SOCIAL INNOVATION SKILLS DEVELOPMENT IN PROJECT-BASED
CAPSTONE CLASSES IN CIVIL ENGINEERING: A CASE STUDY OF THE CIVIL
ENGINEERING PROGRAM AT THE UNIVERSITY OF MISSOURI KANSAS
CITY

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CAPSTONE CLASSES IN CIVIL ENGINEERING: A CASE STUDY OF THE CIVIL
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ABSTRACT

Engineering schools play a key role in developing students' skills to appeal to an increasingly socially responsible job market. To do so, engineering educators must teach future professionals "social innovation skills": the ability to identify a community's social needs and transform this information into innovative technical solutions.. This study explored to what extent do engineering students exhibit social innovation skills in an industry-driven capstone project in the program of civil engineering at a Midwestern research-intensive institution. A qualitative case study was used on a civil engineering capstone design class where data collection included interviews, document review, and thematic analysis. The results suggest new directions for future research, such as integrating community engagement and learning the structure of the government as platforms to facilitating social innovation skill learning among engineering students. I proposed the new concept of Engineering Social Innovation Skills: complex social problem solving, integrated skills to interact with communities, creativity to address social needs, and community-driven systems thinking. "Social impact" was found as a critical element to foster social innovation skill learning. This dissertation offers insights into potential curriculum improvement for engineering capstone classes and suggests new avenues for future research and career opportunities.

Key words: Engineering education; social innovation; experiential learning.

SECTION ONE: INTRODUCTION TO THE DISSERTATION-IN-PRACTICE

Introduction

The current engineering curriculum was initially designed for engineers in the industrial age – an economy centered on the physical production of goods (Uhl-Bien, Marion, & McKelvey, 2007). At that time, engineers were expected to work in manufacturing and industry, utilizing only technical skills. Engineering education continued to progress with the transition to the information age, also known as the information technology revolution (Castells, 2010), where engineers in all fields had to learn non-technical skills like management and sales (Dukhan & Rayess, 2014). More recently, there has been a shift to non-technical skills development in the engineering curriculum learned through practical experience (Martin, 2017; Paloniemi, 2006). This new phase highlights the need for non-technical skills like collaboration, creation, and workplace learning (Leberman & McDonald, 2016).

Today, engineering education is being called to educate professionals able to fill a job market gap of specialists capable of understanding community needs, like social workers, and transforming those needs into innovative solutions (Bourn & Deal, 2008; Bozic & Dunlap, 2013). Industry is closing that gap by pushing engineering education to increase non-technical skill development to prepare professionals to perform corporate social responsibility duties from the profession (Heywood, 2016; Mehta & Gorski, 2016; Perkmann et al., 2013). Corporate social responsibility is the industry's commitment to managing the social, environmental, and economic effects of its operations in line with public expectations and a new phase of career opportunities for professionals capable of social innovations (Harvard Business Review). Social innovations, by definition, are a collection of new goal-oriented practices that use a series of strategies and tools to support communities. The goal is to improve

communities' quality of life while focusing on social capital instead of just economic capital (Dawson & Daniel, 2010). I have personally seen the benefits of being an engineer capable of social innovations for the community's benefit and the opportunities that I have transferred to students. As that practice informs positive impacts in the communities I have served, highlighting non-technical skills for social innovations in engineering is likely to increase the capacity of community engagement from the profession in corporate social responsibility projects (Jackson, 2008). Community engagement is a mutually beneficial collaboration between academia, industry, and communities (Bringle & Hatcher, 2002). It is likely to enhance job opportunities for engineers sensible to social innovation (Dart, 2004; Wyman, 2016). However, the literature on engineering education and curriculum designs do not address social and community-based problems in the engineering curricula that might lead to social innovations (Bozic & Dunlap, 2013; Gray & Koncz, 2017). Social innovation is transforming the scope of professions that simultaneously addresses (a) human needs and (b) technological solutions for both communities and businesses. Across industries, we find social and human sciences intermediating between communities and the engineering profession (Susskind & Susskind, 2015). Engineers have a role in humanitarian work (Helgesson, 2006) and still rely on human and social sciences to intermediate communications with communities to understand their needs. Thus, engineers exhibiting social innovation skills are called to “reintermediate” (Susskind & Susskind, 2015, p. 121) the communications with communities and the engineering profession to fulfill that role. Therefore, enhancing social innovation skill learning strategies into engineering curricula may result in more favorable employability rates (Morrissey, Beckett, Sherman, & Leininger, 2017). To address this issue, the purpose

of this dissertation in practice is to explore to what degree students exhibit social innovation skills in their culmination capstone class in a civil engineering department at a research-intensive university in the Midwest.

Background of the Study

The engineering workforce has to be able to utilize non-technical skills (Felder & Brent, 2003; Wyman, 2016) in order to supply the demand for professionals capable of aligning both technology and social innovations to increase industry and community engagement (Dart, 2004; Wyman, 2016). Today's engineering job market is integrating with social enterprises on a growing basis, and companies are, more than ever before, creating units that manage social responsibility with a community focus (Dart, 2004; Hirschi, 2018; Lebeman & McDonald, 2016). Current job search engines like Glassdoor.com or Indeed.com show career opportunities in corporate social responsibility for professionals in humanities and social sciences but not in engineering. This industry trend is opening opportunities for engineers to acquire social and other non-technical skills to fulfill these roles as liaisons between industry and communities. However, engineering curricula do not focus on many of these non-technical skills to work with communities (Dukhan & Rayess, 2014). Skills for social innovation are non-technical skills that are meant to involve communities that could be developed through engineering project-based curricula (Mehta & Gorski, 2016). In particular, this dissertation utilizes innovation skills (EU, 2019) to foster four engineering social innovation skills: complex social problem solving, integrated skills to interact with communities, creativity to address social needs, and community-driven systems thinking.

Academia is interested in engaging with industry because it is the major

employer of engineers in the United States (Canfield, Ghafoor, & Abdelrahman, 2012). Those relationships open opportunities to increase job placement for its graduates and attract funding for research and infrastructure (Morrissey, Beckett, Sherman, & Leininger, 2017; Perkmann et al., 2013) while also providing students with real practice and increasing the number of students attending apprenticeships in industry (Acworth, 2008; Mendoza, 2015). This engagement starts with industry providing most of the projects for experiential learning classes, which usually focus only on technical skills development (Fink, 2013; SCE, 2019). Based on how the UMKC civil engineering curriculum is structured, students currently have few classes to learn how a project impacts a community when working on plans that industry partners offer during their capstone classes (Bringle & Hatcher, 2002; Fink, 2013; Papas, Mora, Jaccheri, & Mikalef, 2018; SCE, 2019), but it is unclear how this knowledge is materialized in practice. Considering the American industry sector's increasing corporate social responsibility actions (Dart, 2004), students prepared to utilize social innovations skill are becoming more relevant.

Currently, professionals from social and human sciences are driving community engagement instead of professionals in engineering capable of social innovations (Jackson, 2008; MacCallum, 2009). For instance, when industry engages with a community to design a civil engineering project, an intermediary profession like sociology, for example, initiates communications and assessments to transmit the community needs to the engineers. This role can be fulfilled by the engineers themselves and then create more effective communication with communities in addressing their needs, reducing the challenges that come with intermediaries. It also means that a new workforce in the corporate social responsibility field will include

engineers with the skills and capacity to create innovative projects that address social needs after the effective interaction with the community they are creating the design for (Murray, Caulier-Grice, & Mulgan, 2010). That is the focus of social innovation.

Social innovation skills in the engineering profession could lead to community engagement. In this scenario, community engagement in engineering is a reciprocally beneficial interaction wherein faculty and students propose innovative solutions to community problems during project-based classes (Bringle & Hatcher, 2002). In practice, engineers with social innovation skills effectively interact with communities who are beneficiaries of industry social responsibility (Cajaiba-Santana, 2014). For instance, designing assistive technologies like mobility aids for people with disabilities require students to interact with a community, in a real environment, to learn more about the problem they are solving and the context for implementation.

Social innovations diverge from technological innovations in the anticipated results (Dawson & Daniel, 2010). Specifically, technical innovations in engineering stimulate the creation of new products, physical and digital, even when those serve to resolve social problems (Cajaiba-Santana, 2014). Engineers equipped with social innovation skills accelerate the design and delivery of new products, processes, and programs useful for communities (Starr & Minchella, 2016). For example, engineers involved in the creation of mobility aids, for instance, if they are directly in contact with the community the aids are meant to serve, they can understand daily routines, values, and other issues impacting final users of their products as well as the environment in which that innovation will operate (Murray et al., 2010).

Traditionally, engineering schools in the United States utilize project-based curricula to promote skill development. Project-based learning activities have links with

the cognitive processes of acquiring critical skills, with the stimulus for learnings, and with the provision of meaningful problems that motivate learners (Kearsley & Shneiderman, 1998; Krajcik & Blumenfeld, 2006). ABET includes a social focus in the student learning outcomes, and the civil engineering curriculum adopted it into projects provided by industry (see Table 6 in Section 3 and Appendix E). Thus, the interaction between students and communities provides opportunities for the enhancing of these non-technical skills learning in the project-based curriculum (Dawsib & Danie, 2010). Also, a project-based classes would promote technical and non-technical skills, simultaneously, to respond to the emerging challenges in industry with community engagement by having professionals that are equipped to directly interact with communities instead of hiring professionals in the social sciences (National Academy of Engineering, 2004; Pol & Ville, 2009).

Although ABET's role is to ensure that today's college students are prepared to develop solutions that make life on our planet safer and more sustainable (ABET, 2018), the "how" to make that vision a reality in the classroom is not well described in the accreditation standards. ABET in its publication Sustainable Engineering 2018 states that engineering should grow global citizens through social services and promote that schools cultivate an interest in social innovation at home and at abroad. There are only two out of seven student learning outcomes related to social aspects but still too broad for enhancing social innovation skills (see Table 6 in Section 3). Thus, the contribution of this dissertation in practice is to provide capstone classes with strategies that fulfill ABET accreditation standards and while support communities by providing scenarios to exhibit social innovation skills.

More than 3,000 engineering and technology programs in the United States

design their curricula to meet the standards set by the Accreditation Board of Engineering and Technology (ABET, 2018A). ABET accreditation criteria state that learning outcomes “describe what students are expected to know and be able to do by the time of graduation” (ABET, 2018, p. 3). These learning outcomes relate to the knowledge, skills, and behaviors that students acquire as they progress through the program. ABET criteria intend to provide learning outcomes that broadly describe the skills for innovating, managing complex systems, and maneuvering within realistic social constraints (ABET, 2018, ABET 2018A; Dukhan, Schumack, & Daniels, 2008).

To become an ABET-accredited program, the curriculum for the Civil Engineering at UMKC has been designed by the faculty and continuously evaluated by the program constituents to assure programs that provide relevant, competent, and sustainable engineering professionals. Currently, following ABET standards, the curricula provide: (a) the technical foundation classes critical for disciplined thought, team communication, and a lifetime of professional re-invention (see Appendix E); (b) the general education classes that provide written and oral communication skills, and an understanding of societal constraints; (c) the professional courses that prepare students for a transition to practice or research and create a balanced view of production and productivity; and (d) the design classes that provide skills for systematic integration of constraints and sustainable solutions. In this case, denominated industry-driven project based or capstone classes. In accreditation field-visits, ABET requires samples of class assignments to evidence that the class activities are aligned to the curriculum learning outcomes (see Appendix E), that is a method that ABET program evaluators utilize to determine if programs meet the criteria. That is why I am studying the capstone project reports to identify if there are indications of students exhibit social

innovation skills. In the absence of an standardized assessment to evaluate student skill learning at the capstone class in study.,

The importance of an ABET accreditation is the possibility to provide employers with a workforce that follows standardized program curricula that support new skill development ; in which student outcomes map to and support program educational objectives; and in an institution in which program educational objectives are consistent with the mission of the university and the profession.

This Dissertation in Practice Proposal has its foundation on qualitative case study research in a capstone class at the ABET-accredited program of Civil Engineering at the University of Missouri Kansas City (UMKC). One component to reach ABET accreditation criteria as UMKC is through continuous improvement of capstone design courses – engineering culminating project-based courses – where students work on real-world industry-driven projects. Adding projects from industry into curricula is a typical leadership strategy to engage industry while achieving accreditation (Tedesco, Opertti, & Amadio, 2014). However, those learning outcomes, like those presented by ABET (see Table 6 in Section 3), are only related to industry-driven project based learning, leaving out community-based activities that lead to social innovation skills learning (Frank, Lavy, & Elata, 2003; Heywood, 2016). For instance, the concept of Engineers without Borders, in which students interact with communities to find appropriate solutions for their infrastructure and basic human needs, is an example of how community-based activities could form socially innovative engineers (Helgesson, 2006). Another component to reach ABET accreditation is to include student learning outcomes for each class in the program in the syllabi narrative (see Appendix E). The ABET general criteria for baccalaureate-level programs,

Criterion 3 - Student Outcomes, describes that the program must have documented student outcomes that support program educational objectives (see Table 6 in Section 3), plus any additional outcomes that may be articulated by the program (ABET, 2019). The current seven ABET learning outcomes do not directly align the skills definitions with industry non-technical skills requirements. However, Criterion 3 leaves open the opportunity to include new learning outcomes that highlight social innovation skill learning.

Industry usually defines non-technical skills in public job postings skills in supervisory, thought leadership, change management, and negotiation (Burning-glass, 2019; EU, 2019), but not related to community engagement or social innovation. Thus, the introduction of social innovation skill learning into engineering capstone courses entitles two opportunities for engineering schools. First, adding new non-technical skills such as social innovation skills to engineering curricula that satisfy both ABET and industry workforce demands of skilled workers capable of interacting with communities can be documented in the ABET self-evaluation report as a continuous improvement to curricula to fulfill the ABET criteria (ABET, 2018A; Burning-glass, 2019; Dart, 2004). The second opportunity arises from the fact that engineering schools have to innovate and use new strategies to effectively compete in the higher education market by increasing pre-graduation job placement rates (Christensen, Horn, Caldera, & Soares, 2011).

Based on the background literature of this case study and the literature presented in this proposal, it is possible to promote engineering social innovation skill learning within project-based industry-driven courses. Thus, this dissertation proposes contributions to scholarship and practice as follows. From the scholarship

perspective, I will submit the results to the peer-reviewed journal of the American Society for Engineering Education – *Journal of Engineering Education JEE*. This publication will, potentially, offer the opportunity for engineering schools to emphasize social innovation skill learning in capstone courses to respond to the new challenges in industry and society (EU, 2019; National Academy of Engineering, 2004; Pol & Ville, 2009). I will disseminate the results to practitioners who attend the American Society for Engineering Education (ASEE) 2021, *also utilizing the Journal of Engineering Education JEE*. In this conference, I will present to attendees who are seeking strategies to better position graduates in the job market through social innovation skills.

Statement of the Problem and Purpose of the Study

Civil engineering programs have not embraced social innovations in their program of study as new solutions, initiatives, and experimental methods to improve peoples' lives and community resilience (Murray et al., 2010). This is the problem statement summarizing the larger issue in which there are indications that in practice, many engineering curricula fail to connect current academic standards with the skill sets students need for social innovation and to fulfill industry and community demands in the Twenty-First century (ABET, 2018A; Bourn & Deal, 2008; Bozic & Dunlap, 2013; Canfield et al., 2012; Heywood, 2016; Murray, Caulier-Grice, & Mulgan, 2010). Because innovation and creativity are outcomes of experiential learning activities (Kearsley & Shneiderman, 1998), it is crucial for engineering education to leverage experiential learning for social innovation skills development while providing innovative engineering solutions addressing industry and community needs (Fischer, 1980, Gray & Koncz, 2017; Heywood, 2016; Kearsley & Shneiderman, 1998; National Academy of Engineering, 2004; Padmanabhan et al., 2018). Whereas industry is

utilizing professionals in social and human sciences to address community engagement, engineering education has the opportunity to fill those duties by enhancing social innovation skills learning (Gray & Koncz, 2017). Built on my personal and professional interest to bridge the gap between communities and the engineering profession, the primary purpose of the study is:

- To explore to what degree students exhibit social innovation skills in an industry-driven capstone class in the civil engineering department at a research-intensive university in the Midwest.

Industry-driven project based courses are likely experiential learning scenarios that highlight social innovation skills that students learn during their college degree. If this study gives indications that students exhibit social innovation skills through capstone courses, then this study could lead to redesigning a civil engineering curriculum to reinforce experiencing those these skills when interacting with communities. . However, if I found in this study that social innovation skill learning is not strong enough in these types of capstones, the dissertation in practice would extend conclusions to a proposal for new student learning outcomes in the pre-requisite courses for the next ABET on-site visit (see Tables 4 and Table 5 in Section 2).

Research Design

This study is following a qualitative approach, which is a scientific method for exploring and understanding meanings, concepts, and definitions of social and human problems (Merriam & Tisdell, 2016). Creswell (2009) summarizes that qualitative research methods typically support researching subjects for which there are few studies about a phenomenon. Qualitative research also aids the recognition of the distinctive role of the context in the ability that individuals acquire to build an understanding of a

problem. Therefore, qualitative research focuses on the description, analysis, and interpretation of a given phenomenon rather than testing hypotheses and relationships between variables (Creswell, 2009). Qualitative research collects and analyzes qualitative data to approximate and characterize a phenomenon in its context in a way that provides detailed descriptions and understanding. Unlike quantitative research, qualitative studies do not generalize to populations but to theories, concepts, and understandings. The data collection in qualitative research utilizes methods of observations, one-to-one interviews, open-ended questionnaires, focus groups, among others (Coffey & Atkinson, 1996). I chose a qualitative research approach because (a) there are few studies about social innovation skill learning; (b) qualitative methods would be especially useful in understanding an under-research topic, and that is non-technical skill development among student participants in an industry-driven project-based class that might lead to social innovation skills (Merriam & Tisdell, 2016); and (c) the qualitative approach also facilitated collection and analysis of rich data from class documentation and interviews with participants in order to further understand if students exhibit social innovation skills (Creswell, 2019).

This study uses a qualitative case study design (Baxter & Jack, 2008; Stake, 1995). A case study is a methodology to study the “particularity and complexity of a single case” (Stake, 1995, p. xi) with the purpose of understanding activities within specific circumstances. Case study research focuses on particularization and emphasizes the uniqueness of the case (Stake, 1995); thus, a unique case has a finite number of participants who provided their experiences, meaning, and concepts to the study. The case study strategy is an especially useful method to use when an issue lacks background information (Creswell, 2009) as well as when in-depth description and

analysis can be developed in a bounded system (Merriam & Tisdell, 2016). In case studies, the researcher is the primary instrument of data collection and analysis and has minimum control over events (Stake, 1995; Yin, 2009).

Stake (1995) denominates an *instrumental case study* as a unique case to gain a broader appreciation of an issue and simplifies the understanding of something else.

Researchers in the role of interpreters (Stake, 1995) understand that their background influences their interpretations (Creswell, 2009). As the interpreter, the researcher finds connections to make discoveries understandable to others, turning into an agent of new explanations and new knowledge. Stake (1995) cites that qualitative inquiry is notable for its emphasis on the holistic interpretation of a phenomenon in which knowledge is "constructed rather than discovered" (p. 99).-The most distinctive characteristic of qualitative case study research is its emphasis on interpretation (Stake, 1995).

Moreover, in the instrumental case study, according to Stake, the researcher has an obligation to carefully consider the high importance of the issue where the case becomes instrumental in exploring the issue. In other words, the setting is not of most importance, but the issue at hand. The researcher has to also give careful consideration to the context of the case, and potential restrictions in data analysis, while maintaining continuous, ethical, and robust interpretation to avoid generalizations and provide a rich narrative in the final dissemination of results.

The case study for this dissertation is the civil engineering capstone design class titled CE412/ANCH 311 Spring 2020 class at the University of Missouri Kansas City. The study of this class allowed me to gain an in-depth understanding of the skills students develop during this class and in relation to the four engineering social innovation skills – the issue at hand in this study (Merriam & Tisdell, 2016; Stake,

1995). Although this case study follows the accreditation standards in its structure, it is not typical due to the specifics of students' interaction with industry, local government, and the communities the projects will serve. This case study is not considered unique because multiple capstone courses in engineering bring real-world problems to class (Krajcik and Blumenfeld, 2006).

Case study research is the best approach to address the research question because (a) the class I selected is a case that facilitated the in-depth exploration of non-technical skill learning – the issue – while apprehending rich descriptions of how students and practitioners function in the same learning space where the data is naturally produced: the case – CE412/ANCH 311 Class of Spring 2020; (b) there are no previous studies of industry-driven capstone classes in its real-life context that provide guidance to identify social innovation skill learning; (c) this case is unique because it is context-dependent and is delimited by a syllabus approved by ABET; and in its content and structure is an industry-driven capstone class in engineering education, and so, it can illuminate the design of capstone projects in other contexts.

Researcher Positionality

As the researcher, I do believe that my scholar and practitioner experience supported my role as the interpreter of the data and the ability to describe the results to academic and industrial audiences. I am the primary instrument for data collection and analysis in this case study (Padmanabhan et al., 2008; Seale, 1999; Stake, 1995), and I have built the research question as the result of my personal and professional interest to bridge the gap between communities and the engineering profession. I was born and raised in Colombia in a rural community, and this is where I initiated my engineering profession. I learned technical skills while witnessing community needs, which could

be solved from the engineering profession, like affordable drinking water systems or construction of natural barriers to control river flooding. However, my community only had access to engineering services through government and industry; thus, I created a non-profit organization before graduating as an industrial engineer – Corporacion Cobeii – to address social needs utilizing federal grants to fund engineering capstone projects. In 2000, I engaged engineering schools in the city of Bucaramanga to participate in a project to build a rural elementary school utilizing civil engineering students' talent. Together, the capstone engineering students and I discussed with the community the best design that fit their needs, such as insulation, materials, budget, and maintenance. That was the origin of many projects to support communities from the engineering profession while providing students with real-world opportunities to learn non-technical skills.

In the United States, I have worked as an engineer leveraging synergies between industry, higher education, and social settings. I have worked in the leadership teams of the University of Missouri Extension and the UMKC School of Computing and Engineering performing duties in industry engagement and project management. These administrative positions, in particular, influence the decision-making process within the administrative areas of the organizations. Although my experience and position influence the outcome of the study, and I acknowledge my own preconceptions, it is not likely to introduce substantial influence into this research because I do not participate in ABET accreditation boards, curriculum design teams, or implementation for the CE412/ANCH 311 course. Although my position is as an outsider and researcher in this instrumental case study, I acknowledge my inclination to favor social innovation initiatives. Therefore, in precaution during the analysis of data from documents, I have

added to the research design interviews with three different types of participants as a method of validation of findings and assumptions.

Both the international and local experience in engineering education may also influence the interpretation and methodology used to analyze the data; thus, I utilized literature to contrast the knowledge I obtained from data analysis. Also, I was highly descriptive when reporting findings and disclosed in full any unethical or unintentional influence on my explanation of the results of the case study research. I acknowledge that interpretation is a continuous task during data collection, analysis, and reporting of findings. Thus, it is my commitment to acknowledge limitations and personal views from the interpretation to generate usable reports that other scholars and practitioners trust. Also, the instructor revised the final outcomes and conclusions of the dissertation in the form of validation of the trustworthiness in the data analysis.

As the researcher in this case study, I am taking an active role in data collection and interpretations (Stake, 1995). To increase the integrity of the findings, I utilized *triangulation* from multiple sources of evidence (Yin, 2009), in this case, documents - as the primary source of evidence, and the interviews with three types of participants. The triangulation happened in the thematic analysis in which the themes of the first source of evidence are compared with the themes found in the interviews, and vice versa. With data triangulation, I proposed to “construct validity” (p.116) due to numerous data sources that provided interpretations of the same phenomenon. I recognize that validation demands accuracy in measuring results and logic on inferring the meaning of those measurements (Stake, 1995). As the researcher, I choose triangulation because I have ethical obligations to “minimize misrepresentation and misunderstanding” (p. 109) and to go beyond simple repetition of data collection in an

attempt to find validity in the data I examine. *Trustworthiness* is the most broadly used criterion for evaluating the validity of qualitative research (Hancock & Algozzine, 2017). Shenton (2004) defines four distinct features that a case study should possess to validate its trustworthiness. First, the study is *credible* by reflecting how confident the researcher is in the truth of the findings of the study; thus, in particular for this case, all the data come from participants and literature. Second, the case study is *transferable* by demonstrating that the results have applicability to other contexts, conditions, and situations; thus, this case is a bounded-system study that can be replicable in other engineering capstone classes. Third, the case study is *confirmable*, which refers to the degree of neutrality due to the participants' answers constructing the findings rather than any possible influence of the researcher; in specific, I developed open-ended interviews to learn from participants rather than observe the phenomenon in the class setting. Lastly, the case study is *dependable*, in which the study had enough information to allow other researchers to repeat the study and to obtain similar and consistent findings; therefore, I provided highly descriptive findings and results, as well as for the methods I follow within the entire research process.

Theoretical Framework and Guiding Concepts

The theoretical framework for this study is how skills develop throughout experiential learning. The guiding concepts that complement that theoretical framework are : a definition of social innovation skills, , and Fisher's theory of skill development. In this case study, I used Fisher's theory as an assessment tool for social innovation skills development in the experiential learning context of a capstone class. The setting for the engineering profession used to be solving industrial-technological needs (Gray & Koncz, 2017; Koller, 1995; Pekermann et al., 2013;

Sanders, 1958). That environmental context has been changing to address community needs also (Phillips & Pittman, 2008; Wyman, 2016). This theoretical framework in experiential learning guided conversations with instructors and practitioners about community-engagement strategies at the University of Missouri Kansas City (UMKC) Civil Engineering program. It also supported discussions among stakeholders in the broader profession around the need to shift the engineering skill learning set analyzed towards social innovation.

Experiential Learning and Skill Development

Engineering students develop skills in learning spaces throughout an individual-based process of creating meaning through experience (Kearsley & Shneiderman, 1998; Krajcik & Blumenfeld, 2006; Veglis & Pomportsis, 2014). The CE412/ANCH 311 is the learning space (environment) to highlight social innovation skills as a result of experience with real-world projects that engage in community-based problems from the engineering profession. Although social skill learning happens through experimentation, curriculum design has to consider a) the design of learning spaces – in this case capstone classes, or the community environment, or the project location -; b) the diversity of learning styles to foster social innovation: assimilating, converging, diverging, and accommodating; and c) as explained in Figure 5, a four-stage cycle of social skill experiential learning when select projects and design class activities: concrete experience, reflective observation, mental or abstract conceptualization, and active experimentation (Kolb, Boyatzis, & Mainemelis, 2001; Kolb & Kolb, 2005). Although the study did not evaluate the context of skill learning, I codified data that indicated the influence of the learning space on the students' control of skills. For the purpose of this case study, the environmental context of work for the capstone classes

are the projects and the context for implementation. Thus, it is important to evaluate if a change in the environment, in comparison to the four capstone projects, indicates a variation in the level of control of skills, also known as cognitive development (Fischer, 1980).

Defining Social Innovation Skills

There are established engineering skills systems that could lead to social innovation. For instance, the Kern Entrepreneurship Education Network (KEEN) Engineering describes engineering non-technical skills by applying similes aligned with entrepreneurial concepts (KEEN, 2019). Also, there are new proposals for grouping engineering and non-technical skills, such as the Global Engineering Skills proposed by Bourn and Neal (2008). Global engineering skills include, among others, the capability to take a wide-ranging perspective and apply knowledge across countries to identify the impact that innovations produce in developing communities. Likewise, universities in the U.S. use ABET standards to define engineering non-technical skills in curriculum and public communications to constituents (ABET, 2018A; National Academy of Engineering, 2004; SCE, 2019). ABET establishes engineering non-technical skills such as communication, cognitive skills, problem-solving, and affective skills like the ability to listen, for example (Shuman, Besterfield-Sacre, & McGourty, 2005; Tedesco, Opertti, & Amadio, 2014). The European Commission presented six groups of innovation skills during the *Skills for Industry Strategy 2030*, a high-level conference in June 2019 (EU, 2019), which are: emotional-intelligence skills, innovation skills, managerial and entrepreneurial skills, soft skills, transversal skills, and leadership skills. From this list, I created a set of social innovation skills meant to foster the abilities to design and create solutions for social problems. As presented in Section 3, I

used reports and white papers publicly available at the website <http://skills4industry.eu>.

The skills I adapted to the notion of *social innovation skills* are complex social problem solving, integrated skills to interact with communities, creativity to address social needs, and community-driven systems thinking (see Table 1).

Table 1 <i>Funneling Engineering Social Innovation Skills from Innovation Skills Presented by the European Commission and the result of the Four Skills that Guide the Study</i>
Non-technical Skills for Industry (EU, 2019)
Emotional Intelligence Skills
Innovation Skills
Managerial and Entrepreneurial Skills
Soft Skills
Transversal Skills
Leadership Skills
Innovation Skills (EU, 2019)
1. Complex Problem-Solving Skills
2. Integrated Skills
3. Creativity
4. Systems Thinking skills
Engineering Social Innovation Skills
1. Complex Social Problem-Solving Skills
2. Integrated Skills to Interact with Communities
3. Creativity Skills to Address Social Needs
4. Community-driven Systems Thinking Skills
Note: Top-down extraction of Engineering Social Innovation Skills from Skills4Industry.eu. Section 3 explains the process followed to tailor the engineering social innovation skills.

Fisher's Theory of Skill Development

Although there are new theories that explain skill development, like the Skill Acquisition Theory (DeKeyser, 2007), I am utilizing Fischer's (1980) theory of

cognitive development or *skill theory* as an assessment tool for this study. Fischer (1980) describes the relationships between the construction of cognitive, social, and other skills with the physiological transformation of learning and problem-solving behaviors. In this theory, *skills* are defined as the individual's capability to control the behavior, thinking, and feelings within a given environment and context. Skills include "emotions, motivations, meaning, and actions" (Mascolo & Fischer, 2010, p. 5). The skill then is a "transaction of organism and environment" (Fisher, 1980, p. 479) where the individual, or organism in terms of the skill theory, controls its actions in that particular environment.

Fischer (1980) provides a set of transformational rules for gradually increasing skill complexity from one cognitive development level to the other. A given skill is developed systematically in 10 hierarchical levels, which are divided into three stages: sensory-motor skills, representation skills, and abstract skills. Each level determines a structure that describes the type of behavior that a person can control at each level and, progressively, what can move from one level to the next within the three stages. Accordingly, if there is any indication of social innovation skill learning, this study utilized skill theory to identify at which level(s) of cognitive development the participants self-describe learning a given skill in the capstone class in this study (see Figure 1).

Figure 1. Assessment Tool. Skill theory to identify the level of command of engineering social innovation skill learning.

In the sensory-motor stages, stages 1-4, all abilities are related to a set of sensory-motor actions and perceptions. The set works over entities like items, events, or people. In this stage, the individual develops only practical skills. The skillset bounds how to act on a specific entity but is unable to elaborate a concept or understanding until reaching level four. Representation skills are part of levels 4 to 7 in which the individual utilizes conceptual maps to represent interrelations between entities. However, he or she is still unable to connect multiple systems at the same time. It will be possible when he or she reaches level seven. This level is the culmination of the

representational development phase. The abstract set of skills is acquired from levels 7 to 10. Once the individual is capable of controlling the relation between the two systems, he or she can identify the impact and covariation of changes. At this point, the individual can control entities and construct an abstract concept of that entity. Thus, if there is any indication that students exhibited *engineering social innovation skills in the learning space of this study*, skill theory served to identify at what level of cognitive development students control those skills for the assigned project.

Research Methods

Based on the theoretical framework, the research question guiding this study is: *To what extent do engineering students exhibit social innovation skills in an industry-driven capstone project in the program of civil engineering at a Midwestern research-intensive institution?*

The Case

The case study is the CE412/ANCH 311 System Design II Spring 2020 class (see Appendix E). This is a traditional 3-credit hour course from the UMKC senior level required courses (fourth year of the degree) for the UMKC Bachelor of Science in Civil Engineering (BSCE). The project-based curricula for the BSCE are composed of five required credits of capstone design within the fourth academic year of the degree (see Appendix E) distributed as follows: CE 411 Civil Engineering System Design I is a two-credit studio design class that is offered in fall academic semesters and CE 412/ANCH 311 System Design II that is a three-credit studio design class open for each of the following spring academic semesters for those students who passed CE411 (SCE, 2019A). The two courses are composed of four teams and four projects. The composition of each project design team is ten BSCE students and one practitioner

(professional engineer – PE – in practice). The instructor plays the role of a coordinator and facilitator. The instructor selected the projects for the CE411 Fall 2019 class. The instructor confirmed that the same projects, student teams, and practitioners from the CE411 Fall 2019 class continued in the CE412/ANCH 311 Spring 2020 class. The industry-driven project selection occurs before each fall session of the capstone class (C. Halmen, personal communication, September 9, 2019).

