TEACHING TOWARDS THE VOCATION OF LIFE:

PERSPECTIVES ON PURPOSE IN UNDERGRADUATE

ENGINEERING EDUCATION

by

Elizabeth Margaret Strauss

Dissertation Committee:

Professor William Baldwin, Sponsor
Professor Noah Drezner

Approved by the Committee on the degree of Doctor of Education

Date May 20, 2020

Submitted in partial fulfillment
of the requirements for the degree of Doctor of Education at
Teachers College, Columbia University

2020

ABSTRACT

TEACHING TOWARDS THE VOCATION OF LIFE: PERSPECTIVES ON PURPOSE IN UNDERGRADUATE ENGINEERING EDUCATION

Elizabeth Margaret Strauss

This study examines ideas of purpose in undergraduate engineering education by drawing on John Dewey's conception of "Vocation of Life" and the more recent conception of "Twenty-First Century Skills." Through a single-site case study and utilizing the constant comparative method, this study produced a set of student learning outcomes the faculty at "Oxbow College" describe for their disciplinary teaching that includes technical, professional, and personal skills. The faculty also described a set of department, school, and national level (i.e. ABET accreditation) contexts that impacted their conceptions.

This study is set within a broader landscape of attainment issues in STEM education, and engineering specifically, including: 1) student interest in an engineering

education; 2) persistence in engineering education for all students; 3) attainment of engineering degrees by a diverse set of students representing the broader national population. Addressing these challenges is imperative because engineering remains of great importance to the United States' position of technical authority in the world though the United States confers a significantly lower proportion of bachelors degrees in science and engineering compared with other industrialized nations. Compounding this challenge is the need to broaden engineering education to include non-technical skills without sacrificing technical rigor.

Most noteworthy in the findings of this study, these faculty speak directly to a set of student learning outcomes including technical and non-technical (professional and personal) skills in their disciplinary engineering courses. In doing so, they are expanding the idea of what an engineering education does and what it intends to do. The purpose of an undergraduate engineering education at Oxbow College, as described by faculty, is to prepare students for all aspects of their lives after graduation.

This study provides insight into what these engineering faculty perceive as important in their courses, demonstrating a shift away from the historical divide between professional and liberal education as well as providing an example of the broadening of student learning outcomes – which has implications for calculating the return on investment of a college education. By emphasizing more than just their disciplinary content, these faculty are reflecting a larger societal change regarding the purpose of higher education.

DEDICATION

For my first teachers, my parents, Ann Breheny Strauss and Gary Robert Strauss.

ACKNOWLEDGEMENTS

"The good life is one inspired by love and guided by knowledge" (Bertrand Russell) - I am grateful to and for the following people who have inspired and guided me.

To the participants in this study: thank you for sharing your purpose with me.

During my interview for the doctoral program many years ago, I told my advisor, William Baldwin, that I thought getting a doctorate would be fun – he is the reason that it actually was. Thank you for sticking around to finish this journey with me. Next, I cannot say enough about the incredible mentorship and patience of Katie Conway, who saw in me the potential for something that I am not sure would ever have been possible without her; thank you for being my Yoda. Noah Drezner has guided me both in scholarship and through the thoughtful consideration he routinely shows to all in his leadership of the Higher Education program. Amy Stuart Wells helped expand my engineering meaning-making to larger issues of public importance. Corbin Campbell encouraged me to be proud of the juxtapositions and quirks that make this work my own.

I am thankful for the broader faculty and staff at Teachers College and the Higher Education program, especially Monica Christensen, Anna Neumann, and Aimee Terosky. Lucy Tam has done about a million things I know about and probably a million more which I will never know about to support this dissertation. Myra Luna Lucero, Dana Klainberg, and Russell Gulizia provided invaluable guidance during a daunting process.

Ishara Casellas Connors, Mary Reid Ervin, and Victoria Valdes were my sounding boards, career counselors, and cheerleaders; Jilliann Rodriguez-M'Barki and Christina Shelby set examples of the kind of scholar-practitioner I wanted to be; Liza Bolitzer, Leslie Williams, and Jolie Harris Woodson gave me opportunities to observe

doctoral students at work. Staci Ripkey could be counted on to like my dissertation, even when I did not. Chase Palmer, the other half of my doctoral cohort, has made sure I did not ever feel like I was in this alone. Jessie Ostrow Michel, Maria Anderson-Long, and Jerée Matherson got me across the finish line with advice, encouragement, and snacks.

My Columbia Engineering family has supported every step of this journey. I hope to one day influence someone's life the way mine has been shaped by their examples. Special thanks to Leora Brovman, Chris Colombo, Soulaymane Kachani, Roger Lehecka, and Scott Wright. Scott Kelly inspired me to take my first ever TC class and I would follow his lead any day. Shu-Yi Hsu and Merrell Norden have literally gone to the other side of the world with me during this adventure. Yosimir Acosta ensured I had the most secure data structure imaginable and never laughed at my questions about encryption keys. Adam Elmachtoub provided much needed caffeine that fueled early morning writing sessions and quelled afternoon emergencies. Alfred Ayoub, Celeste Bennett, Tamsin Davies, Irina Katz, Jon Lung, and Peter Valeiras listened to me talk about this topic for more hours than I thought humanly possible with smiles on their faces. Rachel Efron has been next to me for almost as long as I can remember with patience, humor, and a steadfast certainty that I could get through even this; she is an integral part of why.

The PDL, CPO, and IEOR teams have been instrumental to this dissertation actually happening. Jenny Mak allowed me the chance to truly be a scholar-practitioner and guided *my* personal Professional Development and Leadership path. She has supported me even when it made things more difficult for her, she has fortified me when I was ready to give up, and she has reassured me many times that everything would somehow work out. Gabby Lilienthal protected those essential dissertation mornings by

responding to many 7am work emails with a shout across the office of “aren’t you supposed to be dissertating?” Sophia Lee encouraged as a scholar, teacher, and colleague. Alvaro Rojaas-Caamano faced all the disasters with me this year and I could not have gotten through them without him. Tania Velimirovici was my first friend when I came back to SEAS; thank you for always being the better person.

Thank you to my family – Breheny, Melz, Montalbano, and Strauss (plus Strauss Garren). Thank you to my brother Bill, who I have literally and figuratively looked up to my entire life. Thank you to my sister-in-law Melissa who has endeavored to make me seem stylish throughout this process when I would have otherwise lived in pajamas. Thank you to my nieces and nephew – Sabrina, Whitney, and Thomas – who tried to understand why Aunt Liz was always at work. Thank you to Susan, Peter, Katie, and Erica for letting me into your lives all those years ago and letting me stay ever since.

Finally, thank you to my parents. As a child my father allowed me to postpone bedtime if I had good questions to ask, setting the precedent for my tendency to lay awake at night considering “good questions.” He also made sure I never doubted that he was in my corner and I therefore remain the luckiest little girl. My mother has been the powerhouse of this dissertation, steadfastly encouraging me and celebrating every milestone. Thank you for your commitment to every aspect of my education. My parents named me after my great-grandmother, Dr. Margaret Rothenberger, and I proudly now carry both her name and her title. Mom and Dad – thank you for my name, for your support and patience, and most especially for your unwavering belief in me. This work is dedicated to the two of you.

E.M.S.

TABLE OF CONTENTS

I – INTRODUCTION 1
Example of Problem 1
Purpose as a Focus in Undergraduate Engineering Education 3
Background on Undergraduate Engineering Education 5
Statement of the Problem 6
Purpose and Significance 11
Research Questions 13
Theoretical Framework 14
Research Design 15
Definition of Terms 17
Organization of Dissertation 20
II – CONCEPTUALIZING VOCATION OF LIFE: A LITERATURE REVIEW AND CONCEPTUAL FRAMEWORK ANALYSIS 22
Chapter Overview 22
Engineering Education and the Engineering Criterion 23
Engineering Accreditation 23
The assessment movement within and beyond engineering. 26
A Brief History of Engineering Education in the United States 29
Liberal-vocational divide. 36
Why engineering education matters today. 38
Underrepresentation in engineering education. 39
Faculty in Engineering 43
Teaching How They Were Taught 43
Integration across the Engineering Curriculum 44
Problem-Based Education in Engineering 47
Cornerstones and Capstones 49
Faculty Agency 51
Perception of Accreditation and Evaluations of Educational Quality 52
Vocation of Life: A Conceptual Framework 55
Twenty-First Century Skills: A Filter for Understanding Vocation of Life 58
Chapter Summary 62
III – METHODOLOGY 63
Chapter Overview 63
Purpose of the Study and Restatement of Research Questions 64
Research Perspective 65
Methods of Data Collection 67
Case Study Design 67
Site Selection 73
Case Selection 76
Defining the case. 77
Bounding the case. 77
Data Methods 78
Faculty interviews. 80
Sampling strategy. 82

Faculty interview data collection. ... 83
Academic leadership interviews. ... 85
Sampling strategy. ... 86
Academic leadership interview data collection. ... 87
Document review. ... 88
Document sampling strategy. ... 89
Document data collection. ... 90
Field notes. ... 90
Field note sampling strategy. ... 91
Field note data collection. ... 91
Data Processing ... 92
Data Analysis ... 93
NVivo Software ... 93
Interview Transcription ... 94
Data Collection and Data Analysis Timing ... 95
Narrative Analysis Approach ... 95
Stages of the Data Analysis Process ... 96
Identifying data points and assigning codes – constant comparative stage 1. ... 99
Naming conventions. ... 100
Alignment with research questions. ... 103
Development of data themes from codes – constant comparative stage 2. ... 103
Closed coding – constant comparative stage 3. ... 105
Developing data patterns from themes – constant comparative stage 4. ... 106
Code Book ... 108
Internal Validity ... 109
Study Limitations ... 110
Generalizability ... 110
Validity and Reliability ... 111
Researcher Perspective ... 112
Chapter Summary ... 113
IV – UNDERSTANDING VOCATION OF LIFE ... 115
Overview of Chapter ... 115
Data Patterns and Propositions ... 116
Pattern A: Twenty-First Century Skills ... 116
Technical skills: “but in the end, we’re trying to form people who are optimized relative to what they were when they came in and who are engineers.” ... 117
Identifying the problem. ... 118
Problem solving. ... 120
Engineering as inventing and optimizing. ... 122
Summary of technical skills ... 124
Professional skills: “come to Oxbow if you want a broader, general education where your knowledge of fields other than engineering will become important to you career-wise.” ... 125
Communication. ... 126
Ethics. ... 128

Leadership and teamwork. ... 130
Knowledge of contemporary issues and commitment to lifelong learning. ... 133
Summary of professional skills. ... 135
Personal skills: "teaching…engineering is sort of not the important thing, it's about teaching them about life." ... 135
A "feel for that sort of thing." ... 136
Confidence. ... 138
Summary of personal skills. ... 139
Proposition A: faculty describe intended outcomes of their teaching that span the Twenty-First Century Skills, including technical, professional, and personal skills. ... 139
Pattern B: Contexts that Inform Undergraduate Engineering Education ... 140
Department-level context. ... 141
Undergraduate research. ... 142
Capstone senior design. ... 144
Summary of department-level context. ... 147
School-level context. ... 148
First year cornerstone course. ... 149
Liberal arts requirements. ... 151
Mission and vision statements. ... 154
Summary of school-level context. ... 155
National-level context/ABET. ... 156
Too general. ... 157
Minimum standards. ... 159
"We're doing it anyway." ... 160
Summary of national context. ... 163
Proposition B: faculty describe student learning outcomes within a set of department, school, and national contexts that impact their conceptions of important student outcomes in a variety of ways. ... 163
Chapter Summary ... 163
V – GOING BEYOND: THE IMPLICATIONS OF TEACHING TOWARDS THE VOCATION OF LIFE ... 165
Chapter Overview ... 165
Findings in the Context of Oxbow College ... 166
The Specific Case of Oxbow College ... 167
Student Interest in Engineering Education ... 168
Persistence in Engineering Education ... 171
Attainment Demographics ... 174
Implications for Theory: Reflecting on My Conceptual Framework ... 177
Vocation of Life ... 177
Twenty-First Century Skills ... 179
Implications for Practice ... 180
Department Level: For Faculty ... 180
School Level: For Academic Leaders and Administration ... 182
National Level: For ABET ... 183
Implications for Further Research ... 184

Longitudinal Study of the Twenty-First Century Skills and Vocation of Life 184
Twenty-First Century Skill and Vocation of Life at Other Types of Engineering Schools 185
Twenty-First Century Skills and Vocation of Life in Other Disciplines 186
Concluding Thoughts 187

REFERENCES 189

Appendix A: Participants Rights and Informed Consent Form 203
Appendix B: Recruitment Emails 207
Appendix C: Protocol for Faculty Interview 209
Appendix D: Protocol for Academic Leadership Interview 214
Appendix E: Handout for Interviews - ABET Criterion 3 Student Outcomes, 2018-2019 218
Appendix F: Code Book 219

LIST OF FIGURES

Figure

1 Model of Constant Comparative Method…….97

2 Example of Data across Constant Comparative Model……107

I – INTRODUCTION

Example of Problem

John Dewey wrote in 1916 “nothing could be more absurd than to try to educate individuals with an eye to only one line of activity.” However, in the more than 100 years since Dewey’s claim, there has been a prevalent perception that undergraduate engineering programs should do just that – and furthermore an opinion that it was a problem if engineering graduates were not pursuing jobs in a narrowly defined engineering industry. Yet towards the end of the twentieth century a shift within engineering education became noticeable, beginning with calls by engineering faculty for their engineering faculty colleagues to take seriously the educational mission and expanding into conversations about the very purpose of engineering education. Why study engineering in the twenty-first century? Where can an engineering degree lead if not only a pathway into an engineering career? Is an engineering education applicable in

non-engineering fields? And at the heart of this study: what is the purpose of an engineering education?

Mort Friedman, while Senior Vice Dean at my Alma Mater, was frequently quoted for his remark that "engineering is the liberal art of the twenty-first century" (Erving, 2006; O'Brien, 2010). The original use of "liberal" in describing a program of study was not intended to describe the curriculum, but rather the student population. The gentlemen – and at that time they were only white males – who undertook a liberal course of study were free (from the Latin "liber") to do so because they were not burdened by an obligation to learn a trade or occupation; they were men of means and therefore men of leisure who enjoyed the financial security that made vocational preparation unnecessary (Sanderson, 1993). In fact, any study that could be seen as relating to a vocation was seen as less valuable because it indicated the individual was not a member of the aristocratic elite.

There is however a very specific idea of usefulness and purposefulness that is to be valued, even within the liberal arts. Charles Bailey stated that "the liberal arts does not reject utility; it seeks a broader and grander utility than is represented by the specific and the immediate" (Lewis, 1994, p. 200). The liberal arts were seen as "enabl[ing] any man to fill any post with credit and master any subject with facility" (Sanderson, 1993, p. 190). A former Dean of my Alma Mater, Feniosky Peña-Mora, expanded on the idea of engineering as the new liberal art by saying "what it means is that nowadays, with all the technological and scientific advances in society, you have to reconsider what makes a learned person. You need a deep understanding of science and technology to really understand society and how to be a contributing citizen" (O'Brien, 2010).

Towards such ends, engineering schools like the one I attended have been expanding their curricular offerings to emphasize objectives beyond the traditional technical competencies. The focus of engineering is shifting and while experts have some ability to predict the subject areas that will likely get greater emphasis in the future, a spotlight is being shone on the kinds of educational preparation that will be applicable to any such topic and the broader set of skills and competencies that will allow students to adapt to this unknown. Charles Vest, former president of MIT stated it as such: "although we cannot know exactly what they should be taught, we can focus on the environment in which they learn and the forces, ideas, inspirations, and empowering situations to which they are exposed" (Vest, 2008, p. 236).

In the remainder of this chapter, I begin this discussion by describing purpose in undergraduate engineering education, a lens through which I seek to understand how course objectives are determined, operationalized, and evaluated. Following that I expand the discussion to the larger historical context of undergraduate engineering education in the United States, from which I segue into the significance of this study. In addition, this chapter will briefly outline the research questions, theoretical framework, and research design that will structure this dissertation. This chapter concludes with definitions of key terms and an outline of the remainder of the dissertation.

Purpose as a Focus in Undergraduate Engineering Education

"Simply put, there is a growing perception—and evidence—that U. S. Colleges are no longer meeting the United States' needs effectively" (Suskie, 2015, p. 3).

Changing issues in higher education – economic development, return on investment, and the changing college student – have raised new questions and concerns for education professionals and scholars to address (Suskie, 2015). A shift in focus from inputs to outputs and outcomes has resulted in dedicating more attention to determining whether students are learning and what they are learning (Arum & Roksa, 2011; Judd & Keith, 2011; Peebles, 2016; Suskie, 2015; Volkwein, 2011). While previously institutions evaluated themselves based on the quality of their faculty and student credentials upon entry, factors that still bear significant weight for institutional reputation, a shift has occurred to utilize outcomes that measure the results of the educational process (Volkwein, 2011). While outputs measure the what (student grades, degrees awarded, faculty patents and papers), outcomes are concerned with why (student learning, accomplishments, impact of research); an output is what is created at the end of the process, while an outcome is the value created by that process (Chaney Jones, 2014; Judd & Keith, 2011; Mills-Scofield, 2012; Volkwein, 2011). Specifically, questions of outcomes are being tied directly to the overall objectives of the institution as outlined in its mission and purpose. Simultaneously, specific attention is being paid to accreditation and its importance to engineering education; the perception of accreditation – by ABET specifically in engineering – is shifting and engineering faculty are increasingly speaking out regarding its role in curricular innovation.

But what is purpose? Dewey cautions us to remember that education itself, as an abstract idea, does not have an aim; people – teachers and parents – have aims, therefore outcomes are infinitely varied not just to each person but to each situation that person encounters (Dewey, 2008). Dewey supplies an analogy of a farmer who cannot define the

purpose of his farming without considering the context around him: the soil, the climate, or the characteristics of the plant. So too must educators ground their aims in an understanding of their contexts. With that consideration in mind, an educator can determine "how to observe, how to look ahead, and how to choose" (Dewey, 2008, p. 97) in their teaching. Therefore, within this study I asked faculty and academic leaders about the ideas and beliefs that informed their planning, observations, and choices, specifically as it related to their teaching of undergraduate engineering students.

Students pursue undergraduate engineering degrees for any number of reasons just as faculty and leaders at schools of engineering care about educating those students for a variety of reasons. Richard Felder, pioneer in studying engineering education, claimed that one purpose of a school of engineering should be informed by the recognition that the school has "an obligation to society to equip the exceptionally gifted students who come to [it]—those most likely to make the greatest contributions to engineering science and practice to make full use of their gifts when they leave [it]" (Felder, 1982, p. 9). More than 25 years ago Professor Felder was already highlighting that "the problems facing [our] society need broad social perspectives as well as technological expertise" (Felder, 1982, p. 10). The needs for and of engineers are changing and so to should the goals and purpose of undergraduate engineering program.

Background on Undergraduate Engineering Education

Towards the end of the twentieth century, concerns were raised because accreditation of engineering programs was too focused on inputs – faculty numbers and credit hours – and not focused enough on what was being learned by students (Prados,

Peterson, & Lattuca, 2005). Why was such a dramatic shift in engineering accreditation called for? Why is this moment so noteworthy in engineering education? While engineering has long been recognized for its role in innovation and technology (Douglas, Iversen, & Kalyandurg, 2004), engineering education in many institutions has been stagnant for decades (Rugarcia, Felder, Woods, & Stice, 2000). "Undergraduate education in the STEM fields (science, technology, engineering, and mathematics) needs improvement, a conclusion that multiple national reports over the past two decades have reached (American Association of Physics Teachers, 1996; National Research Council, 1989; National Science Foundation, 1996; Steen, 1987)" (Baldwin, 2009, p. 9).

The aim of this study was to contribute to understanding of purpose in engineering higher education by examining the student learning objectives for undergraduate engineering courses as described by the faculty who design and teach them. Through the lens of Dewey's "Vocation of Life," this study explored how faculty teaching these undergraduate engineering courses conceived a diverse set of student learning outcomes as their course objectives and how these ideas were informed by the context within which they faculty work.

Statement of the Problem

The STEM fields have remained a focus for higher education researchers and practitioners. Specifically, three key reasons for the importance of STEM education and engineering education specifically are: 1) the importance of engineering to the US position of technical authority; 2) the low percentage of engineering degrees conferred in the US compared with other industrialized nations; and 3) the challenge to broaden

engineering education to include non-technical skills without sacrificing technical rigor. These concerns align with issues of engineering persistence, engineering demographics, and engineering interest that will be addressed in Chapter V as the implications for this study. However, understanding the importance of those implications requires understanding the importance of engineering education for the United States.

Firstly, the increasingly technical nature of the labor market has increased the demand for technically skilled workers, increasing the importance of STEM fields for the overall efficiency of the American economy (Ferrare, 2013). Beyond the traditional technical jobs, the workforce requires more technical literacy in all college graduates, which emphasizes the importance of quality STEM teaching. Since the 1960s nationalistic concerns driven by the space race and defense concerns have emphasized the importance of educating STEM students to oversee national defense initiatives and help the United States maintain its position in the world (Veysey, 1973). However, between 1990 and 2000 the number of foreign-born scientists in the United States workforce grew four times faster than the number of domestic scientists, reaching a point where those working in engineering with a doctoral degree were split evenly between domestic and foreign workers (Mervis, 2004). An increasing number of those workers are receiving their doctoral education abroad before working in the United States, reflecting the improved quality of doctoral programs but the limited post-doctoral opportunities. The demographics of STEM education and the STEM workforce remain a hot-button issue within the academe and the profession.

Secondly, the United States currently lags in education attainment in STEM fields compared to other leading industrialized nations (Taningco, Mathew & Pachon, 2008;

Thursby, 2014). In 2012 a mere 16 percent of US baccalaureate students graduated with science or engineering degrees,[1] less than half the of the proportion in South Korea and ranked 38th of the 40 most advanced countries (Harrington, 2016). And when STEM degrees are completed in the United States, it is frequently by international students who may not intend to remain in the country after completing their degree (or may not be able to gain the visa to remain in the country long-term). Approximately half of the maters and doctoral degrees in engineering awarded in the United States are conferred upon foreign nationals (Engineering Workforce Commission of the American Association of Engineering Societies, Engineering and Technology Degrees, 1973-2003 cited in Chubin, May, & Babco, 2005, p. 73).

Concerns remain about why domestic students are not earning more STEM degrees. There are particular concerns about educating a STEM student body that better reflects the demographics of the country. Yet for all the importance placed on STEM degrees evidenced by the continued attention shown by government and industry leaders and the enduring perception held by many underrepresented minority groups, first generation Americans, and first generation college students that STEM fields are especially meritocratic avenues through which hard work is rewarded with entry to the middle class (Ferrare, 2013), concerns remain not just about the comprehensive lack of engineers produced in the United States but also about the significant and persistent gaps in who is earning those degrees.

---

[1] More recent statistics are very similar. The latest year available in NCES, 2016-2017, showed 19.3% of bachelors degrees conferred were to STEM disciplines – 8.8% in Natural Science or Mathematics and 10.5% in Computer Science or Engineering (National Center for Educational Statistics, 2018).

Thirdly, engineering is undergoing a renaissance, in part due to efforts to broaden the discipline and better convey the potential impact one could have on the world with an engineering education. This rebranding of engineering has particular implications for groups traditionally underrepresented in engineering. Particularly daunting is the gap between the engineering interest of women and underrepresented minorities compared with their rates of completion in these disciplines. A 1992 study of academically talented students – those who scored in the top five percent on the ACT assessment – found more than a third of Black students chose engineering over 195 other major options (Kerr, Colangelo, Maxey, & Christensen, 1992). The same study found engineering interest to be "very high among all ethnic minority groups except Asian Americans; this is unusual only in the light of popular stereotypes of Asians as being predominantly interested in engineering.

It may be that economic conditions among most ethnic minority groups demand a college major in which a 4-year investment has strong chances of yielding a high-paying job upon graduation" (Kerr, Colangelo, Maxey, & Christensen, 1992, p. 608). Yet, in a similarly timed report focusing on "engineering students from predominantly white schools, the 5-year graduation rates were as follows: for whites, 67%; for Hispanics, 47%; and for blacks, 36%" (Phillips, 1991 cited in Elliott, Strenta, Adair, Matier, & Scott, 1996, p. 683). While a diverse population of students were interested in engineering, the graduation rates were markedly different. (In Chapter II I will discuss in greater detail where the leak in the engineering pipeline is occurring and how that relates to issues of curriculum.) While a better understanding of the purpose of an engineering education will not itself fix issues of retention, the aim of this study is to provide insight

regarding the practices that would support all students, including a diverse student body, in completing an engineering degree.

Despite claims that it is stagnant, engineering is not unaccustomed to undertaking reflective steps to improve engineering education. Each decade since the founding of the American Society of Engineering Education (ASEE) in 1893 there has been a major study of engineering education. Comprehensively, those studies have worked to shift conversation in the discipline from a focus on course content to the idea of developing students as emerging professionals (Shulman, Besterfield-Sacre, & McGourty, 2005). A detailed overview of this history and what it has meant for engineering education is included within the literature review contained in Chapter II.

In the twenty-first century, engineers need to prepare for a market economy where the half-life of their skills is 2.5 to 7.5 years (Wulf, 1998). This reflects not just on the students and the skills they possess, but on the shelf-life of what is being taught in our engineering institutions; only half the information taught will remain current and relevant a few years after the students graduate (Duderstadt, 2008). In order to prevent engineers from becoming "consumable commodities" (Duderstadt, 2008, p. 3) that are shed by companies when they become obsolete, engineers should embrace the necessity of continuing professional development seen in fields such as law or medicine (Bordogna, Fromm, & Ernst, 1993). An engineering institution should embrace its obligation to train students for professional practice, but also for a long-term career requiring adaptability (Steneck, Olds, & Neeley, 2002).

