptions of faculty and students. Results showed that faculty and students agree technical subjects can be effectively delivered via online education, effective communication is a critical component of delivering effective online education, and engineering labs are a hurdle to effectively delivering engineering education online.

The pilot study and the feedback received during its presentation at the 2012 American Society of Engineering Educators (ASEE) annual conference provided several insights and opportunities for refinements that have been carried forward into this study. One significant change was narrowing the scope of the study to focus only on faculty perceptions. The pilot study was quite broad and the comparison between faculty and students did not provide much insight about why engineering courses and programs were lagging other academic areas in moving online. The pilot study employed a small convenience sample, so this research benefits from a much larger population and sample of engineering faculty members across a broader academic demographic of public and private schools and programs of different sizes. The pilot study also only involved faculty and students who were teaching or enrolled in online engineering courses. To truly explore factors or barriers to the implementation of online engineering courses, it is important to hear the perspectives of those with experience as well as those that have not been involved in an online course. This research included all engineering faculty members, regardless if they have taught online courses or not. Finally, the second section of the pilot study explored perceptions of specific online technologies. This information was not particularly insightful as it seemed to be strongly influenced by personal experience with individual technologies and specific implementations of learning technologies in particular engineering programs. Any research in this area is ultimately time dependent as technologies evolve and change over time. Therefore, this research did not include a technology specific section.

Research Design

In order to fully explore the gap in implementation of online education in engineering, it is important to gather information across a broad population of faculty members and to both sample common perceptions across the group as well as probe deeper into individual opinions and experiences to attempt to explain the statistical research results. Therefore, this research study employed a two-phase sequential explanatory mixed methods design (Creswell & Clark, 2007). In the first phase of this design, the researcher collected and analyzed quantitative survey data; in the second phase, qualitative interview data was collected and analyzed to help expand upon and explain significant, challenging, or otherwise interesting results from the first phase.

Between the phases, the results of the quantitative investigation were reviewed and significant results identified to inform the specific data collection in the qualitative second phase, thereby allowing the second phase to build on the first.

A mixed methods approach was chosen for this study because of the multi-faceted nature of the issue of adoption and implementation of online educational methods in engineering. The research problem requires the exploration of faculty perceptions, which can be complex. Mixed methods research allows for triangulation of different data sources to focus in on answers to the research question (Creswell, 2009). A purely quantitative approach would provide a statistical investigation of various factors across different independent variables, which would provide results indicating generalizable perceptions across the population of faculty respondents. However, this approach could not provide deeper insight into why faculty perceived online learning as they do. A purely qualitative approach would provide a deep, rich description of case studies or the opinions of individuals or small groups of engineering faculty, which would provide insight into why they perceive particular factors to be issues based on their individual experience. However, these results could not necessarily be generalized across engineering faculty or engineering programs. Therefore, this research question did not seem to be best addressed using only one research paradigm or analytical perspective. Rather, the ability to utilize multiple analytical tools and techniques as needed and to approach the problem from a holistic point of view, using both an objective and interpretive perspective, pointed to the need for a pragmatic paradigm or worldview.

Essentially, pragmatism is focused on what works best to investigate a particular research problem at hand as opposed to a strict philosophic adherence to a particular epistemology or methodology. The pragmatic research approach considers the research question to be more important than the methods selected or the underlying paradigm, and therefore does not require a choice between postpositivism and constructivism and the commonly associated quantitative and qualitative methodologies (Creswell & Clark, 2007, Tashakkori & Teddlie, 2003). Tashakkori and Teddlie (1998) refer to this as "epistemological relativism" and discuss the advantages of using both the objective and subjective points of view.

Research methods should be tied to and align with the theoretical framework or perspective of the research being undertaken (Koro-Ljungberg, Yendol-Hoppey, Smith, & Hayes, 2009). The pragmatic approach combines an objectivist approach, utilizing surveys and associated quantitative analysis, and an interpretivist approach, utilizing interviews and associated qualitative analysis techniques, to fully explore the research questions (Creswell & Clark, 2007; Tashakkori & Teddlie, 1998). Quantitative research methods are often associated with a postpostivist paradigm, which is a worldview in which the researcher is an impartial observer data can be objectively collected and analyzed toward the end of uncovering a singular "truth." In contrast, qualitative research can be associated with a number of paradigms, such as constructivism, in which researchers can be close to or involved in the data collection and research results are subjective and provide or uncover multiple perspectives of the participants (Guba & Lincoln, 1994; Lincoln, Lynham, & Guba, 2011; Tashakkori & Teddlie, 1998).

Mixed methods research operationalizes the pragmatic paradigm by employing the most relevant combination of qualitative and quantitative approaches in the research process. This method attempts to utilize the strengths of each approach to offset the weaknesses of the other, and present the most complete picture by providing trends and generalizations as well as rich data including individual explanations and perspectives (Creswell & Clark, 2007; Tashakkori & Teddlie, 1998; Tashakkori & Teddlie, 2003). For example, quantitative research attempts to isolate effects and factors, and therefore is often deficient in providing linkage to the context of the phenomena studied. It also attempts to keep the researcher separate from the research and therefore has difficulty accommodating possible personal bias or interpretations. Qualitative research has the difficulty of generalization to a larger population due to often small sample sizes and personal interpretations by the researcher (Creswell & Clark, 2007).

Procedure

This study consisted of two phases – a survey to collect quantitative data regarding perceptions of engineering faculty and a semi-structured interview to explore individual faculty perceptions of online engineering education. A summary of the research plan and schedule is included in Table 1.

For the survey portion of the research, a list of all ABET accredited engineering programs in the state of Texas was compiled. Using this list, email contact information was collected and compiled from university and departmental websites for all faculty members in the programs. The survey instrument was developed using the Qualtrics online survey tool. All email information was loaded into the survey software to facilitate initial email invitations, reminders, and to track responses. Response data from the survey, as well as which participants have responded, was recorded using the survey tool. Invitations to survey participants were sent by e-mail using the survey tool during the 2014 spring semester. The survey response rate was monitored throughout the response period. Individual responses were tracked using the online survey tool, and reminder notifications were sent during the 2014 summer semester (June) and at the beginning of the 2014 fall semester (September) to all invitees who had not responded. The response period closed in September 2014. After the response period closed, data analysis began as noted in the Data Analysis section below.

Table 1

Research Plan and Schedule

Date	Procedure	Data Collected	Processing
March 2014	IRB Update and Amendment	NA	Amend current IRB to include new procedures and survey.
May 2014	Begin Phase I: Distribute Online Survey – Spring Semester	Quantitative Survey Responses from Faculty	Track Response rate; Preliminary Data Analysis
June 2014	Follow-up Reminder / Resend Survey – Summer Semester	Quantitative Survey Responses from Faculty	Track response Rate; Preliminary Data Analysis
September 2014	Follow-up Reminder / Resend Survey – Fall Semester	Quantitative Survey Responses from Faculty	Track Response rate; Preliminary Data Analysis
September 2014	Close Survey / Data Analysis	NA	Statistical Analysis of Survey Data
October 2014	Begin Phase II: Develop Interview Questions / Contact Participants/ Schedule Interviews	Qualitative Interviews with Faculty	Transcribe and Code as Interviews are Complete
October – November 2014	Complete Interviews	Qualitative Interviews with Faculty	Finalize Qualitative Analysis

After the data analysis for the survey phase was complete, the interview items were developed as described previously. A sample of 10 engineering faculty members representing various individual and institutional demographics was contacted via email for interviews.

A common interview protocol was developed and implemented for all interviews. Each interview took between 30 and 45minutes, was conducted via telephone, was digitally recorded using redundant recorders, and was subsequently transcribed. The author was the only interviewer for all of the interviews. The transcripts were the primary working medium for the subsequent qualitative coding and analysis.

Participants and Demographics

This study focused on the perceptions of university level engineering faculty. The state of Texas has 31 different institutions of higher education offering a total of 125 ABET accredited undergraduate engineering degrees in a multitude of engineering disciplines and one institution that offers an ABET accredited graduate engineering degree (ABET, 2013d). Many of these programs also offer Masters and Doctoral level engineering programs. It should be noted that none of these programs offer an ABET accredited engineering program that is fully online (ABET, 2013b). However, many of these programs have courses that are offered in a blended or fully online format, or in some cases, simultaneously online in conjunction with an on-campus face-to-face engineering course. These engineering programs span various engineering disciplines, university types including public and private institutions, and a broad range of institution and program sizes and Carnegie classifications (Carnegie Foundation for the Advancement of Teaching, 2013). As such, the engineering programs available in Texas represent a broad range of different engineering education scenarios and reflect a rich pool of engineering faculty participants from which to draw.

SURVEY

The survey instrument was distributed electronically to all faculty members from ABET accredited engineering programs in the state of Texas. Faculty email contact information was compiled from the websites of 125 engineering programs from the 31 Texas universities with engineering programs. Full time, associate, and adjunct faculty members were included in the distribution list. The initial list consisted of 2,201 faculty contact email addresses.

The contact list was loaded into the Qualtrics survey tool and checked for duplicates, resulting in 43 addresses that were replicated due to faculty members being listed in two or more engineering departments simultaneously (i.e. computer and electrical engineering). After the initial distribution of the survey, another 27 email addresses were returned as undeliverable. This resulted in a total distribution population size of 2,131 engineering faculty members.

In order to get the highest possible response rate, the survey instrument was distributed across three consecutive university semesters during 2014. The survey was initially distributed during May 2014 at approximately the end of the standard spring semester timeframe. The initial distribution resulted in a total of 131 valid responses representing 21 of the universities contacted. A reminder email was sent during June 2014, corresponding to the summer semester, to the population that had not initially responded. This raised the number of responses to 189 from 23 of the universities. The second and third (final) reminders were sent in September 2014, corresponding to the beginning of the fall semester, resulting in a final total of 273 responses to the survey requests. Only 4 universities had no respondents, but all of these were very small programs with 8 or fewer faculty (a total of 28 potential respondents).

The response data set was reviewed to identify any respondents that completed the survey but indicated that they did not consent to the use of the information. In addition, the Qualtrics software allowed for the identification of incomplete responses. Respondents had the option of skipping items and some completed significant portions of the survey but had missing values. Removal of these responses lowered the total number of valid responses to 266 resulting in a final response rate of 12.48%. This rate was lower than the initial targeted response rate; however, it still provided a large enough population to allow for valid statistical analysis.

DEMOGRAPHICS

The survey instrument included a number of demographic questions to provide descriptive information about the respondents and to allow for analysis and comparison of responses across various respondent groups. Descriptive statistics were calculated for each demographic variable.

The gender distribution of the overall initial survey population was similar to the final respondent population, with an initial population breakdown of approximately 87% male and 13% female engineering faculty members, compared to a respondent population of 85% male and 15% female. These results were in line with national engineering faculty data indicating the gender distribution of approximately 12-15% female engineering faculty members (Gibbons, 2011).

Table 2

Age Distribution of Respondents

Age Group	**Number of Respondents**	**Percent**
25 to 34	25	9.4
35 to 44	71	26.7
45 to 54	59	22.2
55 to 64	53	19.9
65 to 74	47	17.7
75 to 84	9	3.4
Unknown or Other	2	0.8
Total	266	100

The survey question concerning faculty age was bracketed according to standard survey groupings recommended by the Qualtrics survey tool and aligned with the U.S.

census (Qualtrics, 2013). The number of respondents was low at the upper and lower ends of the response range, with over 85% of respondents between the ages of 35 and 74. The age distribution was skewed slightly toward the lower end of the age range with 58% of the respondent below the age of 55. Results are listed in Table 2.

Gender and age information were collected because the UTAUT model (Figure 2) indicated that these could be mitigating factors in the acceptance of technology and therefore could have an influence on the implementation of online engineering courses. Comparative analysis in this study indicated that there were no significant results regarding gender or age for any of the survey response questions.

Due to initial research indicating that online engineering programs and courses are primarily taught at the graduate versus the undergraduate level, a question was included asking whether the faculty member primarily taught at the undergraduate or graduate level. It is acknowledged that many faculty members teach both undergraduate and graduate courses, so the question asked about their primary teaching focus. Almost two thirds (66.5%) of the respondents indicated that they teach primarily at the undergraduate level with 33.5% indicating they primarily teach graduate courses. The actual distribution of the initial population is unknown, but it is reasonable that more faculty members teach at the undergraduate level due to the proportion of undergraduate versus graduate enrollments.

In addition, 89.4% of respondents indicated that they are full-time faculty members, with 10.6% indicating they are part-time or adjunct faculty. This question was included to explore whether full-time faculty that spend a predominance of their time teaching and active within academic circles have a different perception of online delivery from those that teach on a part-time or adjunct basis and may also be employed or have experience outside of higher education.

Information concerning primary engineering discipline or program area was collected to explore whether perceptions might vary according to requirements or resources by engineering discipline. Results are listed in Table 3.

Table 3

Primary Program Area Distribution of Respondents

Engineering Discipline	**Number of Respondents**	**Percent**
Aerospace	12	4.5
Agricultural	4	1.5
Architectural	2	0.8
Bioengineering	5	1.9
Chemical	21	7.9
Civil / Structural	38	14.3
Computer Science / Computer Engineering	24	9.0
Electrical	50	18.8
Engineering Management / Systems	3	1.1
Environmental	10	3.8
Industrial	15	5.6
Materials	6	2.3
Mechanical	42	15.8
Nuclear	6	2.3
Petroleum	15	5.6
Software	3	1.1
Other Engineering	10	3.8
Total	266	100

Some engineering disciplines are primarily focused on the physical or built environment (civil or environmental engineering, for example), while others such as electrical or software engineering potentially have a more significant relationship to activities related to computers. High response rates by civil/structural, electrical, and mechanical engineering reflected the fact that these three disciplines represent over 58% of the engineering faculty in the state of Texas as well as the three largest engineering disciplines as indicated by the number of engineering bachelor's degrees awarded in the United States (Yoder, 2012).

Information concerning university type and program size was collected, with 88.7% of respondents indicating they teach at a public university and 10.9% indicating that they teach at a private, non-profit university. Respondents were also asked to estimate their engineering program size, as indicated by total undergraduate and graduate enrollment across all engineering disciplines. Information was collected by enrollment brackets instead of by an open ended numerical response to aid in comparative analysis. The distribution of responses was generally normally distributed with the mode at the 2,501 – 5,000 student group and the number of respondents declining for larger programs. However, a large number of respondents reported teaching at the largest enrollment bracket - very large institutions of 10,000 engineering students or more. Further analysis of this distribution and a review of the estimates that different respondents made for the same institution or program raised doubts about the accuracy and reliability of this demographic information. Therefore, this question was dropped and further analysis was not performed on this data.

Respondents were asked to provide information concerning their experience level with various modes of online course delivery. This survey question was presented as a group of four numeric response items that allowed the respondent to indicate the number of courses they had taught within the last 5 years using each of four delivery modes: online courses, defined as most or all content delivered online with no face-to-face meetings; blended or hybrid, defined as a course that blends face-to-face and online delivery with a substantial proportion of content delivered online; face-to-face, defined as a traditional course involving direct presence of the instructor and students with only very limited use of online technology to deliver course materials; and simultaneous online /

face-to-face, defined as a face-to-face or blended course that is taught synchronously or asynchronously online. A synchronous example of this mode would be a lecture to an in-class group of students while simultaneously broadcasting the lecture via the internet, while an asynchronous version would be a recorded version of an in-class lecture posted and distributed to distance students for viewing at a later time.

Table 4

Average Number of Courses Taught During Previous 5 Years by Delivery Mode

Delivery Method	**Mean Number of Courses**	**Standard Deviation**
Fully Online	0.41	1.73
Hybrid / Blended	0.68	2.02
Simultaneous Online & Face-to-Face	1.00	3.35
Face-to-Face	13.00	9.81

From a demographic standpoint, it was initially thought that it would be helpful to determine the average number of courses that the entire population had taught in each mode. However, the results indicated that very few respondents had taught any significant number of courses online and that most had taught a much larger number of face-to-face engineering courses. Table 4 lists these results.

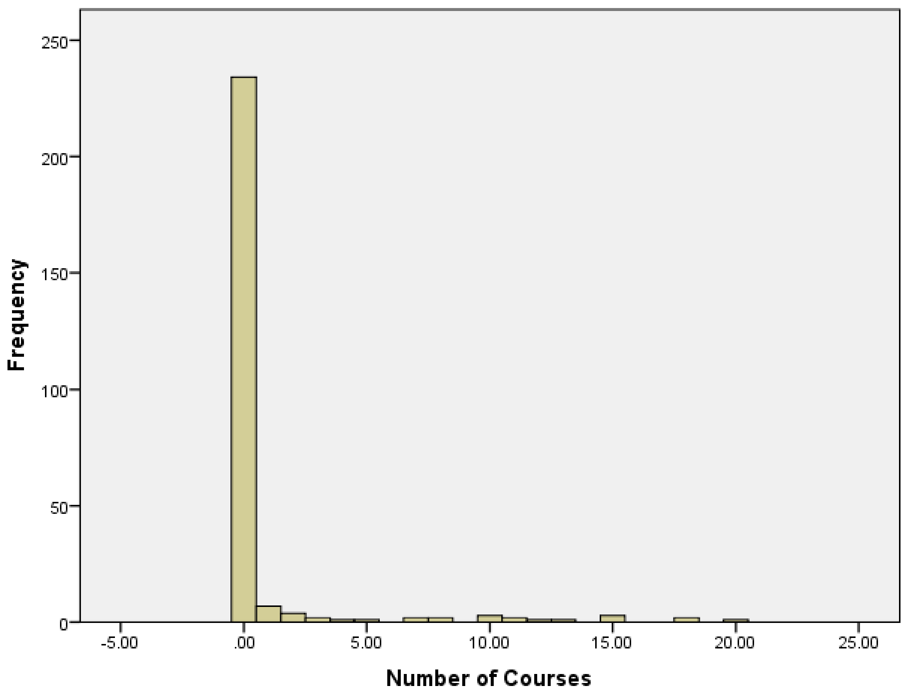

Figure 3 - Number of Courses Taught via Simultaneous Online and Face-to-Face – Distribution of Responses

Further investigation of the distributions of responses for each type of delivery method indicated that the mean number of courses taught was low (at or below 1.00) because a large number of respondents indicated they had no experience with the particular online method. An example of the distribution of responses for the Simultaneous Online and Face-to-Face option is included in Figure 3, which shows that most respondents (*n*=234) had taught no classes via this method, and only a very small number had taught one or more courses. Response distributions for Online and Hybrid / Blended course delivery were similar to the distribution for the Simultaneous Online and Face-to-Face distribution shown in Figure 3.

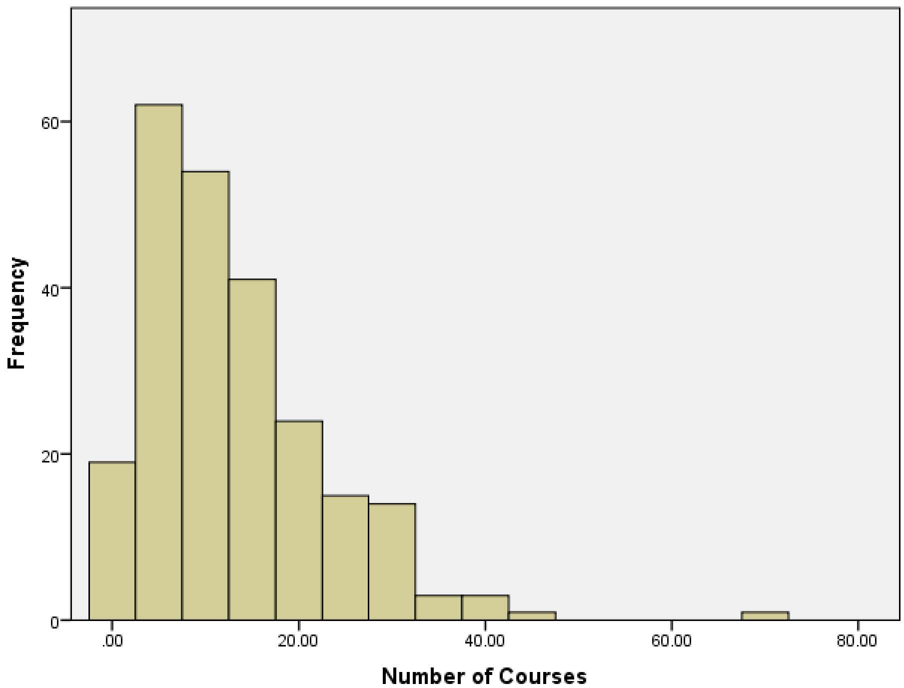

Figure 4 - Number of Courses Taught Face-to-Face – Distribution of Responses

In contrast, Figure 4 shows the distribution of responses for engineering courses taught solely face-to-face was more normally distributed, with a large proportion of respondents having taught multiple face-to-face engineering courses.