The project sources are various local construction firms that have contracts with the government and industry. The deliverable to the industry project provider, at the end of CE412/ANCH311, is a study of the location of the project that includes two components. First, a location study report for the site of the project, for instance, to build a new station of the metro-car, the students study vehicle traffic volume, pedestrians and vehicle accessibility, electric services, current constructions in the surrounding area, businesses in operation, and more that students include in a matrix to evaluate macro and micro-location factors. Second, a report that includes 30% of civil drawings, or site drawings, to show a clear picture and construction considerations about landscaping and other site details. For the CE412/ANCH 311 Spring 2020 class, there are four projects provided by the industry, which the students started in CE411 Fall 2019 and continued through Spring 2020:

- Project 1. *A traffic calm study*. A traffic study client is a Kansas City based national engineering consulting firm that aims to compare before and after traffic volumes and vehicular speeds in the vicinity of the three temporary speed humps. This study revealed an approximate 400 vehicles per weekday and 100 vehicles per weekend day reduction in traffic volumes. However, the speed of vehicles was not significantly reduced in the northern segment

of the road. The reconfiguration of the island has yielded some positive results on the southern segment of the road. As a minimum, the contractor (civil engineering firm which provides the project for the class) and the City would like the modified Belinder/State Park Road island to be designed as permanent improvements as well as the speed humps if supported by traffic count data. However, before any permanent improvements are designed, the City would like a further evaluation of other traffic calming measures and their potential impact on traffic volumes and vehicular speeds as outlined in the city's traffic calming program.

- Project 2. *Structural design for a power station in Kansas City.* La Cygne Station Unit 1 was originally constructed in the early 1970s, and a second unit was constructed later that decade. The plant was later modified to improve the air quality to modern regulations, and in the process, the electrostatic precipitator was replaced with new equipment that now collects fly ash from both units and has significantly increased the volume of fly ash being handled on the site. As a result of these recent changes, a potential need has been identified that may require additional structures to aid in the control of fugitive dust from the fly ash handling system as well as the wash water from the cleanup of the equipment and haul trucks. The goal for this project was been to provide a general arrangement for new structures and a cost estimate for the structure(s) and then provide the structural design for the structure(s).
- Project 3. *Design of an intersection for the Missouri Department of Transportation (MoDOT).* A construction firm has a contract with MoDOT

to study civil engineering solutions for a safety project that has higher than average crashes and either speed or sight distance issues. The project identified the deficiencies along the route and at the intersection that are causing the crashes and developing three design options to improve safety along the route. The goal of the project is not only to find options that worked for the intersection but to find the options that gave the best cost-benefit ratio by incorporating the existing topographic constraints (water tower, driveways, pond) into the evaluations.

- Project 4. *Kansas City South Plaza Streetcar Station*. The KC Streetcar Main Street Extension will serve several important functions, including access to employment, neighborhoods, commerce, and activity centers along the Main Street corridor, which includes some of the densest residential neighborhoods and employment centers in the region, as well as the University of Missouri Kansas City (UMKC). The scope of the project includes suggesting to the City a list of alternatives to address specific requirements for site improvements, including safety, mobility, access, parking, and other amenities. Also, suggest to the City a list of alternatives to address specific requirements for site improvements, including safety, mobility, access, parking, and other amenities.

Participants

The participants are the individuals who actively participate in the CE 412/ANCH 311 Spring 2020 class. There are four types of participants: a) the instructor, b) the four professional engineers in practice, also known as practitioners in the setting of the study, c) an ABET representative for the UMKC SCE, and d) the

faculty of prerequisite classes of the capstone class who have taught them during the time students wherein the program. To start, the instructor is an associate professor of the Department of Civil and Mechanical Engineering is an active faculty member of the UMKC School of Computing and Engineering. This faculty member oversees the CE412/ANCH 311 and its pre-requisite CE411 Systems Design I. Traditionally, the practitioners are employees or shareholders of a civil engineering firm in the Kansas City region. The practitioners have an adjunct professor appointment in addition to their work commitment to industry. UMKC hires four practitioners, each academic year, as part-time instructors who facilitate the technical design for the civil engineering capstone projects. Those professional engineers devote 3 hours per week for 16 weeks in the preparatory course every fall semester and the same workload for every following spring semester course. Holding this double appointment allows the practitioners to utilize projects of their firms in the capstone classes to identify solutions using students' talent. It also guarantees the continuity of a practitioner, at least for the preparatory course (fall) until completion of the senior capstone design (following spring). The practitioners are fully involved in curriculum design and the student's evaluations. The practitioners in CE412/ANC 311 have prior experience in capstone classes CE411 and/or CE412/ANCH. Thus, the practitioners are very familiar with the learning space and the skill development process in capstone classes as well as industry demands. The current ABET representative is an associate teaching professor and an assistant dean of academic affairs of the UMKC School of Computing and Engineering who coordinates ABET on-site visits, coordinate the preparation of key documents and eligibility criteria for accreditation and re-accreditation, also coordinate the self-study reports to submit to ABET prior to that visit (C. Halmen, personal communication,

September 6, 2019). The UMKC School of Computing and Engineering has a dynamic rotation of in-class assignments, usually for the first and second year of the program. After reviewing ABET documentation, I identified the pre-required classes that have group projects as part of the class assignments. Thus, by the time of the data collection process, I formally requested introductions with the last faculty member in charge of each class, from Dr. Halmen, the department chair, or the ABET representative.

Data Collection

Documents are the primary data source in this qualitative case study. The instructor provided documentation of the CE 412/ANCH 311 Spring 2020 class and the prerequisite class CE411 System Design I Fall 2019. The prerequisite class gave insights on the structure of the class for spring 2020: the team formation, the overview of the projects selected, the project management plan that the practitioner assigned, and other high-level information I studied. The following are the documents I utilized:

- Course syllabus, student's final reports, students' final self-evaluations, project descriptions for CE411 Civil Engineering System Design I, fall 2019 and CE412/ANCH 311 System Design II, spring 2020
- ABET self-study documents presented to the evaluation committee in 2019: accreditation policy and procedure manual, criterion 2 – program educational objectives, criterion 3 -student outcomes, criterion 4 – continuous improvement, and criterion 5 -curriculum.
- Syllabi of pre-requirement courses of the case study: Math 266, Physics 240, CE275 Engineering Statistics, CE351 Fluid Mechanics, CE497 Engineering Hydrology, and CE411 System Design I.

The compilation of documents can be physical or electronic and followed

multiple considerations (Bowen, 2009). First, according to the University of Missouri System 100.030 Copyright Regulations, professors generally hold copyrights of curriculums or syllabus. I asked for written permissions to include documents in the case study, and the collection came directly from the instructors (see Appendix A). Second, I identified from literature other documentation, which may affect the results of the dissertation in practice, such as new regulations or new course documentation. Specifically, I looked at the written reports that students and practitioners provide to the instructor, seeking indications of learning of any of the four engineering social innovation skills. Then, I identified if the reports provide key statements that suggest a level of cognitive development for those four skills. Also, the documents for the study include syllabi for the required courses of the class, as well as the ABET self-study documents that provide an overview of the learning outcomes for the entire program.

Interviews took place simultaneously with the gathering and analysis of records and documents from the class. It served to collect various sources of evidence if needed to convey the purpose of the study and to increase the researcher's understanding of the non-technical skill learning in this bounded case study (Stake, 1995). I conducted and record interviews with the instructor and practitioners of the CE412/ANCH 311 Spring 2020 class (see Appendix A and B) and with a UMKC SCE ABET representative (see Appendix C). The first interview with the instructor has the objective to identify the rationale of the capstone curriculum design, the context for non-technical skill learning, the alignment of the class activities with ABET and industry requirements, the skills that the curriculum proposes, as well as engineering social innovation skills the instructor has observed that the students exhibit and are not part of the course description. Appendix A contains the Instructor Interview Protocol, which includes a

questionnaire within ten groups of series of open-ended questions as follows:

professional overview, curriculum design, projects, team dynamics, community engagement, social innovation, social innovation skills, ABET, and additional comments. An initial interview took place for about one hour and included following up interactions for clarification if needed. The second set of interviews were with the professional engineers, individually, via online for recording purposes, of one hour each. They directly interact with the students and face the skills students exhibit while providing their time and expertise to solve the industry project needs. Thus, with this group of practitioners, I also applied nine interview groups of questions (see Table 3). The practitioners were asked, in addition, questions regarding the project selection and the involvement of industry and communities in the capstone class and the final reports. Appendix B includes the Practitioner Interview Protocol. A third interview with the ABET representative took place online with the purpose of identifying opportunities and challenges to modify the curriculum at UMKC SCE to promote social innovation skill learning in project-based classes. Appendix C includes the ABET Representative Interview Protocol.

Table 2 *Initial Interview Transcript Data Aggregation Areas*

Codebook Interview Transcripts			
Groups of Questions	Social Innovation Skills	Ten Levels of Cognitive Development	
Curriculum design	Complex Social	Single sensory-motor sets	Representational
Skills and cognitive	Problem Solving Skills	Sensory-motor mapping	systems
development levels	Integrated Skills to	Sensory-motor systems	Systems of
Projects	Interact with	Systems of sensory-motor	representational
Team dynamics	Communities	systems, which are single	systems, which are
Community	Creativity Skills to	representational sets	single abstract sets
engagement	Address Social Needs	Representational mapping	Abstract mapping
Social innovation	Community-driven		Abstract systems
ABET	Systems Thinking Skills		Systems of abstract systems
Note: Initial areas to condense themes found in data analysis			

Interviews took place on conference call platforms, like Zoom or Skype. It facilitated access to the participants, recording of the meetings. Face-to-face interactions are not in consideration due to potential changes Covid-19 has created in the work environment.

Table 3 <i>Aggregation of Interview Open-ended Questions</i>	
Aggregation of Interview Open-ended Questions	Purpose/Focus
Professional overview	To obtain details of the participants' work and the interaction with the class and other participants
Curriculum design	To understand the process to create and modify curriculum in engineering capstone classes
Skills and cognitive development levels	To identify if there to what extent students exhibit that students the four engineering social innovation skills and at what level of cognitive development the interviewee considers the students are before and after the class
Projects	To identify the role of the projects in engineering social innovation skill learning
Team dynamics	To identify if working in teams has attribution to the learning process of social innovation skills
Community engagement	To seek for understanding of current opportunities for community engagement the class offers to students
Social innovation	To seek for definitions of social innovation from experiences and participants' interaction in engineering education
ABET	To understand in-depth the ABET interaction with non-technical skill learning in an industry-driven capstone class
Additional comments	To identify other themes or topics to expand the understanding of the case
Note: Ten thematic areas of interview questions	

Data Analysis

Following Stake (1995), data analysis includes the revision of raw data under various possible interpretations seeking patterns and links to draw tentative conclusions, identifying categories and themes to initial aggregate results, and then organizing the final report. This study considers two strategic methods for data analysis: categorical aggregation and direct interpretation. Those methods facilitated to “reach new meanings about cases are through the direct interpretation of the individual instance and through the aggregation of instances until something can be said about

them as a class” (Stake, 1995, p. 74). Data analysis for this study included *document review* to serve to analyze data from documents and *thematic analysis* to support the interpretation of data from interviews and literature review.

Document review is an iterative process of skimming, reading, and interpreting content related to the research question (Bowen, 2009). This document analytical procedure includes finding, selecting, appraising, and synthesizing data available in documents relevant to the study (Bowen, 2009; Fink 2013, Stake, 1995). Although document analysis is usually a stand-alone method, in the construction of case studies, I may use triangulation seeking convergence and corroboration from the interview transcripts (Bowen, 2009). Document review examined content from documents related to the classes CE411 System Design I Fall 2019 and CE412/ANCH 311 System Design II Spring 2020. The next step is to code the content of those sources of data into pre-existing themes and categories related to the ten hierarchical levels of cognitive development and the four engineering social innovation skills (Canfield et al., 2012; Eppes et al., 2012; EU, 2019; Felder & Brent, 2003; Fischer, 1980). Finally, the results of the coding of each document was then interpreted in relation to each other using the same pre-existing themes and categories (Hancock & Algozzine, 2017).

Thematic analysis is a process for classifying, storing, and accessing the information from (a) documents and (b) interview transcripts (Hancock & Algozzine, 2017) and served to analyze content from all data sources. Given the thematic analysis is an iterative process (Hancock & Algozzine), the initial fourteen categories that the theoretical framework provided, and I aggregated in Figure 1, served to codify all the data, a codebook for analysis (Coffey & Atkinson, 1996). Overall, I systematically examine each piece of information constructively for answering the research question

(Hancock & Algozzine, 2017; Stake, 1995; Yin, 1994). For this process, I utilized MS Excel files for qualitative data analysis.

Throughout this process, I plan to re-examine the literature in section 3 to eventually propose new holistic engineering social innovation skills that also includes skills like the ones in ABET, KEEN, and industry job postings for future class interventions.

Figure 2. The sequence of activities for data collection and analysis. From UMKC SCE CE412/ANCH 311 System Design II, Spring 2020 class.

Limitations

There are limitations to this study. First, the use of one class at one institution is a limitation; however, other researchers will find insights from the rich descriptions I will provide from this industry-driven case study in order to address the issue of integrating social innovation skills into engineering capstone classes. Second, the study relied on existing documentation to start the data collection process. As the researcher, I

did not know ahead of time the exact type of documents that will be part of the case study.

Significance of the Study

Engineering schools have been increasing job placement efforts in response to intensifying enrollment and to perform on key performance metrics of accreditation standards (Acworth, 2008; Bybee, 2010). The communities that receive the impact of industry social responsibility view academia as an economic development actor that bridges the gap between industry and social innovation needs by providing a skilled workforce (Christensen, Horn, Caldera, & Soares, 2011; Dunkan & Rayess, 2008; Murray et al., 2010; Sanders, 1958). Currently, industry is the primary intermediary responsible for solving social innovation needs. However, industry alone cannot meet community demands for social innovations. Thus, higher education comes in to promote non-technical skill learning as a means of appealing to employers wanting to provide higher social impact on the communities they serve (Dukhan & Rayess, 2014; Gray & Koncz, 2017; Heywood, 2016).

For the School of Computing and Engineering, this is an opportunity to increase non-technical skill development towards elevating industry and community engagement in the engineering profession (Howaldt et al., 2016; Cajaiba-Santana, 2014). Particularly for the UMKC SCE, the ABET next accreditation cycle requires evidence of curriculum improvement (UMKC SCE Dean, personal communication. May 16, 2019). This study served to indicate actions taken to improve the program in the Self-Study Report required for the next on-site reaccreditation review (ABET, 2018). In practice, this study is also significant because it serves as a framework for instructors to create innovative project-based learning curricula (Koller, 1995;

McLurkin et., al 2013). Implementing these curricula is an opportunity for engineering schools to increase their competitive advantage in at least four ways. First, appealing to higher education's target market – students – with high job placement rates (Molesworth, Scullion, & Nixon, 2010). Second, enhancing industry engagement while equipping engineers with social innovation skills (Grimm, Fox, Baines, & Albertson, 2013; Howaldt et al., 2016; Wyman, 2016). Third, provide a guide to integrating new learning outcomes into engineering curricula, which promote the preparation of engineers capable of social innovations (Padmanabhan et al., 2018). Fourth, increasing the engineering schools' prestige as entities that continuously look for activities that match with society, sustainability, and environment (Bozic & Dunlap, 2013; Morrissey et al., 2017; Koller, 1995).

The significance of scholarship for the case study has its foundations on the provision of two scholarly results in a dissertation in practice. First, the study is significant due to its goal of proposing a model to improve engineering project-based curricula. It is a contribution to literature. The proposed model would set the foundations to facilitate engineering social innovation skill learning in industry-driven capstone classes (ABET, 2018A). Second, the study introduces to literature that I denominate *Engineering Social Innovation Skills*, which meet ABET accreditation criteria (ABET, 2018A). I proposed the addition of those non-technical skills to engineering curricula in the form of a learning outcome aligned with social innovation skills, for instance, to prepare engineers to be socially innovative and capable of community engagement. This contribution to scholarship is also essential because social innovation is a tool to engage the community, but the concept is only used in arts and social science schools and not well integrated into the curricula of science,

technology, engineering, and math, also known as STEM (Bozic & Dunlap, 2013; Canfield et al., 2012; Dukhan & Rayess, 2014; Newman, Couturier, & Scurry, 2010). In social sciences, for instance, professionals exhibit social innovation skills by unrolling potential for emancipation, capacity building, improving human rights, and similar. Also, students in social sciences develop strategies built on diversity to support communities and serve in practice to renew cultural identity building (MacCallumm, 2009; Murray, Caulier-Grice, & Mulgan, 2010).

As a scholar, I would possibly make recommendations that lead future class interventions to enhance social innovation skill learning. It includes the hypothetical scenario in which the capstone curriculum includes engineering social innovation skills as part of the learning outcomes and learning objectives for the course CE412/ANCH 311. Considering the bounded system as the context or reality for those skills, I considered Stake's (1995) three realities to interpret qualitative data to build a comprehensive understanding of a case study: (1) an *external reality* capable of stimulating curriculum improvement, in the form of industry workforce needs, for instance; (2) an *experiential reality* facilitating the non-technical skill learning when students interact with real-world projects; and (3) *rational reality* on the participants meaning and definitions of the inquiry of the study. Outcomes of the study of this instrumental case provided transferable conclusions with the holistic picture of the non-technical skills that students exhibit while working in industry-driven problems. Then using my perspective as the researcher, I illustrated the complexity of the topic of the case study: engineering non-technical skills for social innovations in industry-driven project based courses (Hancock & Algozzine, 2017).

In practice, my dissertation could turn into a model to add community-based

problems and the study of learning outcomes within the current industry-driven project based curricula. This practice will allow students to interact directly with the community that gets the project impacts. Therefore, the results of this case study led to recommendations for (a) the application of strategies, (b) measuring results, or (c) validating the impact of the change in the engineering curricula. Thus, the outcomes of this study, potentially, would facilitate the learning of non-technical skills in engineering for social innovation (Gray & Koncz, 2017; Sanders, 1958; Wyman, 2016).

Summary

Engineering education is continually working with industry and communities to fulfill the mission of providing a skilled workforce capable of generating a positive impact in society (Brewer & McEwan, 2010). Thus, higher education institutions continually identify how to engage an industry that is adopting socially-driven endeavors (Dart, 2004) by promoting the skill sets that graduates will use as professional engineers (Maringe & Gibbs, 2008; Molesworth et al., 2010).

Accreditation in engineering programs, like ABET (ABET, 2018), is one of the multiple strategies that engage with industry (Felder & Brent, 2003). Thus, project-based learning in engineering curricula has to fulfill both the academic standards and the non-technical skillsets for social innovation as industry demands (Dart, 2004; Fink, 2013; Heywood, 2016).

The current qualitative case study proposes the analysis of an industry-driven engineering project-based class in the civil engineering program at the UMKC School of Computing Engineering. Built on my personal and professional interest to bridge the gap between communities and the engineering profession, the primary purpose of the study is to identify any indication of the students are exhibiting social innovation skills

in the CE412/ANCH 311 Spring 2020 class. If so, the dissertation in practice will leverage opportunities in the use of industry-driven project based classes, or capstones, for social innovation skill learning. This case study has its theoretical foundation in experiential learning, and uses guiding concepts of skill theory (Fischer, 1980) and non-technical skills that could lead to social innovation as defined by the European Commission in one of the six categories presented in the Skills for Industry Strategy 2030 (EU, 2019). Data collection includes documentation provided by the instructor of the capstone class, interviews with the instructor, and the four practitioners supervising industry-projects. The analysis consisted of document review and thematic analysis of data into pre-existing categories related to social innovation skills development.

The case study results will serve as a reference to practitioners seeking to promote the learning of engineering social innovation skills. As a scholar, I contributed to the literature by describing a path to re-design engineering project-based curricula and submitting a manuscript to a peer-reviewed journal, i.e., Journal of Engineering Education JEE. As an engineer in practice, I aim to provide a presentation at a convention of the American Society for Engineering Education (ASEE). This presentation will be an opportunity to promote non-technical skill development to enhance job opportunities in the profession.

After studying the literature and reflecting on my experience as a former member of the UMKC SCE leadership team and as the researcher, I argue that social innovation skills are a possible means to engage communities better in the engineering profession. This explored how to articulate social innovation skills into engineering project-based curricula.

Definitions of Key Terms

Accreditation Board for Engineering and Technology, Inc (ABET) is an entity that accredits engineering programs in the United States.

Industry engagement is a mutually beneficial relationship between academia and industrial entities like corporations, employers, manufacturing associations, among others.

Community engagement is a mutually beneficial long-term relationship between academia and communities that are beneficiaries of industry social responsibility actions. Its purpose is to address a variety of socio-economic, political, and environmental factors that affect communities. Academia usually promotes community engagement by creating partnerships with community-based organizations. For instance, advocacy groups, non-profit organizations, and other groups of individuals organized to impact society positively.

Industry-driven project is a real-world engineering problem. The entity, which provides the project to a particular engineering class, is looking for students to approach technical solutions while providing students with experiential learning opportunities.

Capstone project, also known as a culminating project, is a team assignment that serves as a culminating academic and intellectual experience for students, usually during the last year in engineering programs.

Community-based problem is a real-world community challenge that leads to social innovations. Currently, communities reach academia and industry as intermediaries to utilize students' talents to approach innovative solutions that positively impact the community involved while providing students with experiential

learning opportunities.

Learning Outcomes for ABET accreditation standards are denominated student outcomes and are intended to provide general information about the focus of student learning. Student learning outcomes are the measurable knowledge or skills that students will walk away with after completing a capstone course. Those describe what a student will be able to do with the knowledge, skills, abilities, and attitudes gained as a result of completing the course. ABET requires engineering programs to demonstrate that their students can apply knowledge of engineering, science, and mathematics; and an ability to conduct experiments, analyze data, and communicate results.

Skill in this study is the ability to perform technical activities in engineering fields; for ABET accreditation standards, skills are abilities to apply knowledge.

Social Innovation is a new concept introduced by industry around the world to engage the workforce capable of working in social settings and promote positive change in society.

SECTION TWO: PRACTITIONER SETTING FOR THE STUDY

Organizational Context

I conducted an empirical investigation utilizing an industry-driven capstone course at the School of Computing and Engineering at the University of Missouri Kansas City (UMKC SCE) in order to determine ways to infuse social innovation skills in these classes. The results of this investigation provided the empirical evidence to generate change in the profession, starting with a department, that is, this case study. This section starts with a descriptive overview of the setting, continues with a historical summary of the UMKC School of Computing and Engineering, and finishes with organizational and leadership analyses of the setting as a means to develop a strategy to generate curriculum change in their capstone at this institution, which can be used as a model for change in the profession at large.

Setting for the Study

Civil engineering is a discipline with the most extensive community interaction (SCE, 2019) as much of the design and creation of its projects that impact communities — for instance, bridges, roads, water systems, and other constructions. Therefore, capstone classes in civil engineering education are also known as project-based classes. Normally, private construction firms provide the projects for civil engineering students to work on in their capstone classes, and so, for the purpose of this study, capstone classes are considered industry-driven project based classes. However, it is important to realize that given the nature of the discipline, these projects are in some ways related to community needs. This study is based on one of the capstone classes at the University of Missouri Kansas City (UMKC). The class in this study, the capstone course CE 412/ANCH 311 Systems Design II, is required for all civil engineering students. This class is a typical capstone class in civil engineering departments in the nation, and so, it

serves as the basis for curriculum design changes in the engineering education community at large. By enhancing the curriculum in a senior capstone course like this one, I studied how UMKC SCE could enhance social innovation skills while still complying with the Accreditation Board for Engineering and Technology (ABET) accreditation criteria (see Table 6 in Section 3) and pre-required classes (see Table 4 and Table 5).

The path of required courses prior to CE412/ANCH 311 System Design II (the case), in order, are Math 266, Physics 240, CE275 Engineering Statistics, CE351 Fluid Mechanics, CE497 Engineering Hydrology, and CE411 System Design I.

Table 4 .
Required Technical Engineering Courses in the CE program in each technical area –

Course	ST	WR	GM	CM	Lab/Exp	Design
CE 321 Structural Analysis	X					X
CE 335 Soil Mechanics			X		X	X
CE 351 Fluid Mechanics		X				
CE 378WI CE Materials			X		X	X
CE 411 System Design I				X		X
CE 412/ANCH 311 System Design II				X		X
CE 422WI Reinforced Concrete	X				X	X
CE 432 Foundation Engineering			X			X
CE 467 Construction Management				X		
CE 497 Engineering Hydrology		X				X

Note: Source - Criterion 5 – Self-study Site Visit 2019

Table 4 lists the courses that fulfill the four required technical areas in civil engineering, including where the students have a required design project and have hands-on laboratory experiences. All CE students have required courses in four

technical areas, including Structures (ST), Water Resources (WR), Geotechnical & Materials (GM), and Construction Management (CM). They conduct experiments as well as analyze and interpret data in at least two of the technical areas, including ST and GM. They also do substantial design work in all four of the technical areas.

Table 5.
Required Technical Engineering Courses in the CE program covering specific topics.

Course	Sustain	Project Mgmt.	Prof Ethics	Licensure
CE 321 Structural Analysis				X
CE 335 Soil Mechanics		X	X	X
CE 378WI CE Materials	X			
CE 411 System Design I		X	X	X
CE 412/ANCH 311 System Design II		X	X	
CE 422WI Reinforced Concrete	X		X	X
CE 432 Foundation Engineering		X		
CE 467 Construction Management		X	X	
CE 497 Engineering Hydrology			X	

Note: Source - Criterion 5 – Self-study Site Visit 2019

Table 5 lists how each of the required courses fulfills the four other aspects as required by the civil engineering program criteria, including sustainability, project management, professional ethics, and licensure.

School of Computing and Engineering at the University of Missouri Kansas City

The history of engineering education at the University of Missouri Kansas City started in 1929. Using its first name – University of Kansas City, it offered a degree in General Engineering through the College of Arts and Sciences. After joining the University of Missouri System in 1964, the University of Kansas City became the

University of Missouri Kansas City (UMKC). In 1974, a new engineering program was launched — the MU/UMKC Coordinated Undergraduate Engineering Program (CUEP), which replaced the General Engineering degree. The CUEP offered bachelor degrees in civil, electrical, and mechanical engineering (SCE, 2019).

In 1984, UMKC merged a degree in computer science, previously managed through the College of Arts and Science and the Computer Science and Telecommunications Program (CSTP). In 1987, the Coordinated Engineering Program (CEP) opened, adding graduate engineering degrees. This strategy responded to the emerging demand for bachelors, masters, and Ph.D. graduates in computer science. In 2001, those programs were the initiation of the UMKC School of Computing and Engineering (SCE), as we know it today. By 2003, the SCE created two departments: The Computer Science and Electrical Engineering Department and the Civil and Mechanical Engineering Department (SCE, 2019). The Department of Civil and Mechanical Engineering (CME) offers a Bachelor of Science in Civil Engineering (BSCE) and a Bachelor of Science in Mechanical Engineering (BSME).

The UMKC School of Computing and Engineering is an ABET-accredited school (ABET, 2018; SCE, 2019). It holds five accredited degree programs within the two departments in engineering and computer science including, (1) the Bachelor of Science in Civil Engineering, (2) the Bachelor of Science in Electrical and Computer Engineering, (3) the Bachelor of Science in Mechanical Engineering, the (4) Bachelor of Science in Computer Science, and the (5) Bachelor of Information Technology programs. The UMKC Bachelor of Science in Civil Engineering (BSCE), the program in this study, received the ABET accreditation on 10/01/1978. The next comprehensive ABET review is scheduled for October 2019 and October 2020 (ABET, 2018A). Thus,

the organization in this study has an interest in continuing improvements to curricula for the next accreditation cycle.

Capstone classes were incorporated into nearly every discipline of engineering due to the influence of ABET, industry, and scholars (Dutson, Todd, Magleby, & Sorensen, 1997). Although the format of capstone design classes varies significantly among engineering schools, ABET provides the minimum requirements for all capstone design courses in all engineering disciplines (ABET, 2018). The purpose of a capstone class is to immerse students in a capstone project to represent new work and ideas as an opportunity to demonstrate the knowledge and skills you have gained during your college career (Dutson, Todd, Magleby, & Sorensen, 1997). Industry is often involved in capstone classes by providing projects, necessary funding, equipment, and expertise to engineering schools to prepare students to demonstrate they can meet the industry need with the knowledge the job market requires. This interaction turns typical capstone classes that follow the profession's academic standards into experiential learning scenarios: industry-driven courses that utilize real-world problems to facilitate skill development (Kolb and Kolb, 2005).

Organizational Analysis

Making changes in the curriculum is a necessary process for improving any academic organization, and that process usually begins with faculty. The reasons for curriculum changes are many, but they all boil down to a singular driving principle: improving learning outcomes as universities respond to an ever-changing world and job market. Faculty need to navigate the structures, politics, and relationships in their units in order to generate buy-in from all stakeholders of curriculum changes, including faculty colleagues, administrators, industry, and accreditation liaisons. In the following sections, I provided an organizational analysis using the structural, human resources, political, and symbolic frames from Bolman and Deal (2013) of the complex landscape that a faculty member must traverse to generate permanent change in the capstone class in the department of this case study.

The Structural Frame

Effective organizational management starts by “dividing work and coordinating it thereafter” (Bolman & Deal, 2013, p. 42) and sets the management strategy on areas of interest for the leadership like goal achievement, division of labor to specialized roles, diverse teams, decision making, and change. It also sets the rules and policies guiding work, including supervisory roles. As such, the structural frame focuses on the way work is organized in order to accomplish goals (Bolman & Deal, 2013).

The structural frame, in this case, is very important since it provides the roadmap of policies and procedures necessary to approve curriculum changes following ABET accreditation criteria and current UMKC policies. It is also based on how research-intensive universities like UMKC are governed.

UMKC SCE has a shared governance structure typical in any type of higher education institution like UMKC, which is divided into administrative and academic bodies. The governing of the academic body is executed by faculty normally through committees and academic freedom. However, given the importance of accreditation in engineering, these committees include an ABET representative, who is also a faculty member of the UMKC SCE. The administrative body at UMKC SCE is led by the Dean, an Associate Dean, and Department Chairs, all of whom hold previous experience as department chairs and professors. Those experiences give them an understanding of the needs of the faculty and what the process of curriculum change entails. During leadership meetings, department chairs present to the Dean and Associate Dean with reports on academic matters, including potentially associated allocation of resources needed. For example, when curriculum changes include the acquisition of new laboratories and equipment or engaging new industry partners. The Dean has a prerogative over the provision of those resources and is also the liaison with industry representatives. Thus, the UMKC Dean usually works with industry representatives on behalf of its faculty on curriculum changes so that those changes appeal to employers while fulfilling both academic and accreditation standards of the profession. This is particularly important for this case because the capstone classes are based on projects provided by industry, and so, it is also necessary to get the buy-in from industry partners.

A faculty member can make changes to a course per academic freedom as long as these changes follow ABET accreditation standards and the regular approval process of the various levels of faculty curriculum committees. Specifically, for UMKC SCE, the approval of the committee at the college level is sufficient for curriculum change.

The college-level committee is made up of members of the UMKC SCE faculty who must first be convinced by the faculty member initiating the change following specified college level policies for this purpose. Though a faculty member and even curriculum committees can make changes to their course(s) of their own accord per academic freedom, these changes must follow the rules of ABET's accreditation criteria. When a change does not yet meet the criteria of ABET, a request to ABET must be made via an internal ABET delegation.

The Human Resource Frame

The human resource frame sees the organization as a work environment in which there are mutually beneficial rewards for employees' individual contributions to the success of the organization. Thus, the organization should provide employees with the tools and support needed to accomplish institutional goals based on the needs and skills of employees. It also recognizes the individuals' needs for personal growth and meaningful jobs (Bolman & Deal, 2013) as a best practice to retain talented and productive employees. Bolman and Deal (2013) define that to reframe organizations utilizing the human resource frame to generate change, it is imperative to understand employees' motivations and the relationships between the organization and their needs.

Institutional efforts to generate positive curricular changes start with nurturing faculty member's internal motivation (Stupnisky, BrckaLorenz, Yuhas, & Guay, 2018), which can be explained by the self-determination theory (Deci & Ryan, 1985) of human motivation, development, and wellness. It identifies autonomous motivation as a predictor of performance. When a faculty meets three basic psychological needs – competence, relatedness, and authority, there are positive effects on autonomous motivation. Those effects are directly related to the implementation of effective

teaching strategies like instructional clarity, higher-order learning, reflective and integrative learning, and collaborative learning. Thus, it is recommended that UMKC SCE enhances strategies to optimize motivation for teaching that include offering faculty choice in course selection as well as teaching content and style. In this way, the faculty's ability to change the curriculum of the senior capstone class in this study as a way to foster social innovation skill learning into engineering education at UMKC is likely to promote autonomous motivation among its faculty.

There are other motivating factors for faculty and administrators that could come from successfully implementing curriculum change that also benefits universities. Administrators at universities like UMKC, including the Dean, are particularly motivated to have a good reputation among employers by graduating students with improved learning outcomes leading to more employable students and a reputation of effective teaching methods (Cable & Graham, 2000).

On the other hand, although a process of ongoing curriculum improvement is grounded in the UMKC mission statements (SCE, 2019), final goals for developing and implementing new curricula need to have strong concordance with the importance of students' success for faculty evaluations, especially for those who are primarily hired to teach. In other words, good student evaluations are a motivating factor for faculty (Felder, Brent, & Prince, 2011). Finally, faculty members who enhance curriculum could attract funding, such as the National Science Foundation grants to improve STEM education. Innovation and other grants have become an integral part of the faculty portfolio that enhances career opportunities, commonly to achieve permanent positions in academic institutions (Sheridan, Savoy, Lee, Filut, & Carnes, 2017).

The Political Frame

The political lens sees organizations as a coalition of individuals and groups who act to serve their own interests given the limited resources available, subjective to the conditions the organization provides individuals to acquire power, and their relationships with other individuals and groups (Bolman & Deal, 2013). This dynamic includes differences among members of the organization that create conflict and competition, especially when the decision-making entitles scarce resources. Thus, power along with bargaining and negotiation skills turn into assets to influence resource allocation in favor of a group or an individual (Bolman & Deal, 2013).