For these reasons – namely the importance of engineering to the United States' position of technical authority (Ferrare, 2013; Thursby, 2014; Veysey, 1973), the low

percentage of engineering degrees conferred in the United States relative to other regions (Harrington, 2016; Taningco, Mathew & Pachon, 2008; Thursby, 2014), and the challenge to integrate non-technical skills while maintaining the rigor of an engineering education (Ollis, Neeley, & Luegenbiehl, 2004; Prados, Peterson, & Lattuca, 2005; Shulman, Besterfield-Sacre, & McGourty, 2005; Thursby, 2014) – this is a watershed moment for studying engineering education. Why engineering matters to the United States is a complement to the question of why someone should pursue such a program of study and by extension the question of purpose in engineering education at the core of this dissertation.

Purpose and Significance

The aim of this study is to contribute to understanding of purpose in engineering higher education by examining the student learning outcomes faculty describe for undergraduate engineering courses. Using Dewey's Vocation of Life as a framework, this study will explore how faculty describe the objectives that they integrate into their teaching – representing the Twenty-First Century Skills that are newly codified as fundamental components of a comprehensive engineering education. In this way a 1916 lens (Vocation of Life) can be focused for 2020 questions through the language of Twenty-First Century Skills.[2]

---

[2] This term has been stylized as both "Twenty-First Century Skills" and "21st Century Skills" in the literature. Throughout this dissertation I opt for the former to convey a name given to this portion of my conceptual framework.

Of the traditional-aged students who begin undergraduate engineering programs, 40% either earn their degree in another field or do not complete their degree (Vogt, 2008). Studies have attributed this to inadequate preparation or a misconception of the nature of engineering (Adelman, 1998) as well as to factors related to faculty and instruction (Vogt, Hocevar, & Hagedorn, 2007). Researchers have also proposed modifications to curriculum that might combat these issues (Knight, Carlson, & Sullivan, 2007). As discussed briefly earlier in this chapter, a particular focus remains on the retention of underrepresented groups because of claims that "if individuals from these underrepresented groups were represented in the U.S. STEM workforce in parity with their percentages in the total workforce population, this shortage [of skilled domestic workers] would largely be filled" (May & Chubin, 2003, p. 27).

But challenges to reforming engineering education remain. Faculty members perceive a relatively small value to be placed on teaching compared with research production, which makes it difficult for even those who are interested to commit their resources to pedagogical developments (Turns, Eliot, Neal, & Linse, 2007). I will discuss in Chapter II how this is especially true for pedagogical issues related to assessment and accreditation that have struggled for broad faculty support. The accrediting body for engineering, ABET, codified within the Engineering Criterion 2000 (aka the "EC2000") a strong statement about the importance of a broad set of learning objectives (a decision that will be discussed in great detail in Chapter II), but researchers continue to believe that when forced to choose what to emphasize engineering faculty will protect their technical content (Vaz, 2012). Is this because they are reproducing their own educational experiences and simply teaching the way they were taught (Smith, Sheppard, Johnson, &

Johnson, 2005) or are they concerned about the perception that taking the practice of teaching seriously reflects a diminished commitment or competency as a researcher (Turns, Eliot, Neal, & Linse, 2007)?

I hope that this study will help improve our understanding of the experience for faculty who are endeavoring to make meaning of Twenty-First Century Skills in their undergraduate engineering courses. My aim is to increase the understanding of what it means for these faculty to teach towards an idea of Twenty-First Century Skills in the context of their academic courses. I also hope it will illuminate the impact of various contexts that shape how these faculty are acting and what this can show about the nature of engineering and engineering education today.

Research Questions

This study is guided by an overall research question: How do faculty make meaning of Twenty-First Century Skills in undergraduate engineering education?

Within that research agenda there are five more specific research questions:

1) How do engineering faculty describe the objectives of their academic teaching?

2) How do they define the skills they want students to develop through their coursework?

3) How, if at all, do they discuss Twenty-First Century skills as objectives of their academic teaching?

4) How do they describe those objectives manifesting in their academic teaching?

5) How do institutional contexts shape faculty making meaning of Twenty-First Century Skills?

Theoretical Framework

Although the divide between academic and vocational pursuits has long existed, Dewey (2008) emphasized that these divides are social constructs and not intrinsic differences between the disciplines. The Greek philosophers, notably Aristotle, developed a hierarchy in which physical tasks were deemed less honorable than those that were purely intellectual. Interestingly, by this definition the fine arts would be classified with menial disciplines because they were chiefly an act of the body. For many years, the surgeon was considered only marginally better than a barber because both acted upon the body and were compensated for their service. Dewey notes that teachers, who vehemently defend their own education as being liberal, failed to see how their training in fact led directly to their professional calling as educators. He emphasized the lack of intrinsic differences between the disciplines, rather focusing on the divide that exists in the methodology and intention of a program of study.

From this perspective, the Engineering Criterion 2000 accreditation standards are outlining the preparation of students as both professionals and people; Dewey's vision of an educated individual was one prepared for the multifaceted nature of their life who could meaningfully contribute at work, at home, and in their community (Dewey, 2008). The ABET standards codify the outcomes the accrediting body believe demonstrate not just a competent engineer, but a competent person. To reach these goals, ABET has integrated vocational and liberal outcomes into the EC 2000; students are asked to be able to "apply knowledge of mathematics, science, and engineering" while also possessing an "understanding of professional and ethical responsibility" (Ollis, Neeley, & Luegenbiehl,

2004, p. xxxi-xxxii; Prados, Peterson, & Lattuca, 2005, p. 171). By emphasizing technical, professional, and personal skills together, ABET is continuing to bridge the ever smaller divide between competencies previously considered disparate and incompatible. Utilizing a Deweyan standpoint, I do not see these as competing types of outcomes, but rather holistically view one set of student learning outcomes that comprehensively describe the idealized engineering graduate. That set is described using the new terminology of "Twenty-First Century Skills," which allows Dewey's historical perspective to be translated for today's needs. A further introduction of Vocation of Life and Twenty-First Century Skills concludes the literature review in Chapter II of this dissertation.

Research Design

This dissertation was conceived as a single-site case study. The methodology will be described at length in Chapter III, but is briefly introduced here as part of overviewing research design and my research perspective for this dissertation. This qualitative study emphasized understanding the viewpoint of the research participants and how they make meaning from within their experiences (Kvale, 1996; Seidman, 1998). Through interviews with faculty and academic leaders, as well as a review of the institutional documents, I seek to understand what the changing objectives of engineering education means for the people on the front line of educating undergraduate engineering students.

In this study I employ an interpretivist epistemology which accepts that reality is multiple and relative (Hudson & Ozanne, 1988) depending on other system for meaning (Lincoln & Guba, 1985). As such, the intent of the study is to capture meaning in human

interactions (Black, 2006) and understand perceptions of reality (Carson, Gilmore, Perry, & Gronhaug, 2001). Therefore, the researcher and the participants are interdependent and interactive because the researcher enters the field with prior knowledge but remains open to the new knowledge developed by the influence of the study participants (Hudson & Ozanne, 1988). "Therefore, the goal of interpretivist research is to understand and interpret the meanings in human behavio[u]r rather than to generalize and predict causes and effects (Neuman, 2000; Hudson & Ozanne, 1998)" (Edirisingha, 2012, para. 13).

This study specifically utilizes a single-site case study. "The classic case study consists of an in-depth inquiry into a specific and complex phenomenon (the 'case'), set within its real-world context" (Yin, 2013, p. 321). That is to say, this study will be what the Dictionary of Sociology describes as a "detailed examination of a single example" (cited in Flyvbjerg, 2006, p. 220). A case study design should be considered when: (a) the focus of the study is on "how" and "why" questions; (b) the study cannot have an experimental design; (c) context is believed to be relevant; or (d) the boundaries between the phenomenon and context are not clear (Yin, 2003 cited in Flyvbjerg, 2006); all four of these criteria seem relevant to the study conducted here and supported the choice of a case methodology.

The intended site for the study is an engineering school within a research university. The engineering school is home to more than two hundred faculty across ten academic units (more than half of which house undergraduate programs accredited by ABET) with roughly 1,500 undergraduates enrolled at any one time. In the last two years the school unveiled a new strategic vision that articulates both the rich history of the institution as well as a plan for the future that pushes innovation in interdisciplinary

research while also emphasizing a substantial commitment to empowering students to become tomorrow's technology leaders. Further description on the selection of the site and the bounds of the case can be found in Chapter III.

Definition of Terms

This research draws on phrases that can have multiple meanings, and those nuances become very important in the understanding of Twenty-First Century Skills in engineering education. Defining each of the key phrases – engineering, student learning outcomes, purpose, vocational and professional, Twenty-First Century Skills – both individually and within higher education will allow for more precise understanding of the ideas described.

Engineering: In many ways, engineering is the simplest part of the concept to define. Webster's College Dictionary (1992) states that engineering is "the practical application of science and mathematics." The American Engineers Council for Professional Development – which went on to become ABET – was significantly more verbose in defining engineering as:

> the creative application of scientific principles to design or develop structures, machines, apparatus, or manufacturing processes, or works utilizing them singly or in combination; or to construct or operate the same with full cognizance of their design; or to forecast their behavior under specific operating conditions; all as respects an intended function, economics of operation and safety to life and property (Engineers' Council for Professional Development, 1947 cited in Dennedy, Fox, & Finneran, 2014, p. 29; Min & Christian, 2017, p. 221; Sen, 2013, p. 3; Simpson & Sastry, 2013, p. 1).

I recall my high school physics teacher defined engineering as using math and science to make or do something. Throughout each of these definitions a runs a common theme: engineering is the application of scientific concepts for a specific purpose.

Student Learning Outcomes: Throughout this dissertation I refer to asking faculty about the student learning outcomes they value for their teaching. Student learning outcomes specify what students know or can do at the completion of a course or program (Oxnard College, "Student Learning Outcomes"). These are measurable and/or observable at the individual student level. I also use the word objective in this dissertation – the two are related but different; objectives are the goals and outcomes are the evidence of whether that goal has been achieved.

Purpose: Certainly, the dictionary provides a definition of the word purpose as a noun to mean both "the reason for which something exists or is done, made, used, etc." and "an intended or desired result; end; aim; goal" (Dictionary.com, "Purpose") which are both definitions that fit the use here. However, throughout the dissertation I typically refer to "purpose in engineering education" rather than "*the* purpose in engineering education." This is not a repeated typo. "The" is a definite article, suggesting whatever follows it is common knowledge or already established. If I say "the teacher" then the assumption is that this particular teacher is known to the reader. In contrast, my entire dissertation is founded on the argument that purpose in undergraduate engineering education is not known and in fact the assumptions that have been made as if there was "the purpose" (i.e. acquisition of technical skills for the aim of securing engineering jobs), is out of date if not simply wrong. Instead through this study I found a broad set of student learning outcomes that faculty at Oxbow College have individually chosen to emphasize in

support of a broad set of post-graduation outcomes. Therefore, in my perspective there is not "*the* purpose of undergraduate engineering education" but rather just "purpose."

Vocational and Professional: Webster's College Dictionary (1992) defines vocational as "of, pertaining to, or providing instruction or training in an occupation or trade" while defining professional as "following an occupation as a means of livelihood" although it is interesting to note that one of the subsequent definitions of professional is an "expert." While the two words may generally be used interchangeably, they refer to very different subsets of higher education. Vocational programs, sharing a name with the secondary education preparation for a career, is typically training related to a specific job that the student will likely assume immediately after completing the necessary training. The difficulty arises because all higher education exists somewhere on a continuum between cultivating a public citizen at one pole and preparing students for professional lives at the other (Dewey, 2008). It is common to categorize certain disciplines as liberal or professional – in large part because the distinction between the liberal arts and liberal education is frequently blurred (Lynton, 1991). There is not a dichotomy; all education is both academic and professional. The degree to which a particular institution, department, or program emphasizes one goal or the other is unique, fluid, and flexible (Delucchi, 1997). In many respects, engineering is lacking a peer discipline for comparison within the vocational or professional grouping. Engineering is frequently considered with the professional disciplines of law, medicine, and business (among others), however these fields typically have pre-professional level programs at the undergraduate level and emphasize the importance of a professional degree beyond the bachelors (Wulf, 1998). The continuing use of the bachelor's degree in engineering as an acceptable level of

academic preparation for professional practice distinguishes it from most other professional disciplines (Wulf, 1998). In contrast, vocational education is typically used to refer to technical education occurring at non-university tertiary schools, frequently two-year trade schools (Grubb & Lazerson, 2005; Labaree, 2006; Lewis, 1997; Lewis, 1998). These institutions are seen as developing a student's skills-base as opposed to the development of a student's knowledgebase that occurs at a college or university level institution (Grubb & Lazerson, 2005; Lewis, 1997).

Twenty-First Century Skills: Throughout this study I will discuss a concept referred to as "Twenty-First Century Skills." Twenty-First Century Skills encompasses the myriad of skills that undergraduate academic programs aim to develop in students throughout their education. These skills include not just the technical competencies that are the hallmark of an engineering education, but the professional and personal skills that have been increasingly important in both technical and non-technical fields. In Chapter II, as part of describing the theoretical frame of this study, this concept will be discussed in greater detail.

Organization of Dissertation

In this chapter I have described what I see as a potential problem in the understanding of undergraduate engineering education and specifically its student learning outcomes as perceived by faculty. To date the field has not sufficiently considered the role of Twenty-First Century Skills in undergraduate engineering programs, particularly in light of the changing demographics of engineering students and the broadening set of post-graduation paths that alumni are pursuing.

In Chapter II, I will outline literature on the place of engineering education in the historical higher education landscape of the United States, the history of engineering education specifically, and the relationships between assessment, accreditation, and purpose. Chapter II will also elaborate on the conceptual framework – Dewey's Vocation of Life – and the adaption of that lens to modern engineering education using Twenty-First Century Skills. In Chapter III I will discuss the research methods that scaffold this study. Chapter IV summarizes the findings of this study into two patterns – the student learning outcomes faculty describe and the contexts that impact their conceptions – and Chapter V describes the implications of those findings for theory, practice, and research.

II – CONCEPTUALIZING VOCATION OF LIFE: A LITERATURE REVIEW AND CONCEPTUAL FRAMEWORK ANALYSIS

Chapter Overview

"Technological innovation has long been the key to US growth and prosperity, and engineering has been an important driver of this innovation" (Thursby, 2014, p. 5). Yet concerns persist that the United States lags behind other nations in education of engineers leading to increased possibility that engineering jobs and therefore engineering innovation will become concentrated elsewhere. In response, engineering as a discipline has begun to reevaluate what is being taught and why engineering is taught to undergraduates. In what ways is an engineering education still a viable preparation at the undergraduate level when faced with so many changes in the field of engineering? Why at this moment would someone study engineering as an undergraduate? One visible change resulting from these conversations is a new set of standards outlined by

engineering's accrediting body as the student learning outcomes of an engineering undergraduate degree.

However, before I attempted to understand engineering student learning outcomes, I wanted to understand the landscape within which the objectives of an engineering education was shifting. This chapter outlines the four pillars of this dissertation: (1) engineering education in the United States, with a specific focus on accreditation; (2) faculty teaching undergraduate engineering and specifically efforts to break the cycle of teaching how they were taught; (3) Vocation of Life, the conceptual framework based on the 1916 writing of John Dewey (2008) that encompasses all professional, personal, and social actions an individual undertakes, and (4) the conceptual framework's modifier: Twenty-First Century Skills, which, as discussed in Chapter I, encompasses a diverse set of fundamental skills missing from those historically associated with engineering to professional, interpersonal, and technological competencies. These ideas are the tent poles of this inquiry and the area between them is the focal point of this study. Understanding each prepares us to answer the questions of purpose that provoked this research.

Engineering Education and the Engineering Criterion

Engineering Accreditation

Accreditation is the process through which colleges and universities in the United States are certified. Accreditation by nongovernmental, peer organizations is undertaken to ensure a basic level of quality such that students who complete coursework at an

accredited institution are considered to have maintained sufficient standards for admission to other institutions or professional organizations (U.S. Department of Education – Accreditation; U.S. Department of Education - FAQs). “The goal of accreditation is to ensure that education provided by institutions of higher education meets acceptable levels of quality” (U.S. Department of Education – FAQs, n.d., para. 1).

I focus here on the accreditation for engineering programs, which is the particular circumstance through which I will investigate educational purpose. Accreditation for engineering institutions began in 1907 with calls for states to regulate the practice of licensing engineers (Prados, Peterson, & Lattuca, 2005). In 1922 the American Institute of Chemical Engineering (AIChE) produced a list of institutions whose programs were considered by AIChE as satisfying their criteria (Prados, Peterson, & Lattuca, 2005). Just over a decade later, in 1935, the first formal accreditation visits were conducted at Stevens Institute of Technology and Columbia University with a list of the first 35 accredited programs being published a year later (Prados, Peterson, & Lattuca, 2005). In 1980 the former Engineers’ Council for Professional Development (founded in 1932) divided into two organization and its accrediting functions were undertaken by what became the Accreditation Board for Engineering and Technology, Inc. or now just ABET (Prados, Peterson, & Lattuca, 2005).

Towards the end of the twentieth century, concerns were raised that accreditation of engineering programs was too focused on inputs – faculty numbers and credit hours – and not focused enough on what was being learned by students (Prados, Peterson, & Lattuca, 2005). In response to these criticisms and calls for more ability to adapt accreditation criteria to program-specific characteristics, ABET began developing the

Engineering Criteria 2000 (Ollis, Neeley, & Luegenbiehl, 2004; Prados, Peterson, & Lattuca, 2005).At the very end of the twentieth century the new standards known as Engineering Criteria 2000 or EC2000 were introduced by ABET for accreditation of engineering programs. At the core of this change was the introduction of 11 learning outcomes – known as the ABET 11 or 3a-k since they were located in Criterion 3 of the proposal – and a philosophical shift that called for individual engineering programs to develop more finely grained definitions of the outcomes, ensure they were incorporated into the undergraduate curriculum, and then evaluate how successful the program was in carrying out those plans for student learning (Prados, Peterson, & Lattuca, 2005; Stephan, 2002).

Criterion 3 of the engineering accreditation guidelines speaks directly to the learning outcomes that the engineering discipline as a whole should view as important for students to be successful. The 11 outcomes, labeled a-k, are: (a) an ability to apply knowledge of mathematics, science, and engineering; (b) an ability to design and conduct experiments, as well as to analyze and interpret data; (c) an ability to design a system, component, or process to meet desired needs; (d) an ability to function on multidisciplinary teams; (e) an ability to identify, formulate, and solve engineering problems; (f) an understanding of professional and ethical responsibility; (g) an ability to communicate effectively; (h) the broad education necessary to understand the impact of engineering solutions in a global/societal context; (i) a recognition of the need for, and an ability to, engage in lifelong learning; (j) a knowledge of contemporary issues; and (k) an ability to use the techniques, skills, and modern engineering tools necessary for

engineering practice (Ollis, Neeley, & Luegenbiehl, 2004; Prados, Peterson, & Lattuca, 2005).

The engineering accreditation process under the EC2000 guidelines begins with broad program education objectives, formulated by each individual program, that address the institutional and program missions (Felder & Brent, 2003). From these objectives, the program formulates the outcomes – knowledge, skills, and attitudes – and links them to the curriculum (Felder & Brent, 2007). A self-study report also addresses assessment of those outcomes and how those assessments will be used to improve the program (Volkwein, 2011). These program defined objectives are also mapped within the self-study onto the ABET 11 student learning outcomes. The result is – ideally – a more comprehensive understanding of the overall mission of a program that will allow for better connections to material from prerequisites and alleviate the previous "disjointedness" felt by students and faculty (Felder & Brent, 2007).

The assessment movement within and beyond engineering. While the codification of the EC2000 by ABET denotes a point in time in which engineering accreditation has undertaken a marked shift, it needs to be understood within a larger accreditation and assessment context. Philosophical shifts in engineering education mirror those happening more broadly in higher education. Since at least the 1960s, the value of analyzing teaching and learning in terms of intended learning outcomes has been recognized, such as Bloom et al. in 1956, Mager in 1962, Krathwohl et al. in 1964, and Popham in 1969 (Harden, 2002). While definitions of assessment vary, for this paper I define assessment as "the process of gathering and discussing information from multiple and diverse sources in order to develop a deep understanding of what students know,

understand, and can do with their knowledge as a result of their educational experiences; the process culminates when assessment results are used to improve subsequent learning" (Huba & Freed, 2000, p. 8).

While the assessment movement has no official "birth date" and roots that extend into earlier scholarship, a claim can be made that the assessment movement existed by 1985 when the First National Conference on Assessment in Higher Education was cosponsored by the National Institute of Education (NIE) and the American Association for Higher Education (AAHE) (Ewell, 2002). One of the greatest challenges was reconciling the various meanings of the term "assessment" itself with the various prior foundational bodies of work and literature, each bringing their own perspective (Ewell, 2002; Suskie, 2009). One conception of assessment dealt with large-scale assessments, intended to benchmark schools and districts rather than examining individual learning (Ewell, 2002). A similar aggregated version of assessment came out of program evaluation, where the term referred to gathering evidence to improve pedagogy and curriculum. These two versions of assessment were countered with the more established tradition from mastery-learning, where assessment referred to observing an individual's performance focusing on the development over time through continuous feedback (Ewell, 2002; Suskie 2009). This tradition harkens back to "the etymological roots of the word 'assessment' in the Latin ad + sedere, 'to sit beside'" (Loacker, Cromwell, and O'Brien, 1986 in Ewell, 2002, p. 7). In this tradition, those undertaking an assessment look not in aggregate but at the individual and the specific; assessment is not coming from a far removed place, but rather is situated close with the program being assessed. They sit beside one another.

Although I focus here on engineering education, higher education more broadly is facing an age of greater performance and outcome measurement (Alexander, 2000). Increasingly assessment, accreditation, and accountability are being discussed together, in a way that challenges institutions to be self-reflective internally while simultaneously protecting themselves from exposing those areas that may be perceived as weaknesses too openly (Volkwein, 2010). “The spirit of assessment requires a diligent search for bad news, but accountability encourages the opposite” (Peters, 1994, p. 23 cited in Volkwein, 2010, p. 4).

Increasingly across disciplines the focus is on measures of quality (or perceived quality), cross-institutional comparisons, and outcomes assessment (Alexander, 2000). In some instances, this performance-based accountability has been operationalized through performance-based funding or other outcomes-based mechanisms for state institutions. The old accreditation philosophies in engineering and beyond frequently focused on inputs and the belief that maximizing the quality of inputs would guarantee quality output (Volkwein, 2010). Since the 1990s the shift has been instead to measure outcomes – to evaluate the direct results of the educational product. While this movement is still comparatively young, and has been met with some challenges – including questions about whether summative assessments occur too late in the game to impact students – the shift across higher education is towards a more prescribed judgement based on outcome characteristics. The experiment continues as educational programs work to balance the need to meet these accreditation standards for accountability while still producing internal assessments that allow for programmatic development and enhancement. Moving

forward I will focus specifically on programs of engineering, but the changes there are not altogether distinct from the larger shift across higher education.

A Brief History of Engineering Education in the United States

What it means to train engineers – the purpose of this education – has changed since such education began in this country. Evolving from an apprenticeship system, formal education of American engineers did not begin for nearly half a century after the Revolutionary War when pressure to regulate the training of individuals who would work for the public good – initially civil and then mechanical engineers – necessitated the development of formal education in engineering with the creation of vocationally focused institutions (Lundgreen, 1990; Mann, 1918).

The Revolutionary War necessitated the American colonies develop workers skilled in the "mechanical arts" (Mann, 1918, p. 3) when the British cut off supplies. However, for five more decades major mechanical innovations in the United States were the product of individuals with no formal engineering training (Mann, 1918). Following the War of 1812, calls for improvement in methods of farming and travel – particularly to aid migration to the West – only increased. The Erie Canal, which did much to address the latter problem, was built between 1817 and 1825 under the supervision of three self-trained American engineers (Mann, 1918). During the time of the canal's construction many state legislatures commissioned reports on agricultural and manufacturing productivity, including a particularly noteworthy presentation to the New York State legislature in March of 1823 urging the state to establish a school of agriculture supported by tax revenue modeled after the Fellenberg School at Hofwyl, Switzerland on land to be

donated by Stephen van Rensselaer. The proposal was rejected and a year later the pioneering engineering school in the country, Rensselaer Polytechnic Institute (RPI), was founded privately in Troy, New York (Lundgreen, 1990; Mann, 1918). For the next quarter of a century, Rensselaer and West Point Military Academy served as the only scientific schools in the country and primarily educated civil engineers for either public or military service, respectfully (Mann, 1918).

The middle of the 19th century (1820-1870) was a period of significant changes in American occupation with the largely agricultural economy shifting to manufacturing, emphasizing the need for an expanded technical curriculum addressing mechanical engineering (Mann, 1918). Prior to the Morrill Act, few technical programs were founded including those at Harvard, Yale, and the University of Michigan, all of whom faced opposition because they were considered dangerous to the academic traditions. In the approximately 45 years between the founding of Rensselaer Polytechnic Institute in 1824 and 1870, there were nearly 900 engineers formally educated in the United States. In the 45 years that followed, from 1871 to 1915 approximately 55,000 engineering degrees were granted. To put this in context, the 11 technical schools of Germany, whose engineering education began in 1770, had educated just 14,000 engineers by that date (Lundgreen, 1990; Mann, 1918).

I have noted that Rensselaer Polytechnic Institute was modeled on the Fellenberg School at Hofwyl, Switzerland rather than the preeminent German or French institutions (Mann, 1918). I have discussed, and will continue to discuss, the contrast between the American ideal of liberal education for the elite and manual labor training for the lower class, but it provides a noteworthy understanding that the inspiration for the first technical

school in the United States, the Fellenberg School, "sought to educate the children of the poor thru [sic] manual work" (Mann, 1918, p. 9). Rensselaer was similarly imagined as providing opportunities for "the sons and daughters of farmers and mechanics" (Mann, 1918, p. 9) to better themselves through the development of practical skills. Engineering education in the United States has, from its founding, been seen as an opportunity for individuals from the lower socioeconomic ranks to elevate their position in society. Technical training in this case did not solidify a lower rank, but instead was a vehicle of class mobility – a view of engineering education that remains today.