Due to the skew in the data toward face-to-face course delivery and the number of respondents that indicated that they had not taught any courses via any of the online delivery methods, the experience data was copied and recoded to allow simple comparisons of responses based on whether the faculty member had no online teaching experience or had taught at least one course via any online method. Basically, the data was recoded from a continuous set of numeric variables indicating to number of courses by type to a simple categorical variable indicating either the respondent had 'some online' or 'no online' experience. The recoded data shows 69.9% of respondents claimed to have no online teaching experience, while 30.1% claim to have taught at least one course using one of the online delivery methods.

Based on the literature concerning the importance of engineering labs and the potential perception of difficulty of delivering lab exercises online, one additional demographic question was included concerning the amount of faculty experience with engineering labs. However, instead of asking for the number of courses delivered via a particular online or face-to-face method, the survey question asked for respondents to estimate the proportion of courses in their engineering program that use one of four lab delivery methods: On-campus hands-on labs, remote labs, virtual or simulated labs, or if their program had no lab courses at all. The proportions were to be reported as percentages of total time with the total for all responses to equal 100%. Upon review of the survey data, a large number of respondents reported that their programs only had hands-on labs. In addition, some respondents seemed to be confused by the request for percentages of total time instead of number of courses, and the fact that the question asked for an estimation of the percentage of labs within a program instead of the experience of the individual faculty respondents. This variation in the type of responses raised doubts about its accuracy and reliability and made the information collected essentially useless for comparison and analysis of other survey responses. Therefore, this question was dropped and further analysis was not performed using this data.

INTERVIEWS

For Phase II, a purposefully selected representative sample of 10 engineering faculty members were interviewed. One question on the survey administered in Phase I asked if the respondent was willing to participate in a short interview related to online engineering education and to provide an email address. Of the 266 usable respondents to the survey, a total of 70 respondents agreed to a follow-up interview and provided an email address. The potential interview subjects were grouped and sorted by primary demographics relevant to the initial survey results. The two demographic groups with the most significant findings in the survey portion were whether the respondent had experience teaching online courses and whether they primarily taught undergraduate or graduate courses. Therefore, these were the primary selection criteria for potential interviewees.

Table 5

Demographics of Interview Subjects

Teaching Level	**Online Experience**	**Gender**	**Public / Private Institution**	**Engineering Discipline**
Undergraduate	None	M	Public	Electrical
Undergraduate	None	M	Public	Civil
Undergraduate	None	M	Public	Chemical
Undergraduate	Some	M	Public	Nuclear
Undergraduate	Some	M	Private	Electrical
Undergraduate	Some	M	Public	Civil
Graduate	None	M	Public	Civil
Graduate	None	M	Public	Electrical
Graduate	Some	M	Private	Software
Graduate	Some	F	Public	Petroleum

Of the 70 survey respondents that had initially expressed interest, ten individuals were purposefully selected to represent the matrix of experience and teaching level variables as shown in Table 5. More undergraduate faculty respondents were selected due to the overall higher rate of undergraduate responses to the survey. An attempt was made to balance individual demographics such as gender and age, and institutional demographics, such as large and small programs, public and private institutions, and engineering disciplines, when selecting interview respondents.

Eight of the initial ten potential interviewees responded to the invitation and agreed to be interviewed. The two individuals that did not respond were from the Undergraduate / No Online group. Therefore, two additional potential interviewees who met the criteria were invited, and both accepted.

Institutional review board (IRB) approval was obtained prior to commencing the study (See Appendix E). As part of the interview protocol, each respondent was provided the informed consent document and the interview instrument prior to the interview. At the start of the telephone interview, each respondent verbally consented to participate and to be recorded for this research. The interview protocol also granted the respondents confidentiality; therefore, they will be referred to by their demographic information only. References to particular institutions have also been redacted and are indicated as such in any quotations as necessary. All electronic and physical data have been kept secure, and even though interviews were recorded, all interview data, transcriptions, and analysis have been kept secure and confidential and individuals have not been identified in this report.

Data Sources

This study consisted of two phases: Phase I, during which the survey was administered; and Phase II, during which the selected group of participants were interviewed. This combination of survey and interview data provided a comprehensive view of faculty perceptions of online learning in engineering education from multiple perspectives.

SURVEY

Phase I of this study consisted of a survey of engineering faculty. The online survey instrument was developed to collect data to address the primary research question.

The survey items were developed based on prior research and theories related to technology adoption, engineering education, online courses in general, and online engineering courses in particular as described in Chapter 2.

The survey consisted of five major sections. The first section consisted of the introduction to the survey and the collection of individual and institutional demographic information. The second section explored respondents' general perceptions about learning and teaching in an online environment and of whether certain topics can be effectively delivered in online courses. Sections three and four explored the concepts of perceived importance and effectiveness from the UTAUT and TAM models of technology adoption as applied to the important aspects of engineering education identified in the review of the literature. Section three asked respondents about their perceptions of the importance of various educational aspects and pedagogical methods used in engineering courses and section four gathered perceptions of effectiveness of the same factors as section three in relation to their use in engineering courses delivered online. Finally, section five explored perceptions of faculty support and barriers to implementation of online engineering courses. The full survey instrument is included as Appendix A.

The first section consisted of the introduction to the survey providing information about the methods and IRB requirements and nine questions designed to collect individual and institutional demographic information, such as age, gender, undergraduate or graduate focus, engineering discipline (civil, mechanical, electrical, etc.), type of institution (public or private), size of engineering program in terms of total enrollment, delivery method of engineering labs (face-to-face, remote, virtual or simulations), and experience with online courses as indicated by number of engineering courses taught by delivery method (online, blended, face-to-face, and simultaneous). These various demographic factors have been shown to be relevant in various models of technology adoption such as the UTAUT (Venkatesh et al., 2003) as well as in other research into adoption and implementation of online classes (Allen & Seaman, 2008, 2010, 2011, 2013, 2014; Osborne et al., 2009).

Sections two through five of the survey contained the non-demographic perception questions. In general, these questions were delivered as statements with responses provided via a 5-point Likert scale (1=Strongly Disagree, 5 = Strongly Agree). The 5-point scale was selected to follow the format used in other research upon which this work is based. While respondents had the option to not answer an item, there was no option for 'not applicable.' Each survey item was designed to be independent and considered to represent a single factor. Due to instrument length and the number of different factors being researched, there were no intentionally redundant items for each concept. This is based on the use of individual items in similar research (Allen & Seaman, 2008, 2010, 2011, 2013, 2014; Osborne, 2010; Osborne et al., 2009).

The second section contained two main questions, each with multiple sub-items. The first question was based on a survey instrument developed by Osborne et al. (2009) to investigate general faculty perceptions of online courses. Since the research by Osborne et al. did not focus specifically on engineering courses, but rather included participants from social science programs, appropriate modifications were made as needed to adapt to this research topic. Many of these questions or variations were also used in the pilot study. There were 16 individual items presented in a list, with each phrased as a statement and responses measured using a 5-point Likert scale (1=Strongly Disagree, 5 = Strongly Agree). An example of this question and its sub-items is as follows:

What are your perceptions of online courses in general?

- Online courses in engineering are easier for students than face-to-face courses.
- Online courses in non-engineering topics are easier for students than face-to-face courses.

The second question contained six sub-items phrased as statements to gather perceptions of which general types of topics can be effectively taught online, such as technical topics, engineering design, or courses heavy in mathematics. Responses were on a 5-point Likert scale (1=Strongly Disagree, 5 = Strongly Agree). An example of this question and its sub-items is as follows:

Can these topics be effectively delivered in online courses?

- Engineering theory courses can be effectively taught online.
- Engineering design courses can be effectively taught online.
- Engineering labs can be effectively taught online.

The third section consisted of a single question intended to explore the importance of certain factors in engineering education in general, and not only in an online context. These factors were developed based on information from the literature concerning important aspects and pedagogical approaches used in engineering education, such as design projects, labs, and real-world problems, as presented and discussed in Chapter 2. The question listed the 16 factors and asked the respondent if they are considered to be important in engineering courses. All responses were provided on a 5-point Likert scale

(1=Strongly Disagree, 5 = Strongly Agree). An example of this question and its sub-items is as follows:

This item is important in teaching ENGINEERING courses.

- Project-based learning activities
- Lab activities
- Team activities

The fourth section was similar to the third section, consisting of a single question intended to explore the perceived effectiveness of the same 16 factors included in section three as they relate to the online delivery of engineering courses. Perceived effectiveness is a significant factor in the adoption of technologies as per the UTAUT model (Venkatesh et al., 2003). All responses were provided on a 5-point Likert scale (1=Strongly Disagree, 5 = Strongly Agree). The items related to effectiveness, when combined with the items in section three relating to importance, allowed for comparisons and identification of factors that might be barriers to implementation of online courses in engineering. An example of this question and its sub-items is as follows:

This item can be effectively delivered or performed in an online format for ENGINEERING courses:

- Project-based learning activities
- Lab activities
- Team activities

The fifth section explored various issues related to faculty support and potential barriers to implementation of online courses as described in the literature in Chapter 2 and incorporated some specific items from other survey instruments (Allen & Seaman, 2008, 2010, 2011, 2013, 2014). This section included 11 sub-items phrased as statements and rated on a 5-point Likert scale (1=Strongly Disagree, 5 = Strongly Agree). An example of this question and its sub-items is as follows:

What are your perceptions of support or barriers in teaching online courses?

- It takes more time and effort to teach an online engineering course than a face-to-face course.
- Faculty have appropriate technical support to develop online engineering courses.

INTERVIEWS

Phase II of this research consisted of semi-structured interviews based on significant and interesting findings from Phase I. After the collection and evaluation of the data from Phase I, interview questions for Phase II were developed to further explore and expand upon interesting or challenging findings from Phase I. These interviews helped explain and expand the understanding of the statistical results using the rich data provided by the individual real-world experiences and opinions of engineering faculty members. A similar process was implemented and found to be effective in the pilot study.

The interview consisted of eleven items: three regarding introductions and demographics, seven items exploring significant results from the quantitative survey, and an open-ended question at the end of the interview to allow respondents the option to share any additional thoughts about online engineering education. Some of the interview items consisted of sub-questions on a particular topic as needed to fully explore the survey results. The full interview instrument is included as Appendix B. Examples of questions from the interview instrument are as follows:

- The final section of the survey asked about specific barriers to implementation of online engineering courses or programs. What do you think about the following results and why?
  a. Respondents felt that faculty are not being compensated for developing and teaching online engineering courses.
  b. Respondents felt that faculty are not receiving appropriate training in the development of online engineering courses.
  c. Two questions correlate and indicate that a lack of acceptance by faculty is a barrier and that faculty do not accept the value and legitimacy of online engineering education.

Once the interview questions were developed, all interviewees received the same items via the same interview protocol. The interviews were semi-structured with initial prepared questions as indicated and asked of all interviewees. Follow-up questions were asked by the interviewer as needed for additional clarification, to expand on a topic, or to further explore a response. The final interview questions are included as Appendix B.

Data Analysis

This research used a two-phase sequential explanatory mixed methods design. This resulted in two data sets – survey results from Phase I and interview results from

Phase II. Each type of data has been analyzed using different methods. As the research question is not focused on hypothesis testing but is rather exploratory and explanatory in nature, all analyses were focused on looking for comparisons between groups of respondents and identifying any significant underlying or emergent factors that may contribute to or explain the gap in implementation of online engineering.

SURVEY

Survey results from Phase I were downloaded from the online survey tool and analyzed utilizing the SPSS 22 statistical analysis software to explore trends, relationships, and interactions between survey items, primary respondent groups, and demographic characteristics.

Data was analyzed to compare responses between different groups and demographic characteristics and to explore possible interactions between factors (Sapsford, 2007). Summary statistics were calculated and reviewed for each response item.

The survey items were constructed independently to assess individual potential factors. To determine if there were underlying factors that would allow the combination of survey items a factor analysis was performed in SPSS. All 65 items in the survey were included in the factor analysis and results indicated that there were 18 factors identified at an eigenvalue > 1.0. A review of the components of each potential factor did not provide for any clear or meaningful definition that would enhance understanding for this analysis. In addition, this large number of factors did not necessarily improve the analysis or make the development and use of a Likert scale a reasonable approach. Therefore, each item is considered to be independent for the purposes of this exploratory analysis.

Table 6

Data Analysis Methods

Independent Variable	**Dependent Variable(s)**	**Analysis**	**Comment**
All Demographic Variables	None	Summary Statistics	Summarize respondent demographics
Gender	Perception Responses *	Independent t-test	Examine influence of gender on survey responses.
Age (bracketed)	Perception Responses *	ANOVA	Examines influence of age on survey responses.
Level (Undergraduate / Graduate)	Perception Responses *	Independent t-test	Compare experiences of undergraduate and graduate faculty members.
Program Area / Engineering Discipline	Perception Responses*	ANOVA	Examine influence of engineering discipline on survey responses.
Institution Type (Public / Private)	Perception Responses *	Independent t-test	Examine influence of institution type on survey responses.
Experience (no online / some online)**	Perception Responses	Independent t-test	Examine influence of experience on survey responses.
Perception Response Comparisons	Two dependent variable questions	Paired t-test	Comparison of results of two survey response questions

Note. *Perception responses are ALL Likert items in sections 2-5 of the survey; **Experience level was re-coded during analysis from ordinal groups to a single two-state categorical variable (no online experience / some online experience)

Due to the large number of statistical analyses in this study there is the potential for compounding of error. To address this issue, a conservative confidence interval level of 99% (p=0.01) was used for all comparative statistical analyses (Armstrong, 2014).

Individual demographic data (age, gender, experience levels, program level, and engineering discipline) and institutional demographic data (institution type, program size) were the independent group variables for the data analysis. In all cases except for one, the independent variables were categorical (e.g. gender, graduate/undergraduate, program area). Independent variables with an underlying continuous nature (program size, age) have been grouped and converted to ordinal categorical data. The only continuous independent variable was the number of courses taught via each method (face-to-face, blended, online). However, after initial analysis, this data were recoded into a two group categorical variable (no online experience / some online experience),

The survey questions concerning faculty perceptions were the dependent variables. The dependent variables were all 5 point Likert items (1=strongly disagree, 5=strongly agree). Summary results for all independent variables have been tabulated and measures of central tendency have been calculated for dependent variables using mean and standard deviation. Comparisons between two categorical groups use independent sample t-tests, comparisons between three or more groups use a one-way Analysis of Variance (ANOVA) and comparisons of dependent variable questions utilize paired sample t-tests (Allen & Seaman, 2007; Sapsford, 2007). Data analysis methods are summarized in Table 6.

The first series of analyses calculated summary statistics for each demographic group to understand the distribution of respondents. The second series of analyses compared each independent categorical group demographic variable against all dependent perception variables to identify differences between groups. Gender and experience were moderating factors in the UTAUT model (Venkatesh et al., 2003); therefore, these independent variables were compared against each individual perception item utilizing an independent samples t-test to determine whether there were any significant effects based on these factors. Age was also a moderating factor in the UTAUT model and was analyzed using a one-way analysis of variance (ANOVA) due to the multiple levels of the age variable collected in the demographic section of the survey. Teaching level was compared due to the difference in adoption and implementation rates between undergraduate and graduate level online engineering programs and to explore what factors might influence or result from this difference.

In addition to these factors related to the individual faculty members, independent variables related to the institutions were analyzed. Some types of engineering practice are more related to computers or electronics while others are generally considered to be related to the physical world (e.g., civil and structural engineering). Therefore, engineering disciplines were compared using a one-way ANOVA to explore if any factors were related to a specific branch or branches of engineering practice. Institution type and program size were analyzed to explore whether potential differences in resources or programs had any influence on the factors related to implementation of online engineering programs. Finally, related survey questions, such as the importance and effectiveness of individual pedagogical methods, were compared using paired t-tests to determine whether there were any significant differences. All significant results have been noted and additional review and analysis included as necessary.

INTERVIEWS

The interviews were transcribed and the transcripts coded by the author using the constant comparative method and an open coding scheme, looking for emergent themes and concepts within responses to individual questions as well as across the entire interview (Strauss & Corbin, 1998). Transcripts and coding information was recorded and combined using the NVIVO 10 qualitative analysis tool as well as a standard word processing program. After the initial round of coding, the codes were grouped axially and a second round of focused coding completed on each transcript with an eye toward emergent large-scale themes on the individual question as well whole interview levels.

All of the interviews were coded by the author only. However, to validate the coding scheme, a type of sample verification was used. This method consisted of asking three peer researchers with familiarity in qualitative coding to utilize the code list and definitions initially developed by the author and independently code two interviews. The initial sample interviews were selected as to not be similar (one was an undergraduate level professor with some online experience, the other a graduate level professor with no online experience) so as to provide a wide range of responses and potential codes. The goal was to revise any coding schemes and to add, modify, or delete any codes or coding definitions. These would then be used by the author to code the remaining eight interviews. An example of initial coding is included in Appendix D.

Since these interview questions were based on the survey results, the goal was to find large scale themes and to search for potential reasons for the survey findings from the perspectives and perceptions of the interviewees. Therefore, coding was not done on individual words or key phrases, but on entire paragraphs or 'thoughts' of the respondents. Each paragraph could therefore have multiple codes. For example, if a respondent was discussing hands-on activities and interactions between students in a lab environment and how this might promote interest in engineering and therefore might impact their motivation to take online courses, codes such as 'hands-on', 'labs', motivation', 'student-student interaction', and 'pedagogy' might be coded for the paragraph.

As a result, the compilation of the results from the three peer reviewers and the author created a large number and broad range of codes for each paragraph. In some cases, codes matched exactly; however, more often than not there were similar but not exact matches for an individual paragraph. Also, there were instances of agreement between two or three reviewers, but not all four, and there were a few examples of the need for revised or additional codes.

The next step was to look at the entire set of responses and codes and look for similarities. The code list was re-grouped axially and simplified from an initial list of 53 individual codes to 7 grouped axial codes. These axial codes represent the overarching themes represented by the initial codes (Creswell & Clark, 2007). A summary of axial codes and their meanings is included in Table 7. A full list of initial and axial codes is included as Appendix C, and an example of coding on interview text is included as Appendix D.

Table 7

Axial Coding Groups and Definitions / Themes

Axial Code Group	**Definitions / Themes**
Concern or Need (for faculty)	Economics (Pay), Obsolescence, Ownership / Intellectual Property, Security, Workload
Engagement and Interaction	Interactive, Student Engagement, Student / Instructor Interaction, Student / Student Interaction
Experience	Age, Distance Ed, Experience, Future, Traditional
Interest and Motivation	Acceptance, Comfort, Interest, Motivation
Stakeholders	Administration, Availability, Companies, Market, Off-Campus, Work at Home
Support	Development Support, Economics (Program Costs), Infrastructure – Resources, Infrastructure – Technical, Resources, Technical Support, Training
Technology and Pedagogy	Asynchronous, Blended, Capstone, Curriculum, Design, Flipped Class, Hands-On, Labs, Lecture, Math, Modules / Chunking, Quality, Replication, Redesign, Simulation, Synchronous, Teams, Video

The initial two interviews were recoded using these axial codes across all peer reviewers. Using this method, there was a high degree of agreement between reviewers, validating the code list developed. After this list was finalized and the initial two interviews validated, the author used the code lists and independently coded the remaining eight interviews.