Although the political frame sees the organization as an entity that faces ongoing conflict and power dynamics between internal and external groups (Bolman & Deal, 2013), at UMKC SCE most of the conflicts around curriculum change have low significance since the ABET requirement is mandatory, which minimizes conflict. However, if a change meets ABET criteria but needs resources, this will activate the political dynamic that the faculty or department chairs will have to navigate to promote the change.

Academic freedom plays an essential role in navigating political arenas at university levels (Russell, 2002). Academic freedom is the right the professors keep teaching without unreasonable interference or restriction from the law, institutional policies, or public pressure, which gives them power (Albatch, 2007; Russel, 2002). However, ABET representatives have an interest, and obligation, to protect accreditation standards. Thus, changes in the curriculum could create friction between the ABET delegate and the pro-change faculty in the faculty curriculum committee. The change suggested by this dissertation, in particular, involves at least two interest groups: the instructor of the capstone class and the ABET committee members. In

addition, as it is common, there might be disagreement among faculty members about the specific curriculum changes, despite the fact the faculty in charge of the class owns the curriculum.

Dr. Ceki Halmen, the CE412/ANCH 311 instructor of this case study, agreed to propose curriculum improvements based on the outcomes of the dissertation in practice. Additionally, he mentioned that his academic freedom to create change in the curriculum has limits considering he must follow the evaluation criteria for curriculum improvements as well as ABET criteria to support his proposal (ABET, 2018). Given this, Dr. Ceki Halmen must navigate the political arena and become a negotiator by networking and seeking support from other faculty colleagues, especially those in the curriculum committee. To negotiate and seek coalitions, Dr. Ceki Halmen must know the ABET criteria and what industry representatives want as employers. As the negotiating faculty member, Dr. Ceki Halmen must address with the ABET representatives how the CE412/ANCH 313 capstone redesigned course can remain ABET-accredited by providing enough evidence of how the introduction of social innovation skill learning into industry-driven capstone classes will a) keep the standards of the profession and b) be sufficient for ABET to introduce this change as a *curriculum improvement* in the evaluation criteria. Here is where the faculty's power given by the academic freedom and negotiation strategies come together to engage ABET on approving the change.

Faculty usually delegates the negotiation to the department chair, who creates coalitions to submit academic requests for obtaining resources to implement curricular changes. Internal negotiations usually happen through committee work. To change the status quo, faculty should stress the importance of focusing on clear and consistent

collective goals and the students' success (Bolman & Deal, 2013). This broad agenda brings the faculty members and administrative staff together to develop logical networks and partnerships that open positive outcomes in keeping with best leadership and practices in the political frame (Bolman & Deal, 2013).

The Symbolic Frame

For Bolman and Deal (2013), the culture of an organization is composed of symbolic forms and activities that “shape the organization’s unique identity and character” (p. 270). The symbolic frame assumes that people create symbols to address the human need for meaning, purpose, direction, faith, and hope to deal with uncertainty and ambiguity. Symbolic forms that provide the meaning for action include vision, values, myths, heroes, rituals, among others.

Any change that a faculty member wishes to make must align with the values and mission of their organization. Improving a curriculum that aligns with the current job market and employer needs will generally align with the mission of the university. Thus, the faculty member must be able to argue that their proposed change will aid the university in succeeding in its mission to ensure students are highly employable.

The core values of the organization and academic standards provide guidance and clarity when discussing curricular modifications and provide a platform to support and elevate change to the administrative and accreditation bodies. Faculty and other stakeholders should follow the values and visions endorsed in strategic plans and other similar institutional documents to introduce curriculum change. The department chair and the Dean often encourage this symbolism to promote faculty participation in institutional change starting with their own work in teaching, research, and service. In this way, faculty becomes an agent of positive change at UMKC if they exhibit in their

work the core values of the organization, which are: learning, collaboration, integrity, accountability, respect, and diversity.

The addition of education outcomes related to social innovation is an example of how the curricular change enhances the core value of *learning* by providing students with new non-technical skills to address job market requirements. This is also a means to promote learning within the School of Computing and Engineering on how to bring new education outcomes into an industry-driven capstone curriculum. The curriculum change is also a *collaborative* action that starts with a highly motivated faculty surrounded by the UMKC SCE colleagues who participate in the approval and implementation of the change. *Integrity* is exhibited at UMKC SCE when curricular changes follow the standards of the profession and the organizational best practices. And then, *accountability, respect, and diversity* are core values the faculty will address in the implementation phase of the curricular change.

UMKC Service-Learning is an example of how the university prepares students to share their time and talent with the community. The program is set up as a competency-based education experience in which students participate in organized activities that meet identified community needs while enhancing students' civic responsibility and other non-technical skills like reflective thinking (www.umkc.edu). This campus-wide program serves the UMKC core values and is highly supported by administrative leadership and faculty. Similarly, adding social innovation skills learning into the School of Computing and Engineering could become an integral piece of fulfilling the UMKC mission by increasing public support and visibility in the community, preparing a new generation of caring and experienced professionals, and prompting students to apply their knowledge and talents in a meaningful way.

Leadership Analysis

Leading into the future of engineering education is a transformational leadership endeavor at all levels of the organization (Northouse, 2016). Furthermore, at engineering schools, transformation starts in the classroom (Fink, 2013). Although changes in the engineering curriculum must fulfill ABET requirements, the leadership analysis here describes how faculty could promote change towards curricula improvement.

Faculty exhibit leadership in the context in which they interact with their constituents: students, faculty committees, ABET representatives, etc. Kotter (1998) sees leadership as different from management because leadership is a change-oriented process of “visioning, networking, and building relationships” rather than planning, organizing, and monitoring (Bolman & Deal, 2013, p. 345). Leadership comes from people in all positions within the organization and does not come automatically with high positions. At UMKC SCE, there are opportunities to exhibit leadership and to promote change. Hence, this analysis provides a series of tools for those faculty who wish to promote change, and, for the instructor of the class capstone, I am studying to implement change in the CE412/ANCH 311 capstone class.

Creating successful change in curriculum requires reframing faculty leadership within the School of Computing and Engineering. The faculty leader should first see opportunities to exhibit leadership traits and reframe leadership around curriculum change for the benefit to the whole organization. To provide elements to reframe faculty leadership, I utilize Bolman and Deal's (2013) concepts for effective leadership based on the organizational analysis above.

As a leader and agent of change, the faculty member, in the case in the

CE412/ANCH311 class, should see the organization through the four lenses I described above in order to create a strategy for change. To navigate the structural frame, the leader becomes an analyst and an architect when designing the new curricular structure and provides a comprehensive proposal to the faculty committees. In the human resource frame, the faculty leader is a servant utilizing his motivations to empower other faculty to initiate similar curriculum changes that support social innovation skill learning for other classes within the engineering curriculum. The results of this study will give the faculty leader knowledge and specific examples to demonstrate the benefits of the change among peers and could lead other faculty members to implement them. In the political frame, the faculty exhibits his leadership being an advocate and negotiator. He is an advocate and creates coalitions with the faculty committee to present the curriculum change to the Department Chair, the Dean, ABET representatives, and skeptical faculty colleagues.

This dissertation is only the beginning of a series of improvements in engineering curricula at UMKC. Results of the study will possibly create an effect in other STEM disciplines to identify social innovation skill learning as a tool to enhance industry-employability rates and assist the university mission towards serving communities. In the symbolic frame, the faculty communicates to the main industry stakeholders via the UMKC SCE leadership on how the integration of social innovation skill learning into capstone classes fulfills the mission by enhancing the curriculum to keep ABET accreditation while providing a workforce ready to fulfill industry and community demands.

Utilizing Kotter's (1998) stages of successful change initiatives as a framework, I provide the following list as a toolkit for the faculty leader to navigate the structural,

human resource, political, and symbolic frames at UMKC SCE in order to generate curriculum change. In no particular order:

- Create a sense of urgency for UMKC SCE to promote social innovation skills in the engineering curriculum that heeds employers' demands for social responsibility from the engineering profession.
- Provide the faculty committee with literature, data, and other information that generates credibility and authority for them to submit the CE412/ANCH311 curriculum change to ABET, department chair, and the Dean.
- Guide the UMKC SCE leaders to create an uplifting vision and strategy for the inclusion of social innovation skills into all the engineering capstone curriculum. That vision should include the model of change as a path other faculty can utilize to promote change in other UMKC SCE classes and how this change would influence tenure positions and access to research funding.
- Remove obstacles for the college-level committee by providing a clear picture of how the curriculum change fulfills both ABET accreditation standards and employers' demands.
- Develop a series of symbols related to project-based learning that appeal to the main UMKC SCE stakeholders. For ABET, frame curriculum changes in terms of learning outcomes to get changes approved by the college-level committee and the ABET representatives. Thus, *novelty* could be part of the symbols to introduce those learning outcomes that entitle the integration of a new set of non-technical skills into industry-driven capstone classes. For the Dean, the symbols are related to skills that the UMKC SCE would use to promote industry engagement and enhance pre-graduation employment rates. The novelty would

also be an asset for the Dean to introduce the capabilities of the new cohorts who will be prepared to address social needs from the engineering profession.

- Be persistent. Although the structure of UMKC SCE is prepared to receive the curricular change, stick with the journey to get the curriculum change approved, even if that implies re-designing the proposal of change.

In summary, we discussed how a faculty member must act as a leader to successfully drive changes in the curriculum by analyzing the organization using Bolman and Deal's (2013) four frames, utilizing a set of leadership tools, and adjusting strategy along the way. Using the setting of UMKC SCE, I described how to navigate the organization to implement changes that will improve learning outcomes, meet accreditation standards, and bolster faculty and university prestige. In contribution to practice, the organizational and leadership analysis would serve both academic and practitioner audiences seeking cases of curriculum change that allow engineering schools to fulfill both accreditation standards and employer demands by equipping students with new skill sets that enhance pre-graduation employment rates.

SECTION THREE: SCHOLARLY REVIEW FOR THE STUDY

Leaders in academia have the responsibility to engage communities and corporations in addressing social challenges (Kearsley & Shneiderman, 1998; Polson, 1958). Academia should integrate skills that allow students to interact with communities in order to prepare a workforce with skills necessary to solve the challenges in the way of community progress (Dawson & Daniel, 2010; Polson, 1958; Sanders, 1958; Stewart & Fenn, 2006). The integration of community engagement in curriculum development creates a framework to enhance the community's access to research and innovation (Ahmed & Palermo, 2010).

Wages for engineers are determined by industry based on the expected outputs that skilled workers produce (Cohn, 1980; Schumpeter, 2017). Likewise, education and skill levels among workers influence access to higher paid jobs and thus define the boundaries of stratifications in society by income distribution (Cohn, 1980). Theoretical concepts in economics describe the production function of education under an input-output framework, where the main output is the student competency measured by the level of knowledge and skills (Brewer & McEwan, 2010; Schumpeter, 2017). Thus, skilled and appropriately educated workers are likely to be aligned with social-economic needs and have access to jobs that require social innovation skills. Given that education enhances labor productivity (Schumpeter, 2017), the inclusion of innovative capacity will promote economic growth based on new knowledge applied to older technologies and traditional community practices and behaviors (Brewer & McEwan, 2010).

In addition, industry is rapidly increasing public awareness of corporate social responsibility by reinforcing commercial activities adjusted to community issues as economies face social, economic, and environmental challenges (Dawson & Daniel,

2010). In the theory of economic development, Schumpeter (2017) mentions that technological innovations contribute to job shortfalls in low-skilled workers. At the same time, social innovation is undertheorized on how this multidisciplinary concept is integrated into the economy. Social inventions are called to re-frame institutions by addressing that labor gap by offering alternatives for the inclusion of engineers with social innovation skills in the workforce (Grimm, Fox, Baines, & Albertson, 2013). Thus, industry expects that academia prepares engineers with technical and social innovation capacities and supports workers displaced by technology who are seeking new career opportunities by acquiring social innovation skills. For all these reasons, it is important to exhibit advances in engineering education in order to graduate engineers with industry-guided skills ready to engage simultaneously with both industry and communities.

Although industry is rapidly increasing its attention to community engagement, engineering schools are still not improving their curricula to address the future job-market demands in this area; that is, *engineers with social innovation skills* (Newman, Couturier, & Scurry, 2010; Schumpeter, 2017). In other words, engineering schools need to prepare students to be socially innovative with a community engagement capacity (Bozic & Dunlap, 2013; Gray & Koncz, 2017). Based on the findings in the literature review presented here, I argue that there is a gap related to engineering social innovation skills development. In particular, there is a lack of literature connecting social innovation with experiential learning in engineering curricula. In this section, I show that when engineers, as leaders, prioritize community-engaged skill development in project-based curricula, they are more likely to produce social changes. (Moini, Fackler-Lowrie, & Jones, 2005).

University-industry partnership liaisons in academia and in engineering schools dialogue in a variety of ways, formally and informally, with employers about their expectations from future professionals based on market needs. Skills standards in engineering curricula stem from these interactions. (Schumpeter, 2017). There are a variety of groups of skills or sets developed by various organizations in the profession. Here in the U.S., engineering schools must abide by ABET (Accreditation Board of Engineering and Technology) standard skills, although schools have the flexibility to incorporate other skills guided by the needs of industry or industry-guided skills.

Methodologies related to skill learning and how to reframe engineering curricula are fundamental in the definition of strategies to incorporate social innovation skills that fulfill ABET standards while meeting industry workforce demands. As such, this chapter provides a literature review on the (a) skills in an industry-driven capstone learning space useful to formulate social innovation skills in the profession, (b) current engineering skill sets leading to social innovation where I propose a new set of social innovation skills, (c) the theoretical framework for this study based on experiential learning that supports its assessment on skill development theory applied to skill learning spaces in engineering such as industry-driven capstone classes, and (d) the conclusion of the opportunities for engineering education when adding social innovation into capstone curricula.

Engineering Skills Development and Social Innovation Skills

In this section, I show how in an industry-driven capstone class learning space, students can develop skills that encompass both ABET skills and social innovation skills (Figure 3). I start with a review of the ABET standard skill set needed for any engineering program to obtain and maintain ABET certification, which is considered the golden standard in the profession. Then, I include a comprehensive discussion of social innovation skills found in the literature. Given that social innovations skills are not explicitly stated as engineering skills, based on the literature on social innovation skills, I draw from multiple industry-guided skills sets in order to propose the inclusion of skills responding to social innovation skills development in an industry-driven capstone class in engineering while abiding by ABET standards. I use the European Commission skill set, given that it is one of the few groups describing industry needs for innovation skills, although not social innovation. This skill set includes the skills of complex problem solving, integrated skills, systems thinking, and creativity. Accordingly, I propose an *engineering social innovation skill* set for industry-driven capstone projects that integrates these skills addressing social needs and community-driven projects, as illustrated in Figure 3.

Figure 3. Engineering Skills Leading to Social Innovation.

As explained in this section, I extracted a group of skills from the set of documents, reports, and white papers publicly available at the website <http://skills4industry.eu> and tailored the proposed Engineering Social Innovation Skills.

ABET Skills

The literature review cites the Accreditation Board of Engineering and Technology (ABET) as the entity that defines the skills required in the curriculum for engineering schools to be accredited in the US. Thus, the ABET Criteria for Accrediting Engineering Programs, 2019 – 2020 is the framework for the current study (ABET, 2018). ABET serves the interest of 35 industry societies, including the American Society of Civil Engineers. As such, this organization leads the ABET criteria for civil and similar named engineering programs.

The general criteria for baccalaureate-level programs have seven areas (criterion 3). The student outcomes needed at these levels are generally described as: “what students are expected to know and be able to do by the time of graduation. These relate to the knowledge, skills, and behaviors that students acquire and exhibit as they progress through the program” (ABET, 2018, p. 3). Table 6 presents these seven student outcomes that prepare graduates to enter the professional practice of engineering. Besides the seven ABET learning outcomes presented in this document, ABET allows the addition of outcomes that may be articulated by the program leaving room for curriculum improvement.

Table 6.

ABET Students Outcomes 2019-20 Cycle

An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.
An ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors
An ability to communicate effectively with a range of audiences
An ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts
An ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.
An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.
An ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

Note. Adapted from ABET. Retrieved from https://www.abet.org/wp-content/uploads/2018/03/C3_C5_mapping_SEC_1-13-2018.pdf

The ABET criterion 5 regarding curriculum specifies that learning outcomes must ensure the students are equipped to enter the practice of engineering (ABET, 2018). To accomplish this, the curriculum must include a culminating significant engineering design experience (e.g., capstone design courses) that is based on skills

acquired in previous coursework, among other considerations. I propose the integration of community-based project learning outcomes into engineering industry-driven project based curricula in order to increase the social innovation skills of future engineers.

These community-based projects must follow the ABET's eight realistic project constraints for engineering curriculum as well as promote the soft skills for engineers (Felder & Brent, 2003), which are the ones that can be tailored towards social innovation skills. Specifically, ABET Criteria 2018 specifies that engineering students should design projects by considering public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors (see Table 6). To work with communities, students should also integrate a set of constraints such as ethical, political, and sustainability aspects related to the community (see Table 7).

Table 7.

ABET Project Constraints

- Economic constraints: type external economic factors that affect a project and are usually outside the project manager's control. The most common economic constraints include the level of supply and demand of a service, the size of a potential market, relationships with suppliers and distributors, among others.
- Environmental constraints: limitations on strategy options due to political, social, cultural, technological, legal factors, or physical like temperature, humidity, and gravity.
- Social constraints: refer to social behaviors and attributes that influence sustainability of an implemented design project within a community. It may include formal practices as government regulations, norms, cultural preferences.
- Political constraints: include poverty, the persistency of practices such as corruption and mismanagement of public resources, lack of resources, groups of influence and interest, other.
- Ethical constraints: in project design, management, and implementation, fundamental ethical issues include accommodating diversity, empathetic decision-making, and compliance and governance consistent with values and mission statements.
- Health and Safety constraints: any constraint that specifies safeguard like mechanisms, features, techniques. In engineering, some health and safety constraints are related programs, guidelines and procedures that protect the safety, welfare and health of any person engaged in work or use of a project.
- Manufacturability constraints: any factor that prevents the project from making progress towards its goals. In manufacturing, constraints are usually referred to as bottlenecks in materials, equipment, process, time, resources, other.
- Sustainability constraints: factors that guarantee or restrict the future operation of a project, like accessibility and availability of resources: nature, biodiversity, soil, water, human resources, financial resources, other

Note. Adapted from ABET. Retrieved from <https://www.abet.org/wp-content/uploads/2015/10/E001-16-17-EAC-Criteria-10-20-15.pdf>

The current syllabus of the CE412/ANCH 311 course targets three ABET criteria, as presented in Table 6, and follows a set of competencies to fulfill the project-based learning outcomes as follows (SCE, 2019A): these ABET *criteria* are: (a) an ability to apply engineering design to produce solutions that meet specified needs

with consideration of public health, safety, and welfare, as well as global, cultural, societal, environmental, and economic factors; (b) an ability to communicate effectively with a range of audiences; and (c) an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives. In addition, according to the UMKC web catalog, students will acquire *competencies* in managerial and professional aspects like (a) comprehensive and realistic design project using the systems approach, (b) design choices and their effect upon the environment, and (c) design constraints include constructability, minimization of environmental impact and cost-effectiveness (SCE, 2019A).

Social Innovation Skills

Social innovation was recently introduced to the social sciences as a way to mitigate social problems (Agostini, Viera, Tondolo & Tondolo, 2017) and as an alternative to meet social needs (Cajaiba-Santana, 2014; Matei & Antonie, 2015). Dawson and Daniel (2010) define social innovation as a collection of new goal-oriented practices composed of a series of strategies and tools to support communities. The goal is to improve the quality of life while focusing on social capital instead of economic capital. At institutional levels, social innovation is a transformative force produced by collective social actions (Cajaiba-Santana, 2014). In social innovation ecosystems (e.g., corporate environments where public, private, and non-profit institutions impact the same community), academia plays the critical role of information providers that help empower communities to increase their capacity to meet social challenges (Howaldt, Schröder, Kaletka, Rehfeld, & Terstriep, 2016).

The World Business Council for Sustainable Development (WBCSD) provided

an initial approach to social innovation skills. This Council presented eight skills that industry evaluates when looking for individuals capable of driving social innovation (WBCSD, 2016). Those skills are creativity, dealing with ambiguity, business acumen, motivating others, interpersonal savviness, perspective, listening, and dealing with paradoxes (WBSDC). Although the report provides recommendations to employers, those eight skills can be part of following current ABET professional or non-technical skills: communications, teamwork, understanding ethics, comprehending the impact of engineering solutions, professionalism, lifelong learning, and awareness of current issues (Mehta & Gorski, 2016; Shuman, Besterfield-Sacre, & McGourty, 2005).

Engaging engineering students with social innovation has been discussed in the literature (Mehta & Gorski, 2016; Pappas, Mora, Jaccheri & Mikalef, 2018). For example, multiple authors have introduced skill sets implicitly linked to community engagement, such as Pinchot and Pellman's (1999) concept of diverse skills for institutional innovation and Baum and Locke's (2004) set of entrepreneurial competencies (passion, tenacity, and new-resource ability). However, there is not a current description of a set of social innovation skills that can be tailored to engineering education, and that can simultaneously fulfill ABET accreditation criteria; curricula to allow students to work on real-world projects and have meaningful learning experiences.

Social innovations differ from technological innovations in the intended results (Cajaiba-Santana, 2014). Social innovations produce novel social practices that create new institutions and unique social systems. Technological innovations engender new products, physical and digital, even when those are designed to resolve social problems (Cajaiba-Santana, 2014). While technological innovations are driven by lucrativeness

and commercial success (Dawson & Daniel, 2010; Stewart & Fenn, 2006), social innovations nurture social change. Scholars and practitioners agree that “technological innovations alone are not capable of overcoming social and economic challenges” (Howaldt et al., 2016, p.7) faced by society; therefore, engineering social innovation initiatives can provide new solutions to challenges faced by communities and contribute to social transformation. Engaging communities in technical innovations can be achieved through experiential learning in the form of applied research in social innovation, and thus, open job opportunities for engineers with social innovation skills (Howaldt et al., 2016; Cajasanta, 2014).

Established Engineering Skills Systems that could Lead to Social Innovation

Fink (2013) said that at the college level, essential learning outcomes such as acquiring intellectual and practical skills through practical experience. Essential learning outcomes would assist students to increase competence levels from novel to expertise while resulting in added skill development. Fink and Heywood argue that adding social innovation skills to the engineering curriculum would fill an important gap in competencies currently found in the experiential learning component of the engineering curriculum (Fink, 2013; Heywood, 2016).

Next, I review a few engineering skills systems that could potentially lead to social innovation skills. The following *industry-guided skills* are the response of academia to industry demands of an engineering workforce able to address social and technological needs. First, the Kern Entrepreneurship Education Network (KEEN) presents a set of *engineering skills* to align entrepreneurship to innovation in higher education (KEEN, 2019). Although UMKC is not a KEEN-affiliated school, the study of this group of skills supported the identification of social innovation skills

engineering education in this study. KEEN is a network of engineering faculty and 45 universities in the United States focusing on preparing undergraduate engineering students with an entrepreneurial mindset (KEEN, 2019). The KEEN engineering skill set is composed of three areas grouped into (a) opportunity, (b) design, and (c) impact. Table 9 presents the KEEN specific skills which are reinforced by the development of an entrepreneurial mindset composed of (a) curiosity, (b) connections, and (c) creating value. And with the education outcomes of (a) engineering thought and action, (b) collaboration, (c) communication, and (d) character. The skills presented in Table 8 compose a comprehensive skill set that can be applied for social innovation skills due to the focus on motivating students to follow entrepreneurial paths. Although the KEEN skills provide a strong foundation for the study of engineering non-technical skills, his primary focus is entrepreneurship rather than innovation, excluding those skills that could be tailored towards engineering social innovation skills.

Table 8.

KEEN Engineering Skills

Design
<ul style="list-style-type: none"> ● Determine Design Requirements ● Perform Technical Design ● Analyze Solutions ● Develop New Technologies ● Create Model or Prototype ● Validate Functions
Opportunity
<ul style="list-style-type: none"> ● Identify Opportunity ● Investigate Market ● Create Preliminary Business Model ● Evaluate Tech Feasibility, Customer Value, Societal Benefits & Economic Viability ● Test Concepts via Customer Engagement ● Assess Policy & Regulatory Issues
Impact
<ul style="list-style-type: none"> ● Communicate Solution in Economic Terms ● Communicate Societal Benefits ● Validate Market Interest ● Develop Partnerships & Build Team ● Identify Supply Chains & Distribution Methods ● Protect Intellectual Property

Note. Adapted from KEEN. Retrieved from

<https://engineeringunleashed.com/SearchResults.aspx?sb=TitleSortAsc>

Second, the *global engineering skills* is a concept developed by Bourn and Neal (2008) that discusses that eight skills for engineering students to acquire before graduation: (a) the capability to take a wide-ranging perspective to apply knowledge across countries, (b) identify the impact that innovations produce in developing communities, (c) understanding of local contexts of development, (d) manage with uncertainty, (e) challenging stereotypes, (f) recognize finite resources, (g) understand the globalization impact, and (h) actively engage in mitigation and adaptation to climate change. Although this skill set does not address social innovation directly, I infer that the applicability of the eight skills has social impacts when engineers utilize them to

address global societal needs. The primary focus of the eight-global engineering skills is to establish a framework to educate global engineers on how to provide low cost solutions that are appropriate to specific cultural, political, social and economic environments. Global engineers address worldwide needs for battling poverty and for securing affordable supplies of clean water and energy, for instance. Thus, global engineers capable of social innovations could meet the needs and expectations of an expanding population, such as identify solutions to reduce our CO2 emissions and the contribution to climate change.

Third, the *engineering of 2020 skills*, as described by The National Academy of Engineering (2004), defined the skill set that will support the “success and relevance of the engineering profession in 2020 and beyond” (p. 53) from the analysis of ABET and industry skill requirements. In the discussion, the authors describe three forces that shape and affect the success of technological innovations: social, cultural, political, and economical. These forces define a set of skills that the engineers should exhibit. That skillset is composed of analytical skills, creativity, practical ingenuity, communication, business and management, leadership, high ethical standards, professionalism, dynamism, agility, resilience, flexibility, and long-life learning. This skill set clearly links ABET and non-technical innovation skills. The engineering of 2020 non-technical skills could be directed towards social innovation skills. For instance, the creativity skills here could include skills to address social needs, analytical skills, and community-driven systems thinking skills. Other non-technical innovation skills, like communication or communication, could be tailored towards skills to interact with communities.

Finally, there are the *European skills for industry*, also known as

Skills4Industry, presented by The European Commission in a high-level conference denominated Skills for Industry Strategy 2030 in June 2019 (EU, 2019). I extracted a group of skills from the set of documents, reports, and white papers publicly available at the website <http://skills4industry.eu>. The selection started with a comprehensive search through the documents looking for skill sets related to innovation. Next, I searched for definitions of innovation, communities, and social problems, excluding terms like manufacturing skills, engineering skills, technical skills, or similar classifications (EU, 2019). Afterward, I aggregated the skills I found into these six categories presented below:

1. Soft skills: problem-solving, critical thinking, communication, teamwork, emotional intelligence, the ability to work and think across disciplines and systems, organizational skills, customer service.
2. Leadership skills: having a strategic vision for technology, digital transformation, and taking innovations to market.
3. Management and entrepreneurial skills: creativity, innovation, invention, proactivity, visionary, an engaged leader, mentoring, intellectual property management, project management, negotiation, continuous learning
4. Innovation skills: design and creation of new things (e.g., complex problem solving, integrated skills, systems thinking, creativity)
5. Emotional intelligence skills: leadership, cooperation, multi-cultural orientation, stress tolerance, self-control,
6. Transversal skills: communications, teams and networks, critical thinking and problem solving, initiative and resilience, digital skills.

This aggregation provides a set of innovation skills that industry currently

demands (EU, 2019). Finally, to conclude the process of selecting a set of skills that serve as a framework for the *engineering social innovation skills set*, I adapted the following innovation skills category (category 4) and turned them into four social innovation skills as shown in Figure 3:

- a) complex social problem-solving skills,
- b) integrated skills to interact with communities,
- c) creativity skills to address social needs,
- d) community-driven system thinking skills.

Social complex problem solving takes place when a given state of the art of a social issue transforms into a new state, and no visible or routine method of solution is available. If to originate a solution to a social problem, the individual must utilize a substantial number of interrelated factors; then, the problem is complex. Social complex problem-solvers attempt to learn the skills by acquiring and applying knowledge to effectively represent and solve social complex problems in a feasible way (Dabbagh, 2020; Wüstenberg, Greiff, & Funke, 2012). *Integrated skills to interact with communities* entitle the effectiveness of an individual to communicate successfully with members of communities by using the four primary language skills altogether: listening, reading, speaking, and writing (Oller, 1972). *Creativity skills to address social needs* are the abilities that determine whether the individual has the power to exhibit creative behavior when proposing solutions to community-based problems. Creativity entitles both originality and effectiveness. Ideas and products to address social necessities that are only original may be useless; thus, innovative ideas or products must be effective to be creative. This ability also entitles that the individual exhibits a remarkable degree to produce results of a creative nature-based upon his

motivational and temperamental traits in both the engineering profession and social settings (Runco & Jaeger, 2012).

Community-driven systems thinking skills is a set of skills derived from the eight skills included in The System Thinking Hierarchical Model (Assaraf & Orion, 2005), which include the following skills: (1) the ability to identify the components of systems and processes within the social system in study; (2) the ability to recognize simple relationships between or among the social system's components; (3) the ability to identify dynamic relationships within the social system; (4) the ability to organize the social systems' components, processes, and their interactions, within a framework of relationships; (5) the ability to identify cycles of within the social system; (6) the ability to recognize hidden dimensions of the social system—to understand phenomena through patterns and interconnections that the researcher does not see on the surface; (7) the ability to make generalizations—to solve social problems understanding systems' mechanisms; and (8) the ability to think temporally such as retrospection and prediction. Social system thinkers understand that some of the interactions within the social system took place in the past, while future events may be a result of present interactions.

Understanding Engineering Skill Development

In the section above, I first presented a theoretical contextualization of the skills needed in the engineering profession based on the ABET standards as articulated in peer-reviewed articles and institutional reports, as well as other engineering skills leading to social innovation skills (see Figure 3). Using experiential learning theories, skill theory, engagement theory, and project-based learning, next, I argue that social innovation skills are the necessary addition to transform engineering skills into a new skill set designed to achieve high levels of cognitive development for social innovation in the engineering profession through experiential learning.

Experiential Learning in Engineering and Social Innovation Skills

Learning is an individual-based process of forming meaning through experience (Kearsley & Shneiderman, 1998; Krajcik & Blumenfeld, 2006; Veglis & Pomportsis, 2014) and is a method useful for transforming engineering skills into a more complex skill set that integrates social innovation skills. Experiential learning in engineering that could be applied to social innovation skill development occurs in a four-stage cycle: substantial or concrete experience, reflective observation, mental or abstract conceptualization (which refers to Fischer's last skill development stage), and active experimentation (Kolb, Boyatzis, & Mainemelis, 2001; Kolb & Kolb, 2005). This model also agrees with the idea of Kearsley and Shneiderman (1998), in which transformational learning happens through experimentation.

First, concrete experience is a new experience or situation in which the student re-interprets the application of knowledge to perform a task. Substantial experience is highly recommended for individuals who prefer hands-on experience and fieldwork. In industry-driven capstone classes fostering social innovation skills, substantial

experiences would be the direct interaction with communities to obtain information to apply to the engineering design, for instance, signage for a new road. Second, *reflective observation* is the amount of importance the student applies to any inconsistency between the experience and his or her level of understanding. An engineering capstone student fostering social innovation skills may identify the need to customize signs to address community needs, like the crossing of animal herds. Third, *abstract conceptualization* is the foundation for fostering social innovation through experiential learning (Pappas, Mora, Jaccheri, & Mikalef, 2018; Veglis & Pomportsis, 2014). At this stage of skill transformation, students in capstone classes work in diverse-learning teams to create a new idea or modify an existing abstract concept. Fourth, *active experimentation* is the application of new ideas into the world. Students utilize laboratories or real-life situations to apply decision-making and problem-solving. Industry-driven capstone classes include presentations of engineering designs to end-users and occasionally a series of tests to validate the applicability of those designs as a means to experiment while learning.

According to Kolb and Kolb (2005), there are four learning styles that are linked to abstract conceptualization to foster innovation: assimilating, converging, diverging, and accommodating, all of which are important to keep in mind in order to attend to the diversity of learning styles among students.

Students with *assimilating* learning styles are best at understanding a wide selection of information and putting it into a concise, logical form. Individuals with an assimilating style are less focused on people and more interested in ideas and abstract concepts. Students with *converging* learning styles are best at finding realistic uses for ideas and theories. They could solve problems and make decisions based on

discovering solutions to inquiries or problems. Students with *diverging* learning styles are best at viewing concrete situations from many different points of view. They perform better working with teams and in situations that call for the creation of ideas, like brainstorming meetings. They are highly interested in people, and so they can help teams to communicate with communities. They tend to be creative, empathetic, good listeners, and open-minded team players with broad social interests. Students with *accommodating* learning styles learn from primarily practical or hands-on experience. They enjoy executing plans and involving themselves in new and interesting experiences and rely more on people for information than on their own technical analysis. Given the diversity of strengths that each learning style brings, ideally, student teams in capstone projects should be diverse in learning styles.