Although the German research tradition is typically held up as a technical model to emulate and RPI was modeled on a Swiss institution, the engineering education system in the United States is much more closely related to the English system than those of other European countries. The major divide between the American/English engineering systems and the German/French systems is the location of engineering education in the hierarchy of higher education (Lundgreen, 1990). In contrast to the American and British history of engineering education, in Germany and France technical colleges are considered to be the elite institutions of higher education. In each of these countries the engineering profession is divided between the state corps of engineers and what are referred to as "civil engineers" – although, I will opt to use the alternative "civilian engineers" in order to avoid confusion with the discipline of civil engineering. In Germany and France, the state engineers were held up as the ideal and yielded incredible power and respect in society because engineering was seen as a meritocratic profession existing outside the patronage that permeated other fields in those countries. Neither England nor the United States developed a state engineering corps, although the United

States does have an Army Corps of Engineers, however they are limited in number and utilized for specific projects, therefore they hold a vastly different place in society than the state engineers in France and Germany (Lundgreen, 1990; Sanderson, 1993). One commonality however is the perception of engineering as meritocratic.

In the absence of a state engineering corps, the engineering ideal in England and the United States became entrepreneurship and apprenticeship, which perpetuated this type of training much longer than in other countries (Labaree, 2006; Lundgreen, 1990). While in Germany and France the state engineers regularly competed with civilian engineers, the system in England and America was one where the only competition was from within the private engineer sector (Lundgreen, 1990). Without a state corps of engineers, there was no governmental push for a standardized engineering education and so the American and English engineering fields remained significantly heterogeneous; RPI was founded in 1824 and the first accreditation visits did not occur until 1935.

Much has been made recently of the quirks of the engineering curriculum in the United States, most notably that the first two years of a University-level engineering education contain very little, if any, engineering (Mann, 1918; Ollis, Neeley, & Luegenbiehl, 2004). A typical engineering student begins with in-depth studies of the pure sciences, courses that have become known as the gatekeepers to engineering (Bordogna, Fromm, & Ernst, 1993). Many engineering schools went so far as to have students complete their first two or three years of college as students within the traditional liberal arts college, as was required at Dartmouth College and Columbia University (Lundgreen, 1990). The course of study was not particularly different at technical institutions; Rensselaer originated with a one-year curriculum divided into

trimesters and only the last nine weeks of the third term were concerned with applied knowledge (Mann, 1918). Twenty-five years after its initial curriculum – which was revised marginally during that period – Rensselaer shifted dramatically to a three year course of study and instituted a curricular plan that resembles today's engineering schools: the first half of the curriculum was concerned with general knowledge (mathematics, chemistry, physics, and English typically being the hallmarks) and the second developed competency in a specialization. In addition to science and mathematics, the first half of the Rensselaer curriculum covered "Logic, Rhetoric, Geology, Geography, and History" (Mann, 1918, p. 12).

As Rensselaer Polytechnic Institute was based on the instructional model of the Fellenberg School, students beginning in their first year made presentations to their classmates on experimental observations in the sciences (Mann, 1918). While the curriculum proved successful, as the number of students increased so did the expense and soon inductive learning was replaced with deductive methods wherein professors presented blackboard demonstrations that were followed by "interrogations" (Mann, 1918, p. 32) of the students. Mann (1918) goes on to question the methods of evaluation in engineering education, namely the reliance on examination, quiz, and laboratory grades, particularly in subjects with heterogeneous teaching practices. He finds particularly noteworthy that early engineering schools were divided on whether English should be taught to engineers in the same way as it was in liberal arts colleges or if there was a better method of English instruction specifically suited to engineers (Mann, 1918; Marsh, 1988). Even in 1918 the roll of non-technical skills in engineering was a debate. In fact, the description of an engineering curriculum and calls for pedagogical reform in

Charles Mann's 1918 report to the joint committee on engineering education of the national engineering societies could practically be lifted and dropped into the twenty-first century debate surrounding the changes to the accreditation process adopted by ABET in 1997 (Prados, Peterson, & Lattuca, 2005; Terenzini, Lattuca, & Harper, 2007).

Programs of engineering education in the United States are unique and differ from both international engineering programs and other domestic professional programs. In contrast to the European systems where virtually every class is based in technical skill, American engineering typically integrates coursework requirements in the humanities and social sciences. However, those requirements are minimal compared to other professional schools, where undergraduates take proportionally fewer technical courses (Stephan, 2002). At one point, circa 1980, ABET actually specified that the equivalent of one full semester, 12.5% of the curriculum, should be devoted to the humanities and social sciences. At the time the rationale was that these courses contributed to a "well-rounded" engineer. However, they perpetuated a divide between technical and non-technical skills by clearly situating them in distinct sets of classes. This divide will be addressed in greater detail in the following section of this chapter.

Engineering faculty differ in their opinions about the subject matter they believe should make up the engineering curriculum and how these topics should be structured.

One such example focuses on the integration (or lack thereof) between engineering and other subjects, which some faculty believe if included should be confined to the perimeter of the curriculum rather than at the center. Engineering faculty "tend to protect analytical content in the curriculum, and can view liberal learning as a 'soft' pursuit less worthy of attention than more technical material" (Vaz, 2012, p. 8).

And so, to properly situate these soft ideas in an engineering curriculum, they are painted with a technical brush. Engineering educators have previously considered “soft skills” to be general education’s contribution to a student’s preparation; feedback from industry about the shortcomings of graduates to address the problems of the real world has led to reevaluating what is needed in an undergraduate degree. Industry leaders are contending that technical knowledge alone is not sufficient for success after college and ABET’s response has put these needed skills right at the center of the new accreditation standards.

Yet when faced with dedicating class time to a technical skill or a “soft” skill, engineering faculty have more frequently chosen the former. However, the call for integrating these other skills into engineering coursework and, further still, to cohesively integrate them across an engineering curriculum is a new challenge for many instructors (Besterfield-Sacre, Shuman, Wolfe, Atman, McGourty, Miller, Olds, & Rogers, 2000). Including these skills in engineering courses is considered revolutionary, the implication of which is that it was not likely to have been present when these educators were students themselves. In part faculty members may be recreating their own educational experiences (Smith, Sheppard, Johnson, & Johnson, 2005). Concerns have been raised that faculty members do think about issues of teaching, and the while body of knowledge on teaching in engineering is growing, faculty members still express concern that emphasizing teaching may negatively impact their standing within their department or their reputation (Turns, Eliot, Neal, & Linse, 2007). Therefore, they fall back on the practice of teaching how they were taught, an idea that will be revisited in the section about engineering faculty. However, questions about how best to include these in coursework remain,

particularly as engineering educators strive to maintain the technical focus of their courses.

A great deal of divergence exists even with regards to the technical aspects of the curriculum: some programs emphasize the latest applications while others rely on practice and apprenticeship steeped in tradition. These differences are not just theoretical, but played out in schools of engineering across the country. One of the major surveys of engineering educators (the Wickenden Report, published in 1930) found that 29% of instructors believed differential equations were an important component of an engineering curriculum. If the faculty have such diverse opinions about the inclusion of differential equations, then there is little likelihood they agree about the inclusion of communication skills or cross-cultural competencies or leadership.

Liberal-vocational divide. Liberal education today is typically associated – and often thought to be interchangeable with – a liberal arts education. The image that likely comes to mind reflects the experience at an elite, selective, liberal arts college where students gain a liberal – that is broad – familiarity with the arts and sciences disciplines and frequently combine that with a deeper study of one such discipline, although the emphasis is on pure knowledge and not its applications (Sanderson, 1993). As introduced in Chapter I, the original use of "liberal" in describing this type of study was not intended to describe the curriculum, but rather the student population. The gentlemen – and at that time they were only white males – who undertook a liberal course of study were free (from the Latin "liber") to do so because they were not burdened by an obligation to learn a trade or occupation; they were men of means and therefore men of leisure who enjoyed the financial security that discouraged or even disparaged a need for vocation

preparation. In fact, any program of study that could be seen as relating to a profession, or at that time any specialization (professional or otherwise), was seen as less valuable because it indicated the individual was not a member of the aristocratic elite.

While the liberal arts refers to a specific subset of disciplines, liberal education refers to study intended to produce a number of specific outcomes including "critical thinking, reflection, and problem-solving skills" (Grubb & Lazerson, 2005, p. 13).[1] This was seen as the polar opposite of the professional nature of engineering education where vocational preparation was historically the primary and only objective. Yet this dichotomy is no longer needed. Technical literacy is increasingly added to traditional liberal arts programs and skills including professional and personal skills are becoming central to historically vocationally disciplines. A codification of student learning outcomes that include non-technical, and in fact quite liberal, competencies by the body tasked with upholding the standards of an engineering education represents not just a blurring of the liberal-vocational divide but a strong step towards its demise. Outcomes like critical thinking and problem-solving are no longer the protected domain of the liberal arts – if they ever were such to begin with – but are key components of a technical education. Similar, technical competencies are warranted within traditionally non-technical disciplines. Engineering education is pushing beyond those historical boundaries and embracing a new definition of educational purpose that while still deeply-

[1] Interestingly in the findings of this study engineering faculty categorized "problem solving" as a fundamental technical skill for engineering. However, Grubb & Lazerson have listed that skill as a fundamental of liberal education as well.

seeded in mastering a discipline, also not just accepts but insists upon a liberal understanding of what constitutes preparation.

Why engineering education matters today. Why was such a dramatic shift in engineering accreditation called for? Why is this moment so noteworthy in engineering education and education writ-large? While engineering has long been recognized for its role in innovation and technology (Douglas, Iversen, & Kalyandurg, 2004), engineering education in many institutions has been stagnant for decades (Rugarcia, Felder, Woods, & Stice, 2000). In many cases, walking into a random engineering classroom one would find it difficult to determine if it was 2020, 1980 or 1940, because the practices of engineering education have remained largely unchanged. "Undergraduate education in the STEM fields (science, technology, engineering, and mathematics) needs improvement, a conclusion that multiple national reports over the past two decades have reached (American Association of Physics Teachers, 1996; National Research Council, 1989; National Science Foundation, 1996; Steen, 1987)" (Baldwin, 2009, p. 9).

In 2012 the President's Council of Advisors on Science and Technology issued a report to President Barack Obama focused on improving the first two years of STEM education in US colleges and universities. The letter that accompanied the report findings explained "fewer than 40% of students who enter college intending to major in a STEM field complete a STEM degree. Merely increasing the retention of STEM majors from 40% to 50% would generate three quarters of the targeted 1 million additional STEM degrees over the next decade" (Olson & Riordan, 2012, n.p.). Of the college freshman who start in an engineering major, less than half will finish the degree with at least half of those leaving doing so during the first year (Besterfield-Sacre, Atman, & Shuman, 1997).

Researchers also remain focused on the persisting gender and racial/ethnic gaps of which college students pursue programs in STEM fields (Turner & Bowen, 1999). Despite efforts to increase the number of students enrolling in STEM fields there are still significant differences in the major declaration and persistence patterns of various demographic groups within higher and postsecondary education.

Faculty members do think about these issues, and the body of knowledge on teaching in engineering is growing, however faculty members still express concern that emphasizing teaching may negatively affect their standing within their department or their reputation (Turns, Eliot, Neal, & Linse, 2007). Yet an evaluation of the discussions between engineering faculty and a curricular consultant found that most faculty concerns focused not on themselves but on the students they were teaching (Turns, Eliot, Neal, & Linse, 2007). Despite their reputational concerns, many instructors are paying attention to the learning and development of their students in ways that may have an impact on the retention of these students.

Underrepresentation in engineering education. As discussed briefly in Chapter I and the previous section of this chapter, engineering educators continue to place great emphasis on increasing the representation of diverse individuals. This is seen as a benefit both because the United States is seeking to educate more domestic engineers and also because of the inherent benefit of educating an engineering population that better resembles the population of the country, just as we have seen in the justification for integration of public schools and as the defense of affirmative action in higher education (Gurin, Nagda, & Lopez, 2004). Contrary to the popular narrative (Schuman, Steeh, Bobo & Krysan, 1997), academically well-prepared students from traditionally

underrepresented minority groups – including Latino, Native-American, Pacific Islander, and African-Americans – express interest in science and engineering careers (Summers & Hrabowski, 2006). White undergraduates enter college with an intention to major in STEM at the same rate as African American and Latino peers, but they are much more likely to earn a degree in those majors (Chang, Sharkness, Hurtado, & Newman, 2014). In 2005 intent to major in science or engineering was as likely for African-American and Caucasian college-bound high school students (Summers & Hrabowski, 2006), and yet the pipeline disproportionately leaks women and minorities, even those with strong SAT scores, impressive grades, and success in high school honors math and science courses (Maton, Hrabowski, & Schmitt, 2000; Seymour & Hewitt, 1997).

Therefore, there are likely to be other factors contributing to retention in these fields, specifically "academic and cultural isolation, motivation and performance vulnerability in the face of low expectations, peers who are not supportive of academic success, and discrimination, whether perceived or actual" (Summers & Hrabowski, 2006, para. 3). Something is happening in classrooms and on college campuses that is disproportionately impacting the students already underrepresented in STEM fields – and while these issues are not limited to STEM fields, they are keenly observable in the populations expressing interest in, enrolling in, and graduating from programs in fields like engineering (Seymour & Hewitt, 1997; Garrison, 1987; Nettles, 1988; Allen, 1992; Steele & Aronson, 1995; Gandara & Maxwell-Jolly, 1999). Additionally, while 75% of all bachelors degrees earned by African Americans in the United States are earned at predominantly majority institutions and the factors that impact retention can have a stronger effect in those contexts (American Council on Education, 2005).

There are also notable demographic differences in the engineering graduate population and faculty ranks. In the United States in 2003, 46 percent of master's degrees and 57 percent of doctoral degrees in engineering were awarded to foreign nationals (Engineering Workforce Commission of the American Association of Engineering Societies, Engineering and Technology Degrees, 1973-2003 cited in Chubin, May, & Babco, 2005) – a trend directly speaks to concerns about the education of the United States technical workforce and the strength of the United States' technical authority. Also, at that time women comprised only 10 percent of the tenured/tenure-track faculty in U.S. engineering colleges and minorities just 5.3 percent (American Society for Engineering Education, Profiles of Engineering and Engineering Technology Colleges, 2003 cited in Chubin, May, & Babco, 2005). If domestic individuals from underrepresented groups – racial minorities, women, and those with disabilities – were represented in the U.S. STEM workforce in parity with their percentages in the total workforce population, the shortage of domestic workers with science, technology, engineering, and mathematics skills would largely be filled (May & Chubin, 2003).

Issues of retention in engineering education are not limited to underrepresented groups. The annual graduation rate in engineering had decreased by roughly twenty percent at the end of the twentieth century (Felder, Felder, & Dietz, 1998) with varying estimates claiming between 40% and 70% of students who begin in engineering do not graduate from the discipline (Hartman & Hartman, 2006). While it is true that across fields less than half of students graduate with a degree in the program where they initially begin, the troubling side of the engineering losses is that there are still striking differences in the population of those who stay or leave by gender and race/ethnicity and

a continued acceptance of the disproven anecdotal explanation that the departing students do not have the academic preparation to be successful (Felder, Felder, & Dietz, 1998). One potential reason we have discussed is that high achieving students may be leaving engineering because of the way it is taught (Hartman & Hartman, 2006). The true explanation is a more complex combination of student attitudes towards engineering, self-confidence levels, aptitude for engineering, and their interactions with instructors and peers (Felder, Felder, & Dietz, 1998). However, many of those factors – attitudes towards engineering, confidence levels, and quality of interactions – are strongly related to their classroom experiences. Compared to their peers in other fields, engineering majors are much more dissatisfied with the quality of their instruction (Astin, cited in Felder, Felder, & Dietz, 1998). Astin, Cross, and other education scholars recommended establishing new pedagogies – rather than the traditional model of lecture, independent work, and norm-referenced (curved) grading – to better engaged and accommodate students (Felder, Felder, Dietz, 1998).

A better understanding of purpose in engineering education is to the benefit of the discipline as a whole, but recognizing that problems in engineering have a disproportionate impact on underrepresented groups underscores the importance of being thoughtful about why someone studies engineering – and in these cases why someone who wants to study engineering ultimately decides not to finish such a degree. Although it is not the main focus of this study, an awareness of specific groups impacted by issues in engineering remains an important consideration for any recommendations.

Faculty in Engineering

Teaching How They Were Taught

The second tent pole of this dissertation was engineering faculty from whom data was collected. Although they have been present throughout the previous sections of this dissertation, I now focus specially on these faculty and the curriculum they deliver to students. One of the challenges facing engineering education and educators is the relatively small value placed on teaching compared with research production (Turns, Eliot, Neal, & Linse, 2007). This makes it difficult for faculty members, even those who are interested, to commit their resources to pedagogical developments. In many ways the teaching of engineering today resembles what would have seen in the 1950s, if not earlier, in part because faculty members may be recreating their own educational experiences (Smith, Sheppard, Johnson, & Johnson, 2005). Faculty members do think about curricular and pedagogical issues, and the body of knowledge on teaching in engineering is growing, however faculty members still express concern that emphasizing teaching may negatively impact their standing within their department or their reputation (Turns, Eliot, Neal, & Linse, 2007). Yet an evaluation of the discussions between engineering faculty and a curricular consultant found that most faculty concerns focused not on themselves but on the students they were teaching (Turns, Eliot, Neal, & Linse, 2007).

Integration across the Engineering Curriculum

The adoption of the EC2000 outcomes by ABET represented a fundamental shift calling for the horizontal integration of the hard and soft skills in technical courses at all levels – during all four years of an undergraduate degree – while also pushing engineering programs to demonstrate a vertical integration of these objectives throughout the curriculum – across all four years of an undergraduate degree (Williams, 2001).

Faculty are now being asked to teach ideas outside not just their specialization within their department but potentially outside their discipline. Concerns have arisen that substantial professional development may be necessary to facilitate this shift (Rosser, 2001). Faculty are being called upon to not just add these new concepts into their class plans, but to coordinate the development of those skills across courses, building upon what students have previously learned. Although most engineering disciplines are highly hierarchical, faculty have admitted to a type of tunnel-vision regarding their individual courses; faculty assume students have learned the necessary prerequisites in prior classwork, but they do not concern themselves with whether they are preparing students for the expectations of the next course (Shulman, Besterfield-Sacre, & McGourty, 2005).

This hierarchical nature of engineering as a discipline puts significant focus on students' prior knowledge. Interconnections among courses within a discipline is imperative for undertaking problems in engineering practice, but the curriculum remains divided into blocks, with faculty rarely taking the time to ensure students are all prepared at the start of a new term (Shulman, Besterfield-Sacre, & McGourty, 2005; Turns, Atman, & Adams, 2000). Prior knowledge is assumed by faculty, leading students to become responsible for manipulating that prior knowledge to create connections to new

subjects (Dym, 1999; Catalano & Catalano, 1999; Turns, Altman, & Adams, 2000). This requires the students to be particularly conscious of what they already know and how it connects to what they are learning.

In fact, this highly interconnected nature of engineering knowledge, if not engineering courses, is a significant challenge to implementing educational reforms. The hierarchical knowledge structure of engineering (Mills & Treagust, 2003) stands in contrast to many other fields in that there is an order in which many areas of subject matter should be taught. On the other hand, in a subject where information is arranged more encyclopedically the order of courses is not as prescribed (Levine, 2006); an English student would be able to take courses in poetry, Shakespeare, and modern novels in a variety of orders. In contrast, it is imperative that an engineer study physics and calculus before studying fluid transport. Because the engineering curriculum is so dependent on prior knowledge, it is difficult to make curricular changes to individual sections; the faculty expect an engineering student arrives in a fluid dynamics class with the requisite knowledge of physics and they anticipate that knowledge to have been obtained in specific ways. Changing how fluid mechanics – or any course – is taught in an effort to integrate the ABET 11 might require an engineering program to change how all previous and following courses are taught. The shift to Engineering Criteria 2000 outcomes might not effectively be done piecemeal, but rather the revolutionary change adopted by ABET might necessitate revolutionary changes for engineering programs as well.

Resistance to change is in part attributed to the culture of the engineering faculty as a whole; they are considered to have remained “conservative [and] technically

focused" (Mills & Treagust, 2003, p. 7). Some researchers attribute this to the largely "engineering science" focus of faculty, rather than one of engineering practice (Wulf, 1998). There are concerns that the standard reward structure for faculty devalues the actual practice of engineering in favor of research defined by the standards used for science faculty (Wulf, 1998; Rugarcia, Felder, Woods, & Stice 2000). At some institutions this has created a faculty of engineering scientists, rather than a faculty who are actively involved in the practice of engineering. In this way, engineering is significantly different from other professional programs like medicine, where most of the faculty continue to practice, and business, where the best faculty are used in programs more directly tied to professional practice (Wulf, 1998).

A driving force of Engineering Criteria 2000 was industry claims that engineering graduates are unprepared for the real-world practice of engineering, but their feedback is difficult to implement because they are so completely disconnected from teaching that is spearheaded by academics who study engineering science rather than practice engineering (Wulf, 1998). If research on bridges continues to be seen as more valuable in the academe than the design of a bridge, the faculty body of engineering will continue becoming more and more separate from the field. Rather than base the reward structure on that of the sciences, engineering could look to the system utilized in art or music where faculty are still expected to remain creative practitioners. By doing so, the field could increase the likelihood that engineering students are being educated in classes more directly tied to the practice of engineering rather than simply the study of engineering. There is an argument that faculty who remain practitioners are more likely to use adaptive expertise to flex their knowledge in response to new situations. Therefore,

perhaps these faculty could make better connections between courses which will assist in producing deeper student understanding and long-term recollections (Bransford, Brown, & Cocking, 2000; Felder, Woods, Stice, & Rugarcia, 2000; Mills & Treagust, 2003; Turns, Atman, & Adams, 2000).

Problem-Based Education in Engineering

In recent years engineering education has seen the adoption of new pedagogies aiming to increase engagement and retention. Some faculty in engineering – as well as those in the sciences and other disciplines – have sought teaching practices that would allow for a better replication of real world situations (Dym, Agogino, Eris, Frey, & Leifer, 2005; Shulman, Besterfield-Sacre, & McGourty, 2005). A 1997 National Science Foundation report called for, among other things, further adoption of problem-based learning or PBL (Dym, Agogino, Eris, Frey, & Leifer, 2005). Problem-based learning seeks to allow for greater transfer of skills learned in one context to a new application. Much of the attention on problem-based learning has come from its adoption within medical education to improve the diagnostic skill of students[2] (Dym, Agogino, Eris, Frey, & Leifer, 2005). Today, instances of problem-based learning can be found across a number of professional disciplines: in medical, engineering, business, and legal education (Dym, Agogino, Eris, Frey, & Leifer, 2005).

Problem-based learning is a student-centered approach that emphasizes self-direction, collaboration, and links coursework to practice (Perrenet, Bouhuijs, & Smits,

---

[2] Interestingly, the Harvey Mudd Engineering Clinic program was named such due to its desire to replicate the clinic-based experiences of medical education.

2000). In its original form, a PBL curriculum focused on a set of problems which were the launching point for student learning; nowadays there are hybrid methods where problem-based learning is a part an otherwise more conventional curriculum (Perrenet, Bouhuijs, & Smits, 2000). Problem-based learning begins with a challenge from which students determine the information they would need to solve such a problem; this is frequently contrasted with other models where students are taught what they should know (perhaps through a lecture model) and then later given problems to which they apply those skills. In PBL, the problem drives the skill development rather than problems being selected or designed to match the skills that were taught.

Problem-based learning is one response to viewing learning as a constructive activity. Although it may be efficient to give students the information they are perceived to need, allowing them to construct knowledge structures can make the information they obtain more flexible and transferable at later stages (Bransford, Brown, & Cocking, 2000; Perrenet, Bouhuijs, & Smits, 2000). Developing skills in the foundational technical sciences, such as mathematics and physics, benefits from students' use of metacognition to think about what they are learning and how it relates to both what they already know and the problem they are hoping to solve. Situating new knowledge is especially important in highly structured disciplines like engineering; while one could argue that in encyclopedic disciplines like medicine, missing a topic (such as a particular disease) will not affect a student's ability to learn the next topic, missing or misunderstanding a foundational math or physics concept can be problematic for development of later engineering knowledge (Perrenet, Bouhuijs, & Smits, 2000). For this reason, problem-based learning, although student driven, requires the guidance of a skilled faculty

member who can correct any misunderstandings or direct students to a topic they might have missed. Problem-based learning is seen as attending to a number of recommendations based upon cognitive science, including building upon previously existing knowledge, metacognition, and learning to transfer skills to new circumstances. The last of these – the transferability of knowledge or skills – is seen as indicating a greater level of expertise (Bransford, Brown, & Cocking, 2000; Winslow, 1996).

Cornerstones and Capstones

Additionally, engineering curriculum in the United States today typically includes a set of hallmarks, including a capstone senior design course and more recently a cornerstone first year design course. Since at least the 1950s engineering curricula have largely followed the engineering science model in which the first two years contain very little, if any, engineering (Dym, Agogino, Eris, Frey, & Leifer, 2005; Mann, 1918; Ollis, Neeley, & Luegenbiehl, 2004). A typical engineering student begins with in-depth studies of the pure, basic sciences followed by two years of engineering science where students apply those science principles to technological problems (Bordogna, Fromm, & Ernst, 1993; Dym, Agogino, Eris, Frey, & Leifer, 2005; Kazerounian & Foley, 2007). However, the engineering industry perceived these graduates as being unprepared to practice because of the shift from the practical arts to a theory based education. The response was the establishment of capstone design courses that over the years have evolved from problems designed and assigned by faculty to real-world issues that sometimes are sponsored and supported by engineering companies (Dym, Agogino, Eris, Frey, & Leifer, 2005; Prados, Peterson, & Lattuca, 2005).