After both phases were complete, the statistical quantitative data from the survey was combined with the qualitative interview information and synthesized to address the research question. Quantitative data results have been presented along with supporting or expository interview quotations and narrative text for relevant and significant results related to the research question. This combination of methods and results provide a more complete picture of student and faculty perceptions of online engineering education.

Trustworthiness

Qualitative research methods, such as interviews, are evaluated differently than quantitative statistical research. As this data is collected from individuals and evaluated and interpreted by the researcher, both the producers and consumers of the data want to be assured that the findings can be believed and trusted (Merriam, 2002). To protect from and mitigate potential researcher bias, and therefore enhance trustworthiness of the research, credibility, dependability, transferability, and confirmability must be addressed (Erlandson, 1993; Miles, 1994).

Credibility

Credibility in qualitative research refers to the accurate representation of the perspective of the research participants. This can be demonstrated through prolonged engagement, persistent observation, triangulation, peer debriefing, and member checking (Erlandson, 1993; Tashakkori & Teddlie, 1998). In this study, several of the above methods were used. Due to the short duration and limited scope of the interviews, the first two methods were not used. The engagement of multiple faculty member participants and the comparison with the statistical results from the survey section allowed for triangulation of findings.

Using the coding validation method mentioned in the previous section, a measure of inter-rater reliability was determined for the initial two sample interviews. After initial coding by all peer reviewers and then axial recoding, the first interview ended up with 69 total coding sections, and 66 of the 69 had substantial agreement in coding for an inter-rater reliability of 95.65%. The second interview had a total of 44 coding sections, with 42 of 44 matching for an inter-rater reliability of 95.45%.

To address the five coding sections that did not have agreement, the axially coded paragraphs were returned to the peer reviewers for reconsideration. Ultimately, review and recoding brought four of the five into alignment, for a total inter-rater reliability of 99.11% for the two sample interviews.

Dependability

The ability to replicate research and arrive at a similar outcome or results is referred to as dependability or reliability (Erlandson, 1993; Merriam, 2002). Due to the interpretative nature of qualitative research, dependability is also the ability to track and confirm the procedures were followed and resulted in reliable research. As this study included a selected and representative subset of faculty for interviews, it is likely that replicating the interview portion of this study with different participants would provide somewhat different results in terms of narrative content. Each individual response is relevant to the experiences of the participant. In addition, online course delivery is a quickly developing area in education and future interviews with engineering faculty may provide different insights into the conditions at that time. However, dependability can be addressed through the use of a selected demographic representation and cross-section of the population and clear documentation of the interview instrument and processes. Including multiple participants in this study has made triangulation and cross-checking possible to help verify that the conclusions drawn from the interview and analysis process are reliable and dependable.

Transferability

Transferability is the ability of the results of particular research to be generalized or applied to different contexts (Tashakkori & Teddlie, 1998; Merriam, 2002). This can be a challenge for qualitative research as studies can be focused on descriptions or observations of a particular phenomenon or individual case. In this research, transferability and generalizability were addressed through the mixed methods approach. The results of the qualitative interview section are not stand-alone results, but have been triangulated and integrated with the quantitative survey results to form a composite research outcome. Providing a rich, thick description of the interview responses and context allows consumers of this research to understand whether the outcomes are relevant and transferable to their particular context (Merriam, 2002). Beyond the transferability of particular research results, the research methodology and underlying framework may be relevant to research in distance education or future engineering education research.

Confirmability

Confirmability is the degree to which the findings and the interpretations of the research are supported by the data and are not attributable to the biases of the researcher (Erlandson, 1993; Tashakkori & Teddlie, 1998). Basic interpretive qualitative research inherently involves both the participants and the researcher. While attempts can be made to minimize the potential bias included in data analysis, explicit clarification of potential researcher biases, positions, and perspectives, as well as transparency to the data sources, is important to enhance confirmablity. Triangulation with the quantitative research results in this mixed methods study support confirmability of the qualitative results.

CHAPTER 4: RESULTS

Chapter 4 is organized to present the data, analyses, and information gathered during the study. This research study employed a two-phase sequential explanatory mixed methods design (Creswell & Clark, 2007). In the first phase, survey data was collected and analyzed to identify significant items and demographic comparisons. In the second phase, interview questions were developed from the survey results to further explore and expand on potential barriers or reasons for the gap in online engineering education. This chapter presents the significant quantitative results from the various survey sections and the related qualitative interview results together to provide a more in-depth picture of the various important factors and themes from this research.

General Perception of Online Education

After the introductory demographic questions, the first main section of the survey included two questions related to faculty perceptions of online courses in general. The first question consisted of sixteen five-point Likert items based on a survey instrument developed by Osborne et al. (2009) and modified to pertain to the study topic of engineering education. Many of these questions or variations were also used in the pilot study (Kinney, Liu, and Thornton, 2012). The second question consisted of six items pertaining to respondent perceptions of whether certain topics can be effectively taught online.

Table 8

General Perception Questions – Descriptive Statistics

Question	Mean	Standard Deviation
Online courses in engineering are easier for students than face-to-face courses.	2.49	0.981
Online courses in non-engineering topics are easier for students than face-to-face courses.	3.07	0.884
Learning outcomes are comparable in online and face-to-face engineering courses.	2.60	1.126
Learning outcomes are comparable in online and face-to-face non-engineering courses.	2.81	0.998
Students are less willing to 'speak their mind' in an online class than in a face-to-face class.	3.08	0.945
Students communicate more in an online class than they do in a face-to-face class.	2.56	0.859
Online courses require more time for students to complete successfully than face-to-face courses.	2.91	0.883
Face-to-face classes provide better opportunities for students to interact than online classes.	4.25	0.917
Student and faculty interactions are more effective in face-to-face classes than they are in online classes.	4.32	0.819
More problems occur in online courses than face-to-face courses.	3.37	0.849
More students withdraw from online courses than face-to-face courses.	3.34	0.841
Students who procrastinate should not take an online course.	3.89	0.929
Students require more discipline to succeed in online courses.	4.07	0.787
Online courses can be taught just like face-to-face courses.	1.97	0.983
Online courses require changes to standard face-to-face course content.	3.68	1.049
Online courses require changes to standard face-to-face teaching methods.	4.15	0.838

Note. Likert scale range from 1=Strongly Disagree to 5=Strongly Agree.

Descriptive statistics were calculated for each item and are included in Table 8. The Likert scale for each question ranged from 1=Strongly Disagree to 5=Strongly Agree. Each question was plotted as a histogram to evaluate the shape of the distribution and a Q-Q Plot was generated to evaluate for normality. All responses included in Table 8 were normally distributed except for “Face-to-face classes provide better opportunities for students to interact than online classes” and “Student and faculty interactions are more effective in face-to-face classes than they are in online classes,” which were highly skewed toward the top of the scale indicating that most respondents feel strongly that interactions between faculty and students as well as between students are more effective in a face-to-face class.

Two pairs of questions within this series were included to explore whether engineering faculty felt there is something different about engineering and non-engineering courses, which ties in to the original premise of the research question. The first two questions, “Online courses in engineering are easier for students than face-to-face courses” and “Online courses in non-engineering topics are easier for students than face-to-face courses”, and the second two questions, “Learning outcomes are comparable in online and face-to-face engineering courses” and “Learning outcomes are comparable in online and face-to-face non-engineering courses”, were asked as pairs to allow a direct comparison of responses. Analysis of the first pair of questions using a paired samples t-test indicated a significant difference in responses; $t(263)=-10.431$, $p<0.001$. The comparison of the results from the second pair of questions using the same analysis method also indicated a significant difference in responses; $t(260)=-5.061$; $p<0.001$. The results of the comparison of these two pairs of questions indicated that engineering faculty members felt that online courses are easier and outcomes were better for non-engineering courses than for engineering courses. However, the results did not indicate what information these perceptions are based upon or why respondents believed engineering courses were different.

For the rest of the questions in the first section, most of the responses have mean values that are at or near the center of the response range. However, a few results were worth noting as being particularly high or low. The lowest rated response indicated that most respondents disagreed that "Online courses can be taught just like face-to-face courses"; (*M*=1.97, *SD*=0.963). This result aligns with another question where respondents strongly agreed that "Online courses require changes to standard face-to-face teaching methods"; (*M*=4.15, *SD*=0.838). The two highest rated items were related to interactions, with respondents strongly agreeing that "Student and faculty interactions are more effective in face-to-face classes" (*M*=4.32, *SD*=0.819) and that "Face-to-face classes provide better opportunities for students to interact" (*M*=4.25, *SD*=0.9.17). The last highly rated result indicated that respondents agree that "Students require more discipline to succeed in online courses"; (*M*=4.07, *SD*=0.787).

Table 9

General Perception Items by Undergraduate / Graduate Faculty

Survey Item	**Undergraduate Faculty**		**Graduate Faculty**				
	M	***SD***	***M***	***SD***	***df***	***t(df)***	***P***
Online courses can be taught just like face-to-face courses.	1.85	0.847	2.20	1.116	138.9*	-2.656	0.009
Engineering design courses can be effectively taught online.	2.24	1.104	2.67	1.152	261	-2.941	0.004
Engineering lab courses can be effectively taught online.	1.74	0.931	2.07	1.003	260	-2.660	0.008

Note. Likert scale range from 1=Strongly Disagree to 5=Strongly Agree. Levene's Test for Equality of Variances indicated that equal variances could not be assumed for this item.

Independent samples t-test comparing responses of undergraduate and graduate faculty members with the results of the general perception section of the survey identified several significant differences ($p<0.01$) as shown in Table 9. The first item in this series that showed a significant difference between undergraduate and graduate faculty responses related to whether online courses could be taught just like face-to-face courses. However, in this case both undergraduate and graduate faculty indicated that they disagree strongly that online courses can be taught like face-to-face courses. While the overall low rating may be related to the research question, the difference between undergraduate and graduate faculty responses may not.

For the final two items in Table 9, there were differences in undergraduate and graduate level faculty responses concerning whether design courses and engineering labs can be taught online. While the tests showed there was a statistically significant difference, both groups responded negatively toward both of these items, indicating overall disagreement that engineering design courses and labs can be effectively taught online.

The differences in responses between undergraduate and graduate level faculty prompted the inclusion of a question in the interview phase of the study related to exploring these differences. Two predominant themes emerged from the interviews. The first involved a perceived difference in student motivation and maturity between undergraduate and graduate students. The second posited that engineering labs were more prevalent at the undergraduate level and that labs require more interactive and hands-on approaches, which some felt were difficult to deliver online.

Six of the ten interviewees felt that graduate students were more highly motivated and mature learners and that undergraduate students needed more attention, remediation, and interaction. An undergraduate professor with online teaching experience summarized this general opinion, stating:

> With graduate students I think you have a more mature and engaged student. A graduate student typically is a self-motivated learner….Whereas, an

> undergraduate has to be a little bit more guided and prompted. And sometimes an undergraduate doesn't know how to learn on their own.

They go on to explain why online courses might be more effective at the graduate level:

> If you try to deliver the course in the same way, I can see very easily why a graduate instructor would see that distance learning might be more effective because they are thinking of it in the paradigm of kind of how they traditionally would teach a course….And it gets back to the point where I think we really have to rethink how we do the courses where you can get around these obstacles once you acknowledge there is a difference in learning styles between those two populations.

This insinuates that online courses may inherently require more self-motivation and a certain level of responsibility that may fit a graduate student profile but be lacking at the undergraduate level.

A twist on this theme was raised by a graduate faculty member who had not taught online, noting that a certain level of achievement can be assumed for graduate students, whereas "undergrad seems like the starting point is kind of all over the place. And if the students start asking a lot of basic questions, it could be pretty difficult to deal with online." Therefore, not only was student motivation and maturity a concern, but undergraduate students may need more interaction and remediation, which some believed to be more difficult to deliver online.

A second theme was noted by several interviewees who mentioned that engineering labs were more prevalent at the undergraduate level, and since labs require more interactive and hands-on approaches, they were more difficult to deliver online.

Therefore, undergraduate instructors may have a more negative perception of online labs. One undergraduate professor who had not taught online stated:

> I think the concern about undergraduates is that you have a lot of lab courses and you really have to have hands-on approaches on that. I just don't see how you teach a lab course like that online, I really don't see how it can happen.

A graduate professor that also had not taught online compared undergraduate and graduate lab experiences, stating that his "experience in the undergraduate labs is that the students typically need a lot more guidance in the operation of the equipment….I think that graduate students are typically assumed to have most of those skills in hand." These comments echoed the previous concerns mentioned about labs and the need for interaction.

The comparison via independent samples t-tests of the general perception question items against whether respondents taught at a public or private institution revealed one statistically significant difference. The item related to whether engineering theory could be taught online showed a difference (public institution: M=3.18, SD=1.156; private institution: M=3.73, SD=0.828; $t(44.9)=-3.284$, p=0.002). However, both means were on the positive or 'agree' side of the scale and respondents from private institutions rated the item more positively than those from public institutions. While survey and interview responses do not explain why this might be so, the differences in public and private institution resources, program sizes, etc. may play a role in determining the perceptions of faculty and the implementation of online engineering programs at the individual institutions.

Table 10

General Perception Items by Online Experience Level

Survey Item	No Online Experience		Some Online Experience				
	M	***SD***	***M***	***SD***	***Df***	***t(df)***	***p***
Learning outcomes are comparable in online and face-to-face engineering courses.	2.37	0.996	3.14	1.227	124.3*	-4.941	<0.001
Learning outcomes are comparable in online and face-to-face non-engineering courses.	2.69	0.938	3.11	1.074	262	-3.244	0.001
Online courses can be taught just like face-to-face courses.	1.85	0.848	2.24	1.150	117.5*	-2.679	0.008
Online courses require changes to standard face-to-face course content.	3.80	0.946	3.40	1.218	121.8*	2.624	0.010
Engineering theory courses can be effectively taught online.	3.01	1.101	3.79	1.027	160.0*	-5.566	<0.001
Engineering design courses can be effectively taught online.	2.18	1.068	2.93	1.178	137.5*	-4.880	<0.001
Engineering labs can be effectively taught online.	1.70	0.880	2.24	1.094	125.3*	-3.865	<0.001
Technical /scientific topics can be effectively taught online.	2.94	1.059	3.74	0.990	263	-5.733	<0.001
Courses heavy in mathematics can be effectively taught online.	2.83	1.100	3.64	1.046	263	-5.588	<0.001
Non-engineering courses can be effectively taught online.	3.37	0.912	3.83	0.839	263	-3.839	<0.001

Note. Likert scale range from 1=Strongly Disagree to 5=Strongly Agree. * Levene's Test for Equality of Variances indicated that equal variances could not be assumed for this item

The comparison via independent samples t-tests of faculty experience with online education versus the responses for the general survey questions identified a number of significant results as shown in Table 10. The first two of the items in this section were related to learning outcomes. In each instance, respondents with no online experience disagreed that learning outcomes are similar in online and face-to-face classes, whether in engineering or non-engineering, and rated engineering courses more negatively than non-engineering. In contrast, those with at least some online teaching experience tended to agree that learning outcomes are similar for online and face-to-face courses. This is a significant outcome directly related to the research question in that those that have not taught an online course feel negatively that educational outcomes can be achieved online. Therefore, they may be reluctant to teach or implement online courses or online learning methods, especially in engineering subjects.

A question was included in the Phase II interview section to explore why faculty with some online experience felt more strongly that learning outcomes were comparable, while those with no online experience disagreed and said they were not comparable. An undergraduate professor with online experience opined that respondents with no experience may simply be assuming that online courses are not effective. He stated his "suspicion that self-selection – people that really believe that learning outcomes are not comparable are going to choose not to teach any online."

In contrast, a different theme was shared by three interviewees spanning both the undergraduate and graduate and experience spectra. In summary, they felt that a well-designed online course could have comparable learning outcomes to a face-to-face course. An undergraduate faculty member with some online experience noted that "if you design the class properly, you can have similar outcomes. Probably some of the [survey] response could be biased about how we traditionally put courses together in the past", adding that "you really have to understand the learning objectives and what you want the students to get out of the course and think about how to design properly." A graduate professor with no online experience said an online course could be a challenge, "but you can make the learning experience just as effective." Finally, a graduate engineering professor with online teaching experience stated that "once the criteria was similar … it was hard to tell the difference."

Additionally, instead of directly discussing learning outcomes, several interviewees provided feedback concerning proxies for learning outcomes, such as one graduate instructor with no online experience who noted that attendance was better in online courses, implying that this might somehow be related to learning outcomes. At least two other respondents noted that resistance to change can have an impact on faculty perception of outcomes. One undergraduate professor with no online experience stated

> it is a new thing and… academics maybe more than some other groups, could be resistant to change. You don't really see the possibilities until you have actually done that, and so, people who have done it have a better feeling about it than people who haven't.

The survey item related to whether online and face-to-face courses could be taught the same way showed a statistically significant difference between the response groups with both groups strongly disagreeing with the premise of the question. The respondents with no online experience rated the question more negatively, meaning that they felt more strongly that online courses could require changes to their teaching methods.

For the item relating to whether online courses require changes to standard face-to-face course content, survey results showed that both experience groups agreed and those with no online experience felt more strongly that changes are necessary. This result is comparable to the previous question in that respondents with no online experience felt that both their teaching methods and the content would need to change to present a course online, which could be a reason to not pursue an online course.

The analyses of the remaining items in Table 10 showed a significant difference between those with online experience and those without. In each case, respondents with at least some online experience rated the item more highly, i.e. they agreed more strongly that the topic could be taught online. In some cases, such as engineering theory, both groups felt generally positively about teaching the topic online, while in others such as labs and design courses, both groups felt negatively. In the rest of the topic areas, respondents with no online experience disagreed the topic could be taught online while those with experience felt positively about it. It is also important to note the results of the last item related to teaching non-engineering online. While respondents may or may not have experience teaching non-engineering courses, both groups agreed that non-engineering courses can be effectively taught online (M>3.0). The contrast between this result and results on the labs and design course items could be an important perception related to the gap between the implementation of online courses in engineering and other fields, at least from the perspective of engineering faculty.

Table 11

Effective Delivery of Certain Topics – Descriptive Statistics

Question	Mean	Standard Deviation
Engineering theory courses can be effectively taught online.	3.24	1.136
Engineering design courses can be effectively taught online.	2.40	1.152
Engineering labs can be effectively taught online.	1.86	0.979
Technical/scientific topics can be effectively taught online.	3.18	1.100
Courses heavy in mathematics can be effectively taught online.	3.07	1.144
Non-engineering courses can be effectively taught online.	3.51	0.913

Note. Likert scale range from 1=Strongly Disagree to 5=Strongly Agree.

Descriptive statistics were calculated for each item in the second series of questions in the General Perceptions section as shown in Table 11. These items explored engineering faculty perceptions of whether certain topics important to engineering education as well as non-engineering courses can be effectively taught online. Most responses were generally centered in the response range and are normally distributed, with respondents rating non-engineering courses higher than any of the engineering topics. The two lowest rated topics were engineering labs (*M*=1.86, *SD*=0.979) and engineering design (*M*=2.40, *SD*=1.152), which the literature showed are considered key to an effective engineering education.