Figure 4. The Nine-Region Learning Style Type Grid – Each region has a geographical identifier like NW (north-west), SE (southeast), and so on. (Kolb & Kolb, 2005)

Skill Theory

Fischer's (1980) skill theory is a comprehensive theory of human development that describes mechanisms to transform skills in a developmental sequence and considers the impact of contextual and interpersonal factors of learning. This sequence involves a scale of three major systems of restructuring or transformation of thoughts: sensory-motor skills system, representational skills system, and abstract skills system, in a hierarchical level of cognitive development as presented in Figure 5.

Figure 5. Fisher's Skill Theory Scale of Transformation of Thoughts.

Fischer (1980) states that skills are developed in context, and that environment

facilitates transformative learning. This environment for skills' transformation must include certain properties and situations in order to achieve desired levels of skill development from initial sensory-motor skills to the construction of transformational skills, in which the individual reaches the skill level of abstract representation. Transformative learning, which involves the highest skill level of abstraction, is considered then the highest outcome. It uses five skill transformation mechanisms: focusing, inter-coordination, compounding, substitution, and differentiation. *Focusing* entitles concentration on performing one unique set of skills, like sensory-motor skills that imply repetition, prior to the integration with other groups of skills. *Inter-coordination* is the progression in the development of new skills due to the combination of two separate skills to create a new higher-level skill (e.g., the combination of repetitive sensory-motor skills and training skills into supervisory skills). *Compounding* is the result of combining two skills into a more complex skill at the same level of the two coordinated skills. For instance, a decision-making skill for a machine operator would be a compounding skill set that integrates sensory-motor skills – in repetitive actions –, with data entry actions into a skill set that generates reports for the operator to continue assigned tasks. *Substitution* is the action of changing a certain skill to address a new task. *Differentiation* is concerned with the distinction between two skill sets, either inter-coordinated or compounding skills, which precedes the integration of the two (Kunnen, Bosma, & Harke, 2003).

For the purposes of this dissertation, social innovation skill development in engineering capstone classes can be measured further the interaction between the environment (industrial setting) and the individual (the student) through project-based and experiential-learning scenarios (Fischer, 1980). Transformative learning happens in

industry-driven capstone projects *focusing* on technical skill learning. A modification in the capstone curriculum will set an environment that boosts the *inter-coordination* of technical and non-technical skills into a higher level of cognitive development. This modified environment facilitates *compounding* skills, like behavioral or communication skill sets useful to address community-driven problems. In this new capstone class environment, the students refine abilities to *substitute* and *differentiate* which skill sets they utilize to address social problems, technical issues, or a combination of both.

In industry-driven project courses, students usually develop skills to address technological needs. By integrating the social innovation skill in capstone classes, an inter-coordinated skill set is introduced, it should transform students' learning. The *inter-coordinated* skill set will require a higher level of performance of a specific task in contrast to the outcomes obtained with each skill set separately. For instance, in rural communities, when an engineering student designs and calculates a new road, the student would apply active listening when learning about the community needs (i.e., roads conducive for horses and other transportation modes). In listening to the community needs, the student would utilize a set of technical skills to design a new road that satisfies the community needs and those of other road users. Thus, when the student listens to the community and uses creativity to address the social needs, the new inter-coordinated skill is applied. Accordingly, the project-based curriculum would be promoting transformative learning that includes the five skill transformation mechanisms.

Fisher's theory of skill development is expanded by the engagement theory by Kearsley and Shneiderman (1998). This theory states that transformational learning takes place under the premise that knowledge is built from experiential learning rather

than acquiring information from theoretical instruction alone. Thus, experiential learning is critical for achieving the highest skill levels in Fischer's theory. This supports the notion that a project-based curriculum such as a capstone working in real-life projects with industry and communities is likely to foster skill transformation mechanisms leading to social innovation. Next, I will discuss how these theories operate in experiential learning and social innovation skills in engineering.

Project-based Learning in the CE412/ ANCH 311 Capstone Class

The CE412/ANCH 311 is a learning space (environment) that promotes experiential learning by providing students with real-world projects, meaningful tasks, and problems to be addressed from the engineering profession in four dimensions. First, the skill theory and the experiential learning theory define that *active construction of meaning* is an outcome of experiences and interactions with the environment.

Engineering capstone students could utilize the experience of interacting with communities to construct meaning about solutions to social problems. Second, Kolb, Boyatzis, and Mainemelis (2001) argue that learning new skills occurs in a real-world context where students systematically (a) observe phenomena—visiting the location of a rural road; (b) design investigations—class assignments to design the project plan, (c) make explanations—justifying a decision in the drawings design; and (d) present their knowledge to others—final presentation of the road design from technical and social innovation points of view.

The CE412/ ANCH 311 class instructor provides a list of projects for students to select and provides examples from past projects in the same course as aids to promote *reflective observations*. The instructor shares the evaluation criteria with the

students and the level of support they have access to through the process — for instance, defining research questions, the scope of work, and the project management plan. Third, social interactions promote the construction of *shared understandings*. The primary outcome of social interaction in learning is the construction of a community of learners based on idea sharing, using, and debating. The social interaction for an industry-driven capstone class starts with following a model of the group development of forming, storming, norming, and performing (Levi, 2015). The instructor follows up on teams rather than individuals to facilitate the completion of the evaluation criteria.

Finally, Krajcik and Blumenfeld (2006) discuss the importance of *tools in learning* to promote skill transformation. In technology-based learning, academia and industry provide the tools for project development. However, the selection of tools, like software and hardware, is based on the technological infrastructure that the engineering school possesses, the contributions of the project provider, and the students' career interests (Kearsley & Shneiderman, 1998). Based on the experiential learning and skill theories, a capstone class is a space of transformative skill learning that encompasses the integration of new tools for learning and facilitates students to gain an in-depth understanding of how to address social innovation needs through the engineering profession.

Opportunities for Engineering Education

There are six opportunities for the landscape of engineering education when integrating social innovation skills in the curriculum (see Figure 6). First, there is an opportunity for engineering schools to enhance community engagement by the addition of social innovation skills into the experiential-learning classes, like senior capstone design. Those classes are existing mechanisms that engineering schools utilize to

facilitate technical skill learning in real environments (Canfield et al., 2012; Fink, 2013; Fisher, 1980).

Second, the inclusion of social innovation skills in terms of a new learning outcome into a typical capstone class could provide students with real-world experience before graduation and serves as an employer (industry) engagement tool (Gray & Koncz, 2017; Murray, Caulier-Grice. & Mulgan, 2010). Currently, the Civil Engineering program integrates with the general education requirements with students encouraged to take ANCH 150 Computing and Engineering in Society to provide a framework for scientific reasoning and values covering ethical design during their first year. Students are required to take ANCH 311 Systems Design II as the second semester senior capstone, which includes significant civil and community engagement through their capstone projects (SCE, 2019).

Third, engineering schools can add skills for social innovation learning to the outcomes presented to the accreditation boards. The addition of social innovation skills that fulfill both ABET accreditation and industry demands will (a) open the doors for proposing the inclusion of new learning objectives to prepare professionals capable of social innovations (b) provide evidence for curricula improvements for the ABET accreditation review under the 2019-2020 cycle (ABET, 2018A).

Fourth, there is an opportunity for engineering schools to enhance ABET accreditation metrics like industry engagement and job placement rates. Strengthening industry partnerships starts with graduating professionals capable of adjusting to any technical and cultural setting (Starr & Minchella, 2016; Wyman, 2016). As a result, industry engagement would provide more resources for endeavors, such as improving physical infrastructure. This is a mechanism to facilitate the adoption of the new

curriculum as well as improve student enrollment and job placement rates (Bozic & Dunlap, 2013; Maringe & Gibbs, 2008).

The fifth justification is there are no explicit outcomes in ABET standards that address social innovation (ABET, 2018; ABET, 2018A). Some authors approach non-technical skill learning from its connection to the rapid changes in innovation and technological advances (Starr & Minchella, 2016). Canfield, Ghafoor, and Abdelrahman (2012) studied the importance of project-based learning in STEM higher education and discussed curriculum design to include innovation as a learning outcome to satisfy ABET accreditation standards (McLurkin et al., 2013).

The last justification is a gap in the literature related to social innovation in project-based curriculum design. Existing literature approaches the importance of project-based learning in technological innovation (Bozic & Dunlap, 2013; Padmanabhan, Katti, Khan, Peloubet, & Leelaurban, 2018). Likewise, social innovations are not either part of the current literature dialogues in engineering curricula (Padmanabhan, Katti, Khan, Peloubet, & Leelaruban, 2018) nor industry job postings (Bourn & Neal, 2008; Burning glass, 2019; EU, 2018). Additionally, contemporary literature related to higher education for science, technology, engineering, and math (STEM) does not connect industry-driven project based learning and social innovation skill learning (Fink, 2013). These are two isolated topics (Brewer & McEwan, 2010). Some authors have studied the importance of project-based learning in STEM education (Starr, & Minchella, 2016; McLurkin, Rykowski, John, Kaseman, & Lynch, 2013). Other authors present a connection between non-technical skills like innovation and STEM education (Bozic & Dunlap, 2013; Eppes, Milanovic, & Sweitzer, 2012). Thus, literature is lacking in consideration of the social innovation in

engineering curricula (Bozic & Dunlap, 2013) and the increment of non-technical skill development to prepare professionals capable of social innovations.

Figure 6. Illustration of the opportunities for curriculum improvement in engineering education by adding community-based learning outcomes that promote more comprehensive engineering capstone classes (industry-driven project based).

Summary

The literature review supports the background and opportunity landscape to study the integration of social innovation skill learning into traditional capstone classes.

The literature also provides indications that students would learn social innovation skills in a learning space that merges technical and social innovation skills. This new learning structure for industry-driven engineering curricula would, possibly, encompass social innovation with ABET's project-based learning outcomes (Krajcik & Blumenfeld, 2006). Currently, however, the engineering curricula at UMKC only integrate both industry-guided and ABET standard skill sets without social innovation frameworks (Felder & Brent, 2003). When multiple scholars introduced new non-technical skills in community-based learning literature (Baum & Locke, 2004; Bourn & Neal, 2008; Pinchot & Pellman; 1999), a theoretical definition was missing for engineering non-technical skills to enhance students' social innovation capacity.

The literature also supports that, by the addition of community-based project learning outcomes into typical capstone curricula, civil engineering programs could prepare engineers to be socially innovative and capable of community engagement. For this dissertation in practice, I intend to provide the case study to guide the redesign of the UMKC SCE CE412/ANCH 311 System Design II. Results may improve the engineering curricula by adding the missing theoretical definition of engineering social innovation skills that current courses are lacking.

SECTION FOUR: CONTRIBUTION TO PRACTICE

Plan for Dissemination of Practitioner Contribution

Recipients of the practitioner contribution will be attendees of the American Society for Engineering Education (ASEE) 2021 Annual Conference. The ASEE Annual Conference and Exposition is the only convention dedicated to all disciplines of engineering education. It is devoted to advancing the exchange of ideas, enriching teaching methods and curriculum, and providing top networking opportunities for engineering and technology education stakeholders such as deans, faculty members, and industry and government representatives. The ASEE conference contains more than 400 technical sessions, with peer-reviewed papers covering all disciplines of engineering education (ASEE, 2019).

Type of Dissemination

The dissemination will be a virtual presentation with a slide show at the ASEE annual conference. The slide show will inform the attendees, in both academic and practitioner proceedings, on how to integrate community-based project learning outcomes into industry-driven project based curricula at the UMKC School of Computing and Engineering. The presentation in the practitioners proceeding will provide a white paper regarding recommendations to add community engagement and projects to engineering project-based curricula. The academic proceeding will utilize the scholarly studies and findings summarized in the peer-reviewed paper submitted to the Virtual Issue: ASEE 2022.

Rationale for this Contribution Type

An oral presentation with PowerPoint slides is the most utilized form of dissemination of the information in the ASEE annual conference. I will provide relevant findings applicable to audience members and lead a discussion of how the conclusions of the study applied to the curriculum design and institutional industry relations.

Outline of Proposed Contents

The presentation will include the case study design, research methods, findings, and recommendations described in the peer-reviewed article submitted to a peer-reviewed journal in the engineering education field:

- Overview of capstone curriculum implementation for the senior project-based class 2019-2020 in Civil Engineering degree at the University of Missouri Kansas City.
- ABET skills and the underlying skill definitions for social innovation provided by literature in industry and community engagement.
- Proposal of curriculum design to equip engineering students with social innovation skills to build their community engagement capacity.

Presentation Highlights

Engineering schools are increasingly focused on job placement efforts to boost enrollment and meet accreditation standards (Acworth, 2008; Bybee, 2010). Increasingly, these institutions are seen as economic development hubs that provide a skilled workforce to not only bolster the economy, but also improve communities' social needs, which requires non-technical skills (Christensen, Horn, Caldera, & Soares, 2011; Dunkan & Rayess, 2008; Murray et al., 2010; Sanders, 1958). Higher education has a key role to play in developing students' technical skills and non-technical skills to appeal to an increasingly socially responsible job market (Dukhan & Rayess, 2014; Gray & Koncz, 2017; Heywood, 2016). To do so, engineering educators must teach future professionals "social innovation skills" - the ability to identify a community's social needs and transform this information into innovative technical solutions (Bourn & Deal, 2008; Bozic & Dunlap, 2013). By encouraging engineering schools to increase students' non-technical skills, future engineers will be better equipped to integrate social responsibility into their professional duties (Heywood, 2016; Mehta & Gorski, 2016; Perkmann

et al., 2013), rather than relying on social scientists to act as intermediaries between engineers and the community. However, the literature on engineering education does not address how to best incorporate social and community-based problems in the engineering curriculum to facilitate social innovation (Bozic & Dunlap, 2013; Gray & Koncz, 2017). To address this gap, this case study explored to what degree students exhibit social innovation skills in their civil engineering capstone class at a research-intensive university in the Midwest, the University of Missouri in Kansas City (UMKC).

A New Engineering Job Market

Frederic Taylor – standardization and simplification of work
(Uhl-Bien, Marion, & McKelvey, 2007)

Rapid shift from traditional industry to an economy based on IT.
(Castells, 2010),

Connectivity beyond the rapid information consumption
(Leberman & McDonald, 2016).

SOCIAL INNOVATION SKILLS DEVELOPMENT IN PROJECT-BASED CAPSTONE CLASSES

The historical goal of the engineering profession was to solve industrial-technological needs (Gray & Koncz, 2017; Koller, 1995; Pekermann et al., 2013; Sanders, 1958). That goal has been changing to also address community needs (Phillips & Pittman, 2008; Wyman, 2016). The engineering workforce must be able to utilize non-technical skills (Felder & Brent, 2003; Wyman, 2016) to meet the demand for professionals capable of delivering both technological and social innovations to increase industry and community engagement (Dart, 2004; Wyman, 2016). Today's engineering job market increasingly interfaces with social enterprises and

companies are, more than ever before, creating units that manage social responsibility with a community-oriented focus (Dart, 2004; Hirschi, 2018; Lebeman & McDonald, 2016). Industry usually defines non-technical skills in public job postings as supervisions, thought leadership, change management, and negotiation (Burning-glass, 2019; EU, 2019), but not community engagement or social innovation. Further, current job search engines like Glassdoor.com or Indeed.com show career opportunities in corporate social responsibility for professionals in humanities and social sciences, but not for engineers. This industry trend means that engineers should acquire social and other non-technical skills to successfully compete for these liaison roles between industry and communities. Social innovation skills could be developed through engineering project-based curricula (Mehta & Gorski, 2016). However, engineering curricula do not focus on many of the non-technical skills that enable graduates to interact and engage with communities (Dukhan & Rayess, 2014).

Social Innovation and Engineering Education

(Dart, 2004; Wyman, 2016).

SOCIAL INNOVATION SKILLS DEVELOPMENT IN PROJECT-BASED CAPSTONE CLASSES

Developing social innovation skills in addition to other engineering skills during capstone classes could also lead to greater community engagement. In this scenario, community engagement is a reciprocally beneficial interaction where faculty and students propose innovative solutions to community problems during project-based classes (Bringle & Hatcher, 2002)

Key Terms

Social
Innovation

capstone

Typical
Capstone Class

Accreditation Board
for Engineering and
Technology

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SOCIAL INNOVATION SKILLS DEVELOPMENT IN PROJECT-BASED CAPSTONE CLASSES

Social innovation. Social innovations differ from technological innovations in their anticipated results (Dawson & Daniel, 2010). Specifically, technical innovations in engineering stimulate the creation of new products, physical and digital, even when those serve to resolve social problems (Cajaiba-Santana, 2014). Engineers equipped with social innovation skills accelerate the design and delivery of new products, processes, and programs useful for communities (Starr & Minchella, 2016). For example, if a project involves the creation of mobility aids, engineers who interact directly with the people the aids are meant to serve can better understand their daily routines, values, and other issues impacting the use of the aids and the environment in which that innovation will operate (Murray et al., 2010).

Capstone classes. Traditionally, engineering schools in the United States utilize project-based curricula to promote skill development. Project-based learning activities link the cognitive processes of acquiring critical skills with the stimulus for learning and with the provision of meaningful problems that motivate learners (Kearsley & Shneiderman, 1998; Krajcik & Blumenfeld, 2006).

Accreditation Board of Engineering and Technology (ABET). Although ABET's role is to ensure that today's college students are prepared to develop solutions that make life on our planet safer and more sustainable (ABET, 2018), the "how" to make that vision a reality in the classroom is not well described in the accreditation standards. ABET, in its publication *Sustainable Engineering 2018*, states that engineering education should develop global citizens through social services and encourages schools to cultivate an interest in social innovation at home and abroad. However, only two out of seven student learning outcomes are related to social aspects, yet they are so broad that capstone classes are not taking into consideration strategies to highlight or enhance social innovation skills. ABET accreditation is important for engineering schools because it enables them to provide employers with a workforce that follows standardized program curricula that supports new skill learning.

Statement of the Problem

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There are indications that in practice, many engineering curricula fail to connect current academic standards with the skill sets students need for social innovation and to fulfill industry and community demands in the Twenty-First century

(ABET, 2018A; Bourn & Deal, 2008; Bozic & Dunlap, 2013; Canfield et al., 2012; Heywood, 2016; Murray, Caulier-Grice, & Mulgan, 2010).

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Civil engineering programs have not embraced the concept of social innovation in their program of study. (Murray et al., 2010). In fact, there are indications that in practice, many engineering curricula fail to connect current academic standards with the social skillset students need to meet today's industry and community demands (ABET, 2018A; Bourn & Deal, 2008; Bozic & Dunlap, 2013; Canfield et al., 2012; Heywood, 2016; Murray, Caulier-Grice, & Mulgan, 2010). Because innovation and creativity are outcomes of experiential learning activities (Kearsley & Shneiderman, 1998), it is crucial for engineering education to leverage experiential learning for social innovation skills development while providing innovative engineering solutions addressing industry and community needs (Fischer, 1980, Gray & Koncz, 2017; Heywood, 2016; Kearsley & Shneiderman, 1998; National Academy of Engineering, 2004; Padmanabhan et al., 2018). Industry currently uses social and human science professionals to carry out its community engagement activities. These duties, however, could be carried out by engineers if they learned social innovation skills in their academic curriculum (Gray & Koncz, 2017).

Purpose of the Study

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To explore to what degree students acquire social innovation skills in a typical industry-driven capstone class in the civil engineering department at a research-intensive university in the Midwest

SOCIAL INNOVATION SKILLS DEVELOPMENT IN PROJECT-BASED CAPSTONE CLASSES

Although there are indications that project-based engineering courses *could* enhance social innovation skills development, it is unclear to what degree these experiential learning activities are effective in creating socially competent engineers. (Kolb & Kolb, 2015; Kolb & Kolb, 2012).

Research Question

To what extent do engineering students acquire social innovation skills in an industry-driven capstone project in the program of civil engineering at a Midwestern research-intensive institution?

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SOCIAL INNOVATION SKILLS DEVELOPMENT IN PROJECT-BASED CAPSTONE CLASSES

Components Theoretical Framework and Guiding Concepts

Experiential Learning and Skill Development

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In this case study of experiential learning, I applied Fisher's theory of skill development as a tool to measure the level of command of social innovation skills in the context of a capstone class. This theoretical framework guided the conversations with instructors and practitioners about community-engagement strategies at the UMKC Civil Engineering program and the need to shift the engineering skill learning towards the addition of social innovation skills.

Experiential learning theories state that learning is an individual-based process of forming meaning through experience (Kearsley & Shneiderman, 1998; Krajcik & Blumenfeld, 2006; Veglis & Pomportsis, 2014) and is a method useful for transforming typical engineering skills into a more complex skill set that integrates social innovation skills. Engineering students develop skills in learning spaces through an individual-based process of creating meaning through experience (Kearsley & Shneiderman, 1998; Krajcik & Blumenfeld, 2006; Veglis & Pomportsis, 2014). In this study, the CE412/ANCH 311 course is the learning space

(environment) for social innovation skills development as a result of experience with community-based projects. Experiential learning in engineering that could be applied to social innovation skill development occurs in a four-stage cycle: substantial or concrete experience, reflective observation, mental or abstract conceptualization), and active experimentation (Kolb, Boyatzis, & Mainemelis, 2001; Kolb & Kolb, 2005). This model also agrees with the idea of Kearsley and Shneiderman (1998), in which transformational learning happens through experimentation.

Components Theoretical Framework and Guiding Concepts

Assessment Tool:

Fisher's Theory of Skill Development

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Skill theory is considered an assessment tool for practitioners as it provides a set of transformational rules for gradually increasing skill complexity from one cognitive development level to the other (Fischer, 1980). A given skill is developed systematically in 10 hierarchical levels, which are divided into three stages: sensory-motor skills, representation skills, and abstract skills. Each level determines a structure that describes the type of behavior that a person can control at each level and, progressively, what is required to move from one level to the next within the three stages. Accordingly, scholars and practitioners could utilize skill theory to

identify at which level(s) of cognitive development the participants self-describe learning a given skill in a civil engineering capstone class.

In the sensory-motor stages, stages 1-4, all abilities are related to a set of sensory-motor actions and perceptions. The set comprises entities like items, events, or people. In this stage, the individual develops only practical skills. The skillset defines how to act on a specific entity but is unable to elaborate a concept or understanding until reaching level four. Representation skills are part of levels 4 to 7 in which the individual utilizes conceptual maps to represent interrelations between entities but unable to connect multiple systems at the same time. This will be possible when he or she reaches level seven. This level is the culmination of the representational development phase. The abstract set of skills is acquired from levels 7 to 10. Once the individual is capable of controlling the relation between the two systems, he or she can identify the impact and covariation of changes. At this point, the individual can control entities and construct an abstract concept of that entity.

Fischer (1980) describes the relationships between the construction of cognitive, social, and other skills with the physiological transformation of learning and problem-solving behaviors. In this theory, *skills* are defined as the individual's capability to control the behavior, thinking, and feelings within a given environment and context. Skills include "emotions, motivations, meaning, and actions" (Mascolo & Fischer, 2010, p. 5). The skill then is a "transaction of organism and environment" (Fisher, 1980, p. 479) where the individual or organism, in terms of the skill theory, controls its actions in that particular environment.

Components Theoretical Framework and Guiding Concepts

3. Defining Social Innovation Skills

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There are established engineering skills systems that could lead to social innovation. For example, ABET establishes engineering non-technical skills such as communication, cognitive skills, problem-solving, and the ability to listen, for example (Shuman, Besterfield-Sacre, & McGourty, 2005; Tedesco, Opertti, & Amadio, 2014).

The European Commission presented six groups of innovation skills during the *Skills for Industry Strategy 2030*, a high-level conference in June 2019 (EU, 2019), which are: emotional-intelligence skills, innovation skills, managerial and entrepreneurial skills, soft skills, organizational skills, and leadership skills. From this list, I created a set of social innovation skills meant to foster the abilities to design and create solutions for social problems. The skills I adapted to the notion of *social innovation skills* are complex social problem solving, integrated skills to interact with communities, creativity to address social needs, and community-driven systems thinking. Table 1 presents the top-down funneling process I followed to extract the four engineering social innovation skills that guided starting with the six categories identified in the

review of skills⁴industry proposed by the European Commission. I continued with the category of innovation from which I extracted four skills, which were tailored into four engineering social innovation skills.

In particular, I tailored the definitions of these innovation skills to propose four social innovation skills as follows:

- *Complex social problem-solving skills* take place when a given state of the art of a social issue transforms into a new state, and no visible or routine method of solution is available. If an individual must utilize a substantial number of interrelated factors to solve a social problem, the problem is complex. Complex social problem-solvers attempt to learn skills by acquiring and applying knowledge to effectively represent and solve complex social problems in a feasible way (Dabbagh, 2020; Wüstenberg, Greiff, & Funke, 2012).
- *Integrated skills to interact with communities* refer to the effectiveness of an individual to communicate successfully with members of communities by using the four primary language skills altogether: listening, reading, speaking, and writing (Oller, 1972).
- *Creativity skills to address social needs* are the abilities that determine whether the individual has the power to exhibit creative behavior when proposing solutions to community-based problems. Creativity entails both originality and effectiveness. Ideas and products to address social necessities that are only original may be useless; thus, innovative ideas or products must also be effective to be creative. The individual exhibits a remarkable degree of effort to produce results of a creative nature-based upon his motivational and temperamental traits in both the engineering profession and social settings (Runco & Jaeger, 2012).
- *Community-driven systems thinking skills* is a set of skills derived from the eight skills included in The System Thinking Hierarchical Model (Assaraf & Orion, 2005), which

include the following skills: (1) the ability to identify the components of systems and processes within the social system in study; (2) the ability to recognize simple relationships between or among the social system's components; (3) the ability to identify dynamic relationships within the social system; (4) the ability to organize the social systems' components, processes, and their interactions, within a framework of relationships; (5) the ability to identify cycles and patterns within the social systems; (6) the ability to recognize hidden dimensions of the social system—to understand phenomena through patterns and interconnections that the researcher does not see on the surface; (7) the ability to make generalizations—to solve social problems understanding systems' mechanisms; and (8) the ability to think temporally such as retrospection and prediction. Social system thinkers understand that some of the interactions within the social system took place in the past, while future events may be a result of present interactions.

Components Theoretical Framework and Guiding Concepts

Example: Skills with the notion of social innovation - Creativity skills to address social needs

Self-healing Concrete
source: Raconteun.comc

Modular Construction
source: Raconteun.comc

Qualitative Research Design

The Case:

UMKC SCE Senior Capstone Design II
CE412/ANCH 311 Spring 2020

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Case Study Research

- **Qualitative approach** due to few studies in social innovation related to engineering education
- **Case study:** in depth understanding on the issue in a unique case
 - Participants in the **same learning space** where data is naturally produced
 - **No previous previous studies** on a typical capstone class in its real-life context to identify social innovation skills
- **Unique case:** context-dependent, limited by a syllabus approved by ABET
- **Typical** capstone class in content and structure

(Merriam & Tisdell, 2016; Stake, 1995)

SOCIAL INNOVATION SKILLS DEVELOPMENT IN PROJECT-BASED CAPSTONE CLASSES

This study followed a qualitative approach, which is a scientific method for exploring and understanding meanings, concepts, and definitions of social and human problems (Merriam & Tisdell, 2016). In particular, I used an instrumental qualitative case study design (Baxter & Jack, 2008; Stake, 1995).

The case study is the civil engineering capstone design class titled CE412/ANCH 311 System Design II (Spring 2020) at the University of Missouri Kansas City (System Design II capstone course). Given that this class is typical in civil engineering programs studying this class allowed me to gain an in-depth understanding transferrable to other programs about the skills students develop during experiential learning and in relation to the four engineering social innovation skills – the issue at hand in this study (Merriam & Tisdell, 2016; Stake, 1995),

The classes, in this case, are traditional 3-credit hour courses from the UMKC senior level required courses (fourth year of the degree) of the UMKC Bachelor of Science in Civil Engineering (BSCE). The project-based curricula for the BSCE include five required credits of capstone design within the fourth academic year of the degree distributed in two classes: CE

411 Civil Engineering System Design I, a two-credit studio design class that is offered in fall academic semesters, and System Design II, a capstone course of a three-credit studio design open for each of the following spring academic semesters for those students who passed CE411. The two courses are split into four teams with four different projects. The members of each team are ten students and one practitioner (professional engineer – PE – in practice who works in industry and is in charge of mentoring students acting as adjunct professors for the class). The instructor plays the role of a coordinator and facilitator and selects the projects for the two sequel classes in the fall and spring semesters. For this particular case, the instructor confirmed that both classes in the fall 2019 and spring 2020 had the same projects, practitioners, and student teams.

Research Methods

- **Participants**
- **Data Collection**
 - a. Documents
 - b. Interviews
- **Recruitment**
- **Data Analysis**
 - a. Document Review
 - b. Thematic Analysis

Participants. The participants in the case study included the individuals who actively participated in the System Design II capstone class in spring 2020, including the instructor and the practitioners alongside an ABET representative for the UMKC SCE, and faculty of prerequisite classes of the capstone class who have taught them during the time students were in

the program.

The projects for the class came from various local construction firms with contracts with the state and local governments and industry. The deliverable to the industry project provider, at the end of System Design II capstone course, was an engineering design that included two components: a) a study of the area in where the civil engineering project will be located, and b) 30% of the site drawings showing a clear picture of the construction site and plans including landscaping and other details. For this case study, there were four projects: Project 1: *A traffic calm study*. The goal of this project, commissioned by a Kansas City-based national engineering consulting firm, was to compare before and after traffic volumes and vehicular speeds in the vicinity of three temporary speed humps. Project 2: *Structural design for a power station in Kansas City*. The goal of this project, commissioned by La Cygne Station Unit 1, was to evaluate additional structures to aid in the control of fugitive dust from the fly ash handling system as well as the wash water from the cleanup of the equipment and haul trucks. Project 3: *Design of an intersection for the Missouri Department of Transportation (MoDOT)*. The goal of this project, commissioned by a construction firm working with MoDOT, was to propose civil engineering solutions to improve safety along a traffic route that had higher than average crashes due to either speed or sight distance issues. Project 4: *Kansas City South Plaza Streetcar Station*. The goal of this project, commissioned by the Kansas City government, was to provide the city with a list of alternatives to address specific site improvements (safety, mobility, access, parking, etc.) in the surrounding area of the future station.

Data collection. Data collection consisted primarily of documents related to the class and interviews with participants. In particular, documents provided by the instructor were the primary data source, including the course syllabus, students' final reports, final evaluations, and project descriptions for each capstone class. Other documents utilized in the study were the 2019 ABET

self-study documentation, including the accreditation policy and procedure manual, program educational objectives, student outcomes, continuous improvement plan, and the curriculum. The documentation from the prerequisite classes provided insights about the structure of the spring 2020 class in terms of how teams were formed, an overview of the projects, and the project management plans designed by the practitioners.

The interviews took place via the web-conference platform Zoom. Face-to-face interactions were not a consideration due to the Covid-19 pandemic. I conducted six online interviews, with a one-hour duration each: one with the CE412 instructor, three with the practitioners of the System Design II capstone class, one with the UMKC SCE ABET representative, and one with an instructor for a pre-requisite class CE420. The objective of the first set of interviews started with the CE412 instructor to identify the rationale of the capstone curriculum design, the opportunities for learning non-technical skills in the capstone class, the alignment of the class activities with ABET and industry requirements, the skills that the curriculum proposes, as well as engineering social innovation skills the instructor had observed in students that are not part of the course description. The Instructor Interview Protocol included a questionnaire with ten groups of open-ended questions that were organized into the following themes: professional overview, curriculum design, projects, team dynamics, community engagement, social innovation, social innovation skills, ABET, and additional comments. An interview with the instructor for a pre-requisite class (CE420) was conducted with the same interview protocol utilized with the CE412 instructor. The second set of interviews with the professional engineers used the same interview groups of questions used for the instructor's interview. In addition, the practitioners were asked questions to clarify the process they follow to a) identify the real-world projects for each capstone class, b) determine the scope of the project, and c) design the activities with industry and communities during the capstone class and

the presentation of final reports. The third interview with an ABET representative sought to identify opportunities and challenges to modifying the curriculum at UMKC SCE, and the process of proposing and integrating new learning outcomes into curricula.

Document review. The document review method consisted of an iterative process of skimming, reading, and interpreting content related to the research question (Bowen, 2009). This document analysis procedure included finding, selecting, appraising, and synthesizing data available in the documents of the study (Bowen, 2009; Fink 2013, Stake, 1995). I used triangulation to seek convergence and corroboration from the interview transcripts (Bowen, 2009). During the document review, I examined content from the CE411 System Design I Fall 2019 and CE412/ANCH 311 System Design II Spring 2020 classes. The next step was to code the content into keywords extracted from the research question and pre-existing categories in literature: social innovation skill development, curriculum improvement, industry-driven projects, and experiential learning (Canfield et al., 2012; Eppes et al., 2012; EU, 2019; Felder & Brent, 2003; Fischer, 1980). Finally, the results of coding each document were interpreted in relation to each other using the same pre-existing categories (Hancock & Algozzine, 2017).

Thematic analysis. Thematic analysis was also used as a process for classifying, storing, and accessing the information from (a) documents and (b) interview transcripts (Hancock & Algozzine, 2017). This thematic analysis included content from all data sources previously aggregated into the pre-existing categories. Given that thematic analysis is an iterative process (Hancock & Algozzine), I ran the first cycle of coding to the aggregated data obtained from documents and interview transcripts (Saldaña, 2015; p. 67). Due to there was no evidence of the level of command of social innovation skills as presented by Fischer (1980), I applied a second cycle code organized in a codebook for analysis (Coffey & Atkinson, 1996; Saldaña, 2015; p.233) using six categories: the curriculum, advisors, engagement, project scope,

skill development, and social innovation. Then, I used axial coding methods to group the open codes from the six categories to finally obtain the three themes described in the results section. Overall, I systematically examined each piece of information constructively to answer the research question (Hancock & Algozzine, 2017; Stake, 1995; Yin, 1994). For the entire process, I used Microsoft Word and Excel.