The newest wave of design courses are intended for first year engineering students who due to curricular structure may feel disconnected from the engineering faculty and even the discipline itself (Dym, Agogino, Eris, Frey, & Leifer, 2005). To combat these trends, some institution have introduced "cornerstone design courses" into the first year program of study that expose students to some of what engineers actually do through engagement with a design project. Cornerstone design courses not only expose engineering students to the practice of engineering, but also to the faculty. The engineering science model separates first and second year engineers from the discipline and by extension from the instructors. The benefit of first year design can go both ways; cornerstone courses also allow the faculty an opportunity to engage underclassmen with whom they would otherwise be unlikely to interact. For all the attention focused on faculty and their desire to reach students, it is important to recognize that opportunities for faculty to engage underclassmen can be limited by curricular structure.

Beyond earlier engagement with faculty, pedagogies of engagement (liked PBL and design courses) are seen as having a number of positive outcomes for engineering students. Cooperative learning has been found to, on average, increase academic success when compared with competitive or individualistic approaches (Smith, Sheppard, Johnson, & Johnson, 2005). Cooperative learning has also been found to improve the quality of relationships among students and between students and faculty. These two findings are important in light of research that failure to establish a social network or becoming academic engaged in class are reasons students may not persist in college. Finally, cooperative learning is seen to improve self-esteem and social skills, areas where engineering students can be perceived as especially at risk.

Faculty Agency

Beyond faculty conceptions of the skills that should be central to an undergraduate engineering education, this study seeks to understand how faculty strive to put those ideas into practice in their teaching. When faculty discuss their goals in the classroom, one influencing factor is the construct of agency and its influence on a faculty members meaning-making and behavior (Campbell, 2012). Whether and how a faculty member views herself as implementing her ideas of purpose is at least partly a product of her sense that she can be intentional and that she is resourced to carry out these actions (Campbell, 2012; Marshall, 2005; Neumann, Terosky, & Schell, 2006). O'Meara, Terosky, and Neumann's professional growth framework outlines multiple factors, including faculty agency, that "all shape the degree to which faculty make contributions to students, colleagues, institutions, and society" (2008, p. 32, as cited in Campbell, 2012).

In recent years, scholars have moved studies of agency in higher education from focusing on students to faculty members (such as Baez, 2000; Neumann, Terosky, and Schell, 2006; O'Meara & Campbell, 2011; O'Meara, Terosky, and Neumann, 2008). The ability to understand a faculty member's intentional choices – in both meaning-making and behavior – provides insight into the ways a faculty member conceives of purpose, the extent a faculty member infuses that purpose into her teaching, and a faculty member's perception of how her idea of purpose is or is not supported by the institutional context.

Perception of Accreditation and Evaluations of Educational Quality

Engineering program are accredited by ABET, Inc – formerly the Accreditation Board for Engineering and Technology – which describes itself as a "federation of societies organized for the public good" and states "its purposes are educational, charitable, and scientific" (Accreditation Policy and Procedures, para. III.B.1.). ABET further states one of its purposes is assuring educational quality. ABET's description of its purpose additionally includes that assuring the quality of educational programs furthers the public welfare by providing assurances of professional competency (Accreditation Policy and Procedures).

At the time this study was conducted, perceptions of accreditation broadly and ABET specifically were undergoing a very public shift. The typical process of a candidate looking to become a licensed Professional Engineering (PE) – which not every engineering graduate does – included receiving your degree from a four-year ABET accredited engineering program (National Society of Professional Engineers, 2007),[3] however state licensing bodies do allow for those graduating from non-ABET accredited programs to become licensed.[4] Additionally in the fall of 2017 the faculty of the Electrical Engineering and Computer Science (EECS) department at University of California, Berkeley voted not to renew their ABET accreditation, referencing their

---

[3]According to the National Society of Professional Engineers website: "Generally, a candidate for engineering licensure will graduate from a four-year ABET accredited engineering program, take the Fundamentals of Engineering (FE) Examination during his or her senior year, start work in an engineering position immediately after graduation, and begin to accumulate qualifying engineering experience in order to take the Principles and Practice of Engineering (PE) Examination at the earliest opportunity. The usual requirement is four years of qualifying engineering experience."

[4] In New York State this involves a review of your academic transcript by NYSED.

position as a curricular leader and stating that “it does not make sense to limit ourselves by metrics that were previously developed based on a much narrower set of students and career paths” (Demmell, 2017, p. 1). Writing on behalf of the faculty, the department chair noted the privileged position of being a top program afforded them the opportunity to make this choice, but noting they were not the only program to do so. The agency of faculty to make this kind of choice and publicly break with ABET illustrates a moment in time when perception of accreditation is changing.

It is important to note that perceptions of accrediting bodies like ABET, as well as the assessment movement broadly, are varied and deeply held across higher education. There are pockets within higher education that view assessment and accreditation as moving higher education towards a version of knowledge that can be monetized; they fear that higher education is becoming nothing more than “the industrial assembly line, producing educated individuals” otherwise known as human capital (Hursh & Wall, 2011, p. 565). Although higher education has always had a connection to economic development, criticisms of the assessment movement view the current iteration as disconnected from research that considers both the learner and the context (Hursh & Wall, 2011). Instead, the neoliberal push for assessment is seen as commodifying knowledge and education, recasting academics as entrepreneurs whose value is dependent on the revenue they generate – in part from students as consumers whose tuition revenue must be maximized (Hurst & Wall, 2011).

However, while the tension between assessment and improvement – one that seemed inherent at the beginning of the assessment movement – may remain a concern for some faculty, there is a shifting perception that assessment and accreditation can be

employed thoughtfully to improve instruction (Ewell, 2009). This is not to say that all faculty no longer find the practice distasteful, but rather that assessment has become a standard part of doing business at a college. Beyond that, there is some belief that a sizeable minority of faculty have even embraced assessment as useful – particularly in fields such as engineering where programmatic accreditation has made assessment more common.

Moving one step further, faculty must not just see assessment and accreditation as a necessary evil because faculty engagement is essential for real impact on the education of students. “Even the most beautifully collected and interpreted evidence will have no impact on students whatsoever unless it engages an institution’s faculty, staff, governance structures, faculty development programs, and leaders” (Banta & Blaich, 2010, p. 23). In a survey of chief academic officers, two-thirds responded that faculty engagement is particularly key to advancing assessment. Even faculty who are deeply committed to students have struggled to become involved with assessment because it is perceived as externally driven and therefore something that takes away from the time that would otherwise be devoted to students. Additionally, many of these faculty are already struggling to carve out time to commit to the practice of teaching because of competing demands on their time and, as we have previously noted, the prominent role of scholarly research and publication in tenure and promotion decision (Boyer, 1990; Menges & Austin, 2001; Turns, Eliot, Neal, & Linse, 2007). Of course, career growth is not the only reason some faculty feel the pull of research – there is also the belief that active scholarship improves one’s teaching effectiveness (Banta & Blaich, 2010). Asking these faculty to take time away from research and away from student-facing activities in order

to focus on assessment has been met with resistance. But, "if faculty do not participate in making sense of and interpreting assessment evidence, they are much more likely to focus solely on finding fault with the conclusions than on considering ways that the evidence might be related to their teaching" (Banta & Blaich, 2010, p. 24).

Vocation of Life: A Conceptual Framework

The third tent pole of this dissertation is the guiding conceptual framework: "Vocation of Life." American philosopher John Dewey wrote extensively on education and political commentary. Dewey used democracy as the guiding principle of his conception of education, believing that the only true freedom was intellectual (Dow, 2002). He observed the educational system of his time as reinforcing the class divides that already existed by funneling students from lower social status into manual and menial disciplines, sentencing them to a life of hard work that would be governed by the ideas of others. To combat this Dewey called for all students to be educated to do meaningful work, which depended upon them being educated as citizens.

Dewey supported the idea of an education through occupation, yet he did not emphasize job placement and wage attainment as the primary objectives of schooling. In contrast, while education for work was contained within Dewey's objectives, it was paired with education for an individual's personal life, specifically their roles within the home and the community. I refer to this perspective on education as being focused on the Vocation of Life, to include the home, work, and community responsibilities of a person (Dewey, 2008). It should be noted that this definition of vocation – as extended beyond

the professional sphere – is only part of Dewey's extensive writing on education. I have chosen this particular moment from his work because of its role in framing the purpose of an undergraduate education and specifically an undergraduate education in engineering.

Dewey's (2008) Democracy and Education addresses the relationship between the academic disciplines (historically including only the liberal arts) and vocational education, reframing the conversation away from a binary image – where education is either liberal or vocational – to a continuum of subject matter (Labaree, 2006). Dewey addresses both secondary level vocational education as well as professional disciplines in higher education, but at each level he stresses the importance of educating students for both their personal and professional lives (Dewey, 2008). Dewey specifically addresses three points that impact the development of a Vocation of Life: firstly, he clarifies the historical and social – rather than inherent – divide between mental and menial forms of education; secondly he redefines the notion of vocation within the scope of education to include all directed action both professional and personal; and thirdly he emphasized the importance of a vocational education that allows all individuals the opportunity to move beyond their initial social station and cautions that failure to do so cements education as an instrument perpetuating the social hierarchy.

The definitions of vocationalism found in the dictionary refer to skills associated with a specific job or career, however Dewey (2008) calls for a broader understanding of vocation or occupation as any action directed to a specific purpose, whether it be personal or professional. Dewey argues that the opposite of a career is not leisure, but rather idleness; to this end, the leisure pursued by the elite societal class was not the opposite of a vocation, but rather that leisure was the vocation of the upper class. Dewey argues that

professional identity became the defining characteristic of an individual because it was what set people apart; everyone engaged in personal activities such as belonging to a family and a church, therefore the action undertaken for those ends were brushed aside and focus placed on the differences that singled out an individual, notably their trade or lack of trade. If this definition of vocation as inclusive of the professional and personal sphere is accepted, vocational education includes any continuous development of any skill set that will be applied towards a specific purpose. Dewey argues that the dominant vocation of any individual is living and therefore all liberal education is also inherently vocational.

Finally, Dewey emphasized the importance of not relegating the lower class to a trade education, but rather providing them a vocational education that will allow them the opportunity to develop their own course of action rather than blindly accepting direction. Dewey provided a particularly meaningful illustration when he referred to the members of the lower class who are only provided enough education to carry out the will of others as mercenaries, emphasizing that they have no personal stake in carrying out their action beyond monetary compensation. If the education system furthers a tiered structure in which those from the upper class, who demand a liberal education, are the only ones provided with opportunities to study in such a way, they therefore are the only ones who can develop the skills necessary to enact their own will. In such a situation, education loses its transformative power and becomes a machine that perpetuates the social hierarchy. Dewey emphasized that all people should be educated in the history and context of their occupation so that they are not doomed to blindly accept the present conditions, but rather understand that they have the agency to transform their own lives.

From this perspective, the EC2000 accreditation student learning outcomes outline the preparation for students as both professionals and people; the ABET standards codify the outcomes the accrediting body believe demonstrate not just a competent engineer, but a competent citizen, the importance of which has been underscored by the Council for Higher Education Accreditation (Volkwein, Lattuca, Harper, & Domingo, 2006). To reach these goals, ABET has integrated ideas that have historically been categorized as vocational and liberal outcomes, those that are both manual and mental, into the EC 2000. By emphasizing both types of student learning outcomes together, ABET is bridging the divide between types of skills. Utilizing this Deweyan standpoint I do not see these as competing types of outcomes, but rather holistically view one set of results that comprehensively describe the idealized engineering graduate. However, this dissertation sought to understand if engineering faculty would describe something similar as the student learning outcomes they view as important outcomes of their teaching in undergraduate engineering courses.

Twenty-First Century Skills: A Filter for Understanding Vocation of Life

The fourth and final tent pole of this dissertation is Twenty-First Century Skills, which I use as a filter to focus the 1916 lens of Vocation of Life for 2020 use. In 2007, just shy of ten years after its founding, Google hired Prasad Setty away from Capital One to head up a group called People Analytics within the people operations division – People Ops being Google-speak for Human Resources (Garvin, Wagonfeld, Kind, 2013). Google had been founded in 1998 as a company "built by engineers for engineers" (Garvin, Wagonfeld, Kind, 2013, p. 2) according to one of its employees and decisions were

determined by consensus, a practice that was becoming unfeasible as the company grew. A company that famously valued its flat organization was struggling to grow a management structure (Garvin, Wagonfeld, Kind, 2013). In 2009 Google undertook an internal process to determine if management mattered in the company – in other words they wanted to know if mangers mattered in their organization – and they found that it did: "It turned out that the smallest incremental increases in manager quality were quite powerful. Good managers do matter" (Garvin, Wagonfeld, Kind, 2013, p. 5).

Google's undertook a full study, named Project Oxygen, which set the groundwork for a renewed interest in understanding the value of non-technical competencies in a technical setting. Of the eight key findings from Project Oxygen about the qualities that made someone successful as the advanced in their career to a management level position, only the eighth and final was technical. The so-called soft skills of coaching and communication ranked higher than technical competency (Impraise Blog, n.d.). Capturing the full spectrum of important skills for developing engineering students, engineers, and engineering leaders necessitates looking beyond the technical competencies. Google is only one example of the movement to pay attention to non-technical skills in engineering, the movement that led to the adoption of the EC2000 criterion.

As introduced in Chapter I, the combination of technical, professional, and personal skills being considered in this dissertation will be referred to as Twenty-First Century Skills. "The term '21st century skills' is used often in educational circles to refer to a range of abilities and competencies that go beyond what has traditionally been taught in the classroom, including problem solving, communication, collaboration, creativity

and innovation. Others define the term as ‘information literacy, media literacy, and information, communication and technology literacy’” (Kurshan, 2017, para. 1).

It is difficult to pinpoint the moment when the term “soft skills” entered our lexicon, but the concepts they typically refer to have been part of the professional dialogue since at least 1936 when Dale Carnegie wrote *How to Win Friends and Influence People* (Britt, 2016). The phrasing was likely used to define these skills in contrast with the traditional hard skills that can be measured and assessed easily (Watkin, 2017). Soft skills are frequently the intangible skills that are more difficult to quantify. However, the connotations associated with “soft” skills – the implication of malleability and therefore weakness – has long left these skills as secondary considerations seen as less valuable (Britt, 2016; Watkins, 2017). Referring to them as such in this paper undermines their increasing importance.

In searching for an alternative, phrasing such as “interpersonal skills,” “people skills,” “communication skills,” and “emotional intelligence” were all considered, but each seems to address a subset of the full list of competencies that are being developed. The idea of “human skills” was considered, but seemed almost too broad and indiscriminate as if breathing were being elevated to the same level as teamwork. Managing a program focused on the Professional Development and Leadership skills of graduate engineering students, I wondered if “leadership skills” or “professional skills” helped clarify these concepts of interest, but the former seemed too limited and the latter suggested an job-focused orientation that somehow dismissed the importance of these skills not just for employability but also for the interpersonal and individual benefits they bring to society. Furthermore, although an MS in engineering is most likely a degree

earned specifically for career advancement, professionalizing undergraduate students, or at least the competencies of undergraduate students, feels contrary to the very nature of engineering as the liberal art of the twenty-first century.

In truth, I could have perhaps simply relied on calling them "technical" and "non-technical" skills, but in addition to a hesitation to define these important skills primarily by what they are not, the binary system perpetuated a historical dichotomy between these sets of skills when in fact that gap is disappearing. Instead, these varied competencies are being increasingly integrated, as I ultimately found in this study. Returning to that central focus of integrating disparate types of skills brought me to the idea of Twenty-First Century Skills (Azzam, 2007; Kurshan, 2017) which encompasses technical, mathematical, computational, socio-emotional, interpersonal, and leadership skills.

By defining these skills sets under one unifying term, I seek to reinforce the idea that it is important to understand them together as they related to purpose for an undergraduate engineering degree in today's world. That is to say very definitively that Twenty-First Century Skills reflects an integration of historically separated competencies and within a Twenty-First Century Skills framework, I sought to consider how technological literacy informs communication, how collaboration improves problem solving, and how creativity and innovation are connected. Schools of engineering are no longer teaching engineers only the technical competencies they need for employment nor are they seeking to equip them with two distinct skill sets – technical and non-technical – as part of their education, but rather an integrated set of student learning outcomes including the broad and varied skills students need today.

Chapter Summary

While Chapter I introduced the purpose and significance of this dissertation, Chapter II provided a deeper review of the current landscape within which this work was done. This study sits in the area between four core pillars: (1) engineering education in the United States; (2) engineering faculty; (3) Vocation of Life; and (4) Twenty-First Century Skills. I describe these ideas as tent poles because the four of them allow me to define the space within which I undertook this research. The area between them is the focal point of this study and understanding each in detail provides the background needed to answer the questions of purpose at the center of this study. In Chapter III the methodology for conducting that study will be described and Chapter IV contains the resulting findings of that study. Finally, in Chapter V the findings are situated alongside the ideas from this chapter's literature review to emphasize the implications of the findings moving forward.

III – METHODOLOGY

Chapter Overview

This dissertation will employ a single-site case study design to explore faculty perceptions of Twenty-First Century skills in their undergraduate engineering teaching in order to understand what the integration of those skills shows about the purpose of such an education in the modern world. In this chapter I will revisit the purpose of the study and the research questions that guide it. Next I will describe the methods for data collection and analysis, specifically addressing the four main components of the data: (1) semi-structured interviews with faculty teaching undergraduate engineering students in ABET accredited programs; (2) semi-structured interviews with academic leaders – faculty with administrative appointments, such as department chairs – involved in the overall curricular decision making and ABET accreditation of the undergraduate programs; (3) researcher field notes describing the context of interviews and general perceptions of the institution; and (4) document analysis of institutional records

associated with courses and teaching in the undergraduate engineering programs covered by ABET, including both course-level data such as syllabi and institutional-level data such as ABET self-study reports. This includes a detailed description of the constant comparative method for joint coding and analysis. Finally, I will reflect on the possible limitations of the study.

Purpose of the Study and Restatement of Research Questions

The goal of this study was to contribute to an understanding of purpose in engineering higher education by examining the student learning outcomes for undergraduate engineering courses. Using Dewey's Vocation of Life as a framework, this study focused on how faculty describe the objectives that they integrate into their teaching – representing both traditional technical objectives as well as professional and personal skills as part of Twenty-First Century Skills. The purpose of this study was to examine how faculty made meaning of their student learning outcomes and the contexts that were shaping those perceptions. By examining how faculty conceptualized student learning outcomes, I aimed to improve our knowledge of the experience of these faculty, specifically relating to the integration of Twenty-First Century Skills, Vocation of Life, and ABET's EC2000 criterion in their academic courses. As discussed in Chapter I, this project is guided by the following research questions:

- Overall Research Question: How do faculty make meaning of Twenty-First Century Skills in undergraduate engineering education?
- Research Question 1: How do engineering faculty describe the objectives of their academic teaching?

- Research Question 2: How do they define the skills they want students to develop through their coursework?
- Research Question 3: How, if at all, do they discuss Twenty-First Century skills as objectives of their academic teaching?
- Research Question 4: How do they describe those objectives manifesting in their academic teaching?
- Research Question 5: How do institutional contexts shape faculty making meaning of Twenty-First Century Skills?

Research Perspective

This study is qualitative with the emphasis on understanding the viewpoint of the subjects and how they make meaning from within their experiences (Kvale, 1996; Seidman, 1998). Through interviews with faculty and academic leaders, as well as a review of the contextual field notes and related documentation, I sought to understand what changing objectives of engineering education meant for those people on the front line of educating undergraduate engineering students, namely faculty.

The overarching theoretical philosophy of this study adopted an interpretivist epistemology, which accepts that reality is multiple and relative (Hudson & Ozanne, 1988) depending on other systems for meaning (Lincoln & Guba, 1985). As such, the intent of the study was to capture meaning in human interactions (Black, 2006) and understand perceptions of reality (Carson, Gilmore, Perry, & Gronhaug, 2001). The researcher and the participants are interdependent and interactive because the researcher

enters the field with prior knowledge but remains open to the new knowledge developed by the influence of the study participants (Hudson & Ozanne, 1988). “Therefore, the goal of interpretivist research is to understand and interpret the meanings in human behavior[u]r rather than to generalize and predict causes and effects” (Neuman, 2000; Hudson & Ozanne, 1998 in Edirisingha, 2012, p. 4).

The research questions that guided this study focused on perceptions of faculty and their experience of understanding and integrating Twenty-First Century Skills in their teaching of undergraduate engineering students. As such, an interpretivist epistemology reflected the interest in situating this inquiry within the culture and history of the institution where these faculty teach (Crotty, 1988 in Gray, 2013). This standpoint allowed for the acceptance of each participant’s experience as true, therefore analysis is not about a search for consistency to confirm the data but rather a “focus on exactly those aspects that are unique, individual and qualitative” (Crotty, 1998, p. 68 in Gray, 2013). An interpretivist perspective aligned with the case study method of this study, because it employed multiple types of data seeking to uncover different aspects of the issues being investigated (Dudovskiy, 2018).

The interpretivist philosophy has two central beliefs that I embraced for this study: a relativist ontology wherein reality has intersubjectively based on meanings and understandings and a transactional or subjectivist approach where people cannot be separated from their knowledge, which underscored the link between the researcher and research subject (Dudovskiy, 2018). This study was guided by research questions about what faculty think and do (as they perceive their actions), accepted the participative nature of the researcher, produced knowledge that was bounded by the case in question,

emphasized the specific and unique nature of the experience of these faculty, and was intended to produce an understanding rather than a prediction; these qualities scaffolded the methodological decisions of this study and are reflected throughout in the decisions made and the reasons for those decisions. Interview questions were framed to highlight individual meaning making, so questions were framed with prompts such as "what do you think…" Data analysis was undertaken with the goal of hearing each individual voice and representing their experience and perception by situating their comments within the individual context of their narrative. The reporting of findings prioritized describing the varied perspectives and reiterating that the findings cannot be separated from these individuals in this place at this time. The research was conducted to understand these experiences in hope they can help others, but these findings are irrevocably linked to the boundaries of this study.

Methods of Data Collection

Case Study Design

Selection of a research method was a reflection of my fundamental beliefs "about the nature of reality, about knowledge, and about the production of knowledge" (Merriam, 2001, p. 3). The key philosophical assumption of qualitative research is that "reality is constructed by individuals interacting with their social worlds" (Merriam, 2001, p. 6). I was interested in understanding how the ideas at the core of this study were experienced and understood (Kvale & Brinkman, 2009), but I was also interested in how that meaning interacted with my own perceptions (Merriam, 2001). I do not mean to suggest that the findings of this paper do not truthfully communicate the experiences of

others – their perspective is the "phenomenon of interest" (Merriam, 2001, p. 6) – but I am the instrument of data collection and analysis, so my existence becomes a component of the study.

Case study design in particular is derived from an interest in process, context, and discovery rather than outcomes, variables, or confirmation (Merriam, 2001; Yin, 2018). Case study research is typically an intensive description of a single unit, a structure I sought to employ here in this study. The most defining aspect of a case study is probably that for which it is named: this study investigated a single bounded entity – the ABET accredited undergraduate programs at one school of engineering (Merriam, 2001; Yin, 2018). Case study can be further differentiated by its particularistic, descriptive, and heuristic nature; it focuses on a particular situation, it provides rich details, and it produces insight about the topic under investigation (Merriam, 2001). Case study research produces knowledge that is unique in being more concrete, more contextual, more developed by reader interpretation, and more based on reference populations determined by the reader.

"The classic case study consists of an in-depth inquiry into a specific and complex phenomenon (the 'case'), set within its real-world context" (Yin, 2013, p. 321). That is to say, this study will be what the Dictionary of Sociology describes as a "detailed examination of a single example" (cited in Flyvbjerg, 2006, p. 220). A case study design should be considered when: (a) the focus of the study is on "how" and "why" questions; (b) the study cannot have an experimental design; (c) context is believed to be relevant; or (d) the boundaries between the phenomenon and context are not clear (Yin, 2003 cited in Flyvbjerg, 2006); all four of which were relevant to this dissertation. Firstly, the study

was guided by six research questions focused on how faculty make meaning and the contexts within which that meaning is made; each research question began with "how [if at all] do…" and considered an aspect of faculty perception. Secondly, an experimental design cannot be employed; a case has been selected to provide rich data, therefore there was not a randomized element to the participants. Additionally, I was not in a position to determine cause-and-effect relationships, in part because I could not have a control group who would be separate from the study participants; all members of the case institution, whether participants or not, are part of the context that contributed to the findings. Thirdly, and on a related note, context was important to this study. The participants make meaning within a certain milieu, which was influenced by both their School's philosophy as well as the outside influences of that moment. The zeitgeist of today in engineering education was relevant to the study and needed to be taken into account. Finally, and again related to the points above, the phenomenon in question – the integration of Twenty-First Century Skills into undergraduate engineering courses – was not clearly distinct from the integration of these skills into the accreditation standards and the educational philosophy that surrounds these faculty. I could not clearly differentiate how they were making meaning from the influences they are exposed to within their institution and the broader disciplinary community. Therefore, the case study included not just the interview data with faculty, but researcher notes, document analysis, and interviews with academic leaders – all of which served to enrich my understanding of the contexts within which these faculty were making their meanings. The use of these multiple data sources in conversation, specifically through the constant comparative method across the data components, highlights these connections.

Within the overarching umbrella of case study design there are numerous approaches to case research. Because this study was guided by the theoretical assumptions of Dewey's Vocation of Life, it followed an interpretive case study approach (Merriam, 1988; Merriam, 2001). In such a case study, thick description is used to illustrate, and therefore support or challenge, the preconceptions of Vocation of Life. That is to say, there was a hypothesis that girds this study: from the initial question "How do faculty make meaning of Twenty-First Century Skills in undergraduate engineering education?" and the selection of Vocation of Life, a hypothesis emerged. The selection of this frame and the development of these research questions reflected a supposition that if faculty were considering a set of skills that included a multitude of competencies they valued – technical and non-technical, hard and soft, professional and vocational – then I would be able to discern a broader definition of purpose for an undergraduate engineering.