Importance and Effectiveness of Online Instruction

The next two series of questions asked respondents for their impressions of the importance and effectiveness of particular pedagogical methods and topics that are employed in engineering education based on the background research. Each question asked about an identical list of sub-items. The first series asked whether each of these items was considered to be *important* in engineering education but not necessarily only in an online context. The second series asked if the same items were considered to be *effective* when delivered online. Descriptive statistics were calculated for each question (see Table 12). The Likert scale ranged from 1=Strongly Disagree to 5=Strongly Agree. Each question was plotted as a histogram to evaluate the shape of the distribution and a Q-Q Plot was generated to evaluate for normality. All questions related to importance were normally distributed. Four items related to effectiveness appeared to have bimodal distributions: project-based learning activities, interaction between students, design activities, and student presentations. All of these items show peaks at the 'Disagree' and 'Agree' responses (values of 2 and 4 on the response scale respectively).

All of the items related to importance were rated highly by respondents. This result supports the literature, as the list of survey items was composed of items that the literature indicated were important to engineering education. The most important (highest rated) methods were, in descending order: design projects, real-world problems, project-based learning activities, labs, student-instructor interaction, and hands-on activities (M>4.35). Interestingly, the lowest rated items were the learning activities most commonly related to 'traditional' face-to-face instruction, including lectures and reading texts. These results are shown in Table 12.

Table 12

Importance and Effectiveness of Pedagogical Methods Delivered Online

Pedagogical Method	**Importance in Engineering**		**Effectiveness in Online Delivery**		
	Mean	**Standard Deviation**	**Mean**	**Standard Deviation**	**Difference in Means***
Project-Based Learning Activities	4.40	0.644	2.83	1.172	1.57
Lab Activities	4.36	0.636	2.08	1.003	2.28
Team Activities	4.17	0.769	2.50	1.142	1.67
Interaction –Student & Instructor	4.36	0.606	2.67	1.085	1.69
Interaction – Student & Student	4.33	0.647	2.66	1.111	1.67
Interaction – Student & Content	4.32	0.656	3.33	0.978	0.99
Complex Equations / Mathematics	3.94	0.807	3.16	1.044	0.78
Hands-On Learning Activities	4.35	0.657	2.26	1.112	2.09
Design Projects / Activities	4.45	0.615	2.62	1.191	1.83
Ill-Structured Problems	4.10	0.706	2.99	1.135	1.11
Real-world Problems	4.43	0.642	2.80	1.167	1.63
Lectures	3.83	0.713	3.50	1.149	0.33
Reading Texts	3.87	0.784	3.83	0.953	0.04
Writing Essays / Papers / Reports	3.95	0.796	3.69	1.019	0.26
Student Presentations	4.02	0.875	2.64	1.163	1.38
Specialized Software Packages	3.97	0.836	3.38	1.050	0.59

Note. Likert scale range from 1=Strongly Disagree to 5=Strongly Agree. * Difference in Means = Mean (Importance) – Mean (Effectiveness)

In addition to descriptive statistics, corresponding questions from the importance and effectiveness series were compared using differences of means and boxplots with the goal of determining which pedagogical methods were considered important yet ineffective when delivered online. Items with this configuration of results could be considered to be potential hurdles or barriers to the implementation of engineering education online. Differences in the corresponding means are shown in Table 12.

The items with the largest difference in means between the importance and effectiveness results were labs (Δ=2.28), hands-on activities (Δ=2.09), and design projects (Δ=1.83). This indicates that these pedagogical methods were considered by engineering faculty to be important to engineering education but not effective when delivered online, and could therefore be considered potential hurdles to teaching engineering online. To further explore these important results, questions concerning these items were included in the interview instrument in Phase II of this study.

On the other end of the spectrum, traditional face-to-face pedagogical methods had the smallest differences in means between importance and effectiveness: reading texts (Δ=0.04), writing essays, papers, and reports (Δ=0.26), and lectures (Δ=0.33). The small differences in means were a result of being rated as only moderately important and also being considered to be able to be effectively delivered online.

Table 13

Importance and Effectiveness Items by Undergraduate / Graduate Faculty

Survey Item	**Undergraduate Faculty**		**Graduate Faculty**				
	M	***SD***	***M***	***SD***	***df***	***t(df)***	***p***
Effectiveness –Interaction: instructor and student	2.51	1.068	2.94	1.065	260	-3.092	0.002
Effectiveness – Hands-on Learning / Activities	2.09	1.077	2.55	1.113	260	-3.184	0.002
Effectiveness – Design Projects / Activities	2.43	1.139	2.97	1.217	260	-3.545	<0.001

Note. Likert scale range from 1=Strongly Disagree to 5=Strongly Agree. * Levene's Test for Equality of Variances indicated that equal variances could not be assumed for this item.

The importance and effectiveness of online pedagogical methods were compared against undergraduate and graduate faculty responses using independent samples t-tests. Significant results ($p<0.01$) are included in Table 13. These comparisons indicated three items with significant differences. In every case, both groups rated the items low indicating they disagreed that these items are effective when delivered online; that is, they were not considered to be effective. In every case, undergraduate faculty members rated each item more negatively than the graduate faculty group. This difference, as well as the overall low rating of each item, could be a contributor to the difference in implementation of online engineering courses and programs between the undergraduate and graduate level.

The various results indicating significant differences between responses from undergraduate and graduate faculty members bring focus to this demographic variable as an important one related to the research question. The review of the literature and the current implementation of online courses and programs predominately at the graduate level match with the general negative sentiment from undergraduate faculty respondents concerning delivering engineering courses online. One important question that was unanswered by this survey data analysis is *why* undergraduate faculty had this more strongly negative position, and by contrast, why graduate faculty had a more positive position (albeit still negative in some situations). Could it be something inherent in undergraduate coursework or curricula that does not lend itself to online delivery? Are there some characteristics of the general undergraduate student population that may impact online learning? Does the fact that graduate programs have more courses and programs already online, and therefore faculty already have experience in this area, influence the thinking and responses of graduate faculty respondents?

The comparison of engineering discipline versus the importance end effectiveness of pedagogical methods using ANOVA identified only Importance – Lab Activities as having a significant difference ($F(16, 248)=3.049$, $p<0.001$). While a statistical difference was shown, all responses fell on the agree / strongly agree side of the response scale. In general, the difference in responses for importance alone did not shed any light on the research question.

Comparing the results of the survey for the importance of online pedagogical approaches against online experience groups via an independent samples t-test showed that only the Importance – Hands-On Learning / Activities had a significant difference (no online: $M=4.42$, $SD=0.630$; some online: $M=4.18$, $SD=0.689$; $t(264)=2.881$, $p=0.004$). Both groups of respondents agreed strongly that this item was important, with those with no online experience rating the item more highly. It is interesting that a key aspect of engineering education, such hands-on activities, was found to have a significant difference. However, when combined with the outcomes in the effectiveness section, this result become even more relevant to the research question.

Comparative analysis of the effectiveness of online pedagogical methods against engineering experience using independent samples t-tests showed that every item except one (specialized software packages) had a significant difference between respondents with no online experience and those that had taught at least one online course. The results are shown in Table 14.

Respondents with no online experience rated every item in this section lower than those with some online experience. This is important in that, on the whole, it indicates an overall negative perception toward the effectiveness of online education by those with no experience, no matter what the method or tool employed, relative to those with some experience in online education. These results are directly related to the research question and point to prior online teaching experience as an important factor in the adoption or expansion of online engineering education.

Table 14

Effectiveness Items by Online Experience Level

Survey Item	**No Online Experience**		**Some Online Experience**				
	M	***SD***	***M***	***SD***	***df***	***t(df)***	***P***
Effectiveness – Project-based learning activities	2.59	1.108	3.41	1.122	262	-5.495	<0.001
Effectiveness – Lab activities	1.92	0.884	2.44	1.163	118.2*	-3.588	<0.001
Effectiveness – Team activities	2.31	1.028	2.95	1.270	123.4*	-3.980	<0.001
Effectiveness – Interaction between instructor and student	2.42	1.001	3.24	1.065	263	-5.953	<0.001
Effectiveness – Interaction between student and student	2.44	1.039	3.16	1.114	263	-5.074	<0.001
Effectiveness – Interaction between student and content	3.13	0.996	3.78	0.762	190.0*	-5.772	<0.001
Effectiveness – Complex equations / mathematics	2.94	1.014	3.67	0.930	262	-5.531	<0.001
Effectiveness – Hands-on learning / activities	1.99	0.961	2.87	1.202	122.3*	-5.762	<0.001
Effectiveness – Design projects / activities	2.35	1.096	3.25	1.171	263	-6.015	<0.001
Effectiveness – Ill-structured problems	2.79	1.088	3.47	1.107	263	-4.617	<0.001
Effectiveness – Real-world problems	2.55	1.101	3.41	1.104	263	-5.791	<0.001
Effectiveness – Lectures	3.33	1.169	3.91	0.990	172.4*	-4.152	<0.001
Effectiveness – Reading texts	3.68	1.014	4.16	0.687	212.4*	-4.490	<0.001
Effectiveness – Writing essays / papers / reports	3.53	1.063	4.05	0.799	193.7*	-4.372	<0.001
Effectiveness – Student presentations	2.49	1.102	2.99	1.235	263	-3.210	0.001

Note. Likert scale range from 1=Strongly Disagree to 5=Strongly Agree. * Levene's Test for Equality of Variances indicated that equal variances could not be assumed for this item

While for each item those with no online experience were more negative, there were some instances where both groups agreed that an item is generally effective when taught online. Other items such as interaction between students and content, lectures, writing essays and reports, and reading texts also were rated positively by both groups. In each of these cases, it could be argued that these are the activities and methods that are already commonly translated to an online format through Learning Management Systems or other commonly available tools and have been employed online for a long time, even by instructors that may consider them only supplements to a standard face-to-face course. For example, many texts are currently available in an online format, papers are written on a word processor and submitted to instructors online, and recordings of lectures are commonly available via the internet. Therefore, it makes sense that both groups would have felt comfortable with these items whether they had actually employed them or not (or whether they actually consider this to be 'online education' or just normal modern pedagogical practice).

ENGINEERING LABS AND HANDS-ON ACTIVITIES – TECHNICAL ASPECTS

A couple of items, such as labs and hands-on activities, were rated very low by respondents with and without online experience groups and exceptionally low by the group with no online experience. These results provide support that these are key items that could be considered as barriers to implementation of online engineering courses, especially by those who had not taught an online course before.

Overall, eight of the ten interviewees addressed labs and hands-on activities with responses that can be summarized by a quote from a graduate faculty member with no online experience: "How do you do hands-on if you can't actually get your hands-on?" While this question might seem rhetorical to some extent, it points out an underlying theme of the need or desire to replicate a hands-on activity or experience in an online environment.

A graduate instructor with no online experience concurred that labs can be a problem, feeling that the experiential part of engineering labs is very important. "You learn by doing…. I can see why people ranked them low just because I think they're probably better done in a classroom environment or in a lab type of environment." A graduate professor with some online experience stated that "it's very hard to capture in learning objectives [things like] washing your hands after you have been handling chemicals or those kinds of things, putting your safety glasses on."

While several interviewees talked about the difficulty of providing labs and other important activities in an online environment, several of the same individuals that identified them as a barrier also offered potential solutions to providing them online. Four respondents directly mentioned labs as requiring a hands-on component, and that this may be difficult to address online. However, each one went on to qualify their responses. An undergraduate faculty member with no online experience noted that some aspects of labs, such as demonstrations, could be done online using video recordings of a lab experiment. A graduate professor, also with no online experience, felt that "it is a different experience, but I don't think that it's less effective and I think that if you just sat down and say 'Well, how could be as effective?'" Another undergraduate professor with online teaching experience had more to add, including concerns about labs and recommendations on how to move forward in the future, including redesign of not just courses but of whole curricula. Noting that his department had various types of lab equipment,

> that's just kind of got a visceral feel that would be very difficult I think to replicate with just either videos or a combination of some online type of thing. I think the learning objectives could be met, but I think there is a lot of kind of the subtlety – a lot of the supporting elements that are hard to teach or capture in a

> learning objective, you just don't get. So yes, there could be some difficulties there…. But if you did – if you designed a whole sequence of courses in a curriculum to get a degree, I could imagine you might – you could imagine a whole new way of putting things together that aren't like our traditional course-based approach.

A graduate level professor with extensive online experience opined "that there are certain engineering activities, particularly those involving labs that involve big, heavy equipment, that you can't easily reproduce at home that cannot be as effective online." However, he offered a solution – simulations – and provides a real-world analogy to support their potential effectiveness to replicate hands-on or experiential learning:

> Simulations and things like that have done a remarkably good job of overcoming that and I will point out a very interesting example. Airline pilots don't fly real airplanes until they've spent an awful lot of time on the simulator and they learn an awful lot. Those simulators are really good. I've been in one and I think in the engineering education field we can expect to see more and more lab experiences being replaced by simulation that will enable you to do online things.

A second graduate level educator with online experience provided a slightly different advantage to online labs – accessibility for larger classes or smaller programs with limited resources:

> [if] you have a big class there is no way you have the facilities to allow so many students into the lab to physically do the experiment….I have seen people do some very creative stuff with having one team of students do the lab, while the other students are watching what they do and collecting the same data and they go out and analyze it.

One graduate professor with no online experience, after stating that "obviously labs would be difficult to do online because you wouldn't get that hands-on component", went on to opine that they "suppose you could make a video of people doing the experiments, and you could probably get a lot of the benefit of seeing it that way versus actually doing it yourself." Another undergraduate professor with no online experience, when asked a direct question if there is anything inherent in engineering that can't be taught online, responded, "Very little." Therefore, while it is apparent that labs, hands-on activities, and other aspects of engineering are on the minds of faculty members, and are often voiced as a concern in an online course, some felt that these issues can be addressed and potentially overcome. This issue is a key finding from the quantitative survey section and is explored in more depth in subsequent specific interview questions.

A graduate professor with no online experience described another perceived benefit to online labs:

> You could essentially take virtual field trips. I think that would be pretty beneficial for engineering education. So, like, teaching construction engineers. 'Here's what happened to the field with this connection. You know, it gets rusted or corroded.' And show people what a 40-year-old bridge looks like and what the issues are. And that's harder to communicate necessarily in the classroom. So, there could be some real beneficial things there, and that's why I am saying sort of a hands-on learning could be more beneficial online.

One of the undergraduate professors with some online experience noted that some of the technology needed to do remote or virtual labs is becoming more readily available.

> Electronics and hardware [are] becoming so inexpensive is that it's almost coming to the point where you could actually have like a little lab, a mini-lab that you

carried around with you, that you could plug into your computer and have a few instruments and do some things that I think would be pretty high quality. But it really takes somebody with time and the resources to kind of develop those.

Building on the idea of development and redesign for online classes, a graduate professor with extensive experience provided some guidance regarding rethinking how to do labs and engineering education online:

> I put a lot of effort into redesigning courses to fit the online paradigm. There are so many ways you can rethink the way you teach a concept so that it will work effectively in the online mode, and there is a lot that can be done there…. And little by little I think we're going to find ways to overcome a lot of these obstacles, but it's going to take time. And instead of being all in, it's all switched online, maybe we need to think of some hybrid modes along the way. I am a big fan of getting industry involvement in the education process, and in particular when it comes to expensive labs that require extraordinary amounts of hand-on activity.

ENGINEERING LABS AND HANDS-ON ACTIVITIES - INTERACTION

Another perspective on the issue of labs and hands-on activities was not necessarily the technical or the experiential aspects, but rather the interactive component of the lab experience, and the perception that doing that online might be problematic. Six of the interviewees expressed some concern about interactivity related to labs, whether interactions between instructor and students regarding questions, problems, or guidance, or interactions between students in a team setting.

Two respondents described interactions with the students as an important aspect of pedagogy that they felt is lacking or more difficult in an online setting. One undergraduate faculty member who had not taught online courses reported that interaction with students was important and described his concern with online courses, noting that teaching "is about making the class enjoyable and about interacting with the students, and so, I don't have any particular desire really to do an online course." A second undergraduate faculty member had a similar perspective, comparing face-to-face and online interactions, stating "now what I see when I teach, is I look at the students and I can get a sense of whether they are comprehending or not, and whether it seems like they are getting what I am saying…my thought is that you miss the interaction between the instructor and the students and I think that's very valuable."

Two interviewees that had not taught online concurred that student and instructor interaction in both the classroom and activities such as labs was a concern. "I just can't do as good a job as I would like to with an online course. I really need the class in front of me and we need to have this interaction" stated one graduate level respondent. An undergraduate level instructor said "I have taught enough lab courses to know that you have got to have somebody there helping them out with problems or they get frustrated and they give up." These comments expanded the issues with hands-on activities such as labs beyond just the technical aspects of replicating a real-world activity online. Rather, they approached it from the perspective of the need to create an online environment that facilitates interpersonal interaction. In contrast, no respondents that had taught an online course mentioned interaction between students and instructors, or any type of interaction, as a barrier to teaching online courses.

Several interviewees approached this issue from the perspective of trying to replicate a face-to-face lab experience in an online environment. An undergraduate instructor with no online experience stated that students are

> inevitably going to run into trouble and you are going to need some help, and the best time to get that help is while you are sitting with a circuit in front of you that doesn't work….So, these sort of interactive processes, at least at the moment, I don't see how you are going to do that online.

A graduate professor with no online experience had a similar comment, noting that he thinks that "the team dynamic, working in a team, it's better when you're actually physically next to each other on your team because that's what happens in the real world." Another graduate professor with no online experience opined, "I think there's a lot of learning that happens when you're in a team environment or a group environment. And if you're doing that all virtually, it's more difficult, I think." An undergraduate professor with some online experience put it in terms of richness of communication: "I suspect that the labs and the hands-on activities and the design projects – it's the interaction and the lower bandwidth that you get when you go online as opposed to actually being in a room with someone. You have got incredibly high bandwidth there."

However, not everyone agreed that the interaction and teamwork aspects were a problem. An undergraduate professor with no online experience stated it simply: "there is no reason that teams couldn't, can't work together online." An undergraduate instructor with some online experience noted that "team type activities and kind of collaborative type stuff has changed a little bit. And that's mostly because the students of today are much more comfortable using these tools." A graduate professor with extensive online experience added "I mean, think about all of the social media things that are set up to enable people to communicate with each other instantly and so forth. I think that's probably one that's going to improve fairly quickly."

In summary, in almost every case, respondents indicating that they had no direct experience with online learning rated the survey questions adversely to online learning when compared to those that have taught at least one course online. These results include perceptions of online learning that are shown in the background research to not be the case – i.e. online learning outcomes can be comparable in online and face-to-face courses, teamwork can be effective in an online environment, online labs can be developed and delivered effectively, etc. Overall, whether an instructor has taught an engineering course online has a large and important impact on their perceptions of online learning and can be considered a critical factor related to the adoption and implementation of online engineering courses.

Potential Barriers to Online Engineering Education

The final series of survey questions included items focused on potential barriers and issues related to faculty concerns. Many of the questions in this section were based on survey data from the 2013 Sloan Report (Allen & Seaman, 2013), with additional questions included based on the pilot study (Kinney, Liu, & Thornton, 2012) and the review of the literature. Descriptive statistics were calculated for each question (see Table 15). The Likert scale ranged from 1=Strongly Disagree to 5=Strongly Agree. Each item was plotted as a histogram to evaluate the shape of the distribution and a Q-Q Plot was generated to evaluate for normality. All of the items in this series were normally distributed.

Faculty members generally agreed that it takes additional time and effort to teach an online course (M=3.83, SD=0.891). This result aligns with the results of the Sloan Report where 44.6% of respondents agreed and 45.7% of respondents were neutral on the same question (Allen & Seaman, 2013, p. 38). Note that the Sloan Report used a three level Likert scale for this question.