Limitations and Alternatives

One Class

Limited Participants

Data Collection Timeline

A Pandemic Happened

SOCIAL INNOVATION SKILLS DEVELOPMENT IN PROJECT-BASED CAPSTONE CLASSES

Limitations. There are limitations to this study. First, the use of one class at one institution limits its generalizability to other institutions; however, other researchers will find insights from the rich descriptions I provided from this typical case study in order to address the issue of integrating social innovation skills into engineering a capstone class. The interviews were limited to the number of available participants. Data collection took place after the academic semester ended, and so, practitioners were already fully committed to their industry jobs resulting in three out of four practitioners recruited. Likewise, the pre-required class instructors were already in other endeavors, limiting the interview count to two. Also, the study included only one ABET representative as she coordinates the accreditation process. The study

did not include other individuals involved in accreditation to be interviewed, like advisory board members.

The results presented in this article utilized two essential definitions: a) *social innovation skills* as the abilities to identify community's social needs and transform this information into innovative engineering solutions (Bourn & Deal, 2008; Bozic & Dunlap, 2013); and b) *social impacts* defined as the engineering project's impact on a community's quality of life (Çelik, Kamali, & Arayici, 2017). The *social impacts* is considered a way to foster social innovation skills (Yuan, Cui, & Jiang, 2013). The engineering social innovation skills presented above and used to create the data collection protocols of this study were absent in the documentation analyzed in this study; however, I did find skills students learn through the capstone class relate to these four engineering social innovation skills. In particular, interviews with practitioners and instructors revealed situations where students did exhibit non-technical skills when interacting with community residents (community engagement) or interacting with

the public sector, such as meeting with government officials to discuss a project. Although the results of this study indicate that social innovation skills are present in practice, I found no evidence in the document analysis of assessments that can lead to the study of cognitive development using Fischer's skill theory. However, I believe it can be used as an assessment tool to measure the level of mastery of each of the four social innovation skills in experiential learning classes.

Two overarching needs were identified for skills learning in engineering: (1) the need to incorporate social innovation skills development into the capstone curriculum, and (2) the need to integrate the construct of *social impacts* into the project design and in the civil engineering curriculum for capstone classes. Both engineering practitioners and instructors saw the value of formally adding content on “*social impacts*” into the capstone curriculum as a gateway to developing students' social innovation skills as they enter the workforce. Their insights, which center on the needs noted above, are discussed in further detail below in three themes: 1) integrating social innovation skills in the capstone curriculum, 2) integrating “*social impacts*” content into an engineering project design class and its capstone engineering curriculum, and 3) suggestion for capstone curriculum improvement given by participants.

Results	
Theme 1	
Integrating Social Innovation Skills into Capstone Curriculum	
Sub-Theme 1.1: Learning from real-life experiences for non-technical skill development	<i>The senior design class is intended to bring students into a “real world” environment where students use the skills they have learned in college and apply them not to, as they have before, hypothetical problems but to a “real world” problem (project) as they will encounter in their professional life. (Practitioner 2)</i>
Sub-Theme 1.2: Learning from community engagement and interacting with public and private entities	<i>They'll have to deal with some of the surrounding community because the surrounding community will be utilizing that station....We want our students to bring in these different opinions. So, when they walk away from this project and then the design is handed back to the construction manager and into the design team, it is something that's viable, that can be taken forward to construction. (Practitioner 1)</i>
SOCIAL INNOVATION SKILLS DEVELOPMENT IN PROJECT-BASED CAPSTONE CLASSES	

After analyzing documents and the curriculum, it became clear that social innovation skill development is not explicitly included in the capstone course. However, instructors provided reassurance that, although social innovation may not exist on the documentation, it does appear during students’ practicum experience. Specifically, students are exposed to community engagement activities and interactions with the clients – private companies and public agencies that commission the projects to the capstone class. Similarly, social innovation is evident during the tangible experience gained by students during their practicum experience. Therefore, the integration of social innovation is possible through the real-world experiences for non-technical skill development (sub-theme 1.1) and through community engagement and interacting with public and private entities (sub-theme 1.2), as I explain next.

Sub-Theme 1.1: Learning from real-life experiences for non-technical skill development

The document analysis showed that learning through real-world experience was not explicitly included in the syllabus or class reports. However, interviews revealed a different story. Results from interviews with practitioners and instructors showed agreement that learning through real experience prepares engineering students to address social problems. The capstone is the opportunity to provide those scenarios before joining the workforce. The CE412 Instructor highlighted the need for students to develop critical thinking skills to address societal impacts during project design. Similarly, practitioners agreed that real-world projects prepare students to solve problems they will encounter in their careers and that the project scope helps them to facilitate that learning in the capstone class.

The scope of a real-world project is a tool for social innovation skill learning. Participants mentioned that the scope of the real-world project has a high impact on the opportunities to learn by real experience while keeping the balance between societal expectations and technical feasibility. They also mentioned that the project scope should challenge students and have diverse activities to develop both technical and non-technical skills. And that the project scope facilitates social skill development by allowing students to use creativity and critical thinking on how to use standards and codes to solve community needs:

Thus, students exercise non-technical skills when working on real-world projects that include community engagement and interactions with the client – public and private entities. Yet, analysis of course documents and interview transcripts clearly shows that content on social innovation is missing from the curriculum explicitly. However, according to participants in this case study, the CE412 class has the academic mechanisms and industry-driven projects to facilitate social innovation skill learning among engineering students.

Sub-Theme 1.2: Learning from community engagement and interacting with public and private entities

Analysis of students' assignments and the capstone curriculum revealed that practitioners are fostering the development of students' social innovation skills by providing real-world problems from industry and government because these allowed students to create a technical engineering design for solving social problems.

Although the integration of social innovation skills is not formally established in the curriculum, practitioners have been facilitating community engagement and understanding the role of the government in project design for many academic years in the CE412 Capstone Project. Practitioners concur that community engagement in capstone projects aims to know and integrate all viewpoints into the project design.

Although the curriculum does not require interaction with the community the project will impact, practitioners noted that they require students to use at least one community engagement strategy. For instance, students learn about the community's opinions through data the client (a government agency or private firm) collected by direct interaction with the community or understand communities' needs and expectations based on information from public meetings and events meant to discuss the project and make final decisions.

Community engagement is a recommendation that practitioners should provide to students, but it is not a required activity for the class, in contrast with the high interaction required with industry and the clients. Although engagement with the community that will be impacted by the capstone projects is not formally integrated into the curriculum, participants highlighted the positive impact that alumni report in surveys regarding opportunities to engage communities before graduation.

Results	
Theme 2	
Integrating “Social Impacts” Content into an Engineering Project Design Class and its Capstone Engineering Curriculum	
Sub-Theme 2.1: Students’ benefits of learning about social cost in the capstone engineering curriculum	<p>So, one thing about the public meetings is we wanted them to understand the decisions they make when you’re the designer. It’s just not simple decisions about cost and effectiveness, but it’s also decisions about changing people’s lives and affecting people’s lives. For instance, understanding how people can get back from their work, maybe the project helps them to get home ten minutes earlier, as an effect of what they decided. So that was the biggest fight from the social. I wouldn’t call it social innovation but it’s the social skills that we wanted them to get at the end of this class. (The CE412 Instructor)</p>
Sub-Theme 2.2: Integrating social cost into engineering capstone design class CE412	<p>I think it’s social innovation, bringing those disparate viewpoints and worldviews together and into focus to solve a larger social issue and a larger social issue.... We need the kind of people that can bring those disparate viewpoints together to solve large, complex complicated messy, social problems. (Practitioner 1)</p>
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According to professional engineering practitioners, the “social impacts” of an engineering project design can impact a community’s quality of life. An ability to translate the community needs into the impacts or social impacts of an engineering project is an example of engineering social innovation skills. Integrating “social impacts” into a capstone class would help students identify a project’s potential social impacts and develop alternatives for mitigating these impacts. Introducing the concept of “social impacts” to engineering students was seen by participants as a starting point for learning and practicing social innovation skills. Theme 2 is composed of two sub-themes: (a) students’ benefits of learning about the social impacts in the engineering curriculum and (b) integrating social impacts in the engineering capstone design class.

Sub-Theme 2.1: Students' benefits of learning about the social impacts in the capstone engineering curriculum

The results of the study showed that the ability to define social impacts in an engineering project is an example of learning social innovation skills during the capstone class in the study. Currently, social impacts as a subject of study is a missing component in capstone design projects. Syllabi for the CE412 course only addressed the monetary costs of project design. For example, the current syllabus for CE412 establishes the following objectives for the course: (a) develop design alternatives and (b) develop a deliverable that includes 30% of the engineering drawings of the project, with proposed cost and schedule. These two objectives are important because when engineers design projects, they require students to provide the overall costs of the project. These overall costs should include the *social costs* or *social impact* on the community. Thus, this study will utilize social impacts as the concept to address social impacts in the community. By definition, *social impacts* are the effects on community's quality of life that happens due to an action or inaction, an activity, project, program, or policy (Becker, 2001).

According to participants, the topic of the social impact is not in the capstone design because it is a concept that is neither formally integrated into the engineering curriculum nor in accreditation standards of the profession. Despite this lack of explicit instruction on social impacts, participants indicated that students usually gather sufficient information from the community and the clients during the project design to be able to add social impacts to their reports if they learn about the concept and are instructed to consider it.

Faculty and practitioners want students to learn and include the social impacts in their reports. Participants discussed how the social impacts of engineering projects is needed for students to understand social issues and how a project affects the community. They also noted

that while technical aspects of a project may come easily to engineering students, they need to be able to apply these concepts with social issues in mind.

Practitioners highlighted the need that students are socially acceptable by caring about the public and technical matters. By being aware of social issues and including the social impacts in reports, students could show community impact and demonstrate that they are socially-minded.

According to practitioners, the ability to communicate the social impacts of real-world engineering issues at all levels of an organization during the capstone class involves social innovation skills that could benefit their career seeking.

Additionally, practitioners discussed the benefits of students exhibiting social innovation skills to enhance career success. It starts at the internships. The pre-graduation real practice are platforms for assisting students in building their social innovation skills, but sometimes students only have the opportunity to exhibit technical skills; thus, obtaining a position that allows students to develop social innovation skills would be a great asset during the internship that could help them to secure an engineering position.

Sub-Theme 2.2: Integrating social impacts into engineering capstone design class CE412

Although participants of the interviews discussed that students could learn how to integrate social impacts into the engineering project design class while learning other social innovation skills by interacting with the community, the document analysis findings showed that the current project guidelines are focused on technical aspects only. To bridge that gap between the practitioners' view and the content of the curriculum, instructors stated that the curriculum and accreditation standards allow the inclusion of new components to enhance non-technical skill learning via community engagement. Instructors also believe that social innovation needed to be explicit in the curriculum because, usually, engineers learn social skills

outside of the profession as engineering education does not formally provide non-technical skill learning. Thus, practitioners discussed that the projects selected in capstone classes could bridge that gap because those are suitable to add social impacts as a required outcome for the capstone class.

Practitioners discussed that project scope also takes into account public officials' requirements to address the social impacts of the project design. They mentioned that adding the social impacts to the conclusion of the classwork will be a way to show evidence of learning social innovation skills derived from the community engagement experiences provided in class. For instance, placing ideas on paper during capstone project design would allow students to exhibit social innovation skills when they connect multiple points of view to solve complex problems like evaluating the social impacts of a capstone project.

Students' reports also shed light on how to add social impacts into the capstone class so that students can demonstrate their understanding of an engineering project's social impacts. It was previously noted that in-class documents and student reports are the primary class deliverables where social impacts could be incorporated into recommendations. In one particular instance, students were receiving guidance from professional engineers as defined in documents from an elective class. As part of the discussion, the class addressed how to apply the concepts of building code ACI318 - requirements for design and construction of structural concrete that are necessary to ensure public health and safety, which could be viewed as solving a social problem from the engineering profession or social innovation.

Another curriculum document discussed a required activity related to ethical responsibility in which students are required to read an article on the ethics of using computer programs in designing and analysis (CE422 documentation provided by instructor). In the revision of student reports, there was some evidence of engineering students addressing social

needs, such as providing brief recommendations to consider sidewalks and stairs compliant with the Americans with Disabilities Act and "convenience for pedestrians."

Final reports in the spring semester are designed to place technical ideas on paper, such as working in AutoCAD, preparing presentations, and then working with the practitioner for feedback. One practitioner indicated the feedback is usually focused on understanding what the client wants and provides the students with the changes needed to meet those expectations. From interviews, practitioners discussed the guidance students receive to perform beyond the technical scope and the addition of topics that can facilitate the inclusion of social impacts in the reports.

Results	
Theme 3	
Suggestions for Capstone Curriculum Improvement	
Sub-Theme 3.1: Modifying the Learning Outcomes and the Capstone Class Activities	<p>I reach out to these acquaintances and seek projects that I feel will benefit both the community from which the project comes and the students that will be performing the project.(Practitioner 2)</p> <p>Well, this whole class is built around experiential learning right all the students need to experience how it feels to be outside in the world and to work for a consulting company and working for a client. (Instructor CE412)</p>
Sub-Theme 3.2: Adding Learning Outcomes to the Capstone Curriculum	<p>We don't have any specific community engagement outcomes, but we do make we all we do to a setup changes since we're so intertwined with the Kansas City engineering community that's sort of one of our missions is to make sure that we are serving that community and so the way we do that is rather than through outcomes is through our advisory board. So, the advisory boards are always members of the local engineering community. So, when we meet with them, we always are making sure that our students are graduating with skills that they need in this particular. (The ABET Representative)</p>
SOCIAL INNOVATION SKILLS DEVELOPMENT IN PROJECT-BASED CAPSTONE CLASSES	

According to the ABET representative, one way to reach ABET accreditation criteria is through continuous improvement of capstone design courses – engineering culminating project-based courses – where students work on real-world industry-driven projects. Significant results were extracted from documents and interview transcripts on alternatives to improve the engineering capstone curriculum. Based on those results, curriculum improvement in the

capstone class CE412 is feasible in two ways: (a) by modifying the project scope and class activities (subtheme 3.1) and (b) by adding learning outcomes to the capstone curriculum (subtheme 3.2).

Sub-Theme 3.1: Modifying the Learning Outcomes and the Capstone Class Activities

The first option to improving the capstone curriculum is by modifying the class structure, specifically the project scope and its activities. The project scope was described by interviewees as the roadmap that should state the learning outcomes and objectives for all students regardless of the project assigned. Overall, the project scope assists practitioners in defining the activities with communities and the public sector.

In analyzing interviews and course documents, the project scope was the focal point for improving the class structure. Themes 1 and 2 showed the importance of having a clearly defined project scope and of integrating real-world experiences during a capstone class. Documents from CE411 and CE412 classes showed four customized project scopes. Each practitioner wrote the project scope to address technical design and drawings for the client. The practitioners also described a series of activities for students to work in teams, deliver presentations, and attend public meetings to fulfill the class requirements (work documents CE412 and CE411).

One reason to write a customized project scope is that each real-world project is provided by an engineering firm or a public entity with which the practitioner has a relationship. Another reason for customizing the project scope is that practitioners can transfer their experience to students on how to be consultants and work in teams.

According to responses to the interviews, participants noted that another option for improving the capstone curriculum is to enhance the class activities. Class activities fulfill the learning outcomes outlined in the curriculum and are designed to enhance non-technical skill

learning (ABET Representative). The CE412 Instructor explained that class activities such as teamwork and project management--although not formally defined as learning outcomes--provide students with practical experience as consultants for the real-world projects in a capstone class.

Sub-Theme 3.2: Adding Learning Outcomes to the Capstone Curriculum

All the interviewees noted that the process for implementing all class structural changes described in sub-theme 3.1 must involve the ABET representative and the advisory board of the engineering school. The ABET representative explained that accreditation standards required a minimum of seven learning outcomes to solve engineering problems and leaves the option open to add a new learning outcome to include social innovation skill learning. ABET accepts new learning outcomes in the curriculum, and those are usually aligned to the institutional mission. Learning outcomes are selected by each instructor. New outcomes, like the one to include social innovation skill learning, are agreed to by the instructors and the administrative bodies of the engineering school.

The advisory board represents the engineering community and plays an important role in defining new learning outcomes. The ABET representative explained that UMKC's mission is to serve the community, but there are no learning outcomes for community engagement; therefore, the advisory board is in the position to require new learning outcomes to fulfill the institutional mission and to address industry and community needs.

The ABET representative, the CE412 instructor, and the practitioners have access to the advisory board to discuss curriculum improvement opportunities. Due to the advisory board's high interest in enhancing community engagement, they must learn from the participants about the impacts of social innovation skill learning, like increasing students' employability rates or adding social impacts analysis to real-world project design. The impact unto the student

should motivate the advisory board to request a new learning outcome in the capstone curriculum formally and potentially to all pre-required classes.

Discussion

- Experiential learning using real-world projects in capstone classes enhances social innovation skill learning
- Engineering students exhibit social skills when given real world problems to solve.
- The next step is to require social impacts analysis in the class reports and include a new learning outcome to the class curriculum
- The results suggest new directions for future research, such as the integration of community engagement and learning the structure of the government as platforms to building social innovation skills in the engineering students

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SOCIAL INNOVATION SKILLS DEVELOPMENT IN PROJECT BASED CAPSTONE CLASSES

Results demonstrated that experiential learning using real-world projects in capstone classes enhances social innovation skill learning. However, there is a natural variation in the structure of capstone classes and practitioners differ in how they integrate this skill learning into the class activities and project scope. The three themes extracted from the document review and interview transcripts showed that engineering students exhibit social skills when given real-world problems to solve. Although I did not find results that explicitly address the four social innovation skills proposed in this dissertation, the UMKC School of Computing and Engineering has all the elements to integrate those four skills into the curriculum: complex social problem solving, integrated skills to interact with communities, creativity to address social needs, and community-driven systems. The next step is to require social impacts analysis in the class reports and include a new learning outcome in the class curriculum. The

discussion of the results below summarizes the options for formally improving the curriculum to facilitate social innovation in engineering education.

Discussion

Integrating Social Impacts into the Curriculum for Skill Learning

To facilitate social innovation skill learning, students should provide an overview of the social impacts by utilizing the four engineering social innovation skills:

- Exhibiting integrated skills to interact with the communities to identify the needs, wants, and value of civil engineering projects.
- Using “complex social problem-solving skills” to assess the *convenience* of the expected impacts once the project is implemented.
- Using “community-driven systems thinking skills” to assess if the project’s consequences are socially acceptable.
- Utilizing “creativity skills” to assess and quantify the social impacts in a holistic manner.

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The importance of modifying the curriculum is to utilize an experiential learning scenario (capstone class) to teach the four engineering social innovation skills proposed in this study: Complex Social Problem-Solving Skills, Integrated Skills to Interact with Communities, Creativity Skills to Address Social Needs, and Community-driven Systems Thinking Skills.

The social impacts in an engineering project cannot be calculated using standard estimated methods. Accordingly, one alternative for engineering projects is to classify the social impacts as the eleven categories proposed by Yuan, Cui, and Jian (2013): the cost of health damage; the cost of civil damage rights; effect on the transportation costs; decision-making errors costs; loss of income; loss of decreased productivity; loss of revenues; the cost of pollution; resource costs; property damage; and the destruction of the original building by any effect of the adjacent construction. Thus, to facilitate social innovation skill learning, students

should provide an overview of the social impacts by utilizing the four engineering social innovation skills listed in the slide above.

Discussion

Integrating Social Impacts into New Learning Outcomes

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Addition of a new learning outcome:

An ability to include the social impacts into engineering design .

Assess students' level of command of the social innovation skill of describing social cost in engineering design before and at the end of the capstone class using Fischer's Skill Theory

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SOCIAL INNOVATION SKILLS DEVELOPMENT IN PROJECT BASED CAPSTONE CLASSES

CE214 Senior Design II presents three out of seven ABET outcomes: (a) ABET Outcome #2 – an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, societal, environmental, and economic factors; (b) ABET Learning Outcome #3 -an ability to communicate effectively with a range of audiences; and (c) ABET Learning Outcome #5 – an ability to function effectively on a team whose members together provide leadership, create a collaborative, inclusive environment, establish goals, plan tasks, and meet objectives.

Based on the results of this case study, I propose the addition of a new learning outcome: *an ability to include the social impacts into engineering design*. To evaluate the success of implementing this new learning outcome, instructors must utilize the Fischer Skill Theory. It implies assessing students' level of command of the social innovation skill of

describing social impacts in engineering design before and at the end of the capstone class

Discussion	
Integrating Social Impacts into the Project Scope	
<p>Including the following items into the project scope for the CE411 and CE412 classes:</p> <ul style="list-style-type: none">– Community engagement activities;– Client engagement activities, such as attending public meetings to discuss the project;– Design the social impact method for each project utilizing the 11 phases proposed by Yuan et al. (2013);– Provide a self-assessment of the four engineering social innovation skills utilizing Fischer Skill Theory to rank the level of command at the end of the class (Fischer, 1980).
<p>University of Missouri System COLUMBIA KANSAS CITY ROLLA ST. LOUIS</p>	<p>SOCIAL INNOVATION SKILLS DEVELOPMENT IN PROJECT BASED CAPSTONE CLASSES</p>

Based on document analysis, the capstone class requires that all projects contain drawings of the industry project. Those deliverables for the clients are constructed in teamwork activities divided into two semesters. Each practitioner customizes the project scope; not all students have public meetings or activities to interact with the community. Thus, it is necessary to standardize the project scope to create a methodology for social innovation skill learning. To achieve standardization, I propose the inclusion of four items into the project scope for the CE411 and CE412 classes as presented in the slide above.

Implications

Assessing Social Impacts in Capstone Projects

The main contribution of this study is a concrete proposal for improving the engineering curriculum by using social impacts as the leading element for change.

In practice, this means that engineering professionals would have to negotiate with clients scheduling more meetings with the community and public officials in order to assess the social cost of the projects.

This also implies that more time dedicated to the class by instructors in order to prepare and deliver social innovation and social impacts lectures and design activities, as well as assessments, while balancing with the content of the course's technical and non-technical curriculum.

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SOCIAL INNOVATION SKILLS DEVELOPMENT IN PROJECT-BASED CAPSTONE CLASSES

To balance accreditation standards and the need to prepare engineers to address social problems, this dissertation in practice proposes adding content on the social impacts to the capstone course to facilitate social innovation skill learning. This approach will benefit how future engineers learn social innovation skills by reinforcing social impacts applications in real-world projects. In turn, UMKC and programs alike will share the added value of having well-rounded graduates who can confidently provide employers with strong technical and social capabilities. Increasing the pre-graduation employment rate would be a key benefit of this new curriculum enhancement. Thanks to this study, the transition to a more representative and inclusive capstone curriculum at UMKC has begun. The stakeholders agreed that future capstone projects must align with the right client and be designed to start each fall semester. This practice will create opportunities to continue studying the integration of engineering social innovation skills in industry-driven project-based classes.

This study explored how to integrate social innovation skills into an engineering project-based curriculum. The results of the study turned into an opportunity to increase non-technical skill development by elevating industry and community engagement in the engineering profession (Howaldt et al., 2016; Cajas-Santana, 2014). For the UMKC SCE, the next ABET accreditation cycle requires evidence of curriculum improvement. The UMIC SCE will document actions taken to improve the program in the Self-Study Report required for the next on-site reaccreditation review, specifically, the incorporation of social impacts into their capstone design classes (ABET, 2018). In practice, this study is also significant because it serves as a framework for instructors to create innovative project-based learning curricula (Koller, 1995; McLurkin et., al 2013). Implementing these curricula is an opportunity for engineering schools to increase their competitive advantage in at least four ways. First, appealing to higher education's target market – students – with high job placement rates (Molesworth, Scullion, & Nixon, 2010). Second, enhancing industry engagement while equipping engineers with social innovation skills (Grimm, Fox, Baines, & Albertson, 2013;

Howaldt et al., 2016; Mendoza, 2015; Wyman, 2016). Third, providing a guide to integrating new learning outcomes into engineering curricula, which promotes the preparation of engineers capable of social innovations (Padmanabhan et al., 2018). Fourth, increasing the engineering schools' prestige as entities that continuously look for activities that match with society, sustainability, and environment (Bozic & Dunlap, 2013; Morrissey et al., 2017; Koller, 1995). Altogether, this study provided an opportunity for future engineering students to grow as professionals while facilitating the development of engineering programs to create positive impacts on their communities.

SECTION FIVE: CONTRIBUTION TO SCHOLARSHIP

Target Journal

The target journal for the scholarly contribution of this study is the *Journal of Engineering Education*, a peer-reviewed international publication of the American Society for Engineering Education (ASEE).

Rationale for this Target

The *Journal of Engineering Education (JEE)* is dedicated to advancing research in engineering education. Its primary focus is on cultivating, publicizing, and archiving scholarly research in engineering education. The *Journal of Engineering Education's* mission goes beyond publishing papers. It integrates a global community of engineering societies and associations with access to publications and opportunities to collaborate with their members (ASEE).

Outline of Proposed Contents based on 2021 Requirements

A manuscript of 8,000 to 10,000 words, including references, will be sent to the journal's online portal – ScholarOne – for peer review. Manuscripts submitted through ScholarOne must consist of the following electronic files (ASEE):

- Cover letter,
- Text of the manuscript, blinded for peer review,
- Full title of the manuscript,
- A 250-word structured abstract,
- Keywords,
- Introduction section following the abstract and preceding the main body of the manuscript,
- Main body of the manuscript, appropriately divided into sections,
- Conclusion or summary section following the main body of the manuscript,

- Acknowledgments (blinded for peer review),
- List of references,
- Appendices (as appropriate), and
- Figures and tables, if any, either embedded at appropriate locations within the manuscript (preferred) or appended at the end of the manuscript.

Plan for Submission

I will submit a paper to the *Journal of Engineering Education* upon the defense of the dissertation in practice. The submission will apply to the Virtual Issue: ASEE 2022. The researcher will submit a cover letter and a manuscript, electronically, to the peer-reviewed journal, pay the fees associated with the submission, and transfer the copyrights to the ASEE if applicable.

Submission-ready Journal Article

Social Innovation Skills Development in Project-based Capstone Classes in Civil Engineering: A Case Study of the Civil Engineering Program at the University of Missouri Kansas City

Engineering schools are increasingly focused on job placement efforts to boost enrollment and meet accreditation standards (Acworth, 2008; Bybee, 2010). Increasingly, these institutions are seen as economic development hubs that provide a skilled workforce to not only bolster the economy but also improve communities' social needs, which requires non-technical skills (Christensen, Horn, Caldera, & Soares, 2011; Dunkan & Rayess, 2008; Murray et al., 2010; Sanders, 1958). Higher education has a key role to play in developing students' technical skills and non-technical skills to appeal to an increasingly socially responsible job market (Dukhan & Rayess, 2014; Gray & Koncz, 2017; Heywood, 2016). To do so, engineering educators must teach future professionals "social innovation skills" the ability to identify a community's social needs and transform this information into innovative technical solutions (Bourn & Deal, 2008; Bozic & Dunlap, 2013). By encouraging engineering schools to increase students' non-technical skills, future engineers will be better equipped to integrate social responsibility into their professional duties (Heywood, 2016; Mehta & Gorski, 2016; Perkmann et al., 2013), rather than relying on social scientists to act as intermediaries between engineers and the community.

However, the literature on engineering education does not address how to best incorporate social and community-based problems in the engineering curriculum to facilitate social innovation (Bozic & Dunlap, 2013; Gray & Koncz, 2017). To address this gap, this case study explored to what degree students exhibit social innovation skills in their civil engineering capstone class at a research-intensive university in the Midwest, the University of Missouri in

Kansas City (UMKC). This qualitative case study at UMKC used the literature on experiential learning and skill development theory (Fischer, 1980) to identify ways in which engineering project-based curricula facilitate social innovation skill learning in typical engineering capstone classes. In particular, this study merged the literature on engineering social innovation skills, the literature on experiential learning in engineering, standards of the profession, and accreditation criteria (ABET, 2018A). The addition of innovation skills to engineering curricula has the potential to provide a framework for preparing engineers to be socially innovative and capable of community engagement. Based on this framework, the case study consisted of the civil engineering capstone design class titled CE412/ANCH 311 System Design II (Spring 2020) at the University of Missouri Kansas City (System Design II capstone course). The sources of data included documents from the capstone class and interviews with the instructors of the capstone and pre-requisite classes, practitioners facilitating the capstone project, and the program's accreditation representative.

Results indicated that experiential learning using real-world projects in capstone classes enhances social innovation skill learning. However, given the natural variation of capstone classes, practitioners interviewed differed in how they integrate this skill learning into the class activities and project scopes. This case study suggests that, with the application of the four essential skillsets suggested by the European Commission (EU, 2019), it is possible to standardize an approach to social innovation learning in the capstone curriculum. Those four skills were selected out of a set of innovation skills demanded by industry, and I tailored for engineering education. The engineering social innovation skills I propose in this study are complex social problem solving, integrated skills to interact with communities, creativity to address social needs, and community-driven systems thinking. One key element identified by participants to foster social innovation skill learning is “social impacts.” The social

impacts is defined as the engineering project's impact on a community's quality of life (Becker, 2001; Çelik, Kamali, & Arayici, 2017; Yuan, Cui, & Jiang, 2013). These results offer valuable insights into potential curriculum improvement for engineering capstone classes and suggest new avenues for future research and career opportunities.

In the following sections, I will introduce the literature on the engineering job market and discuss project-based curricula and accreditation standards in the field. Then, I will move to the problem statement and the theoretical framework of this study as well as the research design and results obtained. I conclude with a discussion based on the results on how to generate change in the capstone class to foster social innovation skills.

A New Engineering Job Market

The historical goal of the engineering profession was to solve industrial-technological needs (Gray & Koncz, 2017; Koller, 1995; Pekermann et al., 2013; Sanders, 1958). That goal has been changing to also address community needs (Phillips & Pittman, 2008; Wyman, 2016). The engineering workforce must be able to utilize non-technical skills (Felder & Brent, 2003; Wyman, 2016) to meet the demand for professionals capable of delivering both technological and social innovations to increase industry and community engagement (Dart, 2004; Wyman, 2016). Today's engineering job market increasingly interfaces with social enterprises and companies are, more than ever before, creating units that manage social responsibility with a community-oriented focus (Dart, 2004; Hirschi, 2018; Lebeman & McDonald, 2016). Industry usually defines non-technical skills in public job postings as supervisions, thought leadership, change management, and negotiation (Burning-glass, 2019; EU, 2019), but not community engagement or social innovation. Further, current job search engines like Glassdoor.com and Indeed.com show career opportunities in corporate social responsibility for professionals in humanities and social sciences, but not for engineers. This industry trend means that engineers

should acquire social and other non-technical skills to successfully compete for these liaison roles between industry and communities. Social innovation skills could be developed through engineering project-based curricula (Mehta & Gorski, 2016). However, engineering curricula do not focus on many of the non-technical skills that enable graduates to interact and engage with communities (Dukhan & Rayess, 2014).

Developing social innovation skills in addition to other engineering skills during capstone classes could lead to greater community engagement. In this scenario, community engagement is a reciprocally beneficial interaction where faculty and students propose innovative solutions to community problems during project-based classes (Bringle & Hatcher, 2002). Engineering students who exhibit skills that lead to social innovation create more effective communication with communities. For instance, the concept of Engineers without Borders, in which students interact with communities to find appropriate solutions for their infrastructure and basic human needs, is an example of how community-based activities could form socially innovative engineers (Helgesson, 2006). This example also illustrates the capacity of engineering students to address social needs in the design of engineering projects as a result of interacting with the community during the capstone design process (Murray, Caulier-Grice, & Mulgan, 2010).

Social innovations differ from technological innovations in their anticipated results (Dawson & Daniel, 2010). Specifically, technical innovations in engineering stimulate the creation of new products, physical and digital, even when those serve to resolve social problems (Cajaiba-Santana, 2014). Engineers equipped with social innovation skills accelerate the design and delivery of new products, processes, and programs useful for communities (Starr & Minchella, 2016). For example, if a project involves the creation of mobility aids, engineers who interact directly with the people the aids are meant to serve can better understand their

daily routines, values, and other issues impacting the use of the aids and the environment in which that innovation will operate (Murray et al., 2010).

Project-Based Curricula and ABET Standards

Traditionally, engineering schools in the United States utilize project-based curricula to promote skill development. Project-based learning activities link the cognitive processes of acquiring critical skills with the stimulus for learning and with the provision of meaningful problems that motivate learners (Kearsley & Shneiderman, 1998; Krajcik & Blumenfeld, 2006). Additionally, the Accreditation Board of Engineering and Technology (ABET) includes “social focus” in its student learning outcomes, and the civil engineering curriculum at UMKC adopted it into projects provided by industry (ABET, 2018). Thus, the interaction between students and communities, such as the capstone projects in this case study, provides opportunities to enhance these non-technical skills in the typical project-based curriculum (Dawsib & Danie, 2010).

Although ABET’s role is to ensure that today’s college students are prepared to develop solutions that make life on our planet safer and more sustainable (ABET, 2018), the “how” to make that vision a reality in the classroom is not well described in the accreditation standards. ABET, in its publication *Sustainable Engineering 2018*, states that engineering education should develop global citizens through social services and encourages schools to cultivate an interest in social innovation at home and abroad (ABET, 2018). However, only two out of seven student learning outcomes are related to social aspects, yet they are so broad that capstone classes are not taking into consideration strategies to highlight or enhance social innovation skills. ABET accreditation is important for engineering schools because it enables them to provide employers with a workforce that follows standardized program curricula that supports new skill learning .