Other researches have described types of case studies, rather than types of case study research, and would classify this dissertation as an instrumental case study (Darke, Shanks, & Broadbent, 1998; Dobson, 1999; Stake, 1994; Yin, 1994). Whereas an intrinsic case study is undertaken primarily because of the interest in that particular case, in an instrumental case study such as this one "the case is of secondary interest; it plays a supportive role, facilitating our understanding of something else" (Stake 1994, p. 237). An instrumental case study is a useful tool that "facilitates a deeper understanding of a particular phenomenon" and aids in "developing new theory or testing out existing theory" (Mills, Durepos, & Wiebe, 2010, p. 474). In this case the phenomenon, theory, or

"something else" of interest was the intersection of Vocation of Life and Twenty-First Century Skills to illuminate ideas of purpose in undergraduate engineering education.

In an instrumental case study such as this one, the establishment of a clear theoretical perspective is imperative to guiding data collection (Yin, 2013). The establishment of Vocation of Life as the guiding frame for this study influenced numerous aspects of the research design from the unit of analysis to the criteria for analysis (Yin, 2013). Vocation of Life became the lens through which data was analyzed, focusing the attention on the faculty's efforts to develop technical, professional, and personal skills in engineering students.

While I sought to understand those ideas, they would not be understood in a vacuum; quite the opposite: a specific case was chosen because of the expectation that it would illustrate something that may not be seen in other instances (Harling, 2002). I am not claiming this case is typical; in fact, the description of this selected case later in this chapter will argue the opposite: this case is unique and shows us things that are distinct, particular, and individual to this institution. Just as I was not seeking to make generalizable conclusions from my findings, I also was not seeking to make claims that what was happening at this school is common. In fact, my belief in the opposite is what drew me to this institution, this case, and this topic of study. I believe that engineering education is changing, and I believe that this site is on the forefront of that change. Three key factors illustrate why these institution is a data-rich case for situating the study: 1) the integration of liberal arts coursework into the requirements for all engineering students – not just science and math requirements, but mandating writing, literature or philosophy, and non-technical electives for all students; 2) a first year cornerstone course that focuses

on both engineering design and professional skills that include collaboration, communication, ethics, problem-solving, and project management skills; 3) a professional development program sponsored by the Dean's office that emphasizes continuous attention towards interpersonal, professional, and leadership skills. These activities are not common to all engineering schools and distinguish this institution as one that has made multiple commitments to the development of Twenty-First Century Skills in its students. Therefore, I believed this case would show one way that faculty integrate Twenty-First Century Skills, but I believe those possibilities are dependent on the culture and history of this institution. That uniqueness was at the heart of the choice to undertake a case study dissertation, to adopt an interpretivist epistemology, and to employ an instrumental case study design.

However, I should again note that this case study involved one single case and therefore was not intended to build towards generalizable findings. The interest of this study was to understand the perceptions of the faculty at this specific institution. As such, this case study was an example of practice-oriented research: (1) it was local – the case is defined below as including only specific individuals involved with these issues at one specific institution; (2) it was focused around what made this case unique, rather than searching for similarities to the larger landscape – this case was selected because of the expectation that it would show something not seen at every institution; and (3) theory-building was accompanied by practical applications – a goal was to understand how faculty are making meaning of these ideas in order to provide recommendations for the practice of faculty members, academic leadership, administrators, and accrediting agencies (Fox, 2003). Problems of practice are especially of interest to me in my

development as a scholar-practitioner and my desire to bridge my academic and professional worlds. I therefore selected a problem that fits a few key criteria: it was actionable – there were steps that could be taken to execute change because the power to do so was held by stakeholders involved in this research; it was high-leverage – making these changes would have demonstrable benefit to the students in question; it was reasonable – there was a possibility of impacting this issue from my own position and sphere of influence (Belzer & Ryan, 2013; City, Elmore, Fiarman, & Teitel, 2009). Additionally, problems of practice are frequently those which can be understood through reflection and dialogue – the kind of research I here employed. In the following sections there will be greater discussion of the selection of this site, the methods employed, and the limitations (including the issue of generalizability briefly touched on above) for this study.

Site Selection

This study explored the perceptions of faculty at a school of engineering – which I will refer to within this study as "Oxbow College." Oxbow College is one school within a four-year, private, research university that is categorized as being of the highest research activity (Carnegie Classifications, 2014). This particular research university is organizationally structured into a number of colleges and schools determined by discipline and student population with those schools largely responsible for their own budget and governance. Approximately 20% of the total undergraduate headcount is enrolled within Oxbow College of Engineering and, as is common for engineering programs, those students spend a significant portion of their first two years enrolled in

courses taught by faculty of the liberal arts college – drawing heavily upon a liberal arts and science tradition at the university – although unlike some historical engineering school structures Oxbow students are enrolled in the engineering college from their first year though taking courses outside their home school. The liberal arts and engineering undergraduate populations are highly integrated with regards to co-curricular functions including residential and student life.

The undergraduate population across the university is primarily enrolled for four years as full-time students; the university is highly selective with a higher transfer-in rate than transfer-out rate (Carnegie Classifications, 2014). The university's recently admitted undergraduate Class of 2022 – those in Oxbow College and the other undergraduate colleges of the university combined – had an admissions rate of less than 10%. The university and the graduate engineering program are regularly ranked among the best in the country (US News and World Report, 2018). Oxbow College has undertaken a significant initiative to grow its faculty over the past five years. Approximately 10% of the faculty have been awarded National Science Foundation CAREER Awards over the past four years. This is an institution aiming to position itself on the forefront of the next generation of engineering education, but it is also an institution of great tradition.

As discussed in the literature review of Chapter II, engineering schools suffer from the dueling perceptions that they are seen as being on the cutting edge of research but frequently stagnant in their teaching approaches (Wulf, 1998). Oxbow College is an institution that has committed to growing not just its research portfolio, but also its role in teaching the engineering leaders of the next generation. It requires that all engineering students take a substantial number of liberal arts courses beyond the typical math and

science requirements, it requires a cornerstone course for first years that emphasizes Twenty-First Century Skills, and graduate students are required to participate in professional development. This school has thought critically and carefully about how it teaches today's engineering students.

Oxbow College's university was one of the first chartered institutions of higher education in the United States and its original charter included a directive to teach the subject matter that later developed into the disciplinary offerings of Oxbow College, which was founded as a separate school approximately 100 years after the university was chartered. To reiterate, there are several characteristics that uniquely situate Oxbow College to address a broad set of student learning outcomes: approximately one in five undergraduates is enrolled in engineering with the majority of those undergraduates studying the liberal arts coupled with the standard curricular structure of engineering, including two years of foundational math and science, all of which is further influenced by the deep historical liberal arts tradition of this particular university. Today Oxbow College boasts both tradition and innovation through a philosophy that emphasizes not just professional training, but also a broad exposure that equips students with both humanistic and technical skills along with a commitment to life-long learning and understanding. Oxbow College has integrated the ideas of EC2000 into its core mission, but has also established its own vision of Twenty-First Century Skills in undergraduate engineering education through its requirement of liberal arts coursework, its cornerstone course, and its commitment to professional development for its students at all degree levels.

This school was selected because of its established commitment to the Twenty-First Century Skills central to this dissertation. I will discuss further purposeful sampling below when discussing participant selection, but a similar argument is to be made for site selection: "the logic and power of purposeful sampling lies in selecting information-rich cases for study in depth" (Patton 1990 in Merriam, 2001, p. 61). This institution was selected to provide a rich case study because of the both its history of addressing the ideas of interests in this study and the strong commitment to this concept demonstrated by school leadership. The four pillars of my dissertation study – engineering faculty, Twenty-First Century Skills, Vocation of Life, and undergraduate engineering education – are all encompassed within Oxbow College. Additionally, Oxbow College underwent an ABET reaccreditation study in the academic year when I began data collection and the senior administration was supportive of making the documents and findings from that process available for this study. These contacts were instrumental in gaining access and permission, as well as opening doors to the individuals who participated in this study.

Case Selection

The case at interest in such a study is situated in a real-world context (Stake, 1995; Yin, 2018) with the goal of understanding the complexity inherent in that one instance (Stake, 1995). While I reiterate that part of defining case study is identifying an area of interest that can be bounded – that is a clear definition of what is and what is not part of the case – I should also acknowledge that not all bounds are clear cut; the boundary between the phenomenon and the context may not be as evident (Yin, 2018).

Therefore, the case selection involves two important aspects: defining the case and bounding the case (Yin, 2018).

Defining the case. In defining the case, I asked: in all of this context, what am I going to pay attention to? While that interest may be tied to a particular institution, instructor, course, student, or program, defining the case – specifically with an instrumental case – allowed for the framing of the study towards the phenomenon in question, which here was the intersection of Vocation of Life, Twenty-First Century Skills, engineering education and faculty at this one school of engineering in order to answer the questions I cared about within this research landscape.

This case was about the way faculty in departments with ABET accredited programs conceptualized their teaching and any institutional context that had a bearing on how those faculty have made meaning of their teaching. The research questions that directed this study asked about how these faculty made meaning of the ideas at the center of this study (Stake, 1995).

While there was a danger in focusing on subunits of the case –for example one faculty being interviewed in this study – the research questions were framed around the group of faculty and the institutional contexts to reiterate that the unit of interest was the intersection of these related phenomenon in how faculty – the plural faculty – were making meaning of their teaching.

Bounding the case. Just as in defining the case I asked what I would pay attention to, I needed to also define the bounds of what was to be included within the study, particularly for the purposes of guiding data collection. Typically, those boundaries include the time and space within which the case would be considered. In this

instance, the study was bounded within this school to include only those departments with programs accredited by ABET (as a reminder, engineering accreditation occurs at the program level). It is important here to note that many of the individuals involved with ABET accredited engineering programs will also be involved with graduate education and/or other programs and departments that are not ABET accredited; an individual was considered to be within the bounds of the case if they at least in part fell within the bounds. Therefore, faculty who teach both undergraduate and graduate students, faculty with joint appointments in both ABET accredited and non-ABET accredited departments, and school-level academic leaders were all defined as within the bounds of the case.

The case was demarcated by pre-defined boundaries which clarified the time period covered, the involved group or organization, the types of evidence collected, and the priorities for collection and analysis (Crowe, Cresswell, Robertson, Huby, Avery, & Sheikh, 2011). The research was intended to be carried out in the semester immediately following an ABET reaccreditation cycle, but ultimately extended into an additional semester. A committee of faculty and administrators in the academic year this research began had completed and submitted self-study reports and hosted visits by outside accreditors. Therefore, the particular phenomenon of interest had been discussed and considered extensively within the site school just before the onset of this study.

Data Methods

This study utilized a single-case that integrated semi-structured interviews (with two categories of employees – faculty and Dean's Office administrators, although the latter typically also hold appointments as the former), document review, and

observational field notes. These distinct methods addressed the research questions using multiple data sources. The integration of multiple data collection methods within the case study allowed for triangulation and improved reliability (Creswell, 2012). Additionally, the combination of these varied types of data were important in contributing to understanding of the case as a whole. While the multiple data sources served to confirm information obtained from the other data sources, they also illuminated specific aspects of the case in different ways that added up to a more complete understanding. Faculty interviews allowed me to hear from the individuals in question about their meaning making, while the contexts within which they had those experiences – the departmental contexts, the school contexts, the decisions made by academic leadership – were also illustrated through the other types of data collected. In order to understand the case in question, I required this information about the landscape within which my phenomena of interest were being experienced by faculty, and I received that information by collecting other forms of data. All four data streams were generally gathered and analyzed concurrently, though some efforts were made to order the review of particular data (such as the school-level self-study and the institutional response to ABET) early in the process to inform later conversations. For example, a senior member of the school leadership who had been heavily involved in accreditation agreed to be one of the first interviews, which provided a broad overview of the landscape. However, the Oxbow College Deans Office asked for me to received consent from the department chair or the ABET lead of the department before reviewing documents, which impacted the timeline of when certain documents were available and ultimately prevented me from reviewing some documents I had intended to include in the dissertation (in which case publicly available documents

providing as much related information as possible were used instead). After that point, document review, interviews, and field notes will happen in an interwoven fashion, with the review of documents relevant to that department happening soon before an interview and the documents brought into the conversation through interviews being reviewed soon after the conversation. Each aspect of data collection will be discussed in the following sections.

Faculty interviews. For this dissertation, the primary source of data was in-depth, semi-structured interviews with faculty who teach undergraduate engineering courses. The identification and selection of those faculty will be discussed in the later sampling strategy section. The inclusion of interviews within a case is typical in qualitative research (Merriam, 1988; Yin, 2018). Interviews are conversations "with a purpose" (Webb and Webb quoted in Burgess quoted in Merriam, 1988, p. 71-2) of understanding things cannot directly be observed (Meriam, 1988; Yin, 2018). That is to say, in this dissertation I sought to understand how engineering faculty mad meaning of the ever-evolving purpose of their craft, but I "cannot observe how people have organized the world and the meanings they attach to what goes on in the world – we have to ask people questions about those things. The purpose of interviewing, then, is to allow us to enter into the other person's perspective" (Patton quoted in Merriam, 1988, p. 72).

Interview research addresses both the immediacy of what particular individuals report as being their experience while also considering what can be learned beyond those examples. From the very personal narrative shared by each participant, a larger story became visible by considering what was said by the collective group of interviewees along with the broader literature on the topic of interest. Good interview research keeps

its feet on the ground with the data while raising its head to look for what that data could say about the world beyond (Neumann, Class Notes, May 13, 2014). To that end, I spent approximately six months with the faculty of Oxbow College will also emerging myself in the institutional documents that were available and the relevant literature.

The interview protocol to guide discussions with faculty was derived to include both structured demographic and general background questions, as well as open-ended questions. While developing the protocol, I referred regularly to my research questions to ensure that my interview questions reflected the research questions. The interview protocol was piloted with a colleague who teaches engineering students and based on the experience with the pilot interview I adjusted some phrasing within the protocol. The protocol began with questions about the nature of the participants discipline, how they define their area of expertise, and how they made the decision to specialize in that area. They were designed to start the conversation by asking questions faculty might be more used to answering so they would become comfortable with the dialogue before moving into new areas. These questions also served to help address research questions 1 and 2, which focus on the objectives and skills faculty aim to communicate to and develop within their students. The questions then shifted to issues of purpose in both their immediate teaching and the larger programs within which they teach, to determine the outcomes the faculty believed are important as asked in research questions 3 and 4. Finally, faculty were asked about the support for these ideas that they have experiences or would have wanted to experience, to address research question 5. The ideas of Vocation of Life and Twenty-First Century Skills were woven throughout the protocol, although not called out by name within questions. The ABET 11 outcomes were directly

addressed, and so I furnished a copy of those outcomes when relevant in the discussion. In order to continually return us to each faculty member's perspective during the interview, questions were intentionally formulated to remind them that I was seeking their perspective; any question that during pilot review seemed to suggest faculty were being asked to make a statement about a department, school, or disciplinary-level belief was revised to remind the faculty that I was interested in how they have formulated these ideas and the meanings they have made through their own experiences.

Sampling strategy. The population for faculty interviews in this study was full-time faculty at Oxbow College who were appointed partly or fully in a department accredited by ABET (n≈100). The mainspring of participant selection was a call for participants from this population by email. Faculty were also asked to recommend colleagues for a potential snowball sampling of additional participants (which will be discussed below). "Since generalization in a statistical sense is not a goal of qualitative research, probabilistic sampling is not necessary or even justifiable in qualitative research" (Merriam, 2001, p. 61). The most common form of nonprobabilistic sampling is purposeful sampling based on the assumption that the researcher should select a sampling from which the most can be learned (Merriam, 2001). As with the site selection, participants were chosen in order to learn as much as possible about the issues central to the research. Recognizing that a variety of characteristics shape the experiences of faculty, I aimed for the study sample to include individuals with a diverse set of backgrounds across criteria such as department, rank, years of experience, and extent of involvement with department governance. However, while I was mindful of these characteristics, I was not seeking a representative sample since generalizability was not a

goal. These characteristics were also kept in mind when reviewing the data collected from the interview with each individual.

The exact number necessary for saturation was unknown, but the expectation was approximately 15 interviews. Ultimately 10 faculty were interviewed along with the academic leaders who will be discussed below. Because the academic leaders were also faculty members, I found those conversations often included even more of the topics from the faculty protocol than I had anticipated, which likely contributed to saturation having been reached with a smaller number of faculty interviews.

In the end a small number of faculty were recruited through snowball sampling. Snowball sampling is a form of purposeful sampling. In a purposeful sample (also referred to as a purposive sample or criterion-based selection), the researcher locates individuals matching the list of attributes essential to the study (Merriam, 2001; Weiss, 1994). Snowball sampling is one such type wherein participants in the study refer the researcher to other potential participants (Patton, 1990). Snowball sampling is common in case study research and involves expanding the study sample through "people who know people who know people who know what cases are information-rich [and] good interview subjects" (Patton 1990 in Merriam, 2001, p. 63). At the conclusion of each interview, I asked the faculty member if there were other individuals I should speak with whom they believed would be thoughtful about purpose in undergraduate engineering education. I also employed a similar approach when faculty responded to the initial call for participants that they could not join due to structural reasons (e.g. sabbatical leave).

Faculty interview data collection. Central to this study was my interest in understanding the experiences of these faculty members with respect to the issues of

purpose, accreditation, and curriculum as they reflected on their experiences and their work (Kvale, 1996; Seidman, 1998). Interviews were a conversation between the participant and myself as the researcher, wherein our mutual interest in the topic created moments of meaning-making.

As discussed above, in preparation for these interviews, a semi-structured protocol was created and piloted. This protocol was followed for all interviews, with the addition of appropriate follow-up questions based on participant responses. The probing prompts were designed to assist in illuminating a particular faculty member's perception of the issue at hand; because I was interested in each faculty member's unique experience within the overall fabric of this school, it was important to make individual choices within the protocol to assist in bringing to light that faculty member's experience. In various interviews that required the same type of question to be asked in different ways to connect with the faculty member's experiences. The optional follow-up prompts allowed for that to be done while maintaining a semi-structured frame for the interviews. Beyond that, I encountered a number of cases in which faculty surprised me and I prompted them for further comments based on their responses to the standard questions in the protocol.

I also recorded observations notes about the context of these interviews – both descriptive and reflective accounts of the occurrences (Bogdan & Biklen, 1998). All interviews were carried out only with informed consent of the participant. The interviews were recorded and transcribed to include both what was said and the nuances (pauses, hesitations, or other sounds) that reflect the participants sharing (Kvale & Brinkmann, 2009). Faculty members were asked to reserve 90 minutes on their schedule for interviews to account for all necessary administrative tasks (such as informed consent or

questions from the faculty) along with the interview itself. Interviews were mostly conducted in the office of the faculty member in the engineering building, although a small number took place in other settings (such as a lab) or by phone (if requested by the faculty member). Prior to each interview, I reviewed the participant's curriculum vitae and modified the interview questions based on his or her experience and discipline. Additional notes on the environment of the interviews, which served as a source of data for this study, can be found in the section below on field notes.

Academic leadership interviews. In addition to meeting with faculty members whose primary organizational role is that of faculty member, I also interviewed academic leaders in the school who have been involved with the most recent accreditation cycle and also hold simultaneous faculty appointments. In particular, this included the senior leadership of the school in the Dean's Office and departmental leadership (Department Chair, Director of Undergraduate Program, ABET Review Chair). As with the faculty interviews, these were in-depth, semi-structured interviews. Again, the inclusion of interviews within a case is typical in qualitative research (Merriam, 1988; Yin, 2018), although these interviews additionally provide direct insight into the institutional culture at the highest level of the school. In all cases these academic leaders were also teachers of undergraduate engineering courses, either concurrently or prior to these interviews. Therefore, the protocol echoed some questions from the faculty protocol with the addition of question specifically aimed at addressing research question 5. Over the course of data collection, I found myself using more question from the faculty protocol as follow ups for the academic leaders protocol as they described their own teaching and perception of student learning outcomes. As with the faculty interviews, the purpose of interviewing

was to allow for the understanding of another person's perspective (Patton quoted in Merriam, 1988). In this case those experiences represented a faculty member making meaning of purpose in undergraduate engineering education (which is why some interview questions were included in both the faculty and leadership protocol), but also provided a context for the environment within which the broader group of faculty were responding based on how individuals in positions of greater responsibility for accreditation had developed these ideas and communicated them to their faculty colleagues.

Similar to the faculty protocol, the academic leadership interview protocol was derived to include both structured demographic and general background questions, as well as open-ended questions. Again, I referred regularly to my research questions to ensure that my interview questions reflected the research questions. This interview protocol was piloted, and I adjusted the protocol based on that experience.

Sampling strategy. The population for academic leadership interviews was derived in consultation with the administration of the school to create a list of individuals with faculty appointments who also hold department and school level leadership roles. Some of this information (such as department chairs) is publicly available, but other lists (such as ABET leads) was provided by the school. As with the faculty interviews, there was a call for participants from this population by email followed by, if needed, a snowball sampling of additional participants to reach saturation. Since the population here will be smaller (5 academic deans, 6 department chairs, 6 ABET chairs, and potentially 6 directors of undergraduate study), so was the expected sampling to reach saturation. I expect to speak to approximately 5 academic leaders and ultimately have the

data from 4 included in the study,[1] with representation from each type of role. (Although it should be noted that the structure of who is involved with accreditation varies across each department.) Again, I was not seeking generalizability and therefore a probabilistic sampling was not needed or appropriate.

Academic leadership interview data collection. As with the faculty participants, I was interested in understanding the experiences of these academic leaders with respect to the issues of purpose, accreditation, and curriculum leading to a reflection about their experiences and their work (Kvale, 1996; Seidman, 1998). As with their faculty colleagues, these interviews were a conversation between the participant and myself as the researcher wherein our mutual interest in the topic created moments of meaning-making. Again, these academic leaders were not providing definitive statements about the school or department view of these issues, but rather providing how they conceptualized the ideas in question from their position with the organization – a perspective that allowed for better understanding of how the larger group of faculty within this case may have made their own meanings.

The academic leader interview protocol was followed for all interviews, with the addition of appropriate follow-up questions based on participant responses. As with faculty interviews, I recorded observational notes about the context of these interviews. These interview were carried out in the offices of the participants with their informed consent. The interviews were recorded and transcribed. Prior to each interview, I

---

[1] I conducted 1 additional interview with an academic leader who requested the data not be shared publicly and therefore it must be excluded from this analysis.

reviewed the participant's curriculum vitae and modified the interview questions based on his or her experience and discipline. Additional notes on the environment of the interview, were recorded to serve as field notes.

Document review. This study also involved the collection and analysis of primary, secondary, and tertiary documents and artifacts related to the curriculum, teaching, and accreditation of the school's undergraduate programs. I expected many of these documents to be internal documents, including those collected and shared with the accrediting body although not publicly available. These documents allowed for better contextualization of the overarching institutional response to the changing accreditation standards as well as helped to convey the changes in curricular philosophy over time.

These documents and artifacts, unlike the interviews conducted, were not products of this research itself and were initially produced to serve other purposes typically predating my research (Merriam, 1988; Yin, 2018). The available documents and artifacts existed at two levels: those related to individual faculty or departments – including course syllabus, course assignments, program descriptions, minutes from faculty meetings regarding assessment, ABET self-studies at the program level, and faculty CVs – as well as school level documents – which may include internal communications from the office of the Dean, newspaper articles, and the school-level portions of the ABET self-studies. Many of these documents had recently been assembled for the on-campus visit of the ABET external reviewers and I will discuss below how those documents were augmented to complete the sample of documents reviewed.

Document sampling strategy. Documents were selected for review based on their relation to the case – that is their relation to faculty who teach undergraduate engineering courses within this school. Since the case was bounded by its relation to an ABET review for reaccreditation, the primary sampling strategy was based on relation to that reaccreditation cycle. Therefore, the first round of documents that were sampled were the self-studies produced and the feedback from the review. The self-study reports contained program descriptions, course syllabi, sample student program plans, sample student work, and faculty CVs. Accompanying those documents was the administrative documentation necessary for the assembling of the packets, including agendas or meeting notes from ABET committee meetings.

Beginning with those documents – noting that those are the documents the school and ABET believe are most relevant to accreditation – I then adding in resources to fill in any perceived gaps. This is complementary to the snowball sampling employed in the interviews for this study: the sample begins with those documents that were voluntarily identified by the school (as well as those required by ABET) and the question that followed was "what else would be useful to look at?" Including this method of data collection was imperative to the triangulation of the other sources of data collected and assisted with identifying or filling any gaps in the interview data (Stage & Manning, 2013). These documents also provided further information about the context within which faculty are developing their perceptions of purpose and therefore were referenced primarily in the section of findings related to context.

Finally, documents specifically related to the study participants, if not already included, such as CVs, course syllabi, and statements of teaching philosophy were included to inform data collection and analysis.

Document data collection. Requests for relevant documents was included with the initial request for site access. Administrators overseeing the ABET review were contacted to furnish copies of the self-studies as departments affirmed their consent. Faculty participants in the study were asked for their CV and course syllabi if not public available, so those documents could be reviewed both before and after the interview occurred.

Field notes. Throughout the process of conducting interviews, which largely happened on Oxbow's campus in departmental offices, observational field notes were collected. Prior to each interview, notes about the environment – at the institution and departmental level – were logged. The interview guide document allowed space for recording of observations during the discussion that specifically related to that participant or the nature of the conversation itself. While it was important to note the physical features that surround the interview – the aesthetics of the department office and faculty office where interviews take place – notes about my perception of the participant's experience of the interview – who seemed like they speak about these kinds of ideas regularly versus who seemed to be making meaning in a new way during the interview itself or who seemed particularly ill at ease during the discussion – were important for understanding other contexts of the data.

Additionally, more comprehensive notes were recorded immediately after each interview. These notes were intended to provide both "wide angle" and "narrow angle"

views of the interaction and key words that might be necessary to return to later as well as my own feeling and reactions (Maxwell, 2013; Merriam, 1988). Observational field notes helped to contextualize the transcript of the interview and provided further triangulation, along with documents and artifacts that verify analysis and findings.

Field note sampling strategy. Wherein the field notes exist only due to this study, they were therefore all fully contained within the bounds of this case and considered within the sample of interest to be reviewed for data. Therefore, no sampling of field notes was needed.