Table 15

Potential Barriers and Faculty Issues – Descriptive Statistics

Question	**Mean**	**Standard Deviation**
It takes more time and effort to teach an online engineering course than a face-to-face course.	3.83	0.891
Faculty accept the value and legitimacy of online engineering education.	2.51	0.977
Faculty have appropriate technical support to develop online engineering courses.	2.37	1.076
Faculty are compensated for developing and teaching online engineering courses.	2.12	1.028
Faculty receive appropriate training in the development of online engineering courses.	2.16	0.991
Faculty are encouraged to develop and deliver online engineering courses.	3.10	1.107
Faculty are required to develop and deliver online engineering courses.	2.28	1.095
Lower retention rates in online courses are a barrier to the growth of online instruction.	3.32	0.958
Lack of acceptance of online education by potential employers is a barrier to the growth of online engineering instruction.	3.36	1.007
Lack of acceptance of online instruction by faculty is a barrier to the growth of online engineering instruction.	3.64	0.925
Lack of acceptance of online instruction by administration is a barrier to the growth of online engineering instruction.	2.75	1.020

Note. Likert scale range from 1=Strongly Disagree to 5=Strongly Agree.

Time and preparation needed to develop and deliver an online course was also addressed in the interview section of the study. An undergraduate faculty member that has taught online courses before described two barriers:

> One is just sitting down and getting the videos organized and thought-out and recorded in time for the students to consume them and then the second is figuring out exactly what to do in class now that you are not just filling the space with lectures.

On its face, while this statement seems to be describing a possible barrier to developing an online course, it also hints at an important theme that emerged as responses to other questions were analyzed, and that is the comparison between attempting to *replicate* current face-to-face pedagogical methods and materials in an online format and truly attempting to *redesign* a course or course materials to be effective in an online course environment. A second graduate level online instructor emphasized this point by stating "both faculty and administrator have to be willing to do two things. They first of all have to be willing to support the idea of doing it and secondly they have to be willing to change in order to accomplish it."

Regarding preparation time and effort to convert or create an online class, one undergraduate faculty respondent stated, "The biggest showstopper for me is the time to make, to do the preparation." Another echoed the sentiment and raised the issue of course redesign:

> I think it's going to take a lot of skill and a lot of time to think through and decide how to move from say the content of the course I teach now, how would I move to doing that online? That would really take a lot of time.

Both graduate faculty members that had not taught online also agreed that workload was an issue and one clarified that preparing new or modified course materials would be an issue in their mind:

> Any kind of new prep, you know, faculty which hates a new prep not because they don't want to do it; just like it's–it just takes so much more time than versus getting ready for a class that you've taught before.

Some of the interviewees that had taught online courses before approached the workload and preparation issue from a different perspective while still admitting that it is an issue. They noted that, while it does take time and energy to redesign and develop online materials, it is something that needs to be done to be effective. Said one undergraduate interviewee with online experience:

> You can't essentially take your old slides, your old notes and just replicate it in an electronic form….You have to rethink completely how the course is done and delivered….I think you really have to build in time and effort and sometimes even expertise into developing interactions, where the students can take what they are supposed to be learning and implement it to better understand what's going on.

A graduate level professor with extensive online experience took a more direct approach and described the concerns about additional work or course development as more of an excuse based on fear of change. "There is an unwillingness to change; behind that is always a fear, a fear of it might not work, it's different, I'm not used to it, it's more work, blah blah blah, among the faculty."

Several survey results were rated on the low or 'disagree' side of the scale indicating potential barriers to implementation of online engineering courses. Respondents generally disagreed that faculty are compensated for the development of online courses (*M*=2.12, *SD*=1.028), have appropriate technical training in the development of online courses (*M*=2.16, *SD*=0.991), and have appropriate technical support in developing online courses (*M*=2.37, *SD*=1.076).

Regarding compensation, interview respondents were almost unanimous in their agreement that there are concerns with compensation for faculty members that develop and teach online courses. Only one respondent stated that they were compensated for developing a course. The rest said they were not or did not believe that they would be.

Those that had not taught online agreed that this could be an issue for faculty members that are considering implementing an online course. "I really think that this is a huge impediment because you're asking the person to now spend a lot of time changing direction and probably organize in ways they've never organized courses before" said an undergraduate professor. Others agreed that it takes more time and energy to develop or convert courses for online delivery. "If you're teaching a course that you taught a lot, and now you're going to do it online, you need be given more time or more compensation to accommodate that, and I don't necessarily think that's what is happening." An undergraduate professor that had taught online shared his experience. "There's no extra compensation, at least not here, for that and yes, the new system does require redesign in the class materials. And that was a pretty consuming effort for the first time in the new system." A graduate faculty member with extensive online experience felt that "the whole issue of how you compensate faculty has to be rethought here as part of this process."

Another concern raised by two interviewees in response to the issue of compensation was job security and potential obsolescence. A graduate professor with no online experience described it this way:

> I think that it's more paranoid than it is actual, this perception if – so you want me to create these online courses, that what, a machine could teach? And what, you're going to have – I'm going to not have tenure anymore? Or you're going to replace me with somebody else? Or the job security – why are you doing this? Okay the answer is 'Well, it's more cost effective delivery.' It's like, 'Does that mean that you are going to have fewer professors?' Because right away there's immediate resistance to that idea.

An undergraduate instructor with online experience echoed this sentiment, stating "I think there is also a general fear of being replaced, because once you have a good course available …you really don't need the professor there every day you know lecturing and doing all those kinds of things."

Regarding survey results indicating faculty training was a barrier to implementing online courses, most of the interviewees agreed that training was needed but had some differing opinions on what resources were needed and what was already available. Some respondents stated that their institutions had some sort of learning technology center, but not all had availed themselves of the services, nor were they completely sure what was offered. One undergraduate professor who had not taught online mentioned that they "will videotape our classes" and "give us some hints about doing that." Another noted that "they are developing it [the center] and some of the facilities are probably there; I'm just beginning to know about them." An undergraduate professor with no online experience agreed. "We have a teaching center here at [university] that is working on providing it. Workshops and things like that to help leverage, but there is a lot to learn going in."

In contrast, a number of respondents felt that the individual instructors were left to fend for themselves. One undergraduate professor who had not taught online simply noted that "you just have a bunch of people out there trying to do this on their own and not knowing how to do this." A graduate professor with no online experience added "I think they leave that up to the individual professor to sort of figure that out." An undergraduate professor with online experience noted that faculty members help each other out. "We've actually picked up more from talking to each other that we – kind of learning together how to do it."

Even if there is training, it is not always helpful. A graduate level professor with many years of online experience described it this way:

> If somebody has to be retrained they really don't do a very good job, because most of the time the people doing the retraining don't know all that much. I've spoken with an awful lot of people who are implementing online systems who don't really have the experience that I do and they make all kinds of mistakes and I try to warn them about them, but they don't always listen anyway.

An undergraduate professor who had some online teaching experience expressed a more negative perspective on training, but also provided a vision of training and course development to address the problem.

> Well, I don't think there is any training. I think administration really doesn't have a clue other than they might see other universities are doing it or they see this as a way of growing their market and getting more students. But they don't even know the first thing of what to buy and what to do, so they tell a professor make your course online.
>
> I think that at the university level, if you wanted to have an effective program really you need to develop almost a standalone group that has the capability. And then you bring the subject matter experts in who then provide content that can be developed. And then I think you get buy-in, because the professors would be excited. Because they aren't burdened with stuff that they don't know they have to learn. They are just providing the content that goes into it. And then they get back to the part they like doing of just interacting with the students whether it's face-to-face or in an online type of environment.

Faculty survey responses related to lower retention rates differed somewhat from the responses in the Sloan Report. In this study, responses were close to the center of the range (M=3.32, SD=0.958), while the Sloan Report reported that a total of 69.15% of respondents felt that lower retention rates were an important or very important barrier (Allen & Seaman, 2013, p. 41). Similarly, lack of acceptance by potential employers was rated close to the center of the range in this study (M=3.36, SD=1.007), while 42.8% of the Sloan Report respondents rated this factor as important or very important (Allen & Seaman, p. 41). Note that for these items, the Sloan Report only reported the statistics for responses for ‘important’ and ‘very important’. The overall scale and alternate responses are unknown.

Two questions were included in the survey to explore potential reasons that faculty were embarking on developing and teaching engineering courses online and the influence that the administration or university policy may play a role in this decision. Faculty generally disagreed that they are *required* to develop and deliver online engineering courses (*M*=2.28, *SD*=1.095) while they were generally neutral to whether they feel they are *encouraged* to do so (*M*=3.10, *SD*=1.107). Comparing these two items via a paired samples t-test showed that these distributions were significantly different; $t(263)=12.369$, $p<0.001$. These results indicated that the administration or the university is generally not forcing faculty members to move to an online delivery method which could have the potential to create pushback or problems due to training or preparedness issues.

In a comparison using ANOVA of engineering discipline versus barriers and faculty issues showed that technical support to develop online courses was identified as having a significant difference ($F(16, 247)=2.069$, $p=0.010$). For both items the majority of engineering disciplines fell on the negative / disagree side of the distribution, meaning that almost every engineering field felt that this is a concern related to the implementation of online engineering courses.

Two questions were included in the survey based on the Sloan Report results related to faculty acceptance of online education. Each was worded slightly differently and one was worded in a reverse manner which assists in verifying validity of the responses. In this survey, respondents indicated that they tended to disagree that faculty generally accepted the value and legitimacy of online engineering education (*M*=2.51, *SD*=0.977) and they tended to agree that lack of acceptance of online instruction by faculty could be a barrier (*M*=3.64, *SD*=0.925). For comparison, the data was inverted for the value and legitimacy question (*M*=3.49, *SD*=0.977). The histogram plots are very similar (See Figure 5). These results were interesting in that both questions indicated that faculty members themselves believe that there is a lack of acceptance of online education within the engineering faculty community.

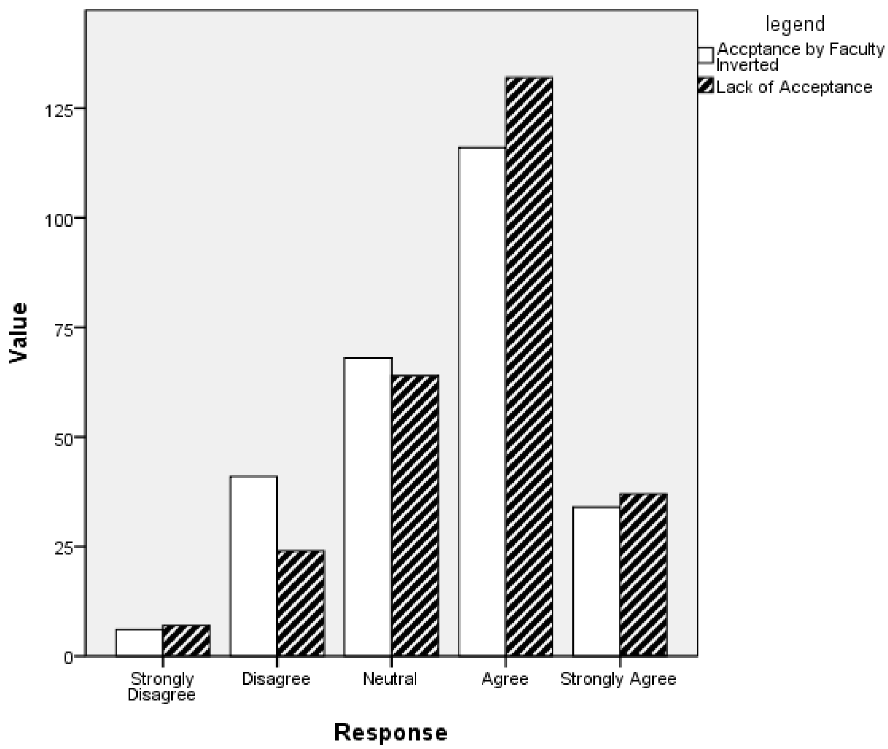

Figure 5 - Comparison of Acceptance by Faculty (Inverted Data) and Lack of Acceptance by Faculty

A comparison by undergraduate and graduate faculty of the items versus potential barriers and faculty concerns showed one item with a significant difference – Faculty Acceptance of the Value and Legitimacy of Online Education (undergraduate: *M*=2.37, *SD*=1.008; graduate: *M*=2.78, *SD*=0.868; *t*(260)=-3.243, *p*=0.001). Both undergraduate and graduate faculty responses fell on the same side of the response scale for this item, matching the relationship between these items as described in Figure 5. However, this comparison indicated that undergraduate faculty felt more strongly that faculty acceptance was lacking and could be an important barrier to adoption of online engineering education.

An interview question explored the results from the survey asking if the lack of acceptance by faculty themselves was considered to be a barrier to implementing online education. Both survey respondents with no online experience and those with some online experience agreed that this was an issue, but there was a significant difference between the groups, with those with no online experience feeling that faculty acceptance was more of a problem.

Interviewees had various ideas as to the reasons for this result. One graduate professor with no online experience felt that the fear of obsolescence might be an issue. "If you truly have online education and it works well, it's potentially job threatening to some faculty." He added, "if you could teach engineering mechanics to 2,000 people at a time, well, you need a whole lot less engineering faculty."

An undergraduate faculty member with online experience said that the impression of other faculty about online education could have a negative impact and implied that a type of self-selection might be involved. "Those that are concerned about promotion and tenure for example are just going to avoid teaching online at [university] until they are tenured."

Two interviewees mentioned age and experience as a potential reason that some faculty members might feel that others don't accept online courses. An undergraduate professor with online experience stated that

> Typically, I've seen older faculty being more against this type of education than younger faculty. And that seems to be getting even more pronounced as we are

getting kind of the Gen-Y people more and more around, the digital natives I guess may be the right word for it. So I would say it almost corresponds to how comfortable the faculty member is with technology and new technology.

A graduate professor with extensive online experience agreed, noting

it is my opinion that the younger faculty are more supportive and the older faculty are less supportive, because, it's kind of like the young students are much more used to an interactive electronic world and the older faculty are still used to text books and, you know, doing things the old-fashioned way.

Another pair of questions in this section explored whether acceptance of online education by faculty members or by administration could be a barrier to the growth of online engineering instruction. While respondents tended to agree that acceptance of online education by faculty members could be a barrier (M=3.64, SD=0.925), respondents tended to disagree that acceptance by administration was a barrier (M=2.75, SD=1.02). Comparing these two items via a paired samples t-test showed that these distributions are significantly different; $t(262)=12.420$, $p<0.001$. When considered with the previous set of results, faculty member respondents felt that influence and acceptance by administration is less of a barrier to adoption of online engineering courses than the level of acceptance from other faculty members.

A comparison via independent samples t-test of full-time and part-time employment of engineering faculty versus barriers and faculty concerns indicated that full-time faculty disagreed that lack of acceptance of online instruction by administration was a barrier (M=2.69, SD=0.986) while part-time and adjunct faculty agreed that acceptance by administration was a barrier (M=3.30, SD=1.171; $t(261)=-2.964$, $p=0.003$). This difference in perception of attitudes of administration by different faculty groups may be related to how closely these faculty members interact with administration as a full-time or part-time employee. It seems reasonable that full-time faculty member may have a more accurate evaluation of the position of administration; however, this data did not provide any conclusive reasons for this result. In general, respondents disagreed that administrative acceptance of online education was an issue (see Table 15) and it was not considered a primary influence on the implementation gap in online engineering courses.

Table 16

Potential Barriers and Faculty Concerns by Online Experience Level

Survey Item	**No Online Experience**		**Some Online Experience**				
	M	***SD***	***M***	***SD***	***df***	***t(df)***	***p***
Faculty are encouraged to develop and deliver online engineering courses.	2.97	1.076	3.39	1.131	263	-2.836	0.005
Faculty are required to develop and deliver online engineering courses.	2.11	0.948	2.66	1.302	117.0*	-3.396	0.001
Lower retention rates in online courses are a barrier to the growth of online instruction.	3.48	0.897	2.96	0.999	263	4.171	<0.001
Lack of acceptance of online education by potential employers is a barrier to the growth of online engineering instruction.	3.58	0.852	2.85	1.148	118.4*	5.079	<0.001
Lack of acceptance of online instruction by faculty is a barrier to the growth of online engineering instruction.	3.75	0.831	3.38	1.072	122.1*	2.786	0.006

Note. Likert scale range from 1=Strongly Disagree to 5=Strongly Agree. * Levene's Test for Equality of Variances indicated that equal variances could not be assumed for this item

Other items in this section were rated negatively by respondents with no online experience and positively by those with some online experience. These results on key engineering items such as real-world problems, mathematics, and design problems may also provide insight into possible reasons for the difference explored in the research question.

The comparative analysis of the last question series in the survey related to potential barriers and faculty concerns indicated a few significant differences as shown in Table 16. The two items asking whether faculty are required to teach online courses or whether they are encouraged to do so had interesting results, with the group with some online experience agreeing that faculty are encouraged to do so, and both groups disagreeing that faculty are required to teach courses. This comparison seems to point out that faculty are generally encouraged to teach courses online and are not required to do so, showing that administration or the university itself is giving faculty the choice to teach online and is encouraging rather than forcing them to do so. These results seem to indicate that potential push-back by faculty against administration initiatives would not necessarily be part of the reluctance to implement online courses.

For the question concerning retention rates, respondents with no online experience agreed more strongly that this could be an issue. This is similar to results from the Sloan report, with 73.5% of respondents indicating that lower retention rates were an important or very important barrier to the growth of online instruction (Allen & Seaman, 2013, p.41).

The question regarding the perceptions of faculty that employers may not be accepting of online engineering education produced a split result, with those with no online experience agreeing that this is an issue and those with at least some online teaching experience disagreeing. This compares to the results of a similar question in the Sloan Report which indicated that 42.8% of respondents felt that acceptance by employers was either important or very important (Allen & Seaman, 2013). This result could influence faculty members that have not taught an online course before and potentially inhibit them from considering implementing online engineering courses based on concerns for the future of their students.

A question concerning whether the lack of acceptance of online education by potential employers could be a barrier to the implementation of online courses was included in the interview portion of the study. Respondents to the survey with no online experience agreed that this could be an issue, while respondents with some online teaching experience felt that this was less of a concern.

A common theme of interviewees was that when an employer thinks of an online course or program, some negative preconceptions of distance learning or correspondence courses could imply to some a lesser quality educational experience. A graduate professor with no online experience stated "I think there's a lot of degree mills that are online, and that's diluting the – or that's creating the perception amongst employers."

A graduate faculty member with online teaching experience as well as industry experience added:

> This is I think an issue, but it's becoming less of an issue. We're in a transition phase and it may take a number of years before this, if you will, the stigma of the online course goes away. Part of the problem has been frankly that the traditional universities have been less likely willing to do this than the non-traditional universities and so when you have a for-profit organization offering online courses there is this stigma of it's a for-profit corporation, they don't have the same standards as the traditional university, all that goes along with it and so it's all bundled together with the online aspect of it.

Others felt that employers care more about the quality of the institution and not whether a course or program is online or not. A graduate instructor with no online experience noted that employers "depend on the institution to ensure the integrity of the process, in that the institution determines that we can teach this course effectively online."

An undergraduate faculty member with online teaching experience added another perspective about the future and how this issue might change and become less of a barrier. "Right now the people that are employing students were taught traditionally." However,

> a lot of internal industry training programs are now done essentially the equivalent of what we are doing in the online education arena. So I think that we are breaking barriers down there is becoming just more accepted. So I actually think that this is more just of a timeframe experience type thing versus a quality, any quality type of thing.

Additional Themes

In the interview portion of the study, several additional themes that could influence implementation of online courses became evident that were not related to a particular set of survey questions or topics. For example, the issues of background, age, and experience were raised both by respondents with no online and some online experience as it related to making just this sort of change. A faculty member with no experience in online teaching discussed faculty member backgrounds, opining that "the faculty aren't–weren't taught that way or not used to teaching that way so there's a lot of prep that goes into that, putting one of those together" while a professor with extensive online experience noted "people get set in their ways and if you're young and new and willing to try something different, you find a way to make it work, whereas if you're old and set in your ways, you try to find ways that it won't work."