This study uses the case of capstone class at the ABET accredited program of Civil

Engineering at the University of Missouri Kansas City (UMKC). One component of meeting ABET accreditation criteria at UMKC is the continuous improvement of capstone design courses where students work on real-world industry-driven projects. Adding projects from industry into curricula is a typical leadership strategy to engage industry while achieving accreditation (Tedesco, Operti, & Amadio, 2014). However, those learning outcomes, like those presented by ABET (ABET, 2018), are only related to industry-driven project based learning, leaving out community-based activities that lead to social innovation skills learning (Frank, Lavy, & Elata, 2003; Heywood, 2016).

Thus, the introduction of social innovation skill learning into engineering capstone courses provides two opportunities for engineering schools. First, adding new non-technical skills to engineering curricula satisfies both ABET and industry workforce demands for skilled workers capable of interacting with communities and can be documented in the ABET self-evaluation report as a continuous improvement to curricula (ABET, 2018A; Burning-glass, 2019; Dart, 2004). Second, adding social innovation skills to the curricula provides an opportunity for engineering schools to be innovative by creating new strategies to compete in the higher education market by increasing pre-graduation job placement rates (Christensen, Horn, Caldera, & Soares, 2011).

Statement of the Problem and Purpose of the Study

Civil engineering programs have not embraced the concept of social innovation in their program of study. (Murray et al., 2010). In fact, there are indications that in practice, many engineering curricula fail to connect current academic standards with the social skillset students need to meet today's industry and community demands (ABET, 2018A; Bourn & Deal, 2008; Bozic & Dunlap, 2013; Canfield et al., 2012; Heywood, 2016; Murray, Caulier-Grice, & Mulgan, 2010). Because innovation and creativity are outcomes of experiential learning

activities (Kearsley & Shneiderman, 1998), it is crucial for engineering education to leverage experiential learning for social innovation skills development while providing innovative engineering solutions addressing industry and community needs (Fischer, 1980, Gray & Koncz, 2017; Heywood, 2016; Kearsley & Shneiderman, 1998; National Academy of Engineering, 2004; Padmanabhan et al., 2018). Industry currently uses social and human science professionals to carry out its community engagement activities. These duties, however, could be carried out by engineers if they learned social innovation skills in their academic curriculum (Gray & Koncz, 2017). Although there are indications that project-based engineering courses *could* enhance social innovation skills development, it is unclear to what degree these experiential learning activities are effective in creating socially competent engineers (Kolb & Kolb, 2015; Kolb & Kolb, 2012). Building upon my personal and professional interest in bridging this knowledge gap, the primary purpose of the study was to explore *to what extent do engineering students exhibit social innovation skills in an industry-driven capstone project in the program of civil engineering at a Midwestern research-intensive institution.*

Theoretical Framework and Guiding Concepts

For this study, the experiential learning context is a capstone class for which Fisher's skill development theory serves as a tool to assess the level of command of engineering social innovation skills (Fischer, 1980). This experiential learning theoretical framework guided the conversations with instructors and practitioners about community-engagement strategies at the UMKC Civil Engineering program and the need to shift the engineering skill learning towards the addition of social innovation skills.

Experiential Learning and Skill Development

Learning is an individual-based process of forming meaning through experience (Kearsley & Shneiderman, 1998; Krajcik & Blumenfeld, 2006; Veglis & Pomportsis, 2014) and

is a method useful for transforming typical engineering skills into a more complex skill set that integrates social innovation skills. Engineering students develop skills in learning spaces through an individual-based process of creating meaning through experience (Kearsley & Shneiderman, 1998; Krajcik & Blumenfeld, 2006; Veglis & Pomportsis, 2014). In this study, the CE412/ANCH 311 course is the learning space (environment) for social innovation skills development as a result of experience with community-based projects. Experiential learning in engineering that could be applied to social innovation skill development occurs in a four-stage cycle: substantial or concrete experience, reflective observation, mental or abstract conceptualization), and active experimentation (Kolb, Boyatzis, & Mainemelis, 2001; Kolb & Kolb, 2005). This model also agrees with the idea of Kearsley and Shneiderman (1998), in which transformational learning happens through experimentation.

Fischer (1980) describes the relationships between the construction of cognitive, social, and other skills with the physiological transformation of learning and problem-solving behaviors. In this theory, *skills* are defined as the individual's capability to control the behavior, thinking, and feelings within a given environment and context. Skills include "emotions, motivations, meaning, and actions" (Mascolo & Fischer, 2010, p. 5). The skill then is a "transaction of organism and environment" (Fisher, 1980, p. 479) where the individual or organism, in terms of the skill theory, controls its actions in that particular environment.

Fischer (1980) provides a set of transformational rules for gradually increasing skill complexity from one cognitive development level to the other. A given skill is developed systematically in 10 hierarchical levels, which are divided into three stages: sensory-motor skills, representation skills, and abstract skills. Each level determines a structure that describes the type of behavior that a person can control at each level and, progressively, what is required to move from one level to the next within the three stages. Accordingly, scholars and

practitioners could utilize skill theory to identify at which level(s) of cognitive development the participants self-describe learning a given skill in a civil engineering capstone class (see Figure 3 in Section 1).

In the sensory-motor stages, stages one to four, all abilities are related to a set of sensory-motor actions and perceptions. The set comprises entities like items, events, or people. In this stage, the individual develops only practical skills. The skill set defines how to act on a specific entity but is unable to elaborate a concept or understanding until reaching level four. Representation skills are part of levels four to seven in which the individual utilizes conceptual maps to represent interrelations between entities but unable to connect multiple systems at the same time. This will be possible when he or she reaches level seven. This level is the culmination of the representational development phase. The abstract set of skills is acquired from levels seven to ten. Once the individual is capable of controlling the relation between the two systems, he or she can identify the impact and covariation of changes. At this point, the individual can control entities and construct an abstract concept of that entity.

Defining Social Innovation Skills

There are established engineering skills systems that could lead to social innovation. For example, ABET establishes engineering non-technical skills such as communication, cognitive skills, problem-solving, and the ability to listen, for example (Shuman, Besterfield-Sacre, & McGourty, 2005; Tedesco, Opertti, & Amadio, 2014).

The European Commission presented six groups of innovation skills during the *Skills for Industry Strategy 2030*, a high-level conference in June 2019 (EU, 2019), which are: emotional-intelligence skills, innovation skills, managerial and entrepreneurial skills, soft skills, organizational skills, and leadership skills. From this list, I created a set of social innovation

skills meant to foster the abilities to design and create solutions for social problems. The skills I adapted to the notion of *social innovation skills* are complex social problem solving, integrated skills to interact with communities, creativity to address social needs, and community-driven systems thinking. Table 1 in Section 1 presents the top-down funneling process I followed to extract the four engineering social innovation skills that guided starting with the six categories identified in the review of skills⁴industry proposed by the European Commission. I continued with the category of innovation from which I extracted four skills, which were tailored into four engineering social innovation skills.

In particular, I tailored the definitions of these innovation skills to propose four social innovation skills as follows:

- *Complex social problem-solving skills* take place when a given state of the art of a social issue transforms into a new state, and no visible or routine method of solution is available. If an individual must utilize a substantial number of interrelated factors to solve a social problem, the problem is complex. Complex social problem-solvers attempt to learn skills by acquiring and applying knowledge to effectively represent and solve complex social problems in a feasible way (Dabbagh, 2020; Wüstenberg, Greiff, & Funke, 2012).
- *Integrated skills to interact with communities* refer to the effectiveness of an individual to communicate successfully with members of communities by using the four primary language skills altogether: listening, reading, speaking, and writing (Oller, 1972).
- *Creativity skills to address social needs* are the abilities that determine whether the individual has the power to exhibit creative behavior when proposing solutions to community-based problems. Creativity entails both originality and effectiveness. Ideas and products to address social necessities that are only original may be useless; thus, innovative ideas or products must also be effective to be creative. The individual exhibits a remarkable

degree of effort to produce results of a creative nature-based upon his motivational and temperamental traits in both the engineering profession and social settings (Runco & Jaeger, 2012).

- *Community-driven systems thinking skills* is a set of skills derived from the eight skills included in the System Thinking Hierarchical Model (Assaraf & Orion, 2005), which includes the following skills: (1) the ability to identify the components of systems and processes within the social system in study; (2) the ability to recognize simple relationships between or among the social system's components; (3) the ability to identify dynamic relationships within the social system; (4) the ability to organize the social systems' components, processes, and their interactions, within a framework of relationships; (5) the ability to identify cycles and patterns within the social systems; (6) the ability to recognize hidden dimensions of the social system—to understand phenomena through patterns and interconnections that the researcher does not see on the surface; (7) the ability to make generalizations—to solve social problems understanding systems' mechanisms; and (8) the ability to think temporally such as retrospection and prediction. Social system thinkers understand that some of the interactions within the social system took place in the past, while future events may be a result of present interactions.

Research Design

This study followed a qualitative approach, which is a scientific method for exploring and understanding meanings, concepts, and definitions of social and human problems (Merriam & Tisdell, 2016). In particular, I used an instrumental qualitative case study design (Baxter & Jack, 2008; Stake, 1995).

The case study is the civil engineering capstone design class titled CE412/ANCH 311 System Design II (Spring 2020) at the University of Missouri Kansas City (System Design II

capstone course). Given that this class is industry-driven in civil engineering programs studying this class allowed me to gain an in-depth understanding transferrable to other programs about the skills students develop during experiential learning and in relation to the four engineering social innovation skills – the issue at hand in this study (Merriam & Tisdell, 2016; Stake, 1995),

The classes in this case are traditional 3-credit hour courses from the UMKC senior level required courses (fourth year of the degree) of the UMKC Bachelor of Science in Civil Engineering (BSCE). The project-based curricula for the BSCE include five required credits of capstone design within the fourth academic year of the degree distributed in two classes: CE 411 Civil Engineering System Design I, a two-credit studio design class that is offered in fall academic semesters, and System Design II, a capstone course of a three-credit studio design open for each of the following spring academic semesters for those students who passed CE411. The two courses are split into four teams with four different projects. The members of each team are ten students and one practitioner (professional engineer – PE – in practice who works in industry and is in charge of mentoring students acting as adjunct professors for the class). The instructor plays the role of a coordinator and facilitator and selects the projects for the two sequel classes in the fall and spring semesters. For this particular case, the instructor confirmed that both classes in the fall 2019 and spring 2020 had the same projects, practitioners, and student teams.

The participants in the case study included the individuals who actively participated in the System Design II capstone class in spring 2020, including the instructor and the practitioners alongside an ABET representative for the UMKC SCE, and faculty of prerequisite classes of the capstone class who have taught them during the time students were in the program.

The projects for the class came from various local construction firms with contracts with

the state and local governments and industry. The deliverable to the industry project provider, at the end of System Design II capstone course, was an engineering design that included two components: a) a study of the area in where the civil engineering project will be located, and b) 30% of the site drawings showing a clear picture of the construction site and plans including landscaping and other details. For this case study, there were four projects: Project one: *A traffic calm study*. The goal of this project, commissioned by a Kansas City based national engineering consulting firm, was to compare before and after traffic volumes and vehicular speeds in the vicinity of three temporary speed humps. Project two: *Structural design for a power station in Kansas City*. The goal of this project, commissioned by La Cygne Station Unit 1, was to evaluate additional structures to aid in the control of fugitive dust from the fly ash handling system as well as the wash water from the cleanup of the equipment and haul trucks. Project three: *Design of an intersection for the Missouri Department of Transportation (MoDOT)*. The goal of this project, commissioned by a construction firm working with MoDOT, was to propose civil engineering solutions to improve safety along a traffic route that had higher than average crashes due to either speed or sight distance issues. Project four: *Kansas City South Plaza Streetcar Station*. The goal of this project, commissioned by the Kansas City government, was to provide the city with a list of alternatives to address specific site improvements (safety, mobility, access, parking, etc.) in the surrounding area of the future station.

Data Collection

Data collection consisted primarily of documents related to the class and interviews with participants. In particular, documents provided by the instructor were the primary data source, including the course syllabus, students' final reports, final evaluations, and project descriptions for each capstone class. Other documents utilized in the study were the 2019 ABET self-study documentation, including the accreditation policy and procedure manual, program educational

objectives, student outcomes, continuous improvement plan, and the curriculum. The documentation from the prerequisite classes provided insights about the structure of the spring 2020 class in terms of how teams were formed, an overview of the projects, and the project management plans designed by the practitioners.

The interviews took place via the web-conference platform Zoom. Face-to-face interactions were not a consideration due to the Covid-19 pandemic. I conducted six online interviews, with a one-hour duration each: one with the CE412 instructor, three with the practitioners of the System Design II capstone class, one with the UMKC SCE ABET representative, and one with an instructor for a pre-requisite class CE420. The objective of the first set of interviews started with the CE412 instructor to identify the rationale of the capstone curriculum design, the opportunities for learning non-technical skills in the capstone class, the alignment of the class activities with ABET and industry requirements, the skills that the curriculum proposes, as well as engineering social innovation skills the instructor had observed in students that are not part of the course description. The Instructor Interview Protocol included a questionnaire with ten groups of open-ended questions that were organized into the following themes: professional overview, curriculum design, projects, team dynamics, community engagement, social innovation, social innovation skills, ABET, and additional comments. An interview with the instructor for a pre-requisite class (CE420) was conducted with the same interview protocol utilized with the CE412 instructor. The second set of interviews with the professional engineers used the same interview groups of questions used for the instructor's interview. In addition, the practitioners were asked questions to clarify the process they follow to a) identify the real-world projects for each capstone class, b) determine the scope of the project, and c) design the activities with industry and communities during the capstone class and the presentation of final reports. The third interview with an ABET representative sought to

identify opportunities and challenges to modifying the curriculum at UMKC SCE, and the process of proposing and integrating new learning outcomes into curricula. It also discussed the central functions of an ABET representative in the committees that approve curriculum design for the capstone course.

The document review method consisted of an iterative process of skimming, reading, and interpreting content related to the research question (Bowen, 2009). This document analysis procedure included finding, selecting, appraising, and synthesizing data available in the documents of the study (Bowen, 2009; Fink 2013, Stake, 1995). I used triangulation to seek convergence and corroboration from the interview transcripts (Bowen, 2009). During the document review, I examined content from the CE411 System Design I Fall 2019 and CE412/ANCH 311 System Design II Spring 2020 classes. The next step was to code the content into keywords extracted from the research question and pre-existing categories in literature: social innovation skill development, curriculum improvement, industry-driven projects, and experiential learning (Canfield et al., 2012; Eppes et al., 2012; EU, 2019; Felder & Brent, 2003; Fischer, 1980). Finally, the results of coding each document were interpreted in relation to each other using the same pre-existing categories in literature, as shown in Table 2 in Section 1 (Hancock & Algozzine, 2017).

Thematic analysis was also used as a process for classifying, storing, and accessing the information from (a) documents and (b) interview transcripts (Hancock & Algozzine, 2017). This thematic analysis included content from all data sources previously aggregated into the pre-existing categories. Given that thematic analysis is an iterative process (Hancock & Algozzine), I ran the first cycle of coding to the aggregated data obtained from documents and interview transcripts (Saldaña, 2015; p. 67). Due to there was no evidence of the level of command of social innovation skills as presented by Fischer (1980), I applied a second cycle

code organized in a codebook for analysis (Coffey & Atkinson, 1996; Saldaña, 2015; p.233) using six categories: the curriculum, advisors, engagement, project scope, skill development, and social innovation (see Table 2 in Section 1). Then, I used axial coding methods to group the open codes from the six categories to finally obtain the three themes described in the results section. Overall, I systematically examined each piece of information constructively to answer the research question (Hancock & Algozzine, 2017; Stake, 1995; Yin, 1994). For the entire process, I used Microsoft Word and Excel.

Researcher Positionality

As the researcher, I do believe that my scholar and practitioner experience supported my role as the interpreter of the data and the ability to describe the results to academic and industrial audiences. I was the primary instrument for data collection and analysis in this case study (Padmanabhan et al., 2008; Seale, 1999; Stake, 1995), and I built the research question as the result of my personal and professional interest to bridge the gap between communities and the engineering profession. I was born and raised in Colombia in a rural community, and this is where I initiated my engineering profession. I learned technical skills while witnessing community needs such as affordable drinking water systems or construction of natural barriers to control river flooding. However, my community only had access to engineering services through government and industry; thus, I created a non-profit organization before graduating as an industrial engineer – Corporacion Cobeei – to address social needs utilizing federal grants to fund engineering capstone projects. In 2000, I engaged engineering schools in the city of Bucaramanga to participate in a project to build a rural elementary school utilizing civil engineering students' talent. Together, the capstone engineering students and I discussed with the community the best design that fit their needs, such as insulation, materials, budget, and

maintenance. That was the origin of many projects to support communities from the engineering profession while providing students with real-world opportunities to learn non-technical skills.

In the United States, I have worked as an engineer leveraging synergies between industry, higher education, and social settings. I have worked in the leadership teams of the University of Missouri Extension and the UMKC School of Computing and Engineering performing duties in industry engagement and project management. These administrative positions, in particular, influenced the decision-making process within the administrative areas of the organizations. Although my experience and position could have influenced the outcome of the study, and I acknowledged my own preconceptions, I did not participate in ABET accreditation boards, curriculum design teams, or implementation for the CE412/ANCH 311 course.

Both the international and local experience in engineering education influenced my interpretation and methodology used to analyze the data. Thus, I utilized literature to contrast the knowledge I obtained from data analysis. I constantly reflected on the potential bias I could bring to this study.

Trustworthiness

Trustworthiness is the most broadly used criterion for evaluating the validity of qualitative research (Hancock & Algozzine, 2017). Shenton (2004) defines four distinct features that a case study should possess to validate its trustworthiness. First, the study is *credible* by reflecting how confident the researcher is in the truth of the findings of the study; thus, in particular for this case, all the data come from participants and literature. Second, the case study is *transferable* by demonstrating that the results have applicability to other contexts, conditions, and situations; thus, this case is a bounded-system study that can be replicable in other engineering capstone classes. Third, the case study is *confirmable*, which refers to the degree of

neutrality due to the participants' answers constructing the findings rather than any possible influence of the researcher; in particular, I developed open-ended interviews to learn from participants rather than observe the phenomenon in the class setting. Lastly, the case study is *dependable*, which means the study had enough information to allow other researchers to repeat the study and obtain similar and consistent findings; therefore, I provide highly descriptive findings and results by adhering to all the required elements of trustworthy, qualitative research.

Limitations

There were limitations to this study. First, the use of one class at one institution limits its generalizability to other institutions; however, other researchers will find insights from the rich descriptions I provided from this industry-driven case study in order to address the issue of integrating social innovation skills into engineering a capstone class. The interviews were limited to the number of available participants. Data collection took place after the academic semester ended, so practitioners were already fully committed to their industry jobs resulting in three out of four practitioners recruited. Likewise, the pre-required class instructors were already in other endeavors, limiting the interview count to two. Also, the study included only one ABET representative as she coordinates the accreditation process. The study did not include other individuals involved in accreditation to be interviewed, like advisory board members.

Results

The dissertation in practice fulfilled its purpose of exploring to what degree students acquire social innovation skills in an industry-driven capstone class in the civil engineering department at a research-intensive university in the Midwest. The case study research also answered the research question concluding that students acquire social innovation skills in the industry-driven capstone class (CE412) in civil engineering at the University of Missouri Kansas City. The level of command of those skills should be measured utilizing Fisher's skill

theory.

The results presented in this article utilized two essential definitions: a) *social innovation skills* as the abilities to identify community's social needs and transform this information into innovative engineering solutions (Bourn & Deal, 2008; Bozic & Dunlap, 2013); and b) *social impacts* defined as the engineering project's impact on a community's quality of life (Becker, 2001; Çelik, Kamali, & Arayici, 2017). Social impacts is considered a way to foster social innovation skills (Yuan, Cui, & Jiang, 2013). The engineering social innovation skills presented above and used to create the data collection protocols of this study were absent in the documentation analyzed in this study; however, I did find skills students learn through the capstone class relate to these four engineering social innovation skills. In particular, interviews with practitioners and instructors revealed situations where students did exhibit non-technical skills when interacting with community residents (community engagement) or interacting with the public sector, such as meeting with government officials to discuss a project. Although the results of this study indicate that social innovation skills are present in practice, I found no evidence in the document analysis of assessments that can lead to the study of cognitive development using Fischer's skill theory. However, I believe it can be used as an assessment tool to measure the level of mastery of each of the four social innovation skills in experiential learning classes.

Two overarching needs were identified for skills learning in engineering: (1) the need to incorporate social innovation skills development into the capstone curriculum, and (2) the need to integrate the construct of *social impacts* into the project design and in the civil engineering curriculum for capstone classes. Both engineering practitioners and instructors saw the value of formally adding content on "social impacts" into the capstone curriculum as a gateway to developing students' social innovation skills as they enter the workforce. Their insights, which

center on the needs noted above, are discussed in further detail below in three themes: 1) integrating social innovation skills in the capstone curriculum, 2) integrating “social impacts” content into an engineering project design class and its capstone engineering curriculum, and 3) suggestion for capstone curriculum improvement given by participants.

Theme 1. Integrating Social Innovation Skills into Capstone Curriculum

After analyzing documents and the curriculum, it became clear that social innovation skill development is not explicitly included in the capstone course. However, instructors provided reassurance that, although social innovation may not exist on the documentation, it does appear during students’ practicum experience. Specifically, students are exposed to community engagement activities and interactions with the clients – private companies and public agencies that commission the projects to the capstone class. Similarly, social innovation is evident during the tangible experience gained by students during their practicum experience. Therefore, the integration of social innovation is possible through the real-world experiences for non-technical skill development (sub-theme 1.1) and through community engagement and interacting with public and private entities (sub-theme 1.2), as I explain next.

Sub-Theme 1.1: Learning from real-life experiences for non-technical skill development

The document analysis showed that learning through real-world experience was not explicitly included in the syllabus or class reports. However, interviews revealed a different story. For example, the interview with the Accreditation Board for Engineering and Technology (ABET) representative provided information on the importance of using real-world projects and the impact that these projects have on ABET accreditation. This representative mentioned that ABET reviewers highlighted the use of real projects in the CE412 Capstone class and the uniqueness of using practitioners to generate engineering designs for real clients, in comparison with similar schools: “That was one of the things that the evaluator truly liked about our

program, that all of our programs have those real-world problems that students work on” (ABET Representative).

Results from interviews with practitioners and instructors showed agreement that learning through real experience prepares engineering students to address social problems. The capstone is the opportunity to provide those scenarios before joining the workforce. The CE412 Instructor highlighted the need for students to develop critical thinking skills to address societal impacts during project design. This instructor said:

... It's really difficult for people to think about these impacts because, at the end of the day, you think I'm just designing the roads, you know. I'm just thinking how many inches. I'm not thinking about what about the guy living around the corner that needs to go into that driveway every day coming from work; how is he going to be affected by that design. (The CE412 Instructor)

Similarly, practitioners agreed that real-world problems prepare students to solve problems they will encounter in their careers and that the project scope helps them to facilitate that learning in the capstone class. For instance, Practitioner 2 said:

The senior design class is intended to bring students into a “real world” environment where students use the skills they have learned in college and apply them not to, as they have before, hypothetical problems but to a “real world” problem (project) as they will encounter in their professional life. (Practitioner 2)

The scope of a real-world project is a tool for social innovation skill learning. Practitioner 2 also stated that as a practitioner, his role is to coach students to gain social innovation skills by bringing their expertise in “performing these real-world projects” and guide students through understanding the project and its requirements. Practitioner 2 also mentioned that the scope of the real-world project has a high impact on the opportunities to learn by real

experience while keeping the balance between societal expectations and technical feasibility. Similarly, the CE412 instructor stated that “...scope is really important; it needs to be small enough that they can attack, but it cannot be too small,” which prevents the development of social innovation and other non-technical skills. This instructor mentioned that the project scope should challenge students and have diverse activities to develop both technical and non-technical skills. He also stated that the project scope facilitates social skill development by allowing students to use creativity and critical thinking on how to use standards and codes to solve community needs:

We don't want them to just design a roadway, right? We want them to think about a little bit of roads, a little bit of utilities, maybe at a VA access ramp. We want to make sure that there is some diversity in the project that thinks about different standards and codes.
(CE412 Instructor)

Similarly, Practitioner 2 stated that learning by real experience requires flexibility in the project scope instead of framing projects in a “box” from the curriculum. This practitioner said: “I’ll give them the right project and give them the right design for the project.... These are real projects that we’re dealing with. And projects sometimes can; they can be mushy, they can move around a little bit.”

Practitioner 1 also agreed on the importance of clearly defining the project scope for the class. He stated that the scope of real projects gives students scenarios where they can learn how to deal with the uncertainties of real work environments:

I'm working with another engineer on trying to craft a project that's suitable for the capstone, but yet they can really experience it. What an engineer would experience in practice when he's working with one of these projects. If it's in the middle of the study of got to deal with the city. If it's, you got to maybe have to deal with utility companies;

you're going to have to deal with permit organizations. You may have to deal with private landholders around them around an area. (Practitioner 1)

In summary, students exercise non-technical skills when working on real-world projects that include community engagement and interactions with the client – public and private entities. Yet, analysis of course documents and interview transcripts clearly shows that content on social innovation is missing from the curriculum explicitly. However, according to participants in this case study, the CE412 class has the academic mechanisms and industry-driven projects to facilitate social innovation skill learning among engineering students.

Sub-Theme 1.2: Learning from community engagement and interacting with public and private entities

Analysis of students' assignments and the capstone curriculum revealed that practitioners are fostering the development of students' social innovation skills by providing real-world problems from industry and government because these allowed students to create a technical engineering design for solving social problems. For instance, documents from the CE411 class show that the scope of work for the project under Practitioner 1 required students to include opinions from civilians or the parties that would utilize services. Practitioners adjusted the scope of work in these projects in order to include opportunities for students to interact with public entities, as well as with the communities that the projects will impact. According to Practitioner 1, capstone classes have to include plenty of activities for community engagement: such activities “provide scenarios of social innovation skill development, students should engage communities from the beginning of the project design” (Practitioner 1). Similarly, the CE412 Instructor stated that communicating with the communities is a way for students to create engagement: “the curriculum should allow students to engage the community

who will use or benefit from the project because informed communities are engaged communities."

Although the integration of social innovation skills is not formally established in the curriculum, practitioners have been facilitating community engagement and understanding the role of the government in project design for many academic years in the CE412 Capstone Project. Practitioners concur that community engagement in capstone projects aims to know and integrate all viewpoints into the project design. In that regard, Practitioner 1 stated the following:

They'll have to deal with some of the surrounding community because the surrounding community will be utilizing that station....We want our students to bring in these different opinions. So, when they walk away from this project and then the design is handed back to the construction manager and into the design team, it is something that's viable that can be taken forward to construction. (Practitioner 1)

Although the curriculum does not require interaction with the community the project will impact, Practitioner 2 noted that he requires students to use at least one community engagement strategy. For instance, students learn about the community's opinions through data the client (a government agency or private firm) collected by direct interaction with the community or understand communities' needs and expectations based on information from public meetings and events meant to discuss the project and make final decisions. He said:

Very seldom does a real-world municipal project does not require community engagement in the form of soliciting stakeholder interest and expectations either in the form of public meetings, citizen surveys, or one-on-one personal encounters. I require community engagement using one or more of these described tools in our projects.

(Practitioner 2)

Similarly, the CE412 Instructor stated that community engagement is a recommendation that practitioners should provide to students, but it is not a required activity for the class, in contrast with the high interaction required with industry and the clients. For example, the curriculum requires that students attend public meetings (activities that the client host to discuss the project) to observe the government interaction with the community. Another activity is to exhibit communication skills when meeting clients representatives - public officials and engineers in practice - to discuss the project design but seldom do those meetings congregate the community the project will impact. The instructor said:

... one assignment is to go to a public meeting and attend a public meeting, and there is a form they fill out after that you know what they have seen over there. The other part is that meeting with our clients, public agencies, or industries. And in addition to the clients, they meet with engineers and contractors--people from engineering firms and contracting firms. And in addition to that, they meet with two different companies actually those are consultants for our clients. Those consultants whose their job is... actually public communication, right? (CE412 Instructor)

Although engagement with the community that will be impacted by the capstone projects is not formally integrated into the curriculum, the ABET representative highlighted the positive impact that alumni report in surveys regarding opportunities to engage communities before graduation. The ABET representative said: "...our students think that our engagement with the community is really good because we've had not only these classes where we have projects, working with the community...". Similarly, alumni appreciate learning from experts in the field. The ABET Representative stated that "...we also have a lot of adjunct instructors that come in from engineering firms and teach classes or give guest lectures..." that facilitates the inclusion of real-world projects into our capstone classes.

In conclusion, Theme 1 showed that engineering education focuses on industry and public (“government”) engagement. The main reason is that industry and government are the main funding source for projects that benefit communities. Practitioners summarized that real-world government projects require that students learn not only community engagement but also understanding the role of public institutions. Particularly, Practitioner 2 said the following:

The client project manager has an obligation to make sure that the needs and requests that pass by his or her hierarchy are made by the students as a participant and as service providers, and that they understand who they are providing services to...And that there is an understanding of the hierarchy of government, who are the top decision-makers, and how do they satisfy those decision-makers. (Practitioner 2)

Theme 2. Integrating “ Social impacts” Content into an Engineering Project Design Class and its Capstone Engineering Curriculum

According to professional engineering practitioners, the “ social impacts” of an engineering project design can impact a community’s quality of life. An ability to translate the community needs into the impacts or social impacts of an engineering project is an example of engineering social innovation skills (Practitioner 1). Integrating “ social impacts” into a capstone class would help students identify a project’s potential social impacts and develop alternatives for mitigating these impacts. Introducing the concept of “ social impacts” to engineering students was seen by participants as a starting point for learning and practicing social innovation skills. Theme 2 is composed of two sub-themes: (a) students’ benefits of learning about the social impacts in the engineering curriculum; (b) integrating social impacts in the engineering capstone design class.

Sub-Theme 2.1: Students’ benefits of learning about social impacts in the capstone engineering curriculum

The results of the study showed that the ability to define social impacts in an engineering project is an example of learning social innovation skills during the capstone class in the study. Currently, social impacts as a subject of study is a missing component in capstone design projects. Syllabi for the CE412 course only addressed the monetary costs of project design. For example, the current syllabus for CE412 establishes the following objectives for the course: (a) develop design alternatives and (b) develop a deliverable that includes 30% of the engineering drawings of the project, with proposed cost and schedule. These two objectives are important because when engineers design projects, they require students to provide the overall costs of the project. These overall costs should include the social impacts or impact on the community. However, according to the instructor of the CE412 capstone class, social impacts are not in the design of the class because it is a concept that is neither formally integrated into the engineering curriculum nor in accreditation standards of the profession. Despite this lack of explicit instruction on social impacts, participants indicated that students usually gather sufficient information from the community and the clients during the project design to be able to add social impacts to their reports if they learn about the concept and are instructed to consider it. During the interview, the CE412 Instructor talked about the social aspects of the projects that could be related to social impacts:

So, one thing about the public meetings is we wanted them to understand the decisions they make when you're the designer. It's just not simple decisions about cost and effectiveness, but it's also decisions about changing people's lives and affecting people's lives. For instance, understanding how people can get back from their work, maybe the project helps them to get home ten minutes earlier, as an effect of what they decided. So that was the biggest fight from the social. I wouldn't call it social

innovation, but it's the social skills that we wanted them to get at the end of this class.

(CE412 Instructor)

Faculty and practitioners want students to learn and include social impacts in their reports. The CE412 Instructor discussed how the social impacts of engineering projects is needed in order for students to understand social issues and how a project affects the community. Practitioner 1 also noted that while technical aspects of a project may come easily to engineering students, they need to be able to apply these concepts with social issues in mind. This instructor stated:

There's a lot of different viewpoints that need to be brought to the table. So, you can be sensitive to broader social issues and bring your engineering experience, your knowledge, skills, and abilities to bear on those larger social issues. Because at the end of the day, civil engineers, what we feel affects a community, and it's the community's asset.

Understanding social impacts turns engineers into contributors to a society whose contributions go beyond technical solutions. (CE412 Instructor)

Practitioner 1 added, "We wanted the students to be socially acceptable, you know, don't come out as engineers who don't really care about the public and just about technical stuff, but we wanted them to understand." By being aware of social issues and including the social impacts in reports, students could show community impact and demonstrate that they are socially-minded.

According to practitioners, the ability to communicate the social impacts of real-world engineering issues at all levels of an organization during the capstone class involves social innovation skills that could benefit their career seeking. One practitioner reported:

"...wouldn't say they learn social innovation skills, but I would say that if they learn how to

calculate the social impacts in a ‘real world’ engineering challenge, those skills will enhance employability” (Practitioner 2). Another practitioner commented on the interpersonal and communication benefits of including social impacts by saying:

...about social innovation, yeah, as an engineer, you have to be able to talk to the heads of companies, right down to the people that are constructing. Then everything in between. You better be able to communicate. (Practitioner 1)

Additionally, this practitioner discussed the benefits of students exhibiting social innovation skills to enhance career success. Practitioner 1 said: “We want to help our students to exhibit those social innovation skills besides the technical skills when they pursue careers, and also when they are in practice.” And continued describing that internships are platforms for assisting students in building their social innovation skills, but sometimes students only have the opportunity to exhibit technical skills; thus, obtaining a position that allows students to develop social innovation skills would be a great asset during the internship that could help them to secure an engineering position. He said:

...a lot of our students do have internships ...some of them simply go into an organization, and they'll be put in front of a computer on a desk ... they'll use very similar engineering skills in a very restricted fashion and not expand that beyond their monitor... but if the students say I learned this new skills, without question they will get a job... (Practitioner 1)

Sub-Theme 2.2: Integrating social impacts into engineering capstone design class CE412

Although participants of the interviews discussed that students could learn how to integrate social impacts into the engineering project design class while learning other social innovation skills by interacting with the community, the document analysis findings showed that the current project guidelines are focused on technical aspects only. To bridge that

gap between the practitioners' view and the content of the curriculum, the CE412 instructor stated that the curriculum and accreditation standards allow the inclusion of new components to enhance non-technical skill learning via community engagement. This instructor reported the following:

The capstone class could have room to put [in] the social innovation component.