Field note data collection. Each interview was scheduled to allow 30 minutes prior to the appointed time for the recording of initial observational field notes about the environment, including broader reflections on the school and campus as well as notes specific to the departmental context of that participant. This time was also used to prepare for the discussion by revisiting some of the faculty member's provided materials. The interview guide was printed with space between and around each question to allow for observational notes to also be recorded easily during the interview. On each interview guide, space was dedicated to recording observations about the participant, the tenor of the interview, and the surrounding environment immediately after the interview concluded. Additional time allocated following the interview for the recording of additional field notes. The fields notes specifically linked to an interview were labeled with only each participant identification number, not the name or any other identifying information.

Data Processing

This section describes the procedures that governed the collection and management of the dissertation data, including the commitment to confidentiality. First, the process for storage of physical and electronic materials will be described. Next is a description of how confidentiality of participants was protected. Finally, this section describes the process of obtaining informed consent from participants.

Physical and electronic dissertation materials were secured in a variety of ways. Physical dissertation materials were kept in a locked drawer inside a locked office. Electronic dissertation materials were maintained in an encrypted folder on a password-protected computer. Interviews was labeled by case number and interview date. Case numbers replaced actual names as codes emerged with aliases being created as needed for findings. The crosswalk file associating case numbers with individuals was kept in a separate encrypted folder away from the interview data.

Research was carried out with a commitment to the confidentiality and the privacy of the participants. Identifying names of people and organizations have been excluded from the final dissertation. Data has been edited, where necessary, to protect that confidentiality and privacy. While these precautions have being taken, it is possible that certain individuals may be identifiable, particularly to people who know them well, through their quotations. These risks were outlined for participants at the beginning of each interview when informed consent was given by each participant.

Data Analysis

This section will describe the process of analyzing this dissertation's data. This section will first describe the software selected to house and manage data analysis. Next, the processing of interviews to produce transcriptions, which served as a source material for analysis, will be described. Additionally, this section will describe the stepwise process beginning with identifying pieces of data followed by the ensuing analysis process that grouped data in codes, codes into themes, and ultimately themes into patterns which became the initial findings of this dissertation. This section does so by outlining the steps of the constant comparative method, describing each step and how it was carried out for this study to scaffold the description of the analysis. This section concludes with a description of the Code Book produced by the data analysis and the strategies to ensure internal validity of that analysis.

NVivo Software

To organize and review the data, analysis was conducted using the NVivo software for qualitative data. NVivo allows for the coding of data from interviews, field notes, and documents. Coding occurred across all data sources simultaneously. This software was selected because it allowed the researcher to readily undertake the constant comparative method, which will be described further below. Details on the use of NVivo for data analysis will be discussed below throughout the analysis description, however, it should be noted that NVivo or any other software package that serves as a computer-assisted qualitative data analysis software is a tool for the researcher's analysis (Fielding & Lee, 1998 in Yin, 2018); while these software and techniques have improved, they are

still tools to assist the researcher in undertaking analysis. It is imperative to note that the software's outputs do not take the place of researcher analysis (Yin, 2018). As the subsequent process for data analysis is described, much of those actions occur within NVivo, but it was used here as a system for organizing data sources and to allow the researcher to move deftly between data sources and codes. All meaning was determined by the researcher.

Interview Transcription

A major source of data for this dissertation case study was interviews with faculty and academic leaders, with those interviews being transcribed for data analysis. Interviews were recorded with the written consent of the participant and transcribed using a transcription service. The researcher then reviewed each transcription with the recording to correct for errors. This allowed for a close listening of the audio and close reading of the interview transcript prior to coding. Transcription occurred concurrently with data collection rather than en masse at the conclusion of interviewing. This allowed for the experience and insight gained during early interviews to inform later data collection. It also provided a period of time for the researcher to reflect on initial hunches, which could be confirmed or rejected as the researcher engaged in further conversations and data collection. These initial impressions were recorded through memos and white-boarding, which allowed for connections between emerging ideas and the research questions.

Data Collection and Data Analysis Timing

Although data collection and analysis are described in subsequent sections of the dissertation, they occur simultaneously in qualitative research (Maxwell, 2013; Merriam, 2001). Qualitative research is "emergent" (Merriam, 2001, p. 155) and depends on working hypotheses that are developing throughout the dissertation process (Maxwell, 2013; Merriam, 2001). The process is largely intuitive (Merriam, 2001) and one that the researcher undertakes based on hunches and feelings while sitting with the data.

The overall structure of that process is described in the following section, but ultimately data analysis occurs in practice in a very experiential way within that structure. The research followed a plan that is outlined below, but within each expected and executed action there were a series of leaps forward and feedback loops to drive an iterative process within each step of data analysis and through the stages of the constant comparative method.

Narrative Analysis Approach

The study utilized a narrative analysis to understand the experiences of the participants through the stories they told in their interviews (Maxwell, 2013; Merriam, 2001). In this approach "emphasis is on the stories people tell and on how these stories are communicated – on the language used to tell the stories" (Merriam, 2001, p. 157). The constant comparative method used here, as developed by Glaser and Strauss, utilized a structure in which a particular point of the data – whether from an interview, document, or field note – was compared to another point of the data and then the comparisons were compared to develop tentative categories which were once again compared (Maxwell,

2013; Merriam, 2001). These comparison occurred at all levels of data analysis – first at the level of individual pieces of data, then at the level of codes, and finally at the level of themes – considering where there were similarities and where there were differences (Merriam, 2001). The next section will describe each phase of the constant comparative method of data analysis in greater detail, emphasizing how each subsequent phase contributed to the emergence of the findings described in Chapter IV of this dissertation.

Stages of the Data Analysis Process

This section describes in detail the steps of the data analysis process for this dissertation. The development of findings occurred by moving from sources of data to data points with associated codes and then comparing codes to develop themes and comparing themes to develop findings. The analysis was undertaken using the constant comparative process that intertwines coding and analysis (Creswell, 2007; Merriam, 2001). As represented in the following figure the constant comparative method can be described in four stages, with a description of the stage and its application in this study described concurrently below. The four stages of the constant comparative method are: (1) identifying and comparing data points to other data points to form codes, (2) integrating data points to the broader understanding of the code, (3) clarifying the theoretical findings, and (4) summarizing and writing the findings (Glaser, 1965).

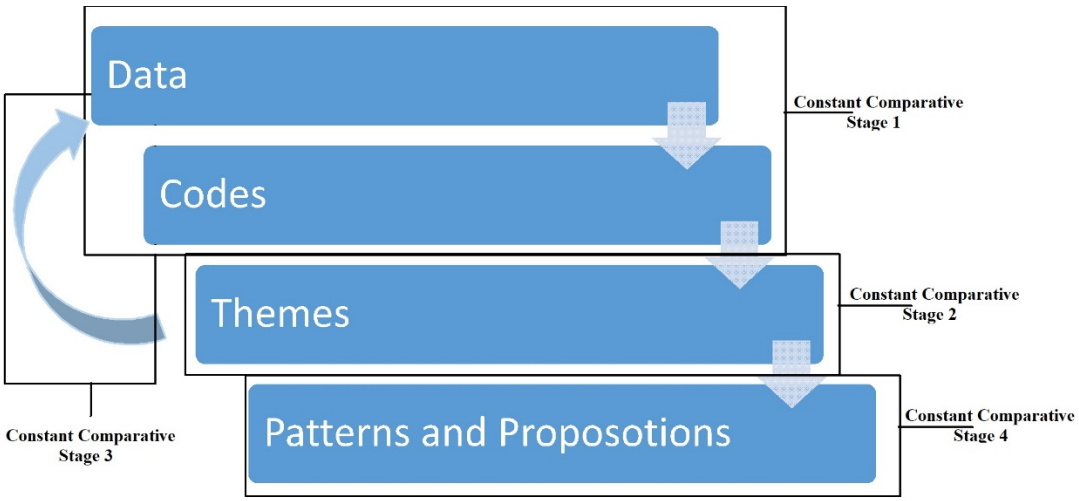

Figure 1 - Model of Constant Comparative Method

As presented in Figure 1, analysis using the constant comparative method progressively moved the findings from data and codes to themes and ultimately patterns and prepositions. Later in this chapter Figure 2 will present an example of one code progressing through the stages.

The purpose of the constant comparative method of concurrent coding and analysis is to generate theory more systematically than allowed by other qualitative procedures by using more explicit coding and analytic procedures (Glaser, 1965). This method was developed in response to sequenced processes of coding and then analyzing where constant redesign and revisiting of theory could delay or even prevent the development of findings. Additionally, the constant comparative method does not forestall the development of theory by adhering completely to the approach that qualitative data should be converted into pseud-quantitative data to test theories, which is designed for provisional testing of hypothesis but not discovery. “In contrast to analytic induction, the constant comparative method is concerned with generating and plausibly

suggesting (not provisionally testing) many properties and hypotheses about a general phenomenon" (Glaser, 1965, 438). Further, no attempt is made to ascertain either the universality or the proof of suggested causes or other properties. Since no proof is involved, the constant comparative method, does not require consideration of all available data as would be expected for analytic induction. All of which is to say, the constant comparative method was applicable to this study because it allowed for an iterative process that refined how Vocation of Life could be understood in a context of undergraduate engineering education and because the objective was generate further knowledge of the phenomenon in question, but not to test an explicit hypothesis.

These incremental stages following the constant comparative method progressively moved the analysis process from data to codes to patterns. The levels of detail for comparison corresponding to data, code, and theme will be described in detail during the subsequent stages of constant comparison. As a very brief foreshadowing, data (i.e. specific words or phrases that are perceived to be noteworthy) is grouped into codes, which are given a name to describe what is included and how it is meaningful for this study. Next, codes are grouped into themes which reflect sets of codes that can be used to address the questions posed within this study.

The ultimate goal of coding and analysis was to respect the native sentiment of the data while also making meaning of both individual pieces of data and larger themes that emerged through the constant comparative process. This process of concurrent coding and analysis allowed for the inherent meaning of the data to guide the development of patterns and the creation of those patterns to inform a more nuanced coding through a structured and phased process of data analysis. The following sections

describe how the four stages of the constant comparative method were employed in this study.

Identifying data points and assigning codes – constant comparative stage 1. Stage 1 of the constant comparative method identifies units of data and assign codes that link units of data to other units of data that seem related. "A unit of data is any meaningful (or potentially meaningful) segment of data…as small as a word a participant uses to describe a feeling or phenomenon or as large as several pages of fields notes describing a particular incident" (Merriam, 2001, p. 179). A unit, which in this dissertation has typically been referred to as either a data point or a piece of data, should meet two criteria: heuristic – it reveals information relevant to the study and stimulates thinking – and is also specific, including "the smallest piece of information about something that can stand by itself" (Lincoln & Guba 1985 in Merriam, 2001, p. 180). Data points should be understandable and interpretable without necessitating supporting information.

Data sources – including interview transcriptions and documents – underwent an initial read as the first in a multi-step process of analysis wherein pieces of data were identified and assigned an initial code or codes. The first round of data coding sought language that described the experience of faculty. Rather than reading with preconceived notions, a close reading of the data was intended to highlight categories developed from what the data itself says. Initially data was coded whenever phrasing in the data either struck the researcher as connected to something (even if the researcher was not sure of the exact connection yet) or felt particularly noteworthy as the researcher encountered it; these were instinctive responses to the data, leading to a larger set of codes than

ultimately contributed to the findings. Whether or not a phrase in the data source became a data point was an instinctive decision made by the researcher.

This first round of coding employed "open coding" (Creswell, 2012; Kvale & Brinkmann, 2009; Maxwell, 2012; Yin, 2013) wherein tentative codes (e.g. "ethics" or "senior design") are assigned to data based on initial impressions of the researcher; some of these codes were also informed by the researcher's knowledge of the topic. For example, "ethics" was an early code both because it was prevalent in the words of the participants but also because the researcher was aware of its inclusion in the ABET Criterion 3 student outcomes. Open coding is not tied to theory but rather focused on what is observed in the data itself, although the researcher is aware of the larger body of literature on the topic. As each data point was identified, it was tagged with a code – a thematic description of the main purpose of that data point; essentially an attempt was made to group by topic the data points that were highlighted by the researcher as important and those groupings become a code. Similarly, to the intuitive process of identifying data point, the initial name given to the code was an intuitive decision made by the researcher. Open coding occurred iteratively with subsequent return visits to data sources.

Naming conventions. Names of codes can originate from the researcher, the participants, or sources beyond the study (Creswell, 2007; Merriam, 2001). These names reflect the purpose of this particular study and are designed to begin answering the research questions. Three criteria were used to create the codes within which data points where grouped.

First, the codes should also be exhaustive such that all data deemed relevant to the study is situated in a code (Merriam, 2001). Codes should also be mutually exclusive such that a piece of data fits into only one code; if the data point seems to fit into more than one then the code or the piece of data needed to be refined. During analysis any data point that was initially coded with more than one code was refined to ideally be exclusively within only one, although the constant comparative method embraces the coding of data points to multiple codes.

Second, it was also important for codes to also be sensitive to what is in the data, which is to say it should be meaningful and telling so that a reader can understand the code and its purpose for the study (Merriam, 2001). This is to say that codes are named intuitively by the researcher based on knowledge of the data points within the code as well as the knowledge of the larger research and the aims of the study. Therefore, these names can be revised as data analysis continues; for example, the cornerstone course at Oxbow College has a distinct course name, which was the initial name for the code that grouped the data points about that course, however as findings were produced and it became clear that the course would typically be referred to generically as "the cornerstone course" the related code was renamed to the generic version.

Third, the codes should be conceptually congruent so that sub-codes with greater level of specificity are situated within codes and all codes at a certain level of the hierarchy have the same level of construction and exactness (Merriam, 2001). As an example, codes about specific Twenty-First Century Skills are at the same level of specificity and the larger categories of technical skills, professional skills, and personal skills are at the same level of specificity, so it would not be appropriate to compare the

individual skill code of ethics to the higher-level category of technical skills. As the coding process progressed the structural relationship of codes was easily modified within NVivo to reflect these developing connections and hierarchy.

Codes – the groupings of data points with those on a similar topic – were given initial names, which were revised as later coded data provided insight into the direction of themes. Some of these names were based upon inductive coding (i.e. meaning being taken from the data) while others were deductive (i.e. meaning was taken based on the literature and theory being employed). For example, deductive codes were created from literature about Twenty-First Century Skills – or competencies that have come to be known as Twenty-First Century Skills – and provided a set of starting codes for the types of student objectives faculty might have described. Additionally, inductive codes were created based on knowledge of Oxbow College and the experience in the interviews, including those that focused on institutional features such as cornerstone and capstone courses. These codes were modified as data analysis progressed to be more closely aligned with the way these concepts existed in this particular data using the language of the data.

Coding was an iterative process in which some codes were renamed, additional codes were created, and sub-codes were created. As coding progressed and connections were made between pieces of data, the working name given to a code might shift to become more inclusive. Eventually sub-codes emerged to be more detailed, such as initial broad coding of comments related to accreditation eventually being differentiated into codes regarding the belief that the student learning outcomes presented by ABET for accreditation were too general in contrast to codes critiquing the process programs must

undertake be reaccredited. Certain pieces of data were initially tagged with multiple codes before ultimately being refined to fit more specific categories. NVivo allowed for the dynamic review of data and coding, which facilitated modifications to the coding as later documents and interviews caused the researcher to refine the codes. The NVivo software allows the researcher to look at all pieces of data identified as belonging to a particular code or to look at a data source highlighted with each code that occurs within the data. This digital dexterity allows the researcher to more readily look across data sources and codes.

Alignment with research questions. During the process of data analysis, the first set of codes were organized based on the research questions, but subsequent analysis and initial findings led to a change in this process. Initially this meant that data related to the definition of a Twenty-First Skill (Research Questions 1 and 2) was segregated from data related to the practice of teaching these skills (Research Questions 3 and 4). Ultimately this data was merged under the code of the skill (which is to say a data point initially coded as being about the practice of teaching could be moved to the code about teamwork if what was described was the practice of teaching teamwork specifically) since many times faculty depictions of teaching towards these skills also provided additional information about how the faculty member was defining the term. In most cases the codes related to context were distinct from codes related to skills, leaving a clear set of codes that addressed Research Question 5.

Development of data themes from codes – constant comparative stage 2. Stage 2 of the constant comparative method is when codes are related to one another and from those comparisons themes are produced. Themes are groups of codes structured in

such a way as to respond to the research questions. The process of producing themes begins with a basic presentation of a descriptive account of the study's discoveries. Codes are grouped together in various configurations to determine which arrangements respond to the various aspects of the guiding research questions. At this point not just were data points linked, but decisions were made about what to include and what to cull out to convey a narrative showing the meaning found from studying this occurrence (Maxwell, 2013; Merriam, 2001). However, analysis should go beyond description to additional layers and levels. The next layer of analysis was to construct categories based on what is implied by the data, beyond the data itself and what the data is saying (Creswell, 2007; Merriam, 2001). As with the identification of pieces of data, the grouping of data points into codes is both systematic and intuitive (Merriam, 2001).

The codes identified in the data were grouped together with seemingly related codes into an initial set of themes. Repeated iterations of grouping the data brought forth three themes – codes related to specific Twenty-First Century Skills, codes related to institutional context, and codes related to ABET accreditation. Within the codes related to Twenty-First Century Skills three sub-themes emerged – codes related to technical skills, codes related to professional skills, and codes related to personal skills. The process of differentiating skills into subgroups was another repeated exercise – as was undertaken to group data points into codes – to determine the most accurate and authentic grouping. Some of these skills, such as "ethics," are applicable to multiple settings, but ultimately they were grouped with other skills that faculty describe using similar contextual markers – that is to say the difference between professional skills and personal skills was

determined based on whether the original data point was framed more often in a capacity related to a career or in a non-career setting.

Closed coding – constant comparative stage 3. Stage 3 of the constant comparative method involves clarifying the theoretical findings through an additional round of coding in which the sources were reviewed again with an eye specifically towards the particular codes related to those patterns to refine and finalize the grouping of data into codes. At this stage of analysis in which patterns were being solidified, each interview and document was reviewed again in its entirety. In contrast to the earlier process of "open coding" the final set of reads through the data could be best described as "closed coding" – codes were assigned or changed based on the existing set of findings to identify any pieces of data that had previously not be connected and to refine the connections between the data points.

As the list of applicable codes had progressed through themes and was approaching the first draft of patterns, this additional round of coding was undertaken in which each data source was read with an eye specifically trained on ensuring the data pieces were attached to the best fit code. During this closed coding process, the data was reviewed with a lens specifically focused on the codes that were contributing to the emerging findings to ensure those codes were exhaustive. In contrast to the open coding where data was identified without preconceived notions, this closed coding was done specifically with the intention of identifying any data not previously highlighted that aligned with one of the previously identified codes that were building towards the study findings. In some cases, data that had previously been part of a different code was reevaluated and recoded based on how the names and definitions of the codes had been

refined over the process of analysis. This additional coding occurred concurrently with the production of a first draft of findings, which allowed the researcher to remain grounded in the data itself while summarizing the data. It also allowed for these summaries to inform decisions about coding with a more defined sense of the codes and patterns than existed during initial open coding.

Developing data patterns from themes – constant comparative stage 4. Stage 4 of the constant comparative method is where findings are summarized. An outline of the emerging themes was produced and discussed as part of peer examination (as described within internal validity below). Through that exercise, the groupings initially considered to be Pattern B (institutional context) and Pattern C (ABET accreditation) were combined under a larger pattern of context that included department, school, and national/disciplinary levels – the latter of which would encompass ABET and national accreditation standards. An initial outline of the findings was produced and shared with members of the dissertation committee as well as being brought for peer examination by the members of the research group of the Higher Education program. The figure below illustrates the example how some data progressed through the four stages of the constant comparative method. The resulting findings, patterns, and prepositions are discussed at length in Chapter IV of this study.

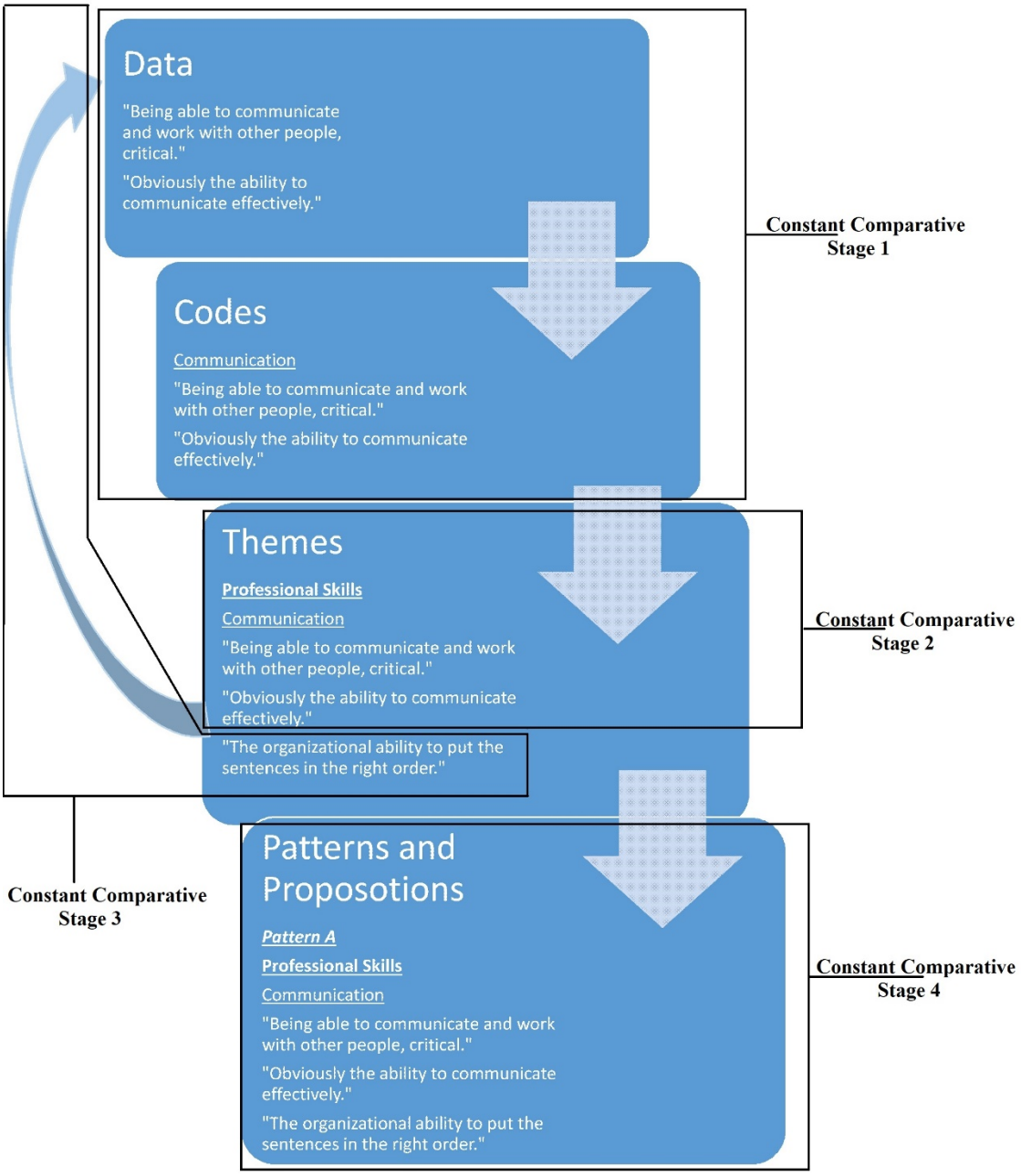

Figure 2 - Example of Data across Constant Comparative Model

As represented in Figure 2, coding and analysis progressed through the four stages of the constant comparative method. In Stage 1 two pieces of data[2] were identified and grouped together under the code "Communication." In Stage 2 that code became part of the "Professional Skills" theme through an iterative process of grouping codes to find the best pattern. In Stage 3 (represented by the arrow from themes back to data) as the set of themes emerged and an additional round of coding began again from data to ensure coverage of the code and accurate coding; in this example a third piece of data is added to the code so that in the blue box labeled "Themes" there are three data points under the Communication code. Finally, in Stage 4 Professional Skills theme became part of Pattern A and was addressed with a Proposition related to the student learning outcomes faculty at Oxbow described.

Code Book

As part of the analysis of the data, the researcher developed a code book to summarize the emerging data. This code book includes both a definition of the code, typically taken from outside the data, along with a sample code illustrating how the code exists within the data itself. Ultimately the code book also came to include an indication of the pattern of the findings with which that code was associated. The complete code book can be found in the appendices of the dissertation.

---

[2] In reality there are many other pieces of data within this theme. For clarity only a few are presented here in the figure as a subset of the process.

Internal Validity

The final important aspect of analysis was ensuring validity – that is to say, the findings should match with reality (Maxwell, 2013; Merriam, 2001). Of course, understanding reality – and accepting a version of what is real – is at the center of qualitative research, although it should be reiterated that by nature qualitative research produces findings that have been filtered through the lens of the participant and the researcher. The French novelist Gustave Flaubert claimed "there is no truth" but rather "there is only perception" and in the case of qualitative research the data itself has likely already reflected the perception of one person (the participant or the author of the document) and the analysis of that data into findings reflects the researcher's perception. To enhance the internal reliability of this study – to produce findings that match reality as closely as possible – this study was mindful of multiple validity strategies (Merriam, 2001), with particular emphasis on the following aspects:

1) Triangulation – using multiple sources of data to confirm emerging findings. Interviews, documents, and field notes have been used to develop holistic understandings.
2) Long-term observations – as the study was conducted over a period of time at one site, the researcher had the opportunity to conduct repeated observations of the institution.
3) Peer examinations –the Teachers College Higher Education program research group members reviewed aspects of this study at various points. Their comments as findings emerged informed the direction of this study.

4) Researcher bias – as will be discussed in greater detail below with regard to researcher positionality, understanding the assumptions a researcher brings to qualitative research as much as possible at the outset and revisiting those understandings as they changed throughout the study helped guide the findings.