Another important theme that emerged was related to a potential advantage of online education related to stakeholders and the ability to reach a larger audience. Respondents with some online experience noted that providing courses online is a "great enabler" that can "allow a different student population you would never have had if you insisted that they have to come there physically to campus." Respondents noted that this population, often at the graduate level, can include working students, students in industry, non-traditional students that cannot attend during standard class hours, and students in the military. Targeting this student audience could be a factor motivating instructors and administrators to develop and deliver online courses.

Financial aspects of online programs were raised by several interviewees, but from different perspectives. One graduate faculty member that had not taught online courses proposed that a reason to pursue online education was that it was "cheaper for the student". No support was given for this assertion, but they went on to imply that since "you can have a lot more students" in an online class, "the university could make some more money." The second graduate faculty member with no online experience agreed that online courses "can be delivered more cost effectively." These perspectives were in contrast to a graduate level professor with extensive online experience, who noted that in actuality, "there is a certain amount of cost for capital equipment needed to make [online courses] possible and … particularly for small schools that may be a prohibitive cost." There was additional mention of financial benefits and costs by the interviewees in other sections of the interview, but it is important to note that this issue was raised in the first discussions of factors that influence online education, both by those that had directly experienced online education and those that had not.

Finally, an interesting theme emerged directly related to the research question and why faculty members thought implementation of online courses in engineering was lagging other disciplines. At least four faculty respondents commented that engineering was different from other disciplines or was otherwise special in some way, and that was why these issues were critical.

A graduate professor with no online experience stated it in terms of complexity of the field, "well, I don't want to say it's more difficult than other fields, but there's a lot of working problems, there's a lot of explanation that has to go into it." An undergraduate educator with no online experience approached this difference from the perspective of faculty, noting that "engineering educators may be a little bit more resistant to change than others….That is just my, sort of, supposition of what engineering educators or what I compare to in other disciplines." A graduate professor with no engineering experience built upon that generalization of engineering faculty and provided a possible explanation for their opposition to change:

> I'll suggest the conservative nature of engineering. I mean, engineering is conservative by nature, right? There's a safety factor in every single design. So, from that standpoint, you learn to be kind of conservative in your approach to pretty much everything, and I think that would include the instructional medium that you're using, and it's, hey, lecture and chalkboard have worked for a long time. So, you know, something that is different than that could be viewed with some skepticism.

However, one undergraduate respondent with some online experience felt that engineering was indeed different, but from a positive leadership perspective. "I actually think that engineering should be leading the way because we are so coupled to new technology and technology in general."

The final question on the interview instrument was a catch-all, asking respondents if they had any additional thoughts on the research topic. Several interviewees reiterated prior comments, but a few who had experience in the area of teaching online provided their vision for a future of online education. An undergraduate professor who had taught online said:

> I think probably years from now or you know, soon we are going to start seeing lessons learned of failures or successes. And I would put money on the successes being programs that developed a strong support network what subject matter experts had support in developing these online courses. Rather than I think the failures which will be 'convert your PowerPoint slides into something online.'

A graduate professor with extensive online experience offered two comments:

> Distance education offers one way of being more productive and it may not be the only one that comes to fruition, but sooner or later we're going to have to do something. So instead of resisting I think faculty should embrace it and say let's do research here, let's find some innovative way to do this and I find the strongest support for that point of view among those who are education researchers, people whose field of study is education as opposed to people who teach as a sideline to whatever their main thing is and so I think it's going to have to happen, you know, we can put if off for a while, but it's like the national debt, you know, sooner or later it is going to crush if you don't do something about it.

He continued:

So there are so many people who have benefited from it and, you know, I can't imagine that it or some son of it is not going to eventually be a major, major factor in the way education happens. I mean, look at young people today. They look at little tutorial things on their smart phones to learn stuff, they don't look it up in a textbook. This is the way it's going to work, and that kind of leads into my other comment which is, I think the younger generation is going to embrace this, especially the students; and ultimately that's going to be what causes it to change.

Summary

The data analyses of the two phases of this mixed methods research combine to build a picture of which factors engineering faculty members perceive influence the implementation of online engineering courses and possible reasons behind them. The quantitative analysis of the survey results, which included descriptive statistics and comparisons of a total of 7 demographic variables and 65 survey questions, highlighted a number of significant factors related to the research question, including the important role that online teaching experience plays in determining perceptions of the effectiveness of pedagogical methods and topics important to engineering education, differences in perceptions between undergraduate and graduate faculty members, and concerns that faculty have regarding training and compensation for online teaching and course development. The qualitative analysis of the interviews of ten faculty members from a broad range of individual and institutional demographics provided insight and explanations for the findings in the survey portion of the research. Interviewees reported concerns about laboratory and hands-on experiences, faculty training, technical and course development resources, and compensation. They also discussed the importance of interactions between students on teams and between students and instructors, and the need to redesign course materials and pedagogical approaches when converting a traditional face-to-face course to online delivery.

CHAPTER 5: DISCUSSION AND CONCLUSIONS

The findings of the survey and interviews portions of the study were provided in Chapter 4. This chapter connects the results of the two research phases together in the context of the background research and theoretical models to address the research question. The organization of this chapter includes a synthesis and discussion of results, implications and recommendations for stakeholders including faculty members, engineering programs and departments, and educational developers and technologists, and concludes with a discussion of the limitations of the study and potential areas of future research.

Important Factors Influencing Adoption of Online Engineering

The purpose of this research was to investigate the apparent lag in implantation in online engineering education as evidenced by a number of studies (Allen & Seaman, 2008, 2011, 2013). This study set out to answer the research question: What factors do engineering faculty members perceive influence the implementation of online engineering courses and why? A review of the relevant literature identified a number of potential factors as well as pertinent models of technology adoption focused on user perceptions that could influence the adoption of online learning. An explanatory mixed-methods design was used, incorporating an extensive survey followed by semi-structured follow-up interviews to gain insight and explanations of the results of the survey analysis.

As can be seen in Chapter 4, this study took a far ranging approach to exploring faculty perceptions of online engineering education, with seven independent demographic variables and sixty-five survey questions covering a wide range of topics concerning multiple facets of engineering education. In addition, the responses to the semi-structured interviews covered a broad range of topics and perspectives from ten interviewees with varied experience levels and perspectives. The analysis of survey results provided a list of potential factors to address the research question, while the interviews provided an in-depth discussion of potential reasons underlying these factors. In considering the array of data and responses, the various factors identified in the survey and interview results have been combined and distilled down into the following three major factors or themes that address the research question: online teaching experience, course development issues, and why engineering is different. Each theme contains several important factors and each is discussed and explored in the following sections.

ONLINE TEACHING EXPERIENCE

Four demographic factors that influence the implementation or acceptance of a particular technology are identified in the TAM (Figure 1) and UTAUT models (Figure 2) (Davis, 1989; Venkatesh et al., 2003). Of those demographic factors identified in the models, gender, age, and voluntariness of use were determined in this study to have very little influence on the perceptions of engineering faculty toward implementation of online engineering courses.

However, the remaining demographic factor in the models that could influence technology adoption - experience - was found to be the most significant individual demographic factor identified in the survey. This result was also supported by the analysis of the interview responses. In this study, experience was simply defined as whether the individual instructor has ever taught an online course or not. Online teaching experience was shown to significantly influence a large number of faculty perceptions about online engineering education. Most importantly, experience influenced respondent perceptions of the effectiveness of every single pedagogical method and technical topic identified in the literature as important to engineering education. Perceptions of effectiveness in this research are analogous to the performance expectancy factor in the UTAUT model, which Venkatesh et al. (2003) indicated is the strongest predictor of intention to use a particular technology, such as online education. In each case, those that had not taught an online course before felt that these activities, such as labs, hands-on activities, design projects, etc., would be less effective in an online course than those that had some online teaching experience.

Faculty experience levels also had an impact on other important factors that could influence the adoption of online engineering education. Instructors with no online experience believed that learning outcomes would not be comparable in a face-to-face and an online class, while those with experience felt that they were. If an instructor does not have confidence that online learning tools or methods will help students effectively achieve their learning goals, it can be a significant barrier to the implementation of online courses. Interviewees supported this concern in the context of replicating current teaching methods in an online format; however, a few interviewees felt that with the right design, an online course could have comparable outcomes.

Engineering faculty members that had not taught an online course before felt that student-to-student and student-to-instructor interaction would be difficult or impeded in an online course, while those that had taught online did not feel it was a problem and rated these interactions positively. In the interviews, several respondents with no online experience wondered how to recreate the student-to-instructor interaction that they felt was necessary to have a successful engineering course. These concerns by educators who had not taught online courses could influence their decisions to adopt online teaching methods.

While the effectiveness of online labs, hands-on experiences, and design projects were not rated highly by either the experienced and non-experienced groups, those with no experience rated them least effective. Generally, respondents wondered how traditional topics and current hands-on labs activities could be replicated in an online environment. However, in the interviews an interesting secondary problem with these activities was raised. While technical aspects of a lab may be important and difficult to replicate in an online environment, faculty members felt that the teamwork and student-to-student and student-to-instructor interaction was critical to the success of these activities, and felt that an online environment might make these interactions difficult and less effective.

All of these factors combine to demonstrate that prior online teaching experience is a very important factor underlying perceptions of online courses and by extension the inclination to implement or teach an online course. Essentially, it shows that there are a large number of negative preconceptions of online education that those that have not taught online before maintain and that need to be overcome for the gap in online engineering education to be addressed. Whether related to learning outcomes, effectiveness, how to teach certain important topics, or how to redesign certain pedagogical methods and activities, these experience-based preconceptions will act as significant barrier to even attempting to migrate or teach an online course.

This research shows that once an instructor has begun to teach online, they realize that learning outcomes are comparable for an appropriately designed course and that there are effective ways to interact with students and for students to interact with each other. While not every face-to-face pedagogical method can be replicated, they can be adapted and redesigned to be effective in an online course. One experienced instructor summed it up simply, “if you design the class properly, you can have similar outcomes.”

It is important to note that each of the concerns identified by those that have not taught online courses have been addressed by prior research as evident in the literature on online education as described in Chapter 2, such as technical aspects of engineering labs (Balamuralithara & Woods, 2009; Corter et al., 2011; de Jong, Linn, & Zacharia, 2013; Ma & Nickerson, 2006; Nickerson et al., 2007), teamwork in labs (Bochicchio & Longo, 2009), online communication and interaction (Abler and Wells, 2005; Tallent-Runnels et al., 2006), or learning outcomes (Abdous & Yoshimura, 2010; Bourne, Harris, & Mayadas, 2005; Tallent-Runnels et al., 2006).

It appears that many engineering faculty members are not aware of such educational research, have not been presented with the relevant information, do not believe what they have heard or learned from others regarding the advantages or capabilities of online teaching, or have other negative perceptions and external inputs to keep them from attempting to teach a course online. However, the results of the compilation of survey data and the descriptions provided in the interviews in this study showed that attitudes and perceptions can and will change once an engineering instructor begins to actually teach online. So, while lack of experience in online engineering education can be a barrier, it is a barrier that can be overcome with additional education and exposure to effective online learning methods.

COURSE DEVELOPMENT ISSUES

A second major theme that emerged from a synthesis of the survey and interview data is related to faculty concerns and problems with development of online engineering courses. This could be considered the manifestation of the "ease of use" factor in the TAM model or more broadly, the "effort expectancy" factor in the UTAUT model as shown in Figures 1 and 2 (Davis, 1989; Venkatesh et al., 2003). This supports findings in the literature, such as faculty concerns with changes to content and methods and additional time and effort to develop and teach online courses (Allen & Seaman, 2011, 2013; Bourne et al., 2005).

In the section of the survey focused on general perception questions (Table 7), respondents felt most strongly that online courses cannot be taught just like face-to-face courses. While both online teaching experience level and undergraduate / graduate teaching level indicated a significant difference in responses across groups, all demographic cross sections rated this item very low and generally agreed that one cannot teach an online course the same as a face-to-face course.

This result is reinforced by the high level of agreement of respondents to a different question that asked if online courses require changes to standard face-to-face teaching methods. Survey respondents also strongly agreed that it takes more time and effort to teach an online engineering course than a face-to-face course.

All of these results, taken together, indicate that engineering faculty members are concerned with course development issues related to the changes necessary to teach online classes and the time and effort to make those changes. This result is further supported by the interview responses. A number of interviewees directly raised the issues of time and effort to support course development. This seemed to be a more prevalent concern with those that had not taught online courses before, indicating that they were either speculating that the development of a course would take longer, or they believed it to be the case from their understanding of the experiences of others.

This is not to say that those with online teaching experience disagreed or denied that online courses took time and energy to develop, but rather their perspective was more of an acknowledgment of this as a reality of teaching online and felt that it was necessary in the sense that, to be most effective, an online course involved the redesign of the materials and pedagogical methods instead of simply replicating a face-to-face course via online tools. In several instances in the interviews, respondents that had not taught online opined that a significant hurdle to teaching online was exactly that – they did not know and could not imagine how to replicate what they are doing in their face-to-face engineering courses. They did not seem to entertain the concept of actually changing what they were doing to take advantage of online affordances or tools.

The issue of redesign versus replication in course development for online delivery was important to several interviewees and something that was repeated by both those with and without online experience. For an online course to be effective, course materials and methods had to be reconsidered, independently or as part of a larger curriculum, and redesigned to utilize and fully exploit the affordances available in an online environment. Part of the confusion and pushback expressed by those that had not taught an online course was a mental model of needing to replicate current face-to-face teaching methods or traditional in-class engineering activities and the disconnect as to how these things might work when delivered online. Therefore, for any online engineering course or program to move forward, a mindset of course redesign is necessary instead of simply trying to convert traditional materials and pedagogical methods to be used online.

Another significant issue related to course development was resources and support in both a technical and course development sense. Survey respondents strongly disagreed both that faculty have appropriate technical support to develop online engineering courses and that faculty receive appropriate training in development of online courses. Interviewees agreed with these findings and while the level of technical support varied in the descriptions, a general theme of limited or non-existent course design and developmental support arose. Respondents described not knowing about any on-campus or departmental course design and development resources, limited familiarity with what was available, concerns about the quality of support, and in some cases described a culture of peer learning and instructors fending for themselves.

An additional factor identified was more practical in nature but still very real – the issue of compensation. As noted in Tallent-Runnels, et al. (2006), faculty felt they should be duly compensated for developing online courses. Survey respondents felt strongly that they were not compensated for developing and teaching online engineering courses. While most agreed that it took additional time and effort to develop an online course, a lack of a comprehensive method to measure their efforts and properly compensate busy faculty members was considered a significant barrier. Nine of the ten interviewees agreed that this was the case, regardless of whether they had previously taught an online course or not.

ENGINEERING IS DIFFERENT

This major theme differs from the previous two in that it does not describe an individual concept or a specific set of concerns that engineering educators expressed. Rather, this thread that ran through the entire research study and is based on multiple factors from the survey and many of the responses in the interviews. Fundamentally, it directly addresses the focus of research problem underlying this study – why does engineering lag behind other academic disciplines in its implantation of online learning? What is it that makes engineering different?

There were several items that surfaced in the survey and were emphasized and described in more detail in the interviews that, when taken together, help provide an understanding of why engineering might be different from other fields; or rather, why engineering faculty *perceive* there to be differences between engineering and other academic disciplines which might therefore influence the adoption and implementation of online learning in engineering.

The first and primary aspect of engineering education that respondents believed makes engineering different is the technical topics and pedagogical methods that are commonly employed in traditional face-to-face engineering courses, such as labs, hands-on activities, design, etc. Survey respondents felt very strongly that these topics could not be effectively taught online. In contrast, respondents generally believed that non-engineering topics can be effectively taught online. The literature indicated that these topics are considered key requirements in an effective engineering curriculum, and survey responses supported this with their high rating on importance (Bourne et al., 2005; Ma & Nickerson, 2006; Nickerson et al., 2007).

Overall, labs were rated the lowest for effectiveness in an online environment. In the interview portion of the study, eight of ten respondents identified labs as a significant hurdle to implementing a fully online engineering program. Interviewees discussed issues related to technology and the need for experiential and hands-on activities and expressed concerns about how to replicate this type of activity in an online environment. Not all interviewees were completely pessimistic concerning lab experiences, citing some specific examples of leveraging computer technology, remote access, and simulations as possible solutions involving redesign and reconsideration of lab activities, similar to solutions and research described in the literature. However, it was generally agreed that this was a significant problem that needed to be addressed as long as labs were considered essential to an engineering education curriculum.

As noted previously in the section discussing the experience theme, an interesting outcome of this study was that the technical and experiential components of labs were not the only issue raised by engineering faculty. Rather, many interviewees also voiced a concern with the interactive and teamwork components of engineering labs and how to support and provide for meaningful and effective interaction in an online environment. Interaction was seen as a critical component of the overall lab experience, almost as much so as the actual learning outcomes of the labs themselves. These comments were supported by the survey results emphasizing the high rating of the importance of student to student and student to instructor interaction coupled with the low rating of the effectiveness of these interactions in on online class (see Table 9). In addition, results from the general survey portion also showed that faculty respondents felt that interactions in face-to-face courses were more effective (see Table 7).

Another factor supporting the theme that engineering is different did not come from a statistical analysis of the quantitative data, but rather was a theme that was independently reported by a number of interviewees. Specifically, it was felt by engineering faculty that engineering, as a field, is conservative by nature and this conservatism is deeply rooted in the practice of engineering. Therefore, engineering faculty, being engineers themselves, are also conservative in their approach and implementation of any new technology or process, including teaching. Several interviewees reported that engineering faculty are particularly resistant to change. The combination of this conservative nature with issues such as the general perception of the ineffectiveness of online learning methods, the belief in worse learning outcomes, concerns about critical components of engineering education such as labs, hands-on activities, and design projects, and perceived additional time and effort to implement a new online course, could lead to reluctance to initiate or implement online engineering courses by those who have never done it. However, once an engineering instructor has developed and/or taught an engineering course online and gained some experience they find out that many of their preconceptions are not necessarily supported and their opinions change, leading to acceptance of online methods as reasonable and applicable to engineering education.

As noted in the literature, engineering courses and programs are more prevalent at the graduate rather than the undergraduate level (Bourne et al., 2005; Reynolds & Huisman, 2011). Interview responses showed that this difference is symptomatic of the nature of engineering courses including experiential activities such as labs. Several items were identified in the statistical comparisons, including that undergraduate instructor respondents rated many pedagogical methods and engineering topics as less effective when delivered online, and that undergraduate faculty felt that acceptance of online education by other faculty was lacking. When considered alone, there could be two reasons for this difference in opinion. Either undergraduate engineering educational topics and methods are actually less effective when delivered online, or because undergraduate engineering programs are rare, fewer undergraduate faculty respondents actually had experience with online courses, which ultimately could influence their perceptions. As it turns out, three times as many of the undergraduate level respondents had no online engineering experience (n=132) compared to those that had taught at least one online course (n=43). This outcome echoes the previous theme that those that do not have any online experience perceive online educational methods more negatively.

Interview respondents also reported that engineering labs and hands-on activities are more prevalent in undergraduate courses and less so in graduate courses. Since the perception is that engineering labs are more difficult to deliver online, this could be a factor in the disparity between undergraduate and graduate level implementation of online engineering courses or availability of online engineering programs at the undergraduate level.

Another outcome related to the undergraduate disparity is related to student motivation. The survey results indicated that faculty members believe that students require more discipline to succeed in online courses, and most interviewees agreed. Interviewees described graduate students as primarily self-motivated and more capable independent learners. They felt that undergraduate students had a broad range of initial abilities and in many cases needed more interaction and support. Since it is believed that online courses need more self-direction and motivation, it seems reasonable that graduate level courses would be considered a better fit for online delivery than undergraduate courses, given the belief that interaction is less effective in an online environment.