Because what I'm placing is implicit in the scope of work, students have community interaction. (CE412 Instructor)

Like the CE412 instructor, the instructor for a pre-requisite class (CE420) also believed that social innovation needed to be explicit in the curriculum. He had to learn social skills outside of the profession as engineering education does not formally provide non-technical skill learning. CE420 Instructor explained:

So, I'm an engineer, and I have to learn all of this extra background on the side, as you mentioned at the beginning. So maybe an internship before capstone class may provide some of these skills that we should learn before going to the workforce. So, we should modify the curriculum. (CE420 Instructor)

Practitioners discussed that the projects selected are suitable to add social impacts as a required outcome for the capstone class. Practitioner 1 said:

It's a real project. We're in the final design of the streetcar now to turn the area into a better place. So, we can incorporate students' suggestions into the streetcar construction. (Practitioner 1)

Likewise, Practitioner 2 discussed that project scope also takes into account public officials' requirements to address the social impacts of the project design. This practitioner said:

Who, the decision-makers are the support people, so students need to spend some time in advance and in meetings with the government, knowing who the mayor is, who the city manager is, who the public parks director is, who the project manager is so that they can make sure that they address the concerns of all of these elected officials, who then negotiate the final design, you know, many times. In an interview with a city councilperson or the city manager or managers representative may sit in on a meeting, and they have the power to incorporate students' suggestions into the construction.

(Practitioner 2)

Practitioner 1 mentioned that adding the social impacts to the conclusion of the classwork will be a way to show evidence of learning social innovation skills derived from the community engagement experiences provided in class. Other similar thoughts were expressed by the CE412 Instructor, who said:

The construction business is all about people skills and starts when students meet clients during the spring semester and attend public meetings. From interacting with public entities and communities, students could use that experience to be ready to go.

(CE412 Instructor).

Similarly, according to Practitioner 1, placing ideas on paper during capstone project design would allow students to exhibit social innovation skills when they connect multiple points of view to solve complex problems like evaluating the social impacts of a capstone project. He said the following:

I think it's social innovation, bringing those disparate viewpoints and worldviews together and into focus to solve a larger social issue and a larger social issue.... We need the kind of people that can bring those disparate viewpoints together to solve large, complex, complicated, messy social problems. (Practitioner 1)

Students' reports also shed light on how to add social impacts into the capstone class so that students can demonstrate their understanding of an engineering project's social impacts. It was previously noted that in-class documents and student reports are the primary class deliverables where social impacts could be incorporated into recommendations. In one particular instance, students were receiving guidance from professional engineers as defined in documents from the elective CE422. As part of the discussion, the class addressed how to apply the concepts of building code ACI318 - requirements for design and construction of structural concrete that are necessary to ensure public health and safety (CE411 Team 2 Final Report).-, which could be viewed as solving a social problem from the engineering profession or social innovation.

Another curriculum document discussed a required activity related to ethical responsibility in which students are required to read an article on the ethics of using computer programs in designing and analysis (CE422 documentation provided by instructor). In the revision of student reports, there was some evidence of engineering students addressing social needs, such as providing brief recommendations to consider sidewalks and stairs compliant with the Americans with Disabilities Act (CE412 Team 1 and Team 2 Final Reports) and "convenience for pedestrians" (CE411 Team 1 Final Report).

Final reports in the spring semester are designed to place technical ideas on paper, such as working in AutoCAD, preparing presentations, and then working with the practitioner for feedback. One practitioner indicated the feedback is usually focused on understanding what the client wants and provides the students with the changes needed to meet those expectations. Thus, he concluded that those activities are “a good time to put [in] a little bit more about social skills” (Practitioner 2).

From interviews, practitioners discussed the guidance students receive to perform beyond the technical scope and the addition of topics that can facilitate the inclusion of social impacts in the reports. Practitioner 2 said:

I don't approach this class strictly from the perspective of engineering design. I incorporate the other aspects of project identification, pursuit, design alternative economics, management, and documentation that others may not. This requires the students to prepare a written Statement of Qualifications, interview with the client for the project assignment, meet with the client to update them on project progress, perform public participation to get project stakeholder input, and document the results of the design in a design report. These requirements mean that the students must use verbal and written communication skills, public speaking and technical writing, marketing of the project and themselves, the strategic thinking of how to pursue the project, life cycle costing of the project, and probably most importantly, development of teamwork skills. (Practitioner 2)

In conclusion, Theme 2 shows that social impacts as a construct is not formally included in the capstone projects and is not part of the requirements for project design or alternatives for mitigation that students document in their reports. Also, neither social impacts nor social innovation are explicitly stated in the syllabus or project guides. However, practitioners believe social impacts can be added to the syllabus of the capstone class as a way to develop social innovation skills.

Theme 3. Suggestions for Capstone Curriculum Improvement

According to the ABET representative, one way to reach ABET accreditation criteria is through continuous improvement of capstone design courses – engineering culminating project-based courses – where students work on real-world industry-driven projects. Significant results

were extracted from documents and interview transcripts on alternatives to improve the engineering capstone curriculum. Based on those results, curriculum improvement in the capstone class CE412 is feasible in two ways: (a) by modifying the project scope and class activities (subtheme 3.1) and (b) by adding learning outcomes to the capstone curriculum (subtheme 3.2).

Sub-Theme 3.1: Modifying the Learning Outcomes and the Capstone Class Activities

The first option to improving the capstone curriculum is by modifying the class structure, specifically the project scope and its activities. The project scope was described by interviewees as the roadmap that should state the learning outcomes for all students regardless of the project assigned. Overall, the project scope assists practitioners in defining the activities with communities and the public sector.

In analyzing interviews and course documents, the project scope was the focal point for improving the class structure. Themes 1 and 2 showed the importance of having a clearly defined project scope and of integrating real-world experiences during a capstone class. Documents from CE411 and CE412 classes showed four customized project scopes. Each practitioner wrote the project scope to address technical design and drawings for the client. The practitioners also described a series of activities for students to work in teams, deliver presentations, and attend public meetings to fulfill the class requirements (Work documents CE412 and CE411).

One reason to write a customized project scope is that each real-world project is provided by an engineering firm or a public entity with which the practitioner has a relationship. Practitioner 2 explained that he is an active member of the industry sector, which provides real-world projects to the capstone class:

The projects in which I have been involved have all been from the municipal arena. Having worked for many years in the Kansas City urban area as both a public and private sector engineer and has served as president of both our local and national professional associations, I know all of the public works directors in the KC area.

(Practitioner 2)

Practitioner 2 also seeks projects that benefit the community and allow the student to make a meaningful contribution: "I reach out to these acquaintances and seek projects that I feel will benefit both the community from which the project comes and the students that will be performing the project."

Another reason for customizing the project scope is that practitioners can transfer their experience to students on how to be consultants and work in teams. The instructor of CE412 explained this method facilitates experiential learning: "Well, this whole class is built around experiential learning right; all the students need to experience how it feels to be outside in the world and to work for a consulting company and to work for a client."

According to responses to the interviews, participants noted that another option for improving the capstone curriculum is to enhance the class activities. Class activities fulfill the learning outcomes outlined in the curriculum and are designed to enhance non-technical skill learning (ABET Representative). The CE412 Instructor explained that class activities such as teamwork and project management--although not formally defined as learning outcomes--provide students with practical experience as consultants for the real-world projects in a capstone class. This instructor said:

I think group dynamics and learning how to work in a group is also a big part of this class as training in their earlier classes they've done group work, but in this class, even though they have deadlines and their practitioners coming in every week, so the stress

level learners have higher compared to the classes that have taken before. (CE412 Instructor)

Sub-Theme 3.2: Adding Learning Outcomes to the Capstone Curriculum

All the interviewees noted that the process for implementing all class structural changes described in sub-theme 3.1 must involve the ABET representative and the advisory board of the engineering school. The ABET representative explained that accreditation standards required a minimum of seven learning outcomes to solve engineering problems and leaves the option open to add a new learning outcome to include social innovation skill learning. The ABET Representative said:

ABET has seven outcomes...a number of them are about solving engineering problems or applying engineering design..., ... things that have to be covered in each engineering curriculum, a number of credit hours in math and science, number of credit hours...So that is sort of mandated by ABET. (The ABET Representative)

The ABET Representative continued saying that ABET accepts new learning outcomes in the curriculum, and those are usually aligned to the institutional mission. Learning outcomes selected by each instructor. The ABET representative explained that the new outcomes, like the one to include social innovation skill learning, are agreed to by the instructors and the administrative bodies of the engineering school:

We sit down, and we look at the outcomes, and each person who teaches a required class says, well, you know what? I cover this in my class, I could assess that outcome, or I cover this in this other class. Also, as a department or program, you can add other outcomes that you feel are important. (The ABET Representative)

In an example, the ABET representative described how a coordinated program added an eighth outcome related to community service:

So, for example, we have a coordinated program with Rockhurst University. They have actually added the eighth outcome.... They want service to be a big part of their curriculum. And so that's something a lot of schools will do if they haven't something that they consider to be important enough, they want to assess the same as all other seven outcomes. (The ABET Representative)

This is a clear example of the feasibility of adding a learning outcome for social innovation skill learning in the capstone curriculum. This possibility is also feasible because ABET permits the addition of learning outcomes upon internal decisions at the engineering schools.

The advisory board represents the engineering community and plays an important role in defining new learning outcomes. The ABET representative explained that UMKC's mission is to serve the community, but there are no learning outcomes for community engagement; therefore, the advisory board is in a position to require new learning outcomes to fulfill the institutional mission and to address industry and community needs. The ABET representative explained:

We don't have any specific community engagement outcomes, but we do make we all we do to a setup changes since we're so intertwined with the Kansas City engineering community that's sort of one of our missions is to make sure that we are serving that community and so the way we do that is rather than through outcomes is through our advisory board. So, the advisory boards are always members of the local engineering community. So, when we meet with them, we always are making sure that our students are graduating with skills that they need in this particular. (The ABET Representative)

The ABET representative, the CE412 instructor, and the practitioners have access to the advisory board to discuss curriculum improvement opportunities. Due to the advisory board's high interest in enhancing community engagement, they must learn from the participants about

the impacts of social innovation skill learning, like increasing students' employability rates or adding social impacts analysis to real-world project design. The impact unto the student should motivate the advisory board to request a new learning outcome in the capstone curriculum formally and potentially to all pre-required classes.

Discussion

These results demonstrate that experiential learning using real-world projects in capstone classes enhances social innovation skill learning. However, there is a natural variation in the structure of capstone classes, and practitioners differ in how they integrate this skill learning into the class activities and project scope. The three themes extracted from the document review and interview transcripts showed that engineering students exhibit social skills when given real-world problems to solve. Although I did not find results that explicitly address the four social innovation skills proposed in this dissertation, the UMKC School of Computing and Engineering has all the elements to integrate those four skills into the curriculum: complex social problem solving, integrated skills to interact with communities, creativity to address social needs, and community-driven systems. The next step is to require social impacts analysis in the class reports and include a new learning outcome in the class curriculum. The discussion of the results below summarizes the options for formally improving the curriculum to facilitate social innovation in engineering education.

Previous research involving social innovation skills in engineering education is limited, and the results of this case study offer valuable insights into potential curriculum improvement for engineering capstone classes. The results relied on current practices of a capstone class to explore ways to develop non-technical skills. The results suggest new directions for future research, such as the integration of community engagement and learning the structure of the government as platforms to building social innovation skills in the engineering students.

The qualitative case study approach to this research contributed considerably to this dissertation's value by leveraging the role of real and practical experience in providing a deep understanding of curriculum improvement to facilitate social innovation skill learning. The results obtained explained the particularity and complexity of the single case CE412/ANCH 311 class of Spring 2020. For instance, I was able to perform an in-depth exploration of non-technical skill learning while obtaining detailed descriptions of how students, instructors, and practitioners' function in the same learning space. Based on the results, I propose to utilize social impacts as the common thread for curriculum improvement for social innovation skill development, as I explain next.

Integrating Social impacts into the Curriculum for Skill Learning

Although interview transcripts suggested that curriculum has to address first the basic non-technical skills like writing or public speaking, the interviewees agreed on the importance of modifying the curriculum to utilize an experiential learning scenario (capstone class) to teach the four engineering social innovation skills proposed in this study: Complex Social Problem-Solving Skills, Integrated Skills to Interact with Communities, Creativity Skills to Address Social Needs, and Community-driven Systems Thinking Skills.

Social impacts in civil engineering projects affect the quality of life, environment, and tangible facilities and infrastructures that solve needs and add value to people (Bartuska, 2007; Çelik, Kamali & Arayici, 2017). The social impacts in an engineering project cannot be calculated using standard estimated methods. Accordingly, one alternative for engineering projects is to classify the social impacts as the eleven categories proposed by Yuan, Cui, and Jian (2013): the cost of health damage; the cost of civil damage rights; effect on the transportation costs; decision-making errors costs; loss of income; loss of decreased

productivity; loss of revenues; the cost of pollution; resource costs; property damage; and the destruction of the original building by any effect of the adjacent construction.

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Integrating Social impacts into New Learning Outcomes

CE214 Senior Design II presents three out of seven ABET outcomes in its syllabus, as explained by the ABET representative. Those outcomes are:

- ABET Outcome #2 – an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, societal, environmental, and economic factors.
- ABET Learning Outcome #3 -an ability to communicate effectively with a range of audiences.
- ABET Learning Outcome #5 – an ability to function effectively on a team whose members together provide leadership, create a collaborative, inclusive environment, establish goals, plan tasks, and meet objectives.

Based on the results of this case study, I propose the addition of a new learning outcome: ***an ability to include the social impacts into engineering design.*** To evaluate the success of implementing this new learning outcome, instructors should utilize a tool to assess the level of command of the social engineering skill of describing social impacts in engineering design before and at the end of the capstone class. Fischer (1980) provides a structure for the assessment in the theory of cognitive development and its ten hierarchy levels (see Figure 1 in Section 1).

According to Hossain and Cumming (2016), for ABET accreditation, engineering schools must demonstrate achievement of learning goals. It requires a systematic understanding of student learning by collecting data with appropriate assessment tools that verifies continuous

improvement. Thus, the new learning outcome should integrate a series of *learning objectives for social innovation skill learning*. To achieve those goals for social innovation skill learning, students will provide an overview of the social cost, during the project design. Those learning objectives are:

- Exhibiting integrated skills to interact with the communities to identify the needs, wants, and value of civil engineering projects.
- Applying “complex social problem-solving skills” to assess the *convenience* of the expected impacts once the project is implemented.
- Using “community-driven systems thinking skills” to assess if the project’s consequences are socially acceptable.
- Utilizing “creativity skills” to assess and quantify the social impacts in a holistic manner.

Integrating Social impacts into the Project Scope

Based on document analysis, the capstone class requires that all projects contain drawings of the industry project. Those deliverables for the clients are constructed in teamwork activities divided into two semesters. Each practitioner customizes the project scope; not all students have public meetings or activities to interact with the community. Thus, it is necessary to standardize the project scope to create a methodology for social innovation skill learning. To achieve standardization, I propose the inclusion of the following items into the project scope for the CE411 and CE412 classes:

- Community engagement activities,
- Client engagement activities, such as attending public meetings to discuss the project,

- Design the social impacts method for each project utilizing the 11 phases proposed by Yuan et al. (2013),
- Provide a self-assessment of the four engineering social innovation skills utilizing Fischer Skill Theory to rank the level of command at the end of the class (Fischer, 1980).

Implications

To balance accreditation standards and the need to prepare engineers to address social problems, this dissertation in practice proposes adding content on social impacts to the capstone course to facilitate social innovation skill learning.

The main contribution of this study is a concrete proposal for improving the engineering curriculum by using social impacts as the leading element for change. In practice, this means that engineering professionals would have to negotiate with clients scheduling more meetings with the community and public officials in order to assess the social impacts of the projects. This also implies that more time should be dedicated to the class by instructors in order to prepare and deliver social innovation and social impacts lectures and design activities, as well as assessments while balancing with the content of the course's technical and non-technical curriculum. Despite these additional burdens, the interviewees agreed that it is feasible to add content on “social impacts” to the engineering curriculum, even in pre-requisite classes. This approach will benefit how future engineers learn social innovation skills by reinforcing social impacts applications in real-world projects. In turn, UMKC and programs alike will share the added value of having well-rounded graduates who can confidently provide employers with strong technical and social capabilities. Increasing the pre-graduation employment rate would be a key benefit of this new curriculum enhancement.

Thanks to this study, the transition to a more representative and inclusive capstone curriculum at UMKC has begun. After data collection for this dissertation ended, conversations between the instructors and practitioners continued. The stakeholders agreed that future capstone projects must align with the right client and be designed to start each fall semester. Thus, it is expected that by Fall 2021, UMKC will acquire projects that require students to apply social impacts methodologies during their CE412 class in Spring 2022. This practice will create opportunities to continue studying the integration of engineering social innovation skills in industry-driven project-based classes.

Conclusion

This study explored how to integrate social innovation skills into an engineering project-based curriculum. The results of the study turned into an opportunity to increase non-technical skill development by elevating industry and community engagement in the engineering profession (Howaldt et al., 2016; Cajaiba-Santana, 2014). For the UMKC SCE, the next ABET accreditation cycle requires evidence of curriculum improvement. The UMIC SCE will document actions taken to improve the program in the Self-Study Report required for the next on-site reaccreditation review, specifically, the incorporation of social impacts into their capstone design classes (ABET, 2018). In practice, this study is also significant because it serves as a framework for instructors to create innovative project-based learning curricula (Koller, 1995; McLurkin et., al 2013). Implementing these curricula is an opportunity for engineering schools to increase their competitive advantage in at least four ways. First, appealing to higher education's target market – students – with high job placement rates (Molesworth, Scullion, & Nixon, 2010). Second, enhancing industry engagement while equipping engineers with social innovation skills (Grimm, Fox, Baines, & Albertson, 2013; Howaldt et al., 2016; Mendoza, 2015; Wyman, 2016). Third, providing a guide to integrating

new learning outcomes into engineering curricula, which promotes the preparation of engineers capable of social innovations (Padmanabhan et al., 2018). Fourth, increasing the engineering schools' prestige as entities that continuously look for activities that match with society, sustainability, and environment (Bozic & Dunlap, 2013; Morrissey et al., 2017; Koller, 1995). Altogether, this study provided an opportunity for future engineering students to grow as professionals while facilitating the development of engineering programs to create positive impacts in their communities.

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SECTION SIX: SCHOLARLY PRACTITIONER REFLECTION

Influence of Dissertation on my Practice as an Educational Leader

As a young girl growing up in a rural community in Colombia, I witnessed my neighbors facing a variety of daily challenges. Many of them could not access clean drinking water. And on rainy days, it was impossible to navigate our community's flooded streets. These were problems that could be readily addressed by technical solutions, but we only had access to engineering services through government and industry. I realized early that I had the ideas to create change in my community, but I did not yet have the tools. Years later, as I was developing my final capstone project before earning an industrial engineering degree, I had my first opportunity to give back. I created a non-profit organization – Corporacion Cobeii – to address social needs by utilizing federal grants to fund engineering capstone projects. Through my first entrepreneurial venture, I engaged engineering schools in the city of Bucaramanga to help build a rural elementary school utilizing the talent of civil engineering students. Together, the capstone engineering students and I met with the community to discuss the best design (insulation, materials, budget, maintenance) to fit their needs. That was the origin of many projects that engaged engineers to support communities while providing engineering students with real-world opportunities to learn non-technical skills. This early formative experience shaped my perspective as an education leader, and instilled a desire to lead others in positive change. In the United States, I have worked as an engineer while at the same time participating in University of Missouri leadership teams where I managed initiatives between industry, higher education, and community settings. These administrative positions were pivotal to influencing the decision-making process within the organization and, admittedly, allowed me to favor the social innovation initiatives close to my heart. Today, as a woman in STEM preparing to attain her doctorate, I am on the cusp of breaking new ground in a traditionally male profession. Yet, I have witnessed amazing women role models who have achieved leadership roles, and that

motivates me to reach the same goals and beyond. At the same time, I am creating my own new model of who I'd like to be: an inspiring, transformative, global academic leader who empowers diverse communities.

Transformational Leadership

I envision a transformation in higher education where social innovation and community engagement are infused into the curriculum and culture of the institution. In this endeavor, transformational leadership is the theoretical foundation that guides my leadership approach and decision-making processes. I have observed transformational leadership traits in various leaders over the years—from Colombia to Missouri to Florida—but always in the shadow of them. As I observed, I noted men and women who were able to show authentic leadership, cultural sensitivity, and effective team building without losing sight of the operational, policy, and learning tasks that lay at the core of their mission. I see myself each day evolving into a leader that continually motivates students, faculty, staff, and administrators, and shows a deep commitment to the success and well-being of the organization.

In my view, the well-being of an organization begins with creating a climate where diverse people are able to reach their potential, and feel confident in their ability to make change. Based on the principles instilled in my doctoral curriculum, I envision a transformation in higher education where equity is a cornerstone of community engagement. As a female engineer that broke barriers by ascending the ranks of American academia, I want others to have the same opportunities I had, and I want them to see they are worthy of having a position of influence. I look forward to engaging diverse backgrounds, nationalities, races, and beliefs and infusing that with cultural sensitivity: In my early career, my engineering skills and cultural awareness were strong, but I was not always able to communicate these values in the manner I would have liked. Over the years, I've had to continually improve my charismatic and

communicative skills to enhance the collective organizational consciousness and approach communities with confidence. Although English is my second language, it is not a deficit; it has shaped my “diversity worldview,” enhanced my charisma, and allowed me to genuinely empathize with differences to bridge cultural divides. In the American context, my race is unique by nature and classified into underrepresented groups. But in Colombia, diversity is associated with economic depression or populations displaced by violence (Giraldo, 2004). Regardless of how I am classified, I am proud to say my multicultural and multilingual profile have shaped my leadership style and coming from humble ranks has positioned me to make the biggest impact.

As I continue to reflect on transformational leadership, I have also learned that I can transform myself. During my early doctoral work, I realized my leadership style needed to shift from transactional (relationships) to transformational (organizational). Changing my natural approach has been challenging, but my role models in engineering leadership have given me valuable insights into how to do this. They have shown me how to empower my staff, influence my organization, and ultimately achieve national priorities. As I shadowed these leaders, I observed that transformational, authentic leaders give power to people in the form of autonomy and meaningful work activities (Bolman & Deal, 2013; Levi, 2015). They inspire self-management (Northouse, 2016) and help diverse teams reach their full potential (Levi, 2015). Transformational leaders successfully achieve goals once the organization accepts and follows the leader’s vision and purpose (Bass, 1990). As I continue strengthening my leadership traits, I realize it is critical to clearly define and communicate my vision and purpose. I want to exhibit authenticity while giving faculty and staff recognition in the organization’s success. Consequently, I envision myself as a professional who supports, advocates, and empowers participation at all levels of the organization, as a path to transforming its culture.

I have also learned that transformation requires input from a variety of perspectives. Similar to the engineering field, where we may work with architects, plumbers, designers, and contractors, it's important to recognize and harness unique talents to achieve shared goals. As I shadowed academic deans over the years, I found that they consistently competed for scarce resources within and across organizations. To survive, they had to partner effectively with other schools to create multidisciplinary programs. I can utilize my experience working with innovation funds-- in both the political and academic arena--to continue creating multidisciplinary teams in the STEM fields. The engineering workforce is evolving towards collaboration, creation, and workplace learning (Leberman & McDonald, 2016) as a means to face the changing demands in the current employment landscape (Hirschi, 2018; Jackson, 2017; Manu, 2016). My new work setting allows me to see the possibilities of engineering collaborating with medicine, nursing, biology, and even the arts, to accomplish new innovations, and I'm excited to see the results. The political arena at American universities also provides an opportunity for me to achieve leadership roles I never envisioned. Successful leadership of multidisciplinary teams is increasingly a barometer of successful leadership in a broader context. For instance, Dr. Elizabeth Loba, the first woman to hold the position as the dean of the University of Missouri College of Engineering, simultaneously performs the role of Vice Chancellor for Strategic Partnerships. That model allows me to dream of a day where I can reframe an entire organization to promote change.

Quite possibly, that change could extend to the global economy. My heritage naturally draws me to international collaborations and comparisons, and thus my leadership and scholarly practice will extend to how countries can learn from each other in their efforts to foster social entrepreneurship. In addition to creating local community partnerships, I look forward to leading efforts to building relationships with academic institutions in other countries and

bridging cultural divides. The EDD in Leadership and Higher Education program, along with my professional experiences leading two Small Business Development Centers (SBDCs), has challenged me to expand my “vision,” and I believe this is necessary to achieve my goal of transforming underserved groups into innovative communities.

Finally, before I started this journey, I could not envision myself linking local needs to national and international policy, and becoming a positive force in how governments shape entrepreneurship. As a leader in STEM, I have the vision to engage communities to bridge the gap between technology innovations and their social needs, and to challenge employers to not merely fund experiential learning programs but to actively engage the community to help themselves while striving toward national STEM prominence. This degree program has been instrumental in equipping me with the analytical, leadership, and communication skills to promote social entrepreneurship at both a national and global level. That vision is transformative.

Influence of Dissertation on my Practice as a Scholar

My initial goal when I started this journey was to enhance engineering social innovation through community engagement by modifying the experiential learning curriculum. However, as a true scholar, I am open to new avenues and pathways beyond what I originally envisioned. I see the broader vision of applying social innovation to other STEM disciplines. I see myself contributing to the literature by applying existing theoretical constructs to new settings, and social entrepreneurship translates easily from discipline-specific interactions, such as engineering, to the broader life sciences. The engineering profession has “broken new ground” in forging social innovation partnerships, and this can serve as a model for other STEM disciplines and be replicated at other institutions. My expertise in establishing this model and validating it for other STEM disciplines would carve a new path in educational scholarship, and

I look forward to advising other institutions on how to make social entrepreneurship a core pillar of their academic endeavors.

As a scholar, my application of the literature on leadership has also been rigorously tested by world events: racial unrest, deep political shifts, and the pandemic, among other events. As a result, I now see my aspirations in a bigger, brighter light. I see myself coming up with *new paradigms*. The literature has prepared us for a fairly normal world, but new societal imperatives have forced us to shift beyond boundaries and progress beyond our comfort zones. We have seen technological innovations come to market rapidly in 2020 based upon the entrepreneurial spirit that responds to urgent needs and situations. As an academic leader, and future dean, I can make insights that go beyond disciplines to academia on a larger scale. Therefore, I see no limit in my ability to grow and make contributions as a scholar, because the community and life are always teaching us. And as long as we listen and respond to social needs, the learning opportunities are endless.

Conclusion

As a transformational leader, my doctoral training has empowered me to promote change, reframe organizations, impact communities, and influence policy, all while exhibiting core values in ethics and diversity. As I write this reflection, my view of this program's impact takes on new meaning. In the final stages of this dissertation, I assumed a new position leading small business development for an entire institution, rather than just one engineering school. Shortly afterward, the world was propelled into a global pandemic and I, along with my colleagues, learned how to lead from quarantine. Now, I must lead my staff through unprecedented change and lead my new neighbors in efforts to recover their business and reimagine their livelihoods in a post-pandemic world. On top of that, I must work with my institution's leadership team to adapt and transform as a university. I must help the institution

rediscover its vision in a world where the space of learning environments has shifted dramatically, and enrollments are evolving. This is challenging, but I rely on my core personality strengths-- deliberation, analysis, self-discipline and self-assurance (Carson, Evans, Gitin, & Eads, 2011) to identify solutions. Now more than ever, I am excited to lead from a place where I am most comfortable: listening to the community and helping them respond to their needs. I feel well equipped, through my degree program, to begin leading in a time of unprecedented change.

More importantly, I look forward to leaving the community-- like a finely engineered structure—better and more resilient than it was before.

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Appendix A

1. Instructor Interview Protocol

Instructor Interview Protocol	
Introduction	<p>Thank you for accepting this interview. As you know, I am working in the Dissertation in Practice to obtain the Doctor of Education at the University of Missouri – Columbia. The primary purpose of the dissertation is to study to what extent do engineering students exhibit social innovation skills in industry driven project-based classes?</p> <p>After studying the documents, you provided, I would like to ask a series of questions to help me interpret the information I have been collecting. Your responses will be recorded and will be kept confidential: nothing you say will be attributed to you personally or to your work. Is that ok with you?</p> <p>The interview is scheduled for one hour. Would it be appropriate if we utilize more time to cover all the topics schedule for the interview?</p>
Professional overview	<p>Although I have some familiarity with your responsibilities as an instructor of the CE 412/ANCH 311 course, in this interview, I would like to get a better sense of the details of your work.</p> <ol style="list-style-type: none"> 1. <i>Of all the functions for which your responsible as instructor, which ones are the most central to the promotion of experiential learning or hands-on experience?</i> 2. <i>[Ask as appropriate, given the responses to the first question.]</i>
Curriculum design	<p>You've mentioned your most important functions as instructor, now I would like to ask you in greater detail about the activities related to curriculum design <i>[and also a few others that have come up in our research.]</i></p> <ol style="list-style-type: none"> 3. <i>Could you briefly describe the process of designing the curriculum for engineering system design classes and the most important factors that influenced its design?</i>
Skills	<ol style="list-style-type: none"> 4. <i>Could you please define non-technical skills the student exhibit during the participation in the CE 412/ANCH 311 course</i>
Projects	<p>The projects in which students worked during the spring semester seem to be one of the strategies to fulfill the learning outcomes described in the CE 412 / ANCH 311 syllabus.</p> <ol style="list-style-type: none"> 5. <i>How the projects are selected?</i>

	<i>6. Is there any particular reason for which industry partners are the only project providers provide projects to this class?</i>
Team dynamics	<p>Another strategy I have noticed is the integration of a practitioner into the student teams.</p> <p><i>7. How do you link the participation of the practitioner with the learning outcomes of the CE 412 /ANCH 311 course?</i></p>
Community engagement	<p><i>8. How do students involve the community in the current coursework?</i></p> <p><i>9. How do you envision the students involvement with communities while working on the projects assigned?</i></p>
Social innovation	<i>10. Would you provide your definition of social innovation?</i>
Social innovation skills	<i>11. Do you consider the students learn social innovation skills in the capstone classes?</i>
Curriculum design and ABET	<p><i>12. What are your thoughts on the curriculum improvement to meet the ABET requirements?</i></p> <p><i>13. How do community projects could be incorporated into ABET requirements for curriculum improvement?</i></p>
Additional comments	<i>14. Do you have any other point of view or recommendation for me to consider in this case study?</i>

2. Instructor of Pre-required Courses Interview Protocol

Instructor Interview Protocol	
Introduction	<p>Thank you for accepting this interview. As you know, I am working in the Dissertation in Practice to obtain the Doctor of Education at the University of Missouri – Columbia. The primary purpose of the dissertation is to study to what extent do engineering students exhibit social innovation skills in industry-driven project based classes?</p> <p>After studying the documents, you provided, I would like to ask a series of questions to help me interpret the information I have been collecting. Your responses will be recorded and will be kept confidential: nothing you say will be attributed to you personally or to your work. Is that ok with you?</p> <p>The interview is scheduled for one hour. Would it be appropriate if we utilize more time to cover all the topics scheduled for the interview?</p>
Professional overview	<p>Although I have some familiarity with your responsibilities as an instructor of the PRE-REQUIRED course code, in this interview, I would like to get a better sense of the details of your work.</p> <p>5. <i>Of all the functions for which your responsible as an instructor, which ones are the most central to the promotion of experiential learning or hands-on experience?</i></p> <p>6. <i>[Ask as appropriate, given the responses to the first question.]</i></p>
Curriculum design	<p>You've mentioned your most important functions as an instructor, now I would like to ask you in greater detail about the activities related to curriculum design <i>[and also a few others that have come up in our research.]</i></p> <p>7. <i>Could you briefly describe the process of designing the curriculum for engineering system design classes and the most important factors that influenced its design?</i></p>
Skills	<p>8. <i>Could you please define non-technical skills the student exhibit during the participation in the PRE-REQUIRED course code</i></p>
Projects	<p>The projects in which students worked during the spring semester seem to be one of the strategies to fulfill the learning outcomes described in the PRE-REQUIRED course syllabus.</p> <p>15. <i>How the projects are selected?</i></p>

	<i>16. Is there any particular reason for which industry partners are the only project providers provide projects to this class?</i>
Team dynamics	<p>Another strategy I have noticed is the integration of a practitioner into the student teams.</p> <p><i>17. How do you link the participation of the practitioner with the learning outcomes of the PRE-REQUIRED course?</i></p>
Community engagement	<p><i>18. How do students involve the community in the current coursework?</i></p> <p><i>19. How do you envision the students involvement with communities while working on the projects assigned?</i></p>
Social innovation	<i>20. Would you provide your definition of social innovation?</i>
Social innovation skills	<i>21. Do you consider the students learn social innovation skills in the capstone classes?</i>
Curriculum design and ABET	<p><i>22. What are your thoughts on the curriculum improvement to meet the ABET requirements?</i></p> <p><i>23. How do community projects could be incorporated into ABET requirements for curriculum improvement?</i></p>
Additional comments	<i>24. Do you have any other point of view or recommendation for me to consider in this case study?</i>