Study Limitations

Generalizability

Case study research does not typically lend itself to what would be considered generalizable findings (Mills, Durepos, & Wiebe, 2010). That is to say that case study findings are "generalizable to theoretical propositions and not to populations or universes" (Yin, 2018, p. 21). This study looks at one institution at one location at one particular point in time. Within that, it will include the experiences of only a small proportion of the faculty teaching there. The goal was to select a broad group of participants, but not necessarily for that group to be representative of this School or the larger faculty population.

As described above in the introduction of this methodology, a case study was selected here to improve the understanding of the context, decisions, and reality of this particular situation (Creswell, 2007; Maxwell, 2013; Merriam, 2001; Yin, 2018). The patterns that emerged from this study are reflective of this particular case. In Chapter V, there is a discussion of how these findings may provide valuable insights for reflecting on the theory at the center of this case, for practice in higher education, and for further research. Therefore, while the specifics of this case are very much of interest, the larger

questions including the dynamic nature of faculty practice, the changing purpose of an undergraduate education, the role of assessment and accreditation in higher education, and the vision of John Dewey have applications in areas beyond undergraduate engineering. “Instrumental case study does not permit generalization in a statistical sense; however, it does attempt to identify patterns and themes…[that can illuminate] the transferability of the case findings” (Mills, Durepos, & Wiebe, 2010, p. 469).

The goal here was to understand Twenty-First Century Skills, EC2000, and the Vocation of Life in the experiences of these individuals. This study aims for those findings to allow professors, academic leaders, administrators, policymakers and professional development staff to find connections to their own practice, whether through a greater understanding of how faculty at this school are making meaning of these ideas, through a greater understanding of how institution context is impacting how faculty make meaning, or through new strategies of how to support faculty as they grapple with these ideas.

Validity and Reliability

Interview research is limited in two important ways: firstly, the participants are reflecting on their own experiences rather than those experiences being observed directly by the researchers and secondly, the participants are limited to their own experience of a situation, wherein they might not be aware of larger institutional contexts that shape the work they do. Accordingly, because of the importance in creating accurate data and findings, attempts to minimize the impact of these limitations include the triangulation of multiple data types (faculty interviews, administrator interviews, and document analysis)

as well as the researcher's own ability to observe this school over a prolonged period of time, which increases the validity of findings (Merriam, 1988).

In order to minimize the possibility of bias, multiple types of data were collected and triangulated. Internal validity was sought, but each interview is treated as a distinct understanding rather than a context that can be generalized, even within this case study. The reliability of this study is tied to the researcher's ability to remain focused on the core ideas and not to skew the direction of the study towards the researcher's own perceptions. To minimize the potential impact the researcher had on the study, it was shared at multiple points with the community of scholars at Teachers College and Oxbow College. The dissertation committee, the research group in the Higher Education program, and the Academic Programs team at the engineering school where the researcher works also provided resources to critique and question the choices being made throughout this study.

Researcher Perspective

The researcher's own standpoint – as a student, administrator, and researcher – framed the interest in and approach to this project. The researcher is an alumna of an ABET accredited engineering program and during the time of the study worked managing a program that emphasizes Twenty-First Century skills for engineering students (although the focus there is not on undergraduates nor is that program integrated into current academic coursework). The interpretivist epistemology employed in this study underscored an interest in how the culture and history of this institution shaped the experiences of these individuals just as the culture and history of the institutions where

the researcher studied and worked shape those experiences of purpose (Crotty, 1988 in Gray, 2013). The researcher's experiences give a unique standpoint for addressing these questions, which should be recognized as part of the conversation along with the distinct standpoints of the study participants with whom the researcher in this dialogue.

Chapter Summary

Chapter III presented the methodology of this case study dissertation. It introduced qualitative research and case study design, repeated the research questions, and discussed how data was collected and analyzed. Finally, it discussed how this methodology supported valid and dependable results. Just as the selection of a topic in chapter I and the conceptual framework in chapter II drive this study, the selection of a methodological approach here in Chapter III contributes to the very nature of this study. The qualitative research design, case study method, and interpretivist epistemology reflect the type of information sought in this study to respond to the research questions that guide it. These choices scaffold a study that aimed to understand the experiences of the faculty making meaning of the phenomena of interest to this study and set up a process through which the research questions at hand were addressed. By using Dewey's Vocation of Life this study sought to understand the individual experiences of faculty considering Twenty-First Century skills in their academic teaching of undergraduate engineers within one engineering school at the moment of an ABET accreditation review. Methodological decisions were an important aspect of producing a study to help understand the challenges and opportunities of these faculty and the broader conversations about purpose, specifically as seen in undergraduate engineering education.

Chapter IV presents two patterns from these findings that seek to expand what is known about the nature student learning outcomes in undergraduate engineering as conceptualized by faculty: the skills faculty speak to as important outcomes of their teaching and the contexts that inform those perceptions. Those findings show that engineering faculty are considering a larger set of outcomes than the literature suggests and are impacted by a variety of contexts that their work occurs within. This dissertation concludes in Chapter V with discussions of the implications of the study findings for theory, practice, and further research.

IV – UNDERSTANDING VOCATION OF LIFE

Overview of Chapter

This study began with my interest in exploring what engineering faculty on the front lines in undergraduate classes conceived as the outcomes of their teaching and the factors that influenced those perceptions. Towards that goal I developed a set of research questions that were developed focusing on how faculty described the objectives of their teaching, how they put those ideas into practice in their classrooms, and the institutional contexts that shaped their conceptions. Using faculty and academic leader interviews as well as institutional documents, my findings emerged around two overarching patterns: the first pattern covering the Twenty-First Century Skills that faculty described as the objectives of an Oxbow College undergraduate engineering education (primarily based upon interview data) and the second pattern covering the contexts that shape those objectives for the faculty (based upon both interviews and institutional documents).

Data Patterns and Propositions

Pattern A: Twenty-First Century Skills

Chapter II described "Twenty-First Century Skills" as referring to a range of student learning outcomes beyond what has traditionally been taught in classrooms. That chapter also introduced a single construct – Twenty-First Century Skills – which I use to bridge the divide between hard and soft skills (also referred to as technical and non-technical skills), skills that had previously been conceived as distinct sets of student learning outcomes, potentially developed by students in separate aspects of their curricular or co-curricular learning. Instead, through this dissertation I sought to understand what an engineering school's faculty viewed as the comprehensive set of student learning outcomes for their teaching in undergraduate engineering courses and whether they described a subset or a spectrum of the Twenty-First Century Skills. My research found that engineering faculty emphasized a large number of distinct skills, describing student learning outcomes along three themes: technical, professional, and personal skills.

The pattern described in this section establishes the specific student outcomes faculty emphasized when describing their teaching of undergraduate engineering students, with detailed descriptions of the codes and themes within that pattern, and concluding with a proposition summarizing the pattern. Analysis of the interview data and institutional documents, as described in Chapter III, revealed a set of codes that could be grouped into three themes of student learning outcomes: technical skills, professional skills, and personal skills. While not all faculty members discussed each of these skills,

Pattern A presents the three themes and the key codes within each theme that depict the outcomes described in this case as a whole. These themes are discussed below to further characterize how individuals at Oxbow College conceptualize of the student outcomes they value for their students that faculty have incorporated into their teaching and those they believe Oxbow College as a community values for its students.

Technical skills: "but in the end, we're trying to form people who are optimized relative to what they were when they came in and who are engineers." It was to be expected that engineering faculty would describe teaching towards engineering competencies in their undergraduate engineering courses. In fact, the first theme within the student learning outcomes Oxbow College faculty describe as an intention of their teaching encompasses technical skills, which are the subject or content-related knowledge and competence specific to a specialty – in this case engineering (Cassidy, 2006). Technical skills are those necessary within a particular discipline. These are the industry-specific knowledge and abilities that indicate a level of disciplinary expertise. As an example, in many engineering disciplines a graduate would be expected to be proficient in CAD software (computer-aided design) the way a marketing graduate should know a CRM system (customer relationship management) or an accounting graduate should know a bookkeeping software. These are the hallmarks that indicate one has been trained within the tradition of a specific industry or discipline.

The skills that faculty at Oxbow describe as technical outcomes of their teaching are often close to their very definition of what engineering is or what an engineer does; however, these skills were frequently applicable broadly to engineering rather than being specific to the faculty member's sub-field of engineering. Across the departments

represented in this case study, three specific types of technical skills were predominant in the narratives of faculty and departments: 1) identifying the problem; 2) problem solving; and 3) invent/optimize. Each of these are discussed at length below.

Identifying the problem. Oxbow faculty described the first important technical skill that is an intended outcome of their teaching to be the ability to identify the problem. This first technical skill was finding a problem that needs a solution, which also encompassed the ability evaluate if a problem was worth solving. Faculty conceptualized this in a variety of ways and orientations – identifying the problem can be done through a mindset of finding a problem that needs a solution, but also by finding a need that has not been met. In many cases the description of identifying the problem also included an important component of understanding who the problem impacted and how the solution would improve their situation. Identifying a problem and deciding to solve that problem was not just an assessment of whether a problem could be solved but also if the solution would have sufficient impact to be worth implementing. Faculty described the importance of recognizing that these problems were related to the lives of individuals and that the thoughtful identification of a problem also meant understanding the impact on people of solving or not solving that problem.

Within the skill of identifying the problem, faculty described the skills of recognizing a need, understanding what problems have not yet been addressed or not addressed sufficiently, and the knowledge of where an engineer's skill can be put to use in an impactful way. To contrast this solution-oriented approach, one faculty member described the outdated conception of engineers designing things and then "throwing it over the wall" to a marketing team who would find a use and customers. The version of

identifying a problem described here emphasized utility – it was important to faculty that student learn to make something that people could use, would use, and would perceive as adding value to their lives or the lives of others. Faculty also tied this utility to financial success – the "idea of communicating with the users of what you make is key to financial success for companies. You don't want to make something and then people don't like to use it, then you can't sell it" – but there were also descriptions of a very humanistic reflection – "Is it actually going to solve people's problems? Is it going to make people's problems worse?" – and that concern for humanity was present throughout faculty descriptions of technical skills. In these depictions, identifying the problem also necessitated listening to people and being thoughtful about the individuals who would be directly impacted – positively and negatively – by the decision to address or not address a particular problem in the world.

Faculty outlined the process for identifying a problem to include defining the problem space and boundaries before proceeding, a description that resembles the process for defining and bounding a case that was included in Chapter III of this dissertation. Part of how I described identifying a problem was to describe it as a process of setting up the constraints within which one would work and how those constraints defined the scope of the solution. That scope impacted how an engineer evaluated the feasibility and worthiness of a problem. Identifying a problem was not just seeing the problem, but also considered the consequences – intended and unintended – of the possible solution. As one faculty member said of an engineering education, "the real strength is figuring out what the problem is."

Problem solving. After identifying a problem, the second key technical skill that Oxbow College engineering faculty described as a student learning outcome of their teaching was problem solving, which one faculty member described as the process of getting from problem statement to an answer. This included a process of determining the known and unknown variables as well as the tools an engineering student could apply to the problem they were solving. Finally, faculty also described the importance of verifying any potential solution – a skill that is similar to one emphasized as part of the personal skills theme later in this chapter. In their descriptions of what engineers are trained to do, faculty repeatedly returned to the idea of solving problems, of following through until they get to a solution, and applying all the skills they possess in support of a defined objective. Moving beyond the identification of a problem as the first skill in this theme, solving a problem necessitated getting to a solution.

Oxbow College faculty emphasized this important distinction between identifying and solving a problem: faculty were expecting students to take a problem and remain with it until they had reached a conclusion. Using a baseball analogy to highlight the importance of this skill, one faculty member described: “We’ve got a lot of starting pitchers here, but it’s the closers that are really the valuable ones.” This became one point where faculty described an issue with the ABET student outcomes, which includes: (a) an ability to apply knowledge of mathematics, science, and engineering; (c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability; and (e) an ability to identify, formulate, and solve engineering problems. The same faculty member who provided the baseball pitcher

analogy connected the importance of problem solving, not just problem starting, to ABET outcomes saying, “I wish sometimes that was reflected in here [the ABET 11] a little bit more. It’s not just the starting to solve the problem, or to formulate the problem. That’s important. But also to finish the problem is huge.” Faculty described the importance of applying knowledge (outcome a) and designing systems (outcome c) being incorporated within solving an engineering problem (outcome e); Oxbow faculty emphasized an ability to apply knowledge and using design systems towards solving a problem.

Another important aspect of this skill was the idea that students might need to acquire knowledge or information in order to solve the problem. Students do not need to know how to solve this particular problem when they begin it, but rather students should have learned to acquire new competencies along the way to solve a problem until they are able to produce a solution. Part of learning how to solve problems was structuring the problem and then figuring out the unknowns along the way. As one faculty member described their own experience with such a problem:

> people would look at me and say you don’t know the answer to that question, and the answer is I don’t need to know the answer to the question. It’s just the way you think about how to get from problem statement to an answer.

In these descriptions, an engineer is focused on solving the problem, even if that problem requires the development of new skills or the acquiring of new knowledge.

To characterize the skill of solving a problem, faculty described an ordered process of moving through steps from problem to solution, something they emphasized was hallmark of engineering. When describing the student learning outcome of problem solving, Oxbow faculty also emphasizing the importance of following through to a solution, even if the student needed to acquire new knowledge along the way to arrive

there. A fundamental skill faculty described of engineering education was that students learned to be "oriented at solving problems" beyond just identifying them.

Engineering as inventing and optimizing. After identifying a problem and problem solving, the third student technical skill faculty described as a student learning outcome of their teaching was the recognition of multiple possible solutions to a problem, especially when solutions can be further optimized. Therefore, faculty emphasized that engineering has two aspects, which I have categorized as inventing and optimizing, and students should learn to orient their thinking towards those multiplicity of solution those aspects allow for as possibilities. In the former (inventing) an engineer needs to design something that works, whereas in the latter (optimizing) she would take something previously created and make it better, faster, or more efficient.

The first two student learning outcomes in the technical skills theme described the importance of identifying and seeing a problem through to solution, with one distinction here being that problems have multiple solutions with various impacts and levels of efficiency, such that engineering skills require a student to be able to solve the same problem in different ways and recognize there is not one singular solution to a problem. As an example of this, one faculty member described how after providing students with a solution to an assigned problem they would also "take the same problem and solve it in a different way [because] there is no one singular solution for everything." Faculty emphasized that most of the time as an engineer you are not inventing something brand new but finding ways to apply what you know to improve what exists and that improvement can take many forms depending on what an engineering choses to emphasize.

I refer to this idea as the conception of engineering as inventing and optimizing, but this student learning outcome was described by faculty with various terminology, including references to the engineering design process and engineering design thinking. Design thinking is a concept that refers to the process by which design concepts are developed, which has in recent years been applied to fields such as education and business. Design thinking can be characterized by the importance of aesthetics and functionality in a solution. Among other things, Design Thinking put particular emphasis on an iterative process, something that Oxbow College faculty drew on when describing how an engineering would invent and optimize.

In some instances, faculty connected inventing and optimizing to mathematical modeling and teaching students to produce increasingly more complex – and ideally therefore more accurate – models of systems or components. When approaching an engineering problem that a student wishes to optimize, one method of solving is to model the solution with changes to the fundamental assumptions of the problem – what if there was a different amount of feed or if the amount of product required was different; what if the amount or type of waste was different – because each of these assumptions changes the possible solutions. Computational modeling allows for very rapid consideration of each of these changes. Therefore, educating students on what computation is capable of in the modern era and how better computational capacity would allow them to model things mathematically rather than going into the lab for physical testing has become an increasingly important part of optimizing an engineering solution. Additionally, recognizing the existence of multiple solutions and a comfort with modeling these possibilities using computation allowed for dexterous changes to the assumptions and a

more rapid consideration of a greater number of options. In characterizing engineering as a process of inventing and optimizing, the Oxbow faculty included the need for students to reflect and consider how their own initial approach and solution could be improved during the process of reaching a solution. Faculty emphasized that the engineering design thinking mindset was one that embraced the need to revisit ideas and embrace not just the existence of multiple solutions but how ongoing technical advancements would require repeated revisiting of important problems.

Summary of technical skills. The three student learning outcomes – (1) identifying a problem; (2) problem solving; and (3) engineering as inventing and optimizing – that make up the technical skills theme addressed learning outcomes that engineering faculty described which were tied directly to their conceptions of engineering and the work of engineers. While it was expected that faculty would address these types of student learning outcomes as intentions of their teaching in undergraduate engineering courses, there was an unexpected emphasis on how engineers identified and solved problems in a way that was directly connected to the lives of other people and broader humanity. Their doing this suggested that not only was the set of skills faculty described broadening to include additional themes, which will be described in the subsequent chapter, but that the traditional engineering outcomes have been modified to address the needs of the twenty-first century. Engineering does not occur in a vacuum, and Oxbow College faculty are teaching technical skills informed by the surrounding contexts that will shape the work these students do after graduation as well.

Professional skills: "come to Oxbow if you want a broader, general education where your knowledge of fields other than engineering will become important to you career-wise." Engineering remains distinct from other disciplines because the undergraduate degree in engineering is considered sufficient preparation to enter the profession. As discussed in Chapter II, this is unique in the United States higher education system – engineering is typically spoken about in comparison with medicine and law, which both require graduate level education to enter the procession. At the larger university within which Oxbow College of Engineering is situated, engineering is the only professionalized undergraduate major offered. Therefore, it was likely that engineering faculty would make reference to a set of student learning outcomes for an undergraduate engineering degree that would be categorized as professional skills. Many of these skills are also explicitly referred to in the ABET 11 outcomes. However, the emphasis engineering faculty placed on these outcomes as intentional objectives of their teaching in engineering subject matter courses was somewhat unexpected given that the literature describes engineering faculty as predominantly dismissive of non-technical outcomes with the exceptions being those faculty who recognize the value of these skills but believe them to be the purview of general education requirements elsewhere in a student's curriculum. Instead, the Oxbow faculty discussed incorporating teaching towards professional skills as student learning outcomes in their teaching of engineering in a thoughtful and meaningful way.

The second theme describing the types of student learning outcomes Oxbow College faculty emphasize as intended objectives of their teaching are professional skills. These may best be described as non-engineering specific skills typically associated with

employment and careers, which have often been considered soft skills, because they cannot be intrinsically measured. Four specific professional skills that emerged from the data will be developed in this section: 1) communication; 2) ethics; 3) leadership and teamwork; and 4) knowledge of contemporary issues, which typically went hand-in-hand with a commitment to lifelong learning. Interestingly, all four of these outcomes are included in the ABET 11, although faculty were frequently bringing these skills into the conversation without an explicit connection to ABET and in some cases the description provided by faculty extended beyond the ABET language.

The final theme that will be discussed is "personal skills," which also includes student learning outcomes related to soft skills; I determined whether a skill was grouped in the professional or personal theme based on the context within which faculty describe the skill being used. For example, although communication is also valuable in an individual's personal life, because it was more frequently referred to by faculty with regard to its professional benefit I have included it within the professional theme.

Communication. The first student learning outcome within the professional skills theme is communication. Oxbow faculty emphasized the importance of communication for student success, encompassing written and oral communication in formal and informal settings. Faculty seemed aware of the common narrative that engineers are not considered good communicators and emphasized that in the modern era communication skills required an explicit emphasis within engineering courses. As one faculty member described: "they've got to be able to write, which is sometimes a bit of a weakness with students specifically in the technical areas. Usually they're very good in the mathematics and some of the hard science, but they're not sometimes as good in communicating

verbally and in written skills." Interestingly, despite a majority of faculty members emphasizing the importance of communication skills, some faculty who mentioned it hedged the comment with the perception that they were likely in the minority for focusing on communication skills. One faculty member expressed the belief that they were likely an outlier for declaring strong communication skills an important focus within their engineering courses.

It was particularly noteworthy to me how faculty emphasized that communication skills should be incorporated into engineering courses, not just a product of coursework elsewhere in the curriculum. As I referred to in Chapter II, engineers do take non-engineering courses as part of their requirements, but historically those are in math and science with perhaps an occasional stand-alone English course requirement. Developing "soft skills" like communication, if required at all in the curriculum, was parsed separately from the engineering courses and seen as a distinct skill development. In contrast, Oxbow requires an extensive set of non-technical courses (see "school-level contexts" later in this chapter) and still individual faculty members are going further by personally emphasizing these skills as part of engineering courses. Communication for Oxbow engineering students is required in liberal arts coursework – a requirement not typical of all engineering schools – but the engineering faculty are not satisfied with communication as a distinct skill and are further working to integrate communication skills into their engineering subject matter courses. In some instances, this was done using traditional written and oral presentations, but this also took more creative forms such as blog posts, TedTalks, and one-on-one conversations.

Effective communication is one of the 11 student outcomes emphasized by ABET (outcome g), however the description of communication provided by Oxbow faculty included a detailed characterization of the type of communication that extended beyond ABET's list. (This sentiment is an example of how faculty perceived the ABET 11 student learning outcomes in comparison to their own, which will be discussed at length as part of findings Pattern B.) Additionally, the faculty in this study did not view communication skill development as relegated to discrete portions of the curriculum distinct from disciplinary training; instead many of them described the strategies they have employed within their technical engineering courses to include communication skills. It was meaningful to see not just that communications skills mattered to engineering faculty but that they felt ownership over developing that skill in their students along with technical competencies.

Ethics. The second student learning outcome in the professional skills theme is ethics. While the majority of the faculty in this study explicitly mention "ethics" as an important skill being developed in their students, a number of faculty also addressed this using other terminology – such as fairness, integrity, character, morality, and lawfulness when discussing the importance of developing a student's sense of right and wrong. There were also references to the professional responsibility that faculty perceive to come with the title of engineer (e.g. one faculty said if "someone think[s] of you as an engineer and not just a student…the things that you say and the answers that you give can start to carry some weight and there's ramifications from that"), which was potentially influenced by the ABET list seeing as it calls for professional and ethical responsibility within a single outcome (outcome f). Faculty also felt there were related issues: one

faculty member emphasized presenting the strengths and weaknesses of a conclusion as an important component of ethics while another faculty member described the importance of an engineer really deeply understanding the facts they present as a type of ethical behavior – again tying it to professional responsibility because if the student was going to represent themselves as an expert, then they must be really sure of the work they do.

While considering it an important student learning outcome, faculty also described their struggles with how to teach ethics in their courses, particularly with a goal of going beyond a superficial level. One challenge faculty described was integrating ethics into their course so that it felt organic to students rather than a disconnected addition. Therefore, faculty selected a variety of entry points to the topic: some faculty began with academic integrity (such as plagiarism) and then progressed to parallels in the practice of engineering while other faculty members described using case studies of high profile professional misconduct to illustrate for students the types of ethical quandaries they might face.

In describing the importance of education students to utilize their professional skills responsibly and ethically, one faculty member referenced the cinematic trope of the mad scientist out to destroy all of humanity: "if every engineer [was trained] in a responsible way…this shouldn't happen in the first place…they should be thinking, 'Be more responsible,' instead of, 'I'm going to kill the whole human society." An entertaining visual, it also emphasizes how important faculty find ethics for individual students and for the field of engineering.

The Oxbow College professional development staff, a relatively new group housed within the Office of the Dean tasked with overseeing primarily the required professional development of graduate students but also providing support to undergraduate students and programs, was brought up by a faculty member who referenced that office providing material to faculty and students on this topic – including for the first year cornerstone course and senior capstone projects course. Some faculty referenced working with this office to produce examples of ethical situations in engineering to guide discussions with students. Interestingly, an issue of the Oxbow College magazine published during data collection for this dissertation included a feature on the integration of ethics across the curriculum.

Finally, some faculty emphasized their hope that they personally modeled ethical behavior for students. Faculty described the importance of being sincere with their students, of demonstrating their own commitment towards achieving a goal in the right way, and of approaching all people with fairness as something they hoped their students saw in them. Not only were Oxbow faculty emphasizing the importance of ethics and not only were they committed to personally teaching it within the subject matter courses in engineering, they also took seriously their obligation to behave in ways that modeled ethical behavior for their students.

Leadership and teamwork. The third set of student outcomes within the theme of professional skills is leadership and teamwork. Although these two concepts were coded distinctly in the data, they are considered here as two sides of the same coin. Faculty emphasized the need for students to learn to work with other people, both in a leadership role as well as in a collaborative way. Speaking about leadership, faculty referenced how

leadership cannot occur in a vacuum, but rather leading required bringing others along with you through your ability to influence them. Similarly, depictions of teamwork emphasized the interpersonal nature of engineering work, including the likelihood that teamwork will include conflict, requiring that students must learn to work with people they disagree with or do not like to complete a project. Interestingly, the ABET outcome that described teamwork (outcome d) focuses on multidisciplinary teams; some Oxbow faculty noted that but also emphasized the importance of working on teams even within one's discipline. Faculty also noted the importance of leadership within teams although it is not explicitly called for by ABET in their outcomes.

There was a strong commitment from the faculty to educate leaders in the field of engineering and beyond; they emphasized that the type of student who enrolls in Oxbow and the type of graduate Oxbow produces should not be limited to specific types of roles (faculty referenced back office jobs) but rather should be primed for what one called "visionary leadership." The traditional conception of engineers as relegated to a back office where they designed a widget that someone else would profit from was a sore spot for a few faculty who emphasized the importance of giving engineers the skills to move beyond the back office role if that was what they wanted. Faculty recognized that some graduates would not want front office or executive roles and would flourish remaining on the process side of engineering, but faculty also recognized the importance of providing students the skills to not be limited to only back office roles if they desired something else.

Faculty also reflected on the nature of engineering work as requiring cooperation and described intentionally having students work together in pairs, in small teams, and in

larger teams throughout the curriculum. This included formal teams that were assigned by an instructor as well as informal teams students could develop amongst themselves for assignments (so long as credit was given to their collaborators). Bridging leadership and teamwork, faculty emphasize that the alternative to leadership is not blind followership, but rather participating as an engaged member of the team who can respectfully question authority for the sake of advancing the team's agenda. Faculty depictions of both leadership and teamwork included references to thinking independently regardless of role.