Implications and Recommendations

The emergent major factors of this research into faculty perceptions of online engineering education point to a number of implications and recommendations to address the gap in implementation of online engineering courses. These recommendations impact several stakeholder groups; namely, engineering faculty themselves, engineering departments and university administration in charge of online programs, and instructional designers and technologists involved in online education.

INSTRUCTIONAL DEVELOPMENT SUPPORT

This study found that faculty members identified development of online courses as an area of concern, including such areas as access to quality educational and technical resources, training, and compensation. Engineering departments and administrators interested in supporting the development and implementation of online engineering education should work to provide appropriate resources to engineering instructors that address these needs in an organized and strategic manner. This could include providing educational development resources for engineering faculty to assist and guide in the development of an online course. Faculty members mentioned a partnership type arrangement, where engineering educators would be in the role of subject matter experts and educational developers would assist in selecting, recommending, and developing the appropriate online course materials and pedagogical methods to support the goals of the instructors. This could include integrating these developmental resources into an engineering department (such as an educational resources center or department), or possibly partnering engineering and educational departments or colleges at the same institution if they are available. This arrangement would allow engineering educators to migrate to an online delivery format appropriate to their instructional needs without having to become an expert in online course development. Ultimately it could lead to an increase in their own skills and knowledge in the area of online instructional design; however, it would do so in a strategic and moderated manner instead of a haphazard or all-or-nothing type approach. Eventually, as instructors gain competency and experience, they could own their course development as was reported to be the case by some interview respondents with extensive online teaching experience.

In addition, faculty experience with online educational methods was an important theme identified in this research and should be acknowledged and integrated into any online program developmental strategy. This is not meant to imply that engineering departments should only hire engineering educators with online educational experience. Rather, a possible approach would be for administration to partner faculty that have taught online courses with those that have not in a type of online course development mentorship system to demonstrate the effectiveness of online instruction, share best practices, and expand the knowledge base for both participants. Inter-faculty communication and sharing of perspectives may help faculty members with little or no exposure to online learning address and potentially dispel negative preconceptions and myths about online learning. This recommendation does not replace the need for partnership with professional instructional and technical developers, but it may help address the concerns and resistance that some faculty members with no online teaching experience express concerning migrating to an online delivery format.

FOCUS ON DESIGN FOR ONLINE DELIVERY

Another recommendation related to online course development is for departments and administration to emphasize and support the initial design of new courses and redesign of traditional face-to-face engineering materials and pedagogical methods for online course delivery as opposed to simply attempting to replicate and migrate current materials to an online format. Faculty members and instructional designers should also embrace a paradigm of course redesign over replication when implementing an online engineering course. As noted previously, replicating face-to-face teaching methods and materials is often the norm in many institutions where standard lectures are simply video recorded, course documents are posted on a website or learning management system, and papers or projects are uploaded or emailed to the instructor. While these methods do employ online technology to some extent, it does not maximize the affordances available in online learning. So, the recommendation is to go beyond a mere suggestion or expectation of administration to 'put your class online', but to provide appropriate tools, resources, and guidance to assist in the development and redevelopment of appropriate online materials and methods.

TECHNICAL SUPPORT

The recommendations related to online course development are different from and in addition to the need for engineering departments and administration to provide appropriate technology focused training and support. While some engineering educators may be proficient in the use of basic instructional technology, many are not experts in this area and could use support in the appropriate selection, implementation, use, and support of specific technologies and tools. Ongoing technical support is also necessary to facilitate changes or addressing problems with the technology. This allows the engineering educators to do what they do best – engineering and teaching - as opposed to attempting to become information technology and multimedia development experts.

As noted in the section of the survey on effectiveness, the most common and simplest pedagogical methods employed (lectures, writing papers, and reading texts) were rated as most effective, possibly because they are the ones the faculty are most familiar with and are easiest to emulate online or in a learning management system. Engineering faculty should be involved in the selection and implementation of online technologies that fit with their pedagogical methods and academic goals and provided training and exposure to new and alternative technologies as options. This is in opposition to the external selection of technologies (at the college or departmental level, for example) which are then passed along to be implemented, which can result in faculty feeling disenfranchised and needing to 'work-around' the technology. This is a disincentive to faculty implementation and a barrier to development of effective online engineering courses.

COMPENSATION AND RECOGNITION

As seen in the survey and interview results, all of the activities regarding redesign, redevelopment, and training are perceived to be extra effort on behalf of the individual instructors. The research also found that an appropriate compensation system is a key concern of faulty and should therefore be considered by administration in developing an effective online engineering program. This includes a review and alignment of departmental and institutional goals, effective methods to recognize and reward developmental efforts by faculty, and providing adequate time and resources to support their efforts in an efficient and effective manner.

INTEGRATING ENGINEERING AND EDUCATIONAL RESEARCH

While some of the findings and recommendations are somewhat general in nature and applicable to different types of online programs in addition to engineering, there are a number of significant barriers specific to the nature of online engineering education itself, including such key topics as labs, hands-on activities, design projects, and the need for teamwork and interaction in these activities. To move online engineering education forward and remove these barriers (or the perceptions of these barriers), it will be very important for engineering and educational researchers to work together and focus additional educational research efforts in these areas and insure that this research is widely disseminated to engineering educators. As shown in the review of the literature, there have been some efforts and successes in online engineering educational research; however, this study did not reflect that the research or results were widely known by survey or interview respondents. Negative perceptions of online education continuing to persist in spite of available research and evidence to the contrary including that online learning outcomes are not comparable to face-to-face courses, interaction between students and faculty and students and instructors can be a significant problem, or the comments by interviewees that they cannot imagine how engineering labs could be implemented online. There is a need for additional engineering-specific educational research, as well as better integration and dissemination of educational research to engineering faculty to assist in addressing these perceptions and removing this barrier to implementation of online engineering courses.

Therefore, integrating educational research and engineering pedagogy is a critical recommendation. This can be achieved through a focus by departments and administration on facilitating this interaction, instead of just allowing it to happen on a random or case-by-case basis. Educational seminars and training can be important, but exposure of engineering faculty to educational research in this area is critical. As noted in the interviews, engineers and engineering faculty are considered to be conservative by nature and engineering itself is considered to be an experientially focused discipline, so demonstrations of effective online teaching methods, widely disseminated educational research that has a focus on engineering specifically and that describes potential educational advantages and effectiveness, and sharing of actual best practices by other engineering educators would be helpful in breaking down the barrier to initial implementation of online education. As was shown in this research, once an engineering educator has taught an online course, perceptions of the applicability and effectiveness improve significantly. So, a goal to moving forward is to demonstrate to more engineering educators that online engineering education, including labs and other activities, can be effective and meet their educational goals.

A final recommendation to address how to best handle labs, hands-on, and design activities in an online educational format is for departments and universities to invest in research and development in these areas. Support for such endeavors is critical, both from a financial investment sense as well as from a developmental and technological sense. The literature provides case studies of individual engineering instructors developing their own remote labs or integrating simulations and software that they developed themselves or modified into their own curricula. These are often isolated situations independent of larger scale departmental efforts. More broad-based hands-on and lab solutions could be developed by educational departments in cooperation with engineering subject matter experts, online technical specialists, and engineering industry or private sector engineering firms. In addition, this area is ripe for development by independent educational technology companies. The availability of educationally robust, cost effective, and user friendly online engineering lab systems and software would be an important step in removing a key barrier related to online engineering education.

Conclusion

This study synthesized the results of a comprehensive survey and focused interviews of engineering faculty members to identify factors that influence the implementation of online engineering courses. Three major factors were identified: online teaching experience, course development issues, and implementation of technical aspects particular to engineering in an online format.

Having previous online teaching experience was shown to positively impact acceptance and understanding of the effectiveness of online educational methods. Course development issues such as time and effort to develop courses, the need to redesign current course materials and methods as opposed to simply replicating them for online delivery, and technical support and compensation were all seen as barriers to implementation of online courses. Concerns about implementing the technical aspects of engineering education, such as labs, design, and hands-on activities, in an online environment were shown to be barriers for some engineering faculty and an important area of development and future research.

Limitations

As with all research, this study had a number of limitations. The first was the lower than expected response rate. The final response rate after numerous attempts to contact faculty members and reminders was 12.48%, with an original target of 20-30%. While the overall number of respondents was adequate for meaningful statistical analysis and represented a wide range of demographic variables and groups, a higher response rate could provide larger populations for some demographic variables with numerous sub-groups such as engineering discipline.

In the survey portion of the study, there were seven independent demographic variables and sixty five dependent survey items. Each survey item was analyzed against each demographic variable using an independent t-test or ANOVA. This created a very large number of analyses, potentially creating an issue with compounding errors. To help minimize this issue, a type of correction was needed in this analysis; therefore the confidence interval was raised from 95% to 99% for all comparative statistical analyses (Armstrong, 2014).

This research was also limited geographically to engineering faculty and departments in a single state. The overall number of institutions involved, as well as the varied institutional demographics such as program size and public and private institutions, should provide a representative cross section of national engineering programs that should allow generalizability of the results.

Based on the background research indicating that engineering labs were considered a potential barrier to implementation of online engineering education, a survey question requesting information on the type of lab experiences in use in a faculty member's engineering program was included. The format of the question was apparently confusing to the survey respondents and ultimately the question was not included in the analysis of the results. A better alternative would have been to collect information from each respondent on their individual experience with various modalities of face-to-face and online labs. This survey question format issue limited the ability to drill down into faculty member experience with labs to try and uncover any information on why labs were considered to be so ineffective in an online format.

Future Research

This research was intended to be an exploratory study looking at a broad range of topics identified in the literature as potential barriers to the implementation of online education. A mixed-methods approach was used, including both quantitative survey data and qualitative interview responses. This study identified a number of factors with significant results and a small group of dominant themes that seem to impact the implementation of online engineering education.

To address the research question, this study focused on one primary stakeholder group - faculty members. Future research could include a comparable study to explore the perceptions of other stakeholder groups, such as students, potential employers, or administrators involved in engineering programs. Students could be considered the customers of online programs, and it would be informative to know what they want, need, or prefer related to online engineering education and how this might drive the implementation of online engineering programs. As identified in this study, perceptions of potential employers about online education were considered as a possible barrier, and it would be informative to know how much an online program actually impacts hiring of engineering graduates. Finally, a study similar to this one but involving administrators would be helpful to determine what their concerns and perceptions might be regarding implementing online engineering programs and courses.

It was also recommended by some respondents and as an outcome of this study to continue to do research on online engineering labs. Future research should focus both on the technical aspects of developing effective online learning experiences using new and innovative technologies in different engineering disciplines, as well as on the development and refinement of methods and technologies to assist in addressing concerns of faculty members regarding learning outcomes and enhancing participant interaction.

The research problem for this study was related to the gap in implementation of online education in engineering programs. Background research indicated that engineering lagged behind other academic disciplines, so this study was developed to explore potential reasons for that gap. For completeness and to provide for comparison data, it may be beneficial to do a similar study on other disciplines identified in the research as having a high level of online implementation. This may also provide information on best practices for engineering programs to implement moving forward.

Concluding Remarks

Online education at the university level has been around in different forms for a number of years. As online technologies evolve and new tools and methods are developed, educators and educational technologists will continue to experiment with different applications and approaches in an attempt to provide better learning outcomes and a better educational experience, both for students and educators. Engineering education is one field that has lagged behind others in the implementation of these technologies and approaches.

Faculty members have expressed a number of opinions concerning perceived barriers to implementation of engineering education online. However, the literature on educational research, along with case studies in certain areas such as labs and learning outcomes, demonstrate that these barriers can be addressed and overcome through focused efforts, research, and support. In a manner of speaking, the gap in implementation is related to the difference in perceptions and the reality of online engineering education combined with the conservative nature of engineering. Continued study, experimentation, design and redesign of tools and methods, developmental and technical support, and education of engineering faculty members are keys to closing this gap in implementation. This study is intended to provide additional information and recommendations to help in moving this field forward.

APPENDICES

Appendix A – Survey Instrument

This survey instrument was delivered via an online survey tool (Qualtrics). Demographic question responses are generally drop-down menus or numeric fields. Likert item responses are via radio-buttons.

Faculty Perceptions of Online learning in Engineering Education

Dissertation Survey Instrument

Part 1: Demographics

1. Gender [M, F]

2. What is your age? [standard bracketed age ranges]

3. I primarily teach: [undergraduate, graduate]

4. Primary Program Area: [engineering discipline: civil, chemical, electrical, mechanical, etc.]

5. Institution Type: [public, private – non-profit, private – for profit]

6. Approximate Engineering Enrollment at your institution (Undergraduate and Graduate, all engineering disciplines): [bracketed ranges]

Lab experiences are an important part of many engineering programs. For the next question, please use the following definitions:

- On campus, Hands-On Labs: Hands-on labs using equipment that requires attendance in person on campus to perform the lab exercise.

- Remote Labs: Students access, view, manipulate, and/or collect data from real lab equipment online through remotely controlled systems. Students do not go to the on-campus labs.

- Virtual or Simulated Labs: Students use computer simulations (online or stand-alone programs) that emulate engineering lab experiences

7. Please estimate the proportion of lab courses in your engineering program that use the following delivery methods. If a lab course employs multiple methods, include all methods in your estimation. Your answers should be in percentages and add up to 100 (do not use % sign in your answers).

Example: 50 Physical / 30 Remote / 10 Virtual / 10 No Labs = 100

- On-Campus/ Hands-On Labs
- Remote Labs
- Virtual / Simulated Labs
- No Labs

Experience:

For the purposes of the questions in this study:

- Online Course - defined as a course with most or all of the content delivered online. Typically there are no face-to-face meetings.

- Blended or Hybrid Course - defined as a course that blends online and face-to-face delivery. Substantial proportion of the content is delivered online and may have a reduced number of face-to-face meetings.

- Face-to-Face Course (F2F) - Traditional course delivery involving direct presence of instructor and students. May use very limited web-based technology to facilitate delivery of course materials.

- Simultaneous Online / F2F Course - Face-to-face or blended course that is taught simultaneously / cross listed with a fully online version of the course. An example would be a Monday / Wednesday course that meets F2F and is also recorded or broadcast via the internet to distance education students.

7. Approximate number of ENGINEERING courses you have taught in the following formats in the last 5 years (whole numbers):

- Online Courses
- Blended/Hybrid Courses
- Face-to-Face (F2F) Courses
- Simultaneous Online / F2F Courses

Part 2: Online Education - General

These questions pertain to your perceptions of online courses in general. Please share your opinion whether or not you have taught a course online.

8. Please rate your agreement with the following statements. [All sub-questions are 5-point Likert, 1= Strongly Disagree, 5=Strongly Agree]

- Online courses in engineering are easier for students than face-to-face courses.
- Online courses in non-engineering topics are easier for students than face-to-face courses.
- Learning outcomes are comparable in online and face-to-face engineering courses.
- Learning outcomes are comparable in online and face-to-face non-engineering courses.
- Students are less willing to 'speak their mind' in an online class than in a face-to-face class.
- Students communicate more in an online class than they do in a face-to-face class.
- Online courses require more time for students to complete successfully than face-to-face courses.
- Face-to-face classes provide better opportunities for students to interact than online classes.
- Student and faculty interactions are more effective in face-to-face classes than they are in online classes.
- More problems occur in online courses than face-to-face courses.
- More students withdraw from online courses than face-to-face courses.
- Students who procrastinate should not take an online course.
- Students require more discipline to succeed in online courses.
- Online courses can be taught just like face-to-face courses.
- Online courses require changes to standard face-to-face course content.
- Online courses require changes to standard face-to-face teaching methods.

9. Can these topics be effectively delivered in online courses? Please rate your agreement with the following statements.

[All sub-questions are 5-point Likert, 1= Strongly Disagree, 5=Strongly Agree]

- Engineering theory courses can be effectively taught online.
- Engineering design courses can be effectively taught online.

- Engineering labs can be effectively taught online.
- Technical/scientific topics can be effectively taught online.
- Courses heavy in mathematics can be effectively taught online.
- Non-engineering courses can be effectively taught online.

Part 3: Importance in Teaching Courses

For this question, think about IMPORTANCE of the following pedagogical approaches IN GENERAL, not necessarily only in an online context.

Please rate your agreement with the following statement for each of the items listed below.

10. This item is important in teaching engineering courses. [All sub-questions are 5-point Likert, 1= Strongly Disagree, 5=Strongly Agree]

- Project-based learning activities
- Lab activities
- Team activities
- Interaction between instructor and student
- Interaction between student and student
- Interaction between student and content
- Complex equations / mathematics
- Hands-on learning / activities
- Design projects / activities
- Ill-structured problems (possibly multiple solution and/or optimization problems)
- Real-world problems (possibly working with industry / capstone-type activities)
- Lectures
- Reading texts
- Writing essays / papers / reports
- Student presentations
- Specialized software packages (Matlab, Labview, CAD, etc.)

Part 4: Effectiveness of Online Delivery

For this question, think about EFFECTIVENESS of the following pedagogical approaches in the ONLINE delivery of engineering courses.

Please rate your agreement with the following statement for each of the items listed below.

11. This item can be effectively delivered or performed in an online format for engineering courses: [All sub-questions are 5-point Likert, 1= Strongly Disagree, 5=Strongly Agree]

- Project-based learning activities
- Lab activities
- Team activities
- Interaction between instructor and student
- Interaction between student and student
- Interaction between student and content
- Complex equations / mathematics
- Hands-on learning / activities
- Design projects / activities
- Ill-structured problems (possibly multiple solution and/or optimization problems)
- Real-world problems (possibly working with industry / capstone-type activities)
- Lectures
- Reading texts
- Writing essays / papers / reports
- Student presentations
- Specialized software packages (Matlab, Labview, CAD, etc.)

Part 5: ONLINE COURSES - Support and barriers

These questions pertain to your perceptions of support or barriers in teaching online courses. Please provide you opinion whether or not you have taught a course online.

12. Please rate your agreement with the following statements.

[All sub-questions are 5-point Likert, 1= Strongly Disagree, 5=Strongly Agree]

- It takes more time and effort to teach an online engineering course than a face-to-face course.
- Faculty accept the value and legitimacy of online engineering education.
- Faculty have appropriate technical support to develop online engineering courses.
- Faculty are compensated for developing and teaching online engineering courses.

- Faculty receive appropriate training in the development of online engineering courses.
- Faculty are encouraged to develop and deliver online engineering courses.
- Faculty are required to develop and deliver online engineering courses.
- Lower retention rates in online courses are a barrier to the growth of online instruction.
- Lack of acceptance of online education by potential employers is a barrier to the growth of online engineering instruction.
- Lack of acceptance of online instruction by faculty is a barrier to the growth of online engineering instruction.
- Lack of acceptance of online instruction by administration is a barrier to the growth of online engineering instruction.

[Open Ended Question]

13. Are there any other barriers to implementation of online engineering courses that aer not listed above?

Appendix B – Interview Instrument

This is the interview instrument utilized in this research study. Respondents were first provided a consent for as required by IRB procedures. Respondents were also provided a copy of this instrument prior to the interview. All interviews were conducted via telephone, recorded digitally, and transcribed.

Dissertation Research

Faculty Perceptions of Online Learning in Engineering Education

Interview Instrument

Researcher: Lance Kinney

IRB Study: 2010-08-0093

1. Introduction and Consent

2. Research Question: What factors do engineering faculty members perceive influence the implementation of online engineering courses and why?

Demographic Information

3. Demographic Information

   a. Verify name, institution, grad/undergrad, engineering discipline(s), program size, number of years teaching engineering

   b. Please provide a brief description of your experience with online teaching: What classes taught online; how many courses / years; type of online course format, experience with online labs. If no online, find out about courses taught, how many, type of course format.