Appendix B

Practitioners Interview Protocol

Practitioner Interview Protocol	
Introduction	<p>Thank you for accepting this interview. As you know, I am working in the Dissertation in Practice to obtain the Doctor of Education at the University of Missouri – Columbia. The primary purpose of the dissertation is to study to what extent do engineering students exhibit social innovation skills in industry-driven project based classes?</p> <p>After studying the documentation of the UMKC Civil Engineering senior design course, I would like to ask a series of questions to help me interpret the information I have been collecting. Your responses will be recorded and will be kept confidential: nothing you say will be attributed to you personally or to your work, or to the entity you represent. Is that ok with you?</p> <p>The interview is scheduled for one hour. Would it be appropriate if we utilize more time to cover all the topics listed for the interview?</p>
Professional overview	<p>Although I have some familiarity with your responsibilities as a practitioner (professional engineer in practice) of the UMKC SCE CE412 class, in this interview, I would like to get a better sense of the details of your work.</p> <p><i>1. Of all the functions for which your response as a practitioner, which ones are the most central to the promotion of experiential learning or hands-on experience?</i></p>
Curriculum design	<p>You've mentioned your most important functions as a practitioner, now I would like to ask you in greater detail about the activities related to the curriculum design [<i>and also a few others that have come up in our research.</i>]</p> <p><i>2. Could you briefly describe your participation in curriculum design for the course and the most important factors that influenced its design?</i></p>
Skills	<p><i>3. Could you please define the non-technical skills the student exhibit during the participation in the CE412 /ANCH 311 class?</i></p>
Projects	<p>The projects in which students are working with you seem to be one of the strategies to facilitate the learning outcomes described in the CE412 syllabus</p> <p><i>4. How are the projects selected?</i></p>

Team dynamics	<p>Another strategy I have noticed is the integration of a practitioner into the student teams.</p> <p><i>9. How do you link the participation of a practitioner with the learning outcomes of the CE412 / ANCH 311 course?</i></p>
Community engagement	<i>10. How do you envision the students involvement with communities while working on the projects assigned?</i>
Social innovation	<i>11. Would you provide your definition of social innovation?</i>
Social innovation skills	<i>12. Do you consider the students learn social innovation skills in the capstone classes?</i>
Curriculum design and ABET	<i>13. How do projects provided directly from the community could be incorporated into current curriculum?</i>
Additional comments	<i>14. Do you have any other point of view or recommendation for me to consider in this case study?</i>

Appendix C

ABET Representative Interview Protocol

ABET Representative Interview Protocol	
Introduction	<p>Thank you for accepting this interview. As you know, I am working in the Dissertation in Practice to obtain the Doctor of Education at the University of Missouri – Columbia. The primary purpose of the dissertation is to study to what extent do engineering students exhibit social innovation skills in industry-driven project based classes?</p> <p>After studying the documentation of the UMKC Civil Engineering senior design course, I would like to ask a series of questions to help me interpret the information I have been collecting. Your responses will be recorded and will be kept confidential: nothing you say will be attributed to you personally or to your work, or to the entity you represent. Is that ok with you?</p> <p>The interview is scheduled for one hour. Would it be appropriate if we utilize more time to cover all the topics listed for the interview?</p>
Professional overview	<p>Although I have some familiarity with your responsibilities as ABET representative of the UMKC SCE, in this interview, I would like to get a better sense of the details of your work.</p> <p>1. <i>Of all the functions for which your responsible as ABET representative, which ones are the most central to the promotion of non-technical skill learning?</i></p>
Curriculum design	<p>You've mentioned your most important functions as ABET representative, now I would like to ask you in greater detail about the activities related to the curriculum design and improvement required by ABET [<i>and also a few others that have come up in our research.</i>]</p> <p>2. <i>Could you briefly describe your participation as ABET representative in curriculum design for the capstone course and the most important factors that influenced its design?</i></p>
Skills	<p>3. <i>Could you please define the non-technical skills the student should exhibit in the UMKC civil engineering, primary in capstone classes ?</i></p>
Projects	<p>The projects in which students are working with you seem to be one of the strategies to facilitate the learning outcomes described in the CE412 syllabus</p> <p>4. <i>How are the projects selected?</i></p>

Team dynamics	<p>Another strategy I have noticed is the integration of a practitioner into the student teams.</p> <p><i>15. How do you link the participation of a practitioner with the learning outcomes of the CE412 / ANCH 311 course?</i></p>
Community engagement	<p><i>16. Using ABET standards as a framework, how do you envision the students involvement with communities while working on the projects assigned?</i></p>
Social innovation	<p><i>17. Does ABET provides or could provide a definition of social innovation?</i></p>
Social innovation skills	<p><i>18. Do you consider the students learn social innovation skills in the capstone classes?</i></p>
Curriculum design and ABET	<p><i>19. How do projects provide directly from the community could be incorporated into the current curriculum?</i></p>
Additional comments	<p><i>20. Do you have any other point of view or recommendation for me to consider in this case study?</i></p>

Appendix D

Skills in Job Postings in the United States

Page 1 of 4. Skill list retrieved from Burning Glass – Program Insight EDU database (<https://programinsight.burning-glass.com/explore/skillist>) on 09/11/2019

Explore	Skills				
Source:	https://programinsight.burning-glass.com/explore/skillist				
Location	Nationwide				
Retrieved by: Sandra Marin	43719				
Degree Level	Bachelor's degree				
Time Period	9/1/2018 - 8/31/2019				
	Screen: skills 1-50				
Selected Skill Clusters	All				
Skills sorted by:	Postings				
Skills Filter defined as:	Skills with the most posting demand				
Skill Cluster	Skill	Posting Demand Benchmark	Projected Posting Growth (2018-2023) Benchmark	Salary Benchmark	No. Employers
1 Basic Customer Service	Customer Service	Very High	Stable	Low	106647
2 Scheduling	Scheduling	Very High	Stable	Average	111753
3 General Sales	Sales	Very High	Declining	Average	84701
4 Budget Management	Budgeting	Very High	Declining	High	112334
5 Project Management	Project Management	Very High	Declining	High	94092
6 Basic Customer Service	Customer Contact	Very High	Declining	Average	60689
7 SQL Databases and Programming	SQL	Very High	Declining	Very High	43441
8 General Accounting	Accounting	Very High	Stable	Average	75592
9 Quality Assurance and Control	Quality Assurance and Control	Very High	Fast	High	55522
10 People Management	Staff Management	Very High	Declining	High	65575
11 Teaching	Teaching	Very High	Declining	Low	42869
12 Software Development Principles	Software Development	Very High	Stable	Very High	33158
13 Java	Java	Very High	Declining	Very High	25025
14 Business Development	Business Development	Very High	Stable	High	49038
15 Basic Patient Care	Patient Care	Very High	Fast	High	11940
16 Retail Industry Knowledge	Retail Industry Knowledge	Very High	Declining	Low	20840
17 Scripting Languages	Python	Very High	Very Fast	Very High	24470
18 JavaScript and jQuery	JavaScript	Very High	Stable	Very High	27549
19 General Sales	Product Sales	Very High	Declining	High	29149
20 Social Media	Social Media	Very High	Fast	Low	65059
21 Software Development Principles	Software Engineering	Very High	Stable	Very High	22655
22 Business Process and Analysis	Business Process	Very High	Stable	Very High	31554
23 Uncategorized	Repair	Very High	Stable	Low	34248
24 Oracle	Oracle	Very High	Declining	Very High	22648
25 Billing and Invoicing	Customer Billing	Very High	Declining	Low	45074
26 Process Improvement	Process Improvement	Very High	Stable	High	35236
27 Technical Support	Technical Support	Very High	Declining	High	37348
28 Uncategorized	Quality Management	Very High	Declining	High	37510
29 Operating Systems	Linux	High	Declining	Very High	22158
30 Data Analysis	Data Analysis	High	Very Fast	High	36676
31 General Sales Practices	Sales Goals	High	Declining	Average	27081
32 Microsoft Office and Productivity Tools	Spreadsheets	High	Fast	Low	40846
33 Administrative Support	Administrative Support	High	Stable	Low	48964
34 Management Information System (MIS)	Information Systems	High	Declining	Very High	33715
35 Customer Relationship Management (CRM)	Salesforce	High	Fast	High	30671
36 Project Management	Project Planning and Development Skills	High	Declining	Very High	34090
37 Employee Training	Onboarding	High	Very Fast	Average	43579
38 General Administrative and Clerical Tasks	Data Entry	High	Stable	Low	41182
39 Business Management	Business Administration	High	Declining	High	43443
40 Enterprise Resource Planning (ERP)	SAP	High	Fast	High	17801
41 Emergency and Intensive Care	Cardiopulmonary Resuscitation (CPR)	High	Stable	Low	18429
42 Procurement	Procurement	High	Stable	High	32994
43 Prospecting and Qualification	Prospective Clients	High	Stable	Average	33388
44 People Management	Supervisory Skills	High	Declining	Average	30997
45 Procurement	Purchasing	High	Declining	Average	36404
46 Key Performance Indicators	Key Performance Indicators (KPIs)	High	Fast	High	33528
47 Sales Management	Sales Management	High	Declining	High	26152
48 General Marketing	Marketing	High	Declining	Average	41994
49 General Medicine	Treatment Planning	High	Fast	Average	10566
50 Product Development	Product Development	High	Stable	Very High	26729

	Explore	Skills				
	Source:	https://programinsight.burning-glass.com/explore/skilllist				
	Location	Nationwide				
	Retrieved by: Sandra Marin	43719				
	Degree Level	Bachelor's degree				
	Time Period	9/1/2018 - 8/31/2019				
		Screen: skills 51-100				
	Selected Skill Clusters	All				
	Skills sorted by:	Postings				
	Skills Filter defined as:	Skills with the most posting demand				
	Skill Cluster	Skill	Posting Demand Benchmark	Projected Posting Growth (2018-2023) Benchmark	Salary Benchmark	No. Employers
51	Enterprise Resource Planning (ERP)	Enterprise Resource Planning (ERP)	High	Stable	High	28604
52	Financial Analysis	Financial Analysis	High	Stable	High	31749
53	Software Development Principles	Scrum	High	Fast	Very High	18549
54	Business Management	Change Management	High	Stable	Very High	23665
55	Merchandising	Merchandising	High	Declining	Low	10346
56	Business Process and Analysis	Business Analysis	High	Declining	High	24042
57	Financial Reporting	Financial Reporting	High	Declining	High	37793
58	Product Management	Product Management	High	Fast	Very High	21393
59	Writing	Technical Writing / Editing	High	Declining	High	26812
60	Account Management	Account Management	High	Stable	High	26205
61	Business Process and Analysis	Cost Control	High	Stable	High	24735
62	Microsoft Development Tools	Microsoft C#	High	Declining	Very High	18333
63	Graphic and Visual Design Software	Adobe Photoshop	High	Declining	Low	39582
64	Performance Management	Performance Appraisals	High	Declining	High	27539
65	Business Strategy	Strategic Planning	High	Declining	High	30386
66	Occupational Health and Safety	Occupational Health and Safety	High	Fast	Average	22738
67	People Management	Conflict Management	High	Stable	High	26466
68	Company Product and Service Knowledge	Product Knowledge	High	Declining	Low	14907
69	Business Strategy	Business Acumen	High	Stable	High	20806
70	Advanced Patient Care	Case Management	High	Stable	Low	21150
71	General Sales	Negotiation Skills	High	Stable	High	24811
72	Performance Management	Performance Management	High	Stable	High	26184
73	Physical Abilities	Lifting Ability	High	Fast	Low	16618
74	Business Strategy	Business Planning	High	Declining	High	21907
75	Customer Relationship Management (CRM)	Client Base Retention	High	Stable	Average	21561
76	Performance Management	Performance Analysis	Average	Stable	High	24380
77	Outside Sales	Outside Sales	Average	Declining	Low	15619
78	Software Development Methodologies	DevOps	Average	Explosive	Very High	13167
79	General Administrative and Clerical Tasks	Record Keeping	Average	Declining	Low	33512
80	C and C++	C++	Average	Declining	Very High	13749
81	Uncategorized	Calculation	Average	Very Fast	High	23256
82	Economics	Economics	Average	Stable	High	23262
83	General Sales Practices	Description and Demonstration of Products	Average	Declining	High	16195
84	Project Management	Stakeholder Management	Average	Fast	Very High	21899
85	Version Control	Git	Average	Very Fast	Very High	14565
86	Operating Systems	UNIX	Average	Declining	Very High	13997
87	Computer and Information Technology Industry Knowledge	Information Technology Industry Knowledge	Average	Very Fast	Very High	14532
88	Data Management	Data Management	Average	Stable	High	23128
89	Administrative Support	Appointment Setting	Average	Stable	Low	21211
90	Financial Risk Management	Risk Management	Average	Stable	Very High	17009
91	Project Management Software	Microsoft Project	Average	Stable	Very High	25522
92	Emergency and Intensive Care	Advanced Cardiac Life Support (ACLS)	Average	Fast	High	5187
93	SQL Databases and Programming	SQL Server	Average	Declining	Very High	17877
94	Financial Reporting	Financial Statements	Average	Declining	High	29303
95	Administrative Support	Administrative Functions	Average	Stable	Low	28683
96	General Accounting	Account Reconciliation	Average	Stable	Low	28090
97	Operations Management	Operations Management	Average	Stable	High	25436
98	Business-to-Business (B2B) Sales	Business-to-Business	Average	Stable	High	19609
99	Microsoft Office and Productivity Tools	Microsoft Sharepoint	Average	Declining	High	19648
100	Training Programs	Training Programs	Average	Declining	Average	21906

Explore	Skills				
Source:	https://programinsight.burning-glass.com/explore/skilllist				
Location	Nationwide				
Retrieved by: Sandra Marin	43719				
Degree Level	Bachelor's degree				
Time Period	9/1/2018 - 8/31/2019				
	Screen: skills 101-150				
Selected Skill Clusters	All				
Skills sorted by:	Postings				
Skills Filter defined as:	Skills with the most posting demand				

	Skill Cluster	Skill	Posting Demand Benchmark	Projected Posting Growth (2018-2023) Benchmark	Salary Benchmark	No. Employers
101	Telecommunications	Telecommunications	Average	Stable	High	14822
102	System Design and Implementation	Systems Engineering	Average	Stable	Very High	12890
103	Software Development Principles	Agile Development	Average	Fast	Very High	14461
104	Cloud Solutions	Software as a Service (SaaS)	Average	Fast	Very High	14906
105	E-Commerce	E-Commerce	Average	Stable	High	17322
106	Graphic and Visual Design Software	Adobe Indesign	Average	Declining	Low	33094
107	Software Quality Assurance	Atlassian JIRA	Average	Very Fast	Very High	15107
108	Database Administration	Relational Databases	Average	Declining	Very High	17385
109	Data Techniques	Data Collection	Average	Stable	Average	22560
110	Graphic and Visual Design Software	Adobe Acrobat	Average	Declining	Low	31703
111	Marketing Strategy	Market Strategy	Average	Stable	High	25271
112	Basic Customer Service	Customer Checkout	Average	Fast	Low	21565
113	Programming Principles	Object-Oriented Analysis and Design (OOAD)	Average	Declining	Very High	12629
114	Medical Support	Acute Care	Average	Fast	High	4835
115	Microsoft Development Tools	.NET	Average	Declining	Very High	14241
116	Extensible Languages	Extensible Markup Language (XML)	Average	Declining	Very High	14786
117	Regulation and Law Compliance	Legal Compliance	Average	Stable	High	20825
118	System Design and Implementation	Systems Development Life Cycle (SDLC)	Average	Declining	Very High	14248
119	Graphic and Visual Design Software	Microsoft Visio	Average	Declining	High	17001
120	Systems Administration	System Administration	Average	Declining	High	18256
121	Packaging and Labeling	Packaging	Average	Stable	High	17371
122	Software Quality Assurance	Unit Testing	Average	Stable	Very High	11972
123	General Accounting	General Ledger	Average	Declining	Average	27565
124	Inventory Management	Inventory Management	Average	Fast	Low	17385
125	Procurement	Request for Proposal (RFP)	Average	Stable	High	20706
126	Logistics	Logistics	Average	Fast	High	16375
127	Programming Principles	Debugging	Average	Stable	Very High	12967
128	Drafting and Engineering Design	AutoCAD	Average	Stable	High	15859
129	Web Development	Web Application Development	Average	Stable	Very High	14410
130	Cybersecurity	Information Security	Average	Fast	Very High	14234
131	Contract Management	Contract Review	Average	Stable	High	21886
132	General Accounting	Generally Accepted Accounting Principles (GAAP)	Average	Declining	High	23768
133	Business Intelligence	Business Intelligence	Average	Stable	Very High	18379
134	Data Visualization	Tableau	Average	Very Fast	Very High	14901
135	Training Programs	Training Materials	Average	Declining	High	21503
136	Chemistry	Chemistry	Average	Declining	Average	13332
137	Medical Billing and Coding	Medical Coding	Average	Fast	Average	10184
138	Estimating	Estimating	Average	Stable	High	16157
139	Leadership and Management	Thought Leadership	Average	Stable	Very High	14239
140	Financial Management	Financial Management	Average	Declining	High	18597
141	Customer Relationship Management (CRM)	Customer Relationship Management (CRM)	Average	Fast	Average	22828
142	Inside Sales	Inside Sales	Average	Stable	Low	15684
143	General Networking	Cisco	Average	Declining	Very High	13521
144	Extraction, Transformation, and Loading (ETL)	Extraction Transformation and Loading (ETL)	Average	Very Fast	Very High	12419
145	Business Strategy	Business Strategy	Average	Stable	Very High	15286
146	Business Process and Analysis	Business Operations	Average	Declining	High	17077
147	Business Management	Business Management	Average	Stable	High	19835
148	Big Data	Big Data	Average	Fast	Very High	10030
149	Business Process and Analysis	Root Cause Analysis	Average	Stable	High	14722
150	Emergency and Intensive Care	Life Support	Average	Fast	Average	3199

Explore	Skills				
Source:	https://programinsight.burning-glass.com/explore/skilllist				
Location	Nationwide				
Retreived by: Sandra Marin		43719			
Degree Level	Bachelor's degree				
Time Period	9/1/2018 - 8/31/2019				
	Screen: skills 151-200				
Selected Skill Clusters	All				
Skills sorted by:	Postings				
Skills Filter defined as:	Skills with the most posting demand				

Appendix E

Capstone Design Class Structure and Syllabi

1. Academic Grid - UMKC SCE Bachelor of Science in Civil Engineering 2019-2020

BACHELOR OF SCIENCE IN CIVIL ENGINEERING, 2019-2020

For more information about policies and requirements, please see the UMKC 2019-20 Catalog.

FIRST YEAR			
FALL SEMESTER	HOURS	SPRING SEMESTER	HOURS
MATH 266 Accelerated Calculus I	4	MATH 268 Accelerated Calculus II	3
CHEM 211 General Chemistry I (FOCUS B)	4	PHYS 240 Physics for Scientists & Engineers I (FOCUS Elective)	5
CHEM 211L General Chemistry I Lab	1	CE 111 First Year Cornerstone (or CE Elective)	3
Anchor I Reasoning & Values Recommend: ANCH 150 Computing, Engineering & Society	3	FOCUS C Human Actions, Values & Ethics Recommend: HST 101, 102, or POLS-SCI 210 to fulfill the Constitution Requirement	3
DISC 100 Discourse I	3	ME 130 Engineering Graphics	3
Shop Safety Class (Take CIMM 101 at MCC)*	1		
TOTAL	16	TOTAL	17

SECOND YEAR			
FALL SEMESTER	HOURS	SPRING SEMESTER	HOURS
MATH 250 Calculus III	4	MATH 345 Differential Equations	4
PHYS 250 Physics for Scientists & Engineers II	5	CE 276 Strength of Materials	3
CE 275 Engineering Statics	3	CE 351 Fluid Mechanics	3
ECE 216 Engineering Computation	4	Anchor II Culture & Diversity	3
		DISC 200 Discourse II	3
TOTAL	16	TOTAL	16

THIRD YEAR			
FALL SEMESTER	HOURS	SPRING SEMESTER	HOURS
CE 319 Engineering Computation and Statistics	3	CE 318 Geographic Information Systems For Engineers	3
CE 321 Structural Analysis	4	CE 335 Soil Mechanics	3
CE 378WI Civil Engineering Materials	3	CE 497 Engineering Hydrology	3
CE 401SV Fundamentals of Surveying	1	CE Interest Area Elective	3
CE 467 Construction Management	3	CE Interest Area Elective	3
FOCUS A Arts & Humanities	3	OSHA Construction Safety (online)	-
TOTAL	17	TOTAL	15

FOURTH YEAR			
FALL SEMESTER	HOURS	SPRING SEMESTER	HOURS
CE 411 System Design I	2	ANCH 311 (CE 412) System Design II	3
CE 422WI Reinforced Concrete	3	DISC 300 Discourse III	3
CE 432 Foundation Engineering	3	CE Interest Area Elective	3
CE Interest Area Elective (300-400 level)	3	CE Interest Area Elective (300-400 level)	3
CE Interest Area Elective (300-400 level)	3	CE Interest Area Elective (300-400 level)	3
TOTAL	14	TOTAL	15

*Can be taken any semester before CE 378WI.

Total Credits to Graduate: 126

CE Elective Interest Areas: Structural; Water Resources; Geotechnical & Materials; Construction Management; General.

UMKC School of Computing & Engineering · DST Student Services Center
336 Flansburg Hall · 5110 Rockhill Road
816-235-2399 · sce@umkc.edu · <http://sce.umkc.edu>

2. Syllabus CE 411 System Design I - Fall 2019

Course Syllabus

Course No. & Title: CE 411 Civil Engineering System Design I

Instructor/Coordinator: Ceki Halmen, Ph.D., P.E., Assoc. DBIA

Course Information:	☒ Required ☐ Elective ☐ Selective Elective	Credit Hours: _____	Contact Hours: _____
Description:	This class is run as a studio design class, without lectures. The students work in teams on unique civil engineering projects for various local clients to develop a location study report and 30% construction drawings. Each design team is overseen by a Professional Engineer in practice, who serves as a coach and mentor to the team. Student teams typically perform a site visit at the beginning of the semester and develop their design study with various alternatives. The alternatives are presented to the clients at the end of the semester at the client's location. During the follow up class CE 412 Civil Engineering System Design II, the teams work on further developing the client selected alternatives and produce 30% complete design drawings.		
Prerequisites:	CE 467 Introduction to Construction Management		
Co-Requisites:	None		
Successors:	CE 412 Civil Engineering System Design II		
Textbooks Title, Author, Publisher, and Edition/Year:			
No Textbook			
Supplemental Materials:			
Different Design Standards and References are utilized based on projects			
Course Objectives:			
Instructional Outcomes:	After successful completion of this class, student will be able to <ul style="list-style-type: none"> ✓ Evaluate project specifics including survey reports and develop design alternatives for a project ✓ Present the preferred design alternative to the client staff ✓ Develop 30% design drawings in the client required format and complete a construction cost estimate and schedule 		
ABET Outcomes:	No ABET outcomes are assigned to this class		
Topics Covered	Students discuss with the Professional Engineer in practice various aspects of their specific design project. Client expectations, proper presentation techniques, cost and schedule impacts of design decisions are covered through interactions with the Professional Engineer.		

3. Syllabus CE 412 System Design II

Course Syllabus

Course No. & Title: CE 412/ANCH 311 System Design II

Instructor/Coordinator: Ceki Halmen, PhD, PE, Assoc. DBIA

Course Information:	☒ Required	☐ Elective	☐ Selective Elective	Credit Hours: 3	Contact Hours: 45
	<p>Description:</p> <p>This class is a studio design class, without lectures. The students work in teams on unique civil engineering projects for various local clients to develop a location study report and 30% construction drawings. Each design team is overseen by a Professional Engineer in practice, who serves as a coach and mentor to the team. Student teams typically perform a site visit at the beginning of the semester and develop their design study with various alternatives. Students will present the alternatives to the clients at the end of the semester at the client's location. During the follow up class CE 412 Civil Engineering System Design II, the teams work on further developing the client selected alternatives and produce 30% complete design drawings.</p> <p>All project groups will meet every Monday and Wednesday at 3:30 PM at their assigned meeting locations to complete the 30% design for their projects. Based on their arrangement, each group will meet at least once (either Monday or Wednesday) with their practitioner to guide them in their work.</p> <p>There will be 3 journal articles as assigned readings. For each of the articles, the students will prepare a summary report as outlined in the assignment.</p> <p>Two of the reading assignments will constitute the basis for an in-class graded discussion moderated by a guest speaker.</p> <p>There will be three all-class meetings scheduled during the semester</p> <ul style="list-style-type: none"> ✓ Public meetings; how and why are they organized ✓ Right of way discussions ✓ Ethics seminar by Dr. O'Bannon - (will have a follow-up) assignment <p>Each student will attend a public project meeting during the semester and fill out a report.</p>				
Prerequisites:	CE 411 System Design I				
Co-Requisites:	None				
Successors:	None				
Textbooks Title, Author, Publisher, and Edition/Year:					
There is no required textbook for this class					
Supplemental Materials:					
Students will use available national and local codes and standards for their designs					
Course Objectives:					
Instructional Outcomes: After successful completion of this class, students will be able to					
<ul style="list-style-type: none"> ✓ Develop design drawings using national and local codes and standards 					

- ✓ Communicate with a diverse audience from a client organization
- ✓ Work in a collaborative group setting to accomplish preset goals of scope, cost, and schedule

ABET Outcomes: 2. an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, societal, environmental and economic factors
 3. an ability to communicate effectively with a range of audiences
 5. an ability to function effectively on a team whose members together provide leadership, create a collaborative an inclusive environment, establish goals, plan tasks, and meet objectives

Topics Covered

Date	Topic
2/13/2019	Reading assignment #1 – Mapping the Dimensions of Successful Public Participation in Messy Natural Resources Management Situation
2/20/2019	Reading assignment #2 – The Civil Engineer's Responsibility to Participate in the Affairs of the Public
2/27/2019	Carol Grimaldi discussion
3/6/2019	Sheila Shockey discussion
3/13/2019	Reading assignment #3 – The Vision for Civil Engineering in 2025
4/3/2019	Ethics discussion by Dr. O'Bannon
4/10/2019	Right of Way discussion by Michael Kelly

4. Example Pre-required Course CE 497 Engineering Hydrology

CE 497 Engineering Hydrology

Instructor

Jerry Richardson, Ph.D., PE, D.WRE

Department of Civil and Mechanical Engineering, School of Computing and Engineering

Office: 370 J

Office Hours: Will be posted. However, if my door is open you are free to stop in.

Phone: 816 235 1282

E-Mail: richardsonj@umkc.edu

Course Information

Spring Semester 2019

Tuesday-Thursday 10:00-11:15am

Room TBD

Course Website: Canvas (*a work in progress*)

Required Text: Engineering Hydrology-Principles and Practice, second edition, 2014, by Dr. Victor M. Ponce- accessible online at <https://ponce.sdsu.edu/enghydro/> Note: The first edition is out of print, but still a good resource. Used copies are available online. However, we will use the assignments that are in the on-line version.

Other Important Course Documents:

APWA Section 5600 Latest Edition (May be downloaded at the Chapter Website -

<http://kcmetro.apwa.net/content/chapters/kcmetro.apwa.net/file/Specifications/APWA5600.pdf>.

TR-55 Manual – May be downloaded at the NRCS Website at:

<http://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/water/?&cid=stelprdb1042901>

Federal Highway Administration Hydraulic Engineering Circular No. 22, Third Edition – URBAN DRAINAGE DESIGN MANUAL Publication No. FHWA-NHI-10-009, September 2009 <https://www.fhwa.dot.gov/engineering/hydraulics/pubs/10009/10009.pdf>

What is “Hydrology” - <http://ga.water.usgs.gov/edu/hydrology.html> “Hydrology is the science that encompasses the occurrence, distribution, movement and properties of the waters of the earth and their relationship with the environment within each phase of the **hydrologic cycle**.”

What is an “Engineering Hydrologist” “The engineering hydrologist, or water resources engineer, is involved in the planning, analysis, design, construction and operation of projects for the control, utilization, and management of water resources.”

Learning Outcomes:

The engineering hydrologist, or water resources engineer, is involved in the planning, analysis, design, construction and operation of projects for the control, utilization, and management of water resources. Therefore, Students completing this class will identify and quantify hydrologic processes relevant to the design of engineering infrastructure. Specifically they will:

1. Use the rational formula to compute peak discharge for a given hydrologic return period.
2. Use TR-55 procedures to compute peak discharges and runoff hydrographs.

3. Route hydrographs through reservoirs and river segments.
4. Evaluate the risk associated with infrequent rainfall/flood events.

ABET Outcomes

ABET 4: Ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must be considered the impact of engineering solutions in global, environmental, and societal contexts.

ABET 7: An ability to acquire and apply new knowledge using appropriate learning strategies.

Schedule/Assignments: See the Schedule-provided as a separate file (click link) (subject to revision). Assignments will be posted on Canvas with Due dates.

Evaluation:

Due to exam security, all students must sit for exams at the designated time. Make up exams will be allowed (with advanced approval) for student athletics, severe personal illness or family trauma). Special make up exams will differ in content, form and evaluation method at the discretion of the instructor, and may include oral assessment. Exams cannot be taken in advance.

Exam #1		25%
Exam #2		25%
Final Exam		25%
Homework/quizzes		20%
Participation/attendance (instructor discretionary)		5%
Total:		100%

Expectations

Home Work:

Late homework: Will not be accepted without prior approval.

Quizzes: could happen anytime.

Rules for Homework:

- Note problem number on of each page.
- Start each Problem on a separate clean piece of engineering grid paper.
- Break the problem down **step by step in a logical order**
- Cite your work if appropriate – this helps in grading
- Write on only **one side** of each Page
- Number each page, i.e. (1/4 ... 2/4 etc.)
- Sketches should be neat, carefully drawn, and large enough to clearly understand!
- Watch your Units!
- Computer printouts must be separate sheets arranged either landscape or portrait.

- **One staple** in the upper left hand corner of portrait pages (and/or upper right hand of landscape pages! **Do not use** any other type of binding device!
- Provide **answer sheet** as first page- note problem number and answer. If answer is a table of values report one or more key results.
- When asked to provide a plot, use quality graph paper, or provide quality computer generated plot. Make sure that the plot is properly titled, axis is properly labeled with variable and units, and that all data points are clearly labeled. For hand plots, use straight edge, French curves and symbol templates to draw plots. Also submit tabular data used to construct the plot.

Attendance Policy: Students are expected to attend and participate in class. Students should notify me of excused absences in advance, where possible. Students who have an excused absence are expected to make arrangements with me for alternative or make-up work.

Recording of Lectures is not allowed - In this class, students may not make any audio or video recordings of course activity (including those recordings prepared by an instructor), except for students permitted to record as an accommodation under Section 240.040 of the Collected Rules. All other students who record and/or distribute audio or video recordings of class activity are subject to discipline in accordance with provisions of Section 200.020 of the Collected Rules and Regulations of the University of Missouri pertaining to student conduct matters. Those students who have written permission from the course instructor to record are not permitted to redistribute any audio or video recordings of statements or comments from the course to individuals who are not students in the course without the instructor's express permission.

Catalog Information

CE 497 Engineering Hydrology Catalog #43563

Description: Fundamental concepts of hydrology in engineering; computation principles of runoff from rainfall; measurement of hydrologic quantities; quantitative and statistical estimation of design stream-flow magnitude and frequency; principles of unsteady routing of hydrographs.

3 Credit Hours, 3 Contact hours, Classroom based

Pre-Requisites CIV-ENGR 319 "Engineering Computation and Statistics", CIV-ENGR 351 "Fluid Mechanics".

Additional University Requirements, Rules and Resources is posted in Canvas at: <https://confluence.umkc.edu/pages/viewpage.action?pageId=55247899>

VITA

Sandra Marin Ruiz is an industrial engineer and currently the Regional Director of the Florida SBDC at the Florida Atlantic University. Exhibiting her technical and social innovation skills, she has occupied important industry and higher education roles in Latin America and the United States. Sandra solves social problems from the engineering profession that involves strategic planning, community engagement, curriculum design, stakeholder management, continuing education, and business assistance programs' daily operations. As a serial entrepreneur, she has fostered best business development practices towards facilitating access to sustainable income to underserved populations and positively impacting their quality of life by implementing engineering and other technical solutions.

Sandra utilizes community engagement as a tool to positively position herself as a professional in the higher education market to increase student enrollment and job placement rates. Within 18 years of engaging communities from academia and industry, Sandra has utilized the student's talents to implement successful programs while providing experiential service-learning opportunities.

Linking industry and academia, she installed a capstone class that provided innovative environmental solutions to small businesses in Colombia. At the University of Missouri System -SBDC, designed and managed the Tech-Series program, which has employed more than 60 students as junior consultants in technology commercialization. For the University of Missouri College of Business, she designed and implemented an internship-required class that provides research services to exporters in semester-based projects. At the University of Missouri Kansas City, she developed a curriculum for the

Augmented and Virtual Reality Unity Development class to the skill-up workforce in partnership with community-based organizations. At the Florida Atlantic University, she promotes entrepreneurship and alternatives for experiential learning for students working in real-world problems while facilitating access to research to the regional business community. Thus, this dissertation in practice summarizes her passion and vision and a path to transfer her experience to engineering education to solve community problems from the engineering profession.