General Questions

4. In your opinion, what factors do you perceive influence the implementation of online engineering courses and why?

5. What barriers do you perceive in the implementation of online engineering courses?

Results from study (these are questions derived from the survey research):

In this section, we will discuss the results of the survey portion of my research. I will lay out some of the significant results and ask for your opinion on why this might be the case. Please share any thoughts you might have on these results.

6. In one portion of the survey, respondents indicated their perceptions of the effectiveness of various aspects of engineering being taught or presented online – such as hands-on activities, engineering labs, lectures, design activities, real-world (capstone) projects, etc. Survey results indicated that there was a difference in responses between undergraduate and graduate faculty members, with undergraduate faculty ranking all of the features as lower – less effective - than graduate faculty. As a(n) [undergraduate / graduate] engineering instructor, what do you think about this result and why?

7. The survey also indicated some statistically significant differences in responses between instructors with no online engineering experience and those having taught at least one online engineering course (whether online, hybrid, or simultaneous). The following are some of the results – what do you think about these results and why? [Note: Scale 1=strongly disagree / 5 strongly agree]

   a. The ‘some online’ group agreed (3.14) and the ‘no online’ group did not agree (2.37) that learning outcomes are comparable in online and face-to-face engineering courses.

   b. The ‘no online’ group rated ALL of the online engineering activities (hands-on activities, engineering labs, lectures, design activities, real-world (capstone) projects, etc.) as less effective than the ‘some online’ group did.

   c. A lack of acceptance of online education by potential employers was indicated as a potential barrier by ‘no online’ respondents (3.58) and as less of a barrier (2.85) by those with ‘some online’ experience.

   d. A lack of acceptance of online education by faculty was considered to be a barrier by both groups, but ‘no online’ felt it was more of a problem (3.75 vs 3.38).

8. In evaluating the effectiveness of various aspects of engineering being taught or presented online – such as hands-on activities, engineering labs,

lectures, design activities, real-world (capstone) projects, etc., the two lowest rated items (by far) were engineering labs and hands-on learning activities, followed by team activities and design projects and activities. Labs, hands-on, and design were also rated as very important for engineering education, but were rated very low on effectiveness. What are your thoughts about these activities being delivered online? Also, describe your experiences have you had with each, if any:

a. Engineering Labs (2.08)

b. Hands-On Activities (2.26)

c. Team Activities (2.50)

d. Design Projects and Activities (2.62)

9. Do you think these low ranked activities are key factors / barriers in the acceptance or implementation of online engineering education?

10. The final section of the survey asked about specific barriers to implementation of online engineering courses or programs. What do you think about the following results and why?

a. Respondents felt that faculty are not being compensated for developing and teaching online engineering courses (2.12).

b. Respondents felt that faculty are not receiving appropriate training in the development of online engineering courses (2.16).

c. Two questions correlate and indicate that a lack of acceptance by faculty is a barrier (3.64) and that faculty do not accept the value and legitimacy of online engineering education. (So, basically, engineering faculty believe that engineering faculty do not value online engineering.)

11. Is there anything else you would like to share about online engineering courses or programs? Barriers, advantages, plusses, minuses, thoughts about the future of teaching engineering online?

Appendix C – Interview Codes

The following are the individual codes and axial group codes generated from the analysis of the interview transcripts.

Axial Codes

1. Concern or need (for faculty) – issues such as pay, obsolescence, security, workload, etc.
2. Engagement and Interaction – student engagement, interaction between students or student and instructors, etc.
3. Experience – issues related to experience of respondent such as traditional teaching, age, etc.
4. Interest and Motivation – acceptance of teaching online, comfort with online instruction, interest, motivation, etc.
5. Stakeholders – administration, students, companies, employers, as well as features that may influence them – work at home, any-time, learning styles, etc.
6. Support – technology related, developmental, infrastructure, resources, training, costs, etc.
7. Technology and Pedagogy – any technology or pedagogical references (labs, hands-on, flipped classes, blended learning, etc.), synchronous / asynchronous, curriculum issues, etc.

Initial Codes

1. Concern or need (for faculty)
   1.1. Economics (Pay)
   1.2. Obsolescence

1.3. Ownership / IP

1.4. Problems

1.5. Security

1.6. Workload

2. Engagement and Interaction (Can be related to pedagogy)

    2.1. Interactive

    2.2. Student Engagement

    2.3. Student / Instructor Interaction

    2.4. Student / Student Interaction

3. Experience

    3.1. Age

    3.2. Distance Ed

    3.3. Experience

    3.4. Future

    3.5. Traditional

4. Interest and Motivation

    4.1. Acceptance

    4.2. Comfort

    4.3. Interest

    4.4. Motivation

5. Stakeholders

    5.1. Administration

    5.2. Availability

    5.3. Companies

    5.4. Learning Style

5.5. Market

5.6. Off-Campus

5.7. Stakeholders

5.8. Work at Home

6. Support

6.1. Development Support

6.2. Economics (Program Costs)

6.3. Infrastructure – Resources

6.4. Infrastructure - Technical

6.5. Resources

6.6. Technical Support

6.7. Training

7. Technology and Pedagogy

7.1. Asynchronous

7.2. Blended

7.3. Capstone

7.4. Curriculum

7.5. Design

7.6. Flipped Class

7.7. Hands-On

7.8. Labs

7.9. Lecture

7.10. Math

7.11. Modules / Chunking

7.12. Pedagogy

7.13. Quality

7.14. Replication

7.15. Redesign

7.16. Simulation

7.17. Synchronous

7.18. Teams

7.19. Technology

7.20. Video

Appendix D – Coding Example

Below is an example of initial coding of a transcript. Names and other identifying information have been removed.

engineering courses, what are the pluses, minuses, why you think people do it or what factors are important in doing these?

Interviewee: Okay. Well first of all there is a certain amount of cost for the capital equipment needed to make this possible and they are particularly for small schools that may be at prohibitive cost. I mentioned that when [university] got started in this back in the 60s it was [company] that provided all the expensive equipment that made it possible and so that's one consideration, but I think there are several other considerations. One of them that was really quite important in the [university] case is student needs. We did this initially because students were working in industry and they wanted to take courses and they didn't want to have to drive all the way down to campus after work and by making it possible to have the classes in the workplace you could offer the courses. During the day you could allow the students not to have to do all that travel. It worked out a lot better when you had inclement weather.

Comment [LK15]: economics, infrastructure - technical

Comment [LK16]: stakeholders, companies, work-at-home, synchronous

In other words, you were actually providing a service to students that particularly at the graduate level was often very, very much needed and very much appreciated. A really interesting example of that is I had a number of students who were in the military and they would be in a different location every semester, but they were still taking courses from me from the same school, getting their degree from the same school and doing them contemporaneously if not in real time because of this kind of capability. You made it possible for a lot of people who would otherwise not have been able to get a graduate degree to get a graduate degree.

Comment [LK17]: advantage, work-at-home, stakeholders, synchronous, asynchronous, technology

And I think very often people lose sight of the fact that that's one of the main pluses of this mode of education is that you are serving a class of people who otherwise you couldn't reach. I think that's one of the most important motivators for doing this, more so I would say than cost, although cost has been something that has been brought up more recently. Another big deal is both faculty and administrator have to be willing to do two things. They first of all have to be willing to support the idea of doing it and secondly they have to be willing to change in order to accomplish it.

Comment [LK18]: advantage, stakeholder, economics, administration, redesign

For example, the administration has to be willing to accept the fact that they can't just set up a calendar based on the on-campus students and expect the distance students to follow the same calendar. There are some practicalities involved there that they have to be willing to deal with and a lot of the time the people who are in charge of that sort of thing don't think about it until it's too late and then have to deal with a problem that, oh they've scheduled graduation on the same day as the final exams for the online students, you know, that sort of thing.

Comment [LK19]: administration, replication, asynchronous, problems, traditional

And so they have to be willing to make changes and I found that that was actually one of the hardest things to do because there is gigantic administration and a gigantic infrastructure and a gigantic system that has been built up over the years to serve on-campus students and when you try to serve the distance students, the online student, sometimes that infrastructure has so many parts and is such a complicated infrastructure that it really takes a long time before it can move.

Comment [LK20]: administration, traditional, problems

A related factor is how they count credit toward a faculty member having taught a class. Normally they say, well, it's contact hours. Well, how do you count a contact hour when the student isn't physically there, you know, and I won't go into details, but there are some situations

Appendix E – IRB Information

- Revised Research Proposal
- Study Approval Letter

Revised Research Proposal

- **Note:** This dissertation proposal was approved by dissertation committee on March 21, 2014. Chair of dissertation committee is Dr. Min Liu (mliu@austin.utexas.edu)

I. Title – Faculty Perceptions of Online Learning in Engineering Education

II. Investigators – Principal Investigator -Lance Kinney

III. Hypothesis, Research Questions, or Goals of the Project

A. Research Question:

What factors do engineering faculty members perceive influence the implementation of online engineering courses and why?

IV. Background and Significance:

The implementation of online learning in higher education has been rapidly expanding, with a predominance of institutions offering online courses or fully online programs. During 2013, over 7.1 million students took at least one course online (Allen & Seaman, 2014). The implementation of online programs is approximately equal for most major discipline areas such as business, liberal arts, education, etc.; however, research indicates that engineering programs have a significantly lower implementation rate and there has been little growth in online engineering programs (Allen & Seaman, 2008, 2011, 2013).

There is no comprehensive research at present to examine the reasons behind the lag in implementation in online engineering education. The proposed research focuses on engineering faculty perceptions regarding online learning and will provide insight into issues and barriers to implementation in engineering education and therefore potential reasons behind the gap in implementation.

To address this research question, the proposed study will use a two-phase explanatory mixed methods design collecting both quantitative and qualitative data to explore and compare various factors identified in the literature related to the adoption of technology and online learning, as well as the unique characteristics of engineering education, to attempt to identify the reasons behind this lag in implementation of online learning in engineering education. The study will first collect and analyze survey data from a broad sample of engineering faculty members, and then interview a subset of engineering faculty members to expand upon and provide a richer understanding of important factors uncovered during the survey phase.

The proposed sample of survey participants for the first phase is all engineering faculty members at ABET accredited engineering programs in Texas. Each will be contacted via email available from their institution websites using Qualtrics survey software. To further investigate and elaborate upon the survey results, the second phase of the study will include interviews of a subset of individual faculty members representing a demographic cross section of the engineering faculty population and their responses qualitatively analyzed.

Allen, I. E., & Seaman, J. (2008). Staying The Course - Online Education in the United States, 2008 | The Sloan Consortium. Retrieved January 14, 2013, from http://sloanconsortium.org/publications/survey/staying_course

Allen, I. E., & Seaman, J. (2011). Going the Distance: Online Education in the United States, 2011 | The Sloan Consortium. Retrieved January 14, 2013, from http://sloanconsortium.org/publications/survey/going_distance_2011

Allen, I. E., & Seaman, J. (2013). Changing Course: Ten Years of Tracking Online Education in the United States | The Sloan Consortium. Retrieved January 14, 2013, from http://sloanconsortium.org/publications/survey/changing_course_2012

Allen, I. E., & Seaman, J. (2014). Grade Change: Tracking Online Education in the United States, 2013 | The Sloan Consortium. Retrieved January 21, 2014, from http://sloanconsortium.org/publications/survey/grade-change-2013

V. Research Method, Design, and Proposed Statistical Analysis:

Survey data will be collected via an online survey delivered to engineering faculty at all ABET accredited engineering programs in Texas. Questions will be statistically analyzed for comparisons within respondent types and sub-groups (graduate / undergraduate; civil engineering, electrical engineering, etc.), and comparisons made between groups.

A subset of faculty participants (10-15 faculty) will be interviewed with follow-up questions. Data will be analyzed using qualitative methods (transcription, coding).

VI. Human Subject Interactions

A. Sources of Potential Participants - The population consists of all engineering faculty at ABET accredited engineering programs in Texas. Since all participants are engineering faculty, they will most likely be over the age of 30. The total population of engineering faculty in Texas is approximately 2,100. The final number of faculty respondents is expected to be approximately 33% or 700. While generally there are more male than female engineering faculty members, there will be no discrimination in respondents. There will also be no discrimination for race or ethnic background. All surveys and interviews will be in English. Study participants will not be under any coercion or undue influence.

B. Procedures for the Recruitment of the Participants. Applicable faculty participant names and contact information will be gathered from publicly available engineering departmental websites. Faculty participants will be contacted directly via email with invitations to the survey. The survey itself contains consent information. Invitations for face-to-face interviews will come directly from investigator based on representative demographic information provided during the survey phase. All participation is voluntary and will not be coerced or related to any influence of the university.

C. Procedure for Obtaining Informed Consent. Consent information for the survey portion will be included via the online survey form. Participants will view study information prior to entering the survey and will be asked to contact the investigator if they have any questions or concerns. The researcher will not obtain written signatures from survey participants due to the research activities taking place completely online. Instead, participants will be asked to complete the survey as an indication of their agreement to be in the study or close the browsing window and to not complete the survey if they do not agree to participate.

Specific representative individuals from the previous respondents to the survey will be contacted for interviews. The faculty participants will be selected from the group of faculty originally contacted for the survey. Interview participants will be provided with a written description of the interview study and consent process prior to the interview, either via email or in person. The interviewee will have an opportunity to review the consent form, discuss the study protocol and consent process, and ask the interviewer questions as need to clarify the interview and consent process. If the participant agrees to participate in the interview, they will indicate their agreement verbally. The interviewee will be allowed to keep a copy of the consent form for their records.

Since all interview data will be collected and reported confidentially, the only record of the interviewee's identity would be the consent form. Since this study exposes participants to minimal risk and research activities would not require written consent when performed outside a research setting, a waiver of written consent is requested. Therefore, written consent forms will not be collected or saved by the researcher.

D. Research Protocol. All survey data will be collected confidentially via an online survey tool Qualtrics. Survey participants will only be asked to complete the online survey. Questions will include basic demographic information (gender, educational level (undergrad / grad), engineering program (civil, electrical, etc.)) and then the main body of the survey data consisting of Likert Scale ratings of participant attitudes and perceptions of different parameters concerning online education. The survey should take 5-10 minutes to complete.

Interview participants will be asked pre-determined interview questions and all responses will be digitally audio recorded, transcribed, and coded. All interview data will be collected via face-to-face interviews. Questions will include basic demographic information as listed above. The interview should take approximately 30 minutes to complete.

E. Privacy and Confidentiality of Participants – For the survey portion, both privacy and confidentiality will be maintained via a secure online survey. The database will include name and email information, but the survey will not. For the interview portion, privacy and confidentiality will be maintained by removing all references to individual identification (names, schools, etc.) from transcripts. After transcription and the completion of the study, recordings will be erased. All data will be delivered only to the researcher and not to faculty members or the university. Surveys will be available online and do not need to be completed in public, at school, or in class and may be completed at a time and place of their choosing. Interviews will be conducted in private with only the interviewer and interviewee in attendance. No names or other identifying information will be collected. Participants may skip questions if they are uncomfortable answering and can stop their participation at any time. All survey responses will be confidential and returned directly to the researcher. The researcher will assign a code such that no personally identifying information is used to label the data.

F. Confidentiality of the Research Data. Survey data will be retrieved via the secure online survey tool Qualtrics with UT EID password protection. All data will be downloaded by the researcher and maintained on a password-protected computer. It will not be available via a network. There will be no paper versions of the survey instrument or responses. Data will be deleted from the Qualtrics system once data collection is complete. All data will be analyzed and only survey statistics will be reported in the study. There will be no identifying information collected in the survey so no individuals will be specifically identifiable.

Interview data will be digitally recorded. The digital recordings will be downloaded by the researcher and maintained on a password-protected computer. Transcriptions and coding will be done on a password-protected computer. Information will not be available via a network. There will be no paper versions of the interview notes or responses. The digital recordings will be deleted once data collection is complete. There will be no identifying information collected or included in the report so no individuals will be specifically identifiable.

G. Research Resources. Survey data will be collected via an online survey tool such as Qualtrics and interviews will be digitally recorded. The survey and interview instruments will be set up by the researcher and all data will only be available to the researcher.

VII. **Potential Risks** – Potential risks are minimal. All participants are over age of 18; participation is voluntary and data will be confidential. Survey data will be kept confidential via an online survey tool; there is no benefit or penalty for participation in the survey; the faculty members nor their university will receive or review the individual data. There are no physical aspects or risks to this study.

VIII. **Potential benefits** – There are no direct benefits to any individuals that participate in the study. The overall benefit will be the investigation of effective distance learning techniques in engineering education.

IX. **Sites or agencies involved in the research project -** None. All faculty participants will be contacted directly.

X. **Review by another IRB.** No other institutions will be involved.

OFFICE OF RESEARCH SUPPORT

THE UNIVERSITY OF TEXAS AT AUSTIN

P.O. Box 7426, Austin, Texas 78713 · Mail Code A3200
(512) 471-8871 · FAX (512) 471-8873

FWA # 00002030

Date: 09/17/13

PI: Min Liu

Dept: Curriculum and Instruction

Title: Faculty and Student Perceptions of Online Learning in Engineering Education

Re: IRB Exempt Continuing Review Determination for Protocol Number 2010-08-0093

Dear Min Liu:

Your research was reviewed to determine if it still meets the requirements of research that is exempt from IRB review. It has been determined that it continues to meet the requirements.
Updated Qualifying Period: 10/01/2013 to 09/30/2016 . *Expires 12 a.m. [midnight] of this date.*
A continuing review report must be submitted in three years if the research is ongoing.

Responsibilities of the Principal Investigator:

Research that is determined to be Exempt from Institutional Review Board (IRB) review is not exempt from ensuring protection of human subjects. The following criteria to protect human subjects must be met. The Principal Investigator (PI):

1. Assures that all investigators and co-principal investigators are trained in the ethical principles, relevant federal regulations, and institutional policies governing human subject research.

2. Will provide subjects with pertinent information (e.g., risks and benefits, contact information for investigators and IRB Chair) and ensures that human subjects will voluntarily consent to participate in the research when appropriate (e.g., surveys, interviews).

3. Assures the subjects will be selected equitably, so that the risks and benefits of the research are justly distributed.

4. Assures that the IRB will be immediately informed of any information or unanticipated problems that may increase the risk to the subjects and cause the category of review to be reclassified to expedited or full board review.

5. Assures that the IRB will be immediately informed of any complaints from subjects regarding their risks and benefits.

6. Assures that confidentiality and privacy of the subjects and the research data will be maintained appropriately to ensure minimal risks to subjects.

7. Will report, by amendment, any changes in the research study that alter the level of risk to subjects.

These criteria are specified in the PI Assurance Statement that must be signed before determination of exempt status will be granted. The PI's signature acknowledges that they understand and accept these conditions. Refer to the Office of Research Support (ORS) website www.utexas.edu/irb for specific information on training, voluntary informed consent, privacy, and how to notify the IRB of unanticipated problems.

1. Closure: Upon completion of the research study, a Closure Report must be submitted to the ORS.

2. Unanticipated Problems: Any unanticipated problems or complaints must be reported to the IRB/ORS immediately. Further information concerning unanticipated problems can be found in the IRB Policies and Procedure Manual.

3. Continuing Review: A Continuing Review Report must be submitted if the study will continue beyond the three year qualifying period.

4. Amendments: Modifications that affect the exempt category or the criteria for exempt determination must be submitted as an amendment. Investigators are strongly encouraged to contact the IRB Program Coordinator(s) to describe any changes prior to submitting an amendment. The IRB Program Coordinator(s) can help investigators determine if a formal amendment is necessary or if the modification does not require a formal amendment process.

If you have any questions contact the ORS by phone at (512) 471-8871 or via e-mail at orsc@uts.cc.utexas.edu.

Sincerely,

James P. Wilson

James P. Wilson, Ph.D.
Institutional Review Board Chair

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