As with ethics, teamwork and leadership were areas about which faculty expressed facing challenges in teaching these ideas; they explained that they have built into the curriculum the opportunities for students to work in teams but that teaching them to work well in teams went beyond simply requiring them to work in teams. For example, one faculty member explained going into great detail with students about how to manage a team (by describing the types of roles that could be assigned and systems that could be put into place to ensure the team was not overly dependent on one member), but still feeling as if she could try to explain the intra-team dynamics of group work to students, but the actual enactment of group work was simply something that she could not control. This instructor felt as if she was teaching students what group work could or should be like, but could not teach group work itself: "you give them those recommendations and sometimes they listen, sometimes they don't." Additionally, the faculty member noted that school projects are not necessarily a strong parallel for workplace teams because the managerial power dynamics are absent from classwork teams. Instead, the students are left to learn the process of working in teams predominantly by working in teams largely

outside the view of their faculty who are aiming to develop good teamwork skills. Therefore, faculty described much of the emphasis being on giving students experience working in teams and providing opportunities to reflect on those experiences in order to facilitate better teamwork through experiential learning.

Knowledge of contemporary issues and commitment to lifelong learning. The fourth set of student learning outcomes within professional skills began to consider learning outcomes beyond the four year undergraduate engineering education where faculty frequently made reference to ensuring students have an awareness of the contemporary issues of their time and instilling in students a commitment to continue developing their knowledge and skillsets as the world around them changes. In some instances, faculty addressed this by highlighting contemporary issues, like global warming, in design projects while other faculty related this to understanding the impact of engineering on the modern world. This could also be coupled with a recognition that contemporary issues will continue to change over time and therefore these students must be committed to remaining current on those issues and developing issues in order to continue their professional development. The ABET 11 includes a number of outcomes on this topic: understanding the impact of engineering on global, economic, environmental, and societal contexts (outcome h); recognition of the need for life-long learning (outcome i); and a knowledge of contemporary issues (outcome j).

One type of reference to this skill faculty emphasized was the need for students to have current knowledge to understand the impact of their work; in some cases, faculty tied this to an ethical responsibility to understand both the factors that impact the student's work but also the ways in which the student's work may impact the

environment around them. One faculty member described living in the modern world as being surrounded by the products of engineers as underscoring the impact engineers could have on the world and the need for engineering students to consider this great potential of their work that could improve or harm the world. Many faculty across engineering disciplines made reference to environmental factors specifically – including global warming and renewable energy – and changing human needs due to advancements in medicine. These faculty wanted to challenge students to think about both the impact on the bottom line and the impact on humanity and the environment due to engineering – an echo of the emphasis faculty described in identifying and solving problems within the technical skills theme.

Additionally, faculty commented on the need to remain current in contemporary knowledge as well as in technical knowledge. Although engineering is perhaps the only remaining profession where you can graduate with an undergraduate degree and be perceived as ready to go directly to industry (as mentioned, at Oxbow College's university it is the only professional undergraduate degree granted), that does not negate the need for learning throughout your career. Harkening back to engineering's historic tradition of apprenticeship training, an undergraduate degree in engineering is meant to provide the fundamentals so that someone can enter the field and gain more experience throughout their career. Faculty also connected this to optimizing and problem solving through statements about the need to continue learning and supplementing the skills already possessed if a project required skills or knowledge the student did not yet have. Addressing both of these points – the need to learn beyond graduation and the need to learn on the job – one faculty described this need by saying, "the idea here is you give

them the fundamentals, you give them the knowledge of the topics that you're expected to know in your field, then they get a job and they get more and more experience." Faculty at Oxbow believe they have taught their students how to approach something new and how to learn, but they also believe they are instilling in students the importance of continued lifelong learning.

Summary of professional skills. The four professional student outcomes – (1) communication; (2) ethics; (3) leadership and followership; and (4) knowledge of contemporary issues and lifelong learning – address the skills faculty directly tied to a student's career success, although not specifically within engineering. These four outcomes all have direct connections to the ABET 11, but in many cases the descriptions of Oxbow faculty extend beyond what ABET has called for and add additional complexity to the outcomes. The connection to the ABET 11 provides a reason why engineering faculty would be aware of these professional skills as important student learning outcomes, but the emphasis by these faculty on teaching these skills within their engineering subject-matter courses demonstrates an unexpected commitment to these outcomes within an engineering context. However, the Oxbow faculty also made reference to the importance of these skills for graduates who may pursue fields other than engineering, but do so with an engineering training.

Personal skills: "teaching…engineering is sort of not the important thing, it's about teaching them about life." Most surprising in speaking with the faculty of Oxbow College was their commitment to the personal development of their students. The commonly accepted narratives of engineers and engineering faculty suggests they shy away from these outcomes. Instead, the faculty at Oxbow described a variety of outcomes

they aimed to develop in their students that were not linked to technical ability or professionalism – a set of skills and competencies that are wholly absent from the ABET 11 outcomes.

This third set of skills Oxbow College faculty describe as an intended outcome of their teaching can be categorized as personal skills, which like professional skills are non-engineering specific. However, these skills are those which contribute to an individual achieving a fulfilling life beyond their specific career. As described in the introduction to professional skills, both the professional and personal skills theme include soft skills, however they have been grouped into themes based on the context within which they were described by the Oxbow faculty. Many depictions of these personal skills are closely linked with the technical and professional skills students are developing simultaneously. Two specific personal skills were described by Oxbow faculty: 1) a "feel for that sort of thing" and 2) confidence.

A "feel for that sort of thing." Faculty at Oxbow describe a number of personal skills which have been grouped here under a heading provided by one faculty member: a "feel for that sort of thing." The first outcome within personal skills, this encompasses the skills of judgement, intuition, creativity, and adaptability. These ideas are all linked together as part of teaching a student to instinctively have a sense of whether something is correct, to approach an unfamiliar problem armed with what they already know, and to call upon the skills and knowledge they already have in appropriate situations. These skills are grouped here because of the descriptions faculty provided of each skill as something that students will eventually be able to just feel.

One example that an Oxbow faculty member described as a feel for something was the ability to look at an estimated answer to a problem and knowing if the order of magnitude[1] made sense. A faculty member described it as an ability to "understand whether a solution makes sense." Faculty also provided an example of students being able to feel appropriate units for a solution. A famous example of units issues was when NASA lost the Mars Climate Orbiter in 1999 because the navigation team used the metric system of millimeters and meters while the team that designed and built the orbiter worked in the English system of inches, feet, and pounds (When NASA Lost a Spacecraft Due to a Metric Math Mistake, 2017). As much as faculty felt the explosion of computational tools, processing power, and resources on the internet was a benefit for students, they also expressed concern that students were becoming reliant on those tools and used them as crutches without being able to feel order of magnitude of units and therefore being blindly reliant on the computational outputs.

Another faculty member specifically pointed towards the online resources as changing the tools a student needed to develop because of the prevalence of resources on the internet; students no longer need to know specific information but rather the skills of how to quickly locate accurate information from the cornucopia of what is available to them. In response to that very modern challenge, faculty are emphasizing more the ability of students to evaluate a solution and determine if it makes sense. When asked how to do

---

[1]Order of magnitude is a classification of size relative to the number of times greater or smaller than the value before – usually a factor of ten as the logarithmic value. As an example, Earth is on average 93 million miles from the Sun, meaning estimates of the distance as 9 million miles and 900 million miles are each off by an order of magnitude.

this, faculty indicated it was repeated practice – the feel for a correct order of magnitude or units becomes intuitive once you have gone through enough problems to make it intuitive. Faculty emphasized the importance of developing these abilities to feel and described that the way to develop these particular feels was by doing.

Confidence. The second student outcome within the personal skills group is confidence. Oxbow faculty described this in a number of ways: students trusting themselves; sureness to approach any problem, including one the student was not familiar with; and comfort to try things. It was also important to faculty that this confidence not be overconfidence, but instead an accurate assessment and a positive regard for your own abilities. Although faculty primarily described confidence outside of the professional sphere (which is why it is part of the personal skills theme), it was also noted that confidence allowed students the self-assurance to apply for jobs outside of engineering and contributed to their success in roles within and beyond engineering. One faculty member described it as a student's belief that they would be successful when trying to "solve some hard quantitative problem, even if [the problem] no longer has to do with engineering."

As faculty described confidence it was related to both problem solving in the technical skills theme as well as the "feel" in personal skills, but it whereas the feel was something that students employed in a way that was outwardly observable, the descriptions of confidence from the Oxbow faculty were primarily about the inwardly trusting of one's self. Although this confidence may be employed when a student is solving a problem or evaluating an answer, confidence faculty described was a more internal, self-reflective feature rather than something externally demonstrable. Regularly

the confidence was about trusting one's self, not having confidence to gain the trust of others. One faculty member went so far as to categorize this as the skill, when applied towards problem solving, that supersedes all others, saying that confidence in quantitative problem solving is the purpose of an engineering education.

Summary of personal skills. Two student learning outcomes – a feel for that sort of thing and confidence – comprise the personal skills theme Oxbow faculty described as important objectives of their teaching. The various competencies within these, including judgement, adaptability, creativity, and intuition along with confidence represent an unexpected emphasis by the engineering faculty on skills that are not specifically related to engineering or professional outcomes. These faculty are illuminating a set of consideration for their students beyond those the literature suggests they would be mindful of for their teaching of disciplinary courses. Their doing so shows that not only have the technical and professional outcomes broadened, but the presence of this third theme of professional skills represents a new domain of student learning outcomes that faculty are choosing to focus on within undergraduate engineering education.

Proposition A: faculty describe intended outcomes of their teaching that span the Twenty-First Century Skills, including technical, professional, and personal skills. The faculty members in this study described a variety of student outcomes they focused on for their teaching: technical skills, professional skills, and personal skills. Recall that Kurshan's initial definition of Twenty-First Century Skills as the range of abilities and competencies that go beyond what has traditionally been taught in the classroom; therefore, the emphasis Oxbow faculty put on these skills as the student learning outcomes of their teaching is particularly noteworthy. Faculty described this

broad set of outcomes as not just important to them in theory or generally important for students of the school, something they focused on in their own teaching within engineering subject matter courses.

Pattern B: Contexts that Inform Undergraduate Engineering Education

The second pattern of this dissertation's findings focuses on the contexts that faculty reference as impacting their conception of student learning outcomes, across the spectrum of Twenty-First Century Skills, for their academic teaching. In this instance, context is defined according to Merriam-Webster as referring to "the interrelated conditions in which something exists or occurs" (Merriam-Webster, n.d.). Context here is an umbrella term encompassing the local and general environments within which the Oxbow faculty work. Analysis of the interview data and institutional documents revealed a set of contexts along three themes: department-level, school-level, and national-level (specifically accreditation). While not all faculty members discussed each of these contexts, Pattern B presents the three themes and key codes within each theme that depict the contexts described in this case as a whole. These themes are discussed below to further characterize the contexts that individuals at Oxbow College describe as relevant to the Twenty-First Century Skills described in Pattern A as the student learning outcomes the faculty taught towards.

Chapter II described the current landscape of assessment and accreditation in higher education as a noteworthy context within which engineering faculty were operating – particularly timely for the site of this study, Oxbow College, had just completed the reaccreditation cycle for ABET (the body that accredits engineering

programs). While ABET did come up in conversation with all faculty, and a review of the ABET 11 student learning outcomes was part of the interview protocol, the faculty's comments on the process, the outcomes, and the larger impact of accreditation went beyond the commonly accepted narratives that faculty are dismissive, if not resentful, of accreditation. Instead, the Oxbow faculty reflected and responded to the ABET 11 outcomes themselves – rather than the process of reaccrediting – in relation to their own student learning outcomes that were described in Pattern A as the first half of this chapter. Additionally, faculty brought up local contexts – at the department and school level – as impacting their perception of the student learning outcomes they valued in their teaching of undergraduate engineering students.

Department-level context. The literature on student persistence in engineering, as well as other fields, emphasizes the importance of connections with faculty and the discipline. While describing the student learning outcomes they intend for their teaching of undergraduate engineering students, faculty at Oxbow College referenced opportunities wherein students became more directly connected to both, highlighting two specific features: 1) involvement of undergraduates with research; and 2) a required senior capstone design project. Both of these are opportunities for undergraduates to engage in a version of engineering practice and closely involve the department's faculty. In those ways they harken back to the apprenticeship model discussed in Chapter II that made the education of American engineers so distinct. The prevalence of attention to these departmental-level contexts by engineering faculty and their recognition of how departmental offerings contribute to the student learning outcomes described in Pattern A

demonstrated a local milieu that faculty perceived as complementary of their own teaching towards those student learning outcomes.

Undergraduate research. The literature on engineering education emphasizes the importance of connecting engineering education to the practice of engineering and not just engineering science (emphasizing the invention and optimization at the core of engineering rather than the application of science principles to technical problems, as described in Chapter II). A number of faculty and all available self-study reports made reference to the benefit of undergraduate research as an opportunity for Oxbow students to further develop the skills faculty emphasized in their courses. Undergraduate research is not a requirement at Oxbow, but opportunities are available in all departments for students throughout their four year degree. One faculty member directly stated that "connecting these students more to research at the early age would be valuable." In multiple data sources, connections were made between undergraduate research and the technical skills developed in the classroom while also highlighting that undergraduate research could be an opportunity to develop the professional and personal skills through their work with graduate students and their exposure to the cutting edge topics in their field.

Participation in research within an engineering department as an undergraduate student was considered by the faculty of Oxbow College as a means to develop a broad variety of skills – technical, professional and personal – relating to all 11 ABET student learning outcomes. In the ABET self-study of one department they explained that undergraduate research contributed to a student's experience through increased knowledge of contemporary issues, experience using modern engineering techniques to

solve real world problems, an appreciation for career path opportunities and the changing nature of engineering, and the opportunity to develop long-lasting relationships with advisors as mentors and with participating industries.

Despite undergraduate research not being required at Oxbow College, the availability of such opportunities is strongly supported in each department represented in this study. Typically, students have the opportunity to conduct undergraduate research work for credit – counting 3 credit units (the equivalent of one course) towards their required department technical electives. Additionally, students who are producing an undergraduate thesis have the opportunity to enroll in additional units of research towards their undergraduate degree requirements. Some of the self-study reports also referenced a school-level program to support summer research (although the research would be conducted within department-level labs) that provided some funding and enrichment opportunities for participating students. Reviewing the publicly available course enrollment data for the ABET accredited programs at Oxbow, participation in departmental research courses varied widely, with the enrollments in research courses representing between 12% and 65% of the declared majors and the centrally sponsored summer research program participation representing approximately 5% of the rising junior and senior classes. Noting that undergraduate research differs because unlike the other contexts not all students are impacted, faculty mentioned this as an important context of the work they did in their academic courses, specifically as an opportunity for students to practice the skills faculty emphasized through their teaching.

Undergraduate research was viewed as not just an opportunity to further develop a student's technical competencies, but also as an opportunity to enhance the broad set of

skills faculty valued. One faculty member explicitly described the importance of connecting research to the engineering education and its relation to developing the Twenty-First Century Skills, further sharing that not only did they encourage undergraduate research for their students but they had found undergraduate research to be such a valuable experience that as the parent of a college applicant they wanted their child to enroll in a program that encouraged undergraduate research. One department described in their self-study the increasing importance of research experience particularly for those students who wish to pursue graduate degrees; graduate study in the field was one of the program educational objectives, along with a career in industry and career in non-engineering fields that require a technical education. This trinity of outcomes: a career in the discipline itself, graduate study in the discipline or a related field, or a career in a related technical (but non-engineering) field were common for the departments represented here. Undergraduate research however was one of the places where faculty connected a context to one specific outcome of the three. The departments at Oxbow have placed an increased emphasis in recent years on augmenting their undergraduate research opportunities in order to support the education of their students, but also with an intentional eye towards how these opportunities support a broader undergraduate education and further an exploration of career paths within and beyond the discipline.

Capstone senior design. The literature on engineering education emphasizes the importance of capstone experiences in preparing engineering students for industry. Therefore, it is not unexpected that engineering faculty would mention the senior design experience in relation to student learning outcomes; however, it is noteworthy that faculty connected the capstone to personal skills as well as technical and professional skills.

All departments at Oxbow College include a capstone senior design experience for their students as part of the curriculum.[2] Although the experience varies somewhat across programs, there are common elements: the students work in teams to produce an engineering project which they present to their faculty (as well as in some cases fellow students and industry advisors). I had the opportunity to attend the senior design showcase at Oxbow and speak with students about their projects, which ranged from poster presentations to displaying the actual products students had created. One department also provided sample senior design project reports for this study that I could review. Recalling my own senior design experience from many years ago, my group in chemical engineering designed a plant to desalinate water while cogenerating enough surplus power to run the plant while a friend in mechanical engineering was part of a group that designed a robot that could compete in the common frat house game colloquially known as "beer pong."

The structure of the senior design experience varies across departments. Within some departments this is a two-semester experience while in others it is focused within one semester. Some departments provide strict criteria for the project topics while other departments allow the students to select their own projects. Each spring students across departments gather to share their projects with the Oxbow community. This is designed in such a way that the students "are supposed to demonstrate that the courses they learned

---

[2] Chapter II included a description of both first year cornerstone and senior year capstone courses as curricular features of engineering programs. It is important to note that while both the first year cornerstone and senior year capstone experience are required of all students at Oxbow, the cornerstone is administered school-wide and therefore discussed within the second theme while the capstone is managed individually within each department and therefore frequently thought of by faculty as purview of the department and included with this first theme of Pattern B.

in their first four years eventually lead to the design of the concept that ideally they came up with" as one faculty member described. Faculty characterized this as a culminating experience not just for the academic curriculum but for the various skills described earlier in this chapter; capstone senior design is where students put their ability to identify and solve a problem together with their ability to communicate and work on teams.

As described in Chapter II, the capstone design project has become a common feature of engineering programs to address the concern that a theory based education was not sufficiently preparing graduates for practice. One faculty member reiterated this perception by explaining that in his department as well as others the capstone experience was where students demonstrated that their coursework led to an ability to undertake engineering design. Approximately half of the faculty in the study explicitly referred to capstone senior design as a place where the competencies and skills students had developed over four years were put on display.

Capstone design is seen as the culmination of a student's engineering education, but departments are mindful of injecting aspects of design throughout the curriculum to prepare students for this final project. The cornerstone design project is discussed at length below as a school-level context, however between those two bookending experiences departments have very thoughtful approaches to preparing students for the greatest level of impact with the capstone senior design. The self-study of one department describes the curricular decision to include "practice oriented coursework" in all four years of the undergraduate experience to lengthen the time students are exposed to formal engineering design. The hope was that this prolonged exposure to design would lead to better learning and retention. Additionally, this would allow for the capstone design to be

explicitly focused on results – not on learning the process of engineering design – and demonstrating the competency students had acquired across their four years at Oxbow College. This serves as an example of how Oxbow departments have intentionally designed their curriculum to build towards the capstone senior design to have the maximum effect as the culmination of a four-year undergraduate engineering degree.

Finally, faculty and the department self-studies made reference to the capstone senior design as being the culmination of not just the technical and professional skills a student developed but also the personal skills faculty valued across the four years of an undergraduate education. For example, the self-study report of one department included a chart showing which ABET a-k outcomes were related to each required course of their curriculum and the senior design course was indicated to related to all 11 student outcomes, including those connected to concepts that have been grouped as technical, professional, and personal skills. (The self-studies of other departments ranged in their assessment with all available self-studies stating their senior design course addressed at least 8 of the ABET 11 outcomes). One Oxbow department explicitly describes senior capstone design as "the most comprehensive way of observing the demonstration of outcomes specified by ABET Criterion 3 (a-k)," declaring that the department views the capstone senior design as a place for students to demonstrate the broad-ranging set of skills valued as outcomes for an undergraduate engineering education, both those codified by ABET and those described by the Oxbow faculty.

Summary of department-level context. Two department-level contexts – undergraduate research and the capstone design experience – were noted by Oxbow faculty as contributing to and supporting the student learning outcomes they aimed to

develop through their teaching of undergraduate engineering students. Faculty described this very local context that influenced their decisions but also provided reinforcement for the work faculty were doing in their classes. Their emphasis of these department-level contexts shows the importance of contexts that support the work faculty are doing to broaden the scope of student learning outcomes for undergraduate engineering education.

School-level context. Chapter II provided a broad summary of the relevant literature on undergraduate engineering education, including the typical curricular structure of engineering programs: students typically spend two years in foundational math and science courses before moving into discipline-specific coursework as upperclassmen. This has frequently been critiqued as disconnecting engineering students from engineering faculty and the practice of engineering – likely two factors that contribute to the attrition of students, especially women and underrepresented minorities (which will be discussed in more detail in Chapter V as a result of the findings presented in this section). In light of this literature, the emphasis faculty at Oxbow College placed on school-level contexts, especially the first year cornerstone course and the liberal arts requirements students primarily complete in their first two years, is especially noteworthy. What I define here as School-level contexts must be recognized as part of the institutional milieu within which Oxbow College of Engineering operates; the curricular decisions made here are possible because Oxbow is a school within a larger university. The school climate within Oxbow is tied to the broader campus climate for the university, however this study is concentrated on the engineering school and conversations with faculty did not reflect a bifurcation that would have led me to separate school and university contexts. In particular the liberal arts requirement is possible because of the

liberal arts college at the university – the membrane separating Oxbow from the university is certainly porous – but the governmental structure of the university is one where the schools are perceived to be mostly self-contained. Faculty repeatedly pointed towards three Oxbow College characteristics (i.e. the school context) as influencing the intended student learning outcomes of their teaching and of a student's four year degree as described in Pattern A: 1) the first year cornerstone experience; 2) the breadth requirements in the liberal arts; 3) Oxbow College's mission and vision statement. There was a belief among the faculty that their individual sense of the purpose of an engineering degree was congruent with the message being conveyed by the senior administration of Oxbow and demonstrated in the school-level context of their teaching.

First year cornerstone course. As described in Chapter II, one of the new components in many engineering curricula is a first year cornerstone design experience. A matching bookend of the senior year capstone, this is a design experience for first year engineering students aimed to provide exposure to what engineers actually do. A major perceived benefit of this course is the connection it provides first year students to the practice of engineering and to engineering faculty – two things that had previously been delayed until junior and senior years. Additionally, Chapter II highlighted research by Dym, Agogino, Eris, Frey, & Leifer as well as Smith, Sheppard, Johnson, & Johnson that found design-based courses, as with other pedagogies of engagement, are seen to increase academic success – in large part because of the increased connection among students as well as between students and faculty.

All first year students at Oxbow – who have enrolled in an engineering school but who have not yet declared a major within engineering – enroll in a first year course to

familiarize them with the fundamentals of engineering. Faculty described that course as the foundation of the competencies that students develop later in their programs. In addition to weekly instruction, students worked in teams on engineering projects designed by faculty from the various engineering disciplines to provide some introduction to the school's majors. A faculty member described this particular course as "quintessentially Oxbow" because of its emphasis on engineering within a larger context. Faculty across departments pointed to this as a place where Oxbow College's values are instilled in students early on, with one faculty member calling it "a really Oxbow engineering course" because of the unique view of engineering and engineering education emphasized in the course. Along with the department-led capstone senior design project described in the previous theme, the cornerstone course serves as one of the bookending experience for the Oxbow curriculum.

The first year cornerstone course at Oxbow College also serves to transition students from high school to an undergraduate engineering education, and as such serves as the introduction to the student outcomes the faculty of Oxbow College value and emphasize across the curriculum. The syllabus for the cornerstone course describes the course as: "our way of welcoming you to Oxbow and to the profession of engineering." It further states that in this course the fundamental concepts of science and mathematics learned in high school will be used to demonstrate how new things are created within engineering. Beyond that, the syllabus also indicates the course will consider legal, business, social, and ethical implications of engineering.

Faculty point towards this course as establishing early on Oxbow's vision of engineering and communicating that vision to students (a vision that will be discussed a

length as the third component of the school-level context). Recalling the technical and professional competencies faculty described as important skills to develop as an undergraduate engineer, the self-study of one department described the first year cornerstone course as the place where many students receive their first exposure to the profession of engineering. That self-study went further in saying that the course sets the tone for the four year experience and introduces early on the idea that engineering must solve design problems. In fact, the first year cornerstone is also referred to as the first year engineering design course, emphasizing the importance of engineering design as fundamental to engineering and an Oxbow College education. Oxbow has a clearly defined perspective on both engineering and the type of engineers it graduates, a perspective to which students are exposed starting with their first year cornerstone course.

Liberal arts requirements. The discussion in Chapter II notes that it is typical for undergraduate engineering programs to require first and second year students to enroll in foundational math and science courses such as calculus and physics. The modal engineering curriculum is very hierarchical, and students typically complete these foundational courses before being asked to apply that knowledge in engineering coursework. While this kind of pure math and science preparation is common at many engineering schools, Oxbow has additionally required liberal arts courses in writing, literature and philosophy, and the arts. In total, the required liberal arts coursework for an engineering student at Oxbow College accounts for approximately 20% of a student's total number of courses.

When describing the case of Oxbow College in Chapters 1 and 2, it was noted that this school of engineering is situated within a larger research university. Chapter II also described how early engineering programs frequently involved students enrolling in a liberal arts college for two years to complete foundational course work before beginning engineering training in earnest. The inclusion of these liberal arts courses for Oxbow engineering undergraduates reflects both of these points – the engineering students, although enrolled in the engineering school for all four years – take an extensive portion of their courses at the liberals arts college of the university during the first half of their undergraduate experience. These courses are taught by the faculty of the liberal arts college and enroll both engineering and liberal arts students. These are not courses specifically intended for the engineering students (this is not "English for Engineers" in the vein of "Physics for Poets") but rather the general course offerings of the liberal arts college that engineering students enroll in through a cross-registration process.

This extensive non-engineering requirement is one aspect that makes Oxbow distinct, something faculty who were educated at other institutions are often surprised by when they arrive. One faculty member recalled initially questioning why nearly two full years of an engineering education would be focused on this, but having learned more the faculty member described not just understanding but appreciating and liking the curricular structure. The faculty member likened it to an engineer earning a PhD, which is a doctor of philosophy:

> talking to a lot of…very successful engineers, I realize they have lot of training in humanities…like a PhD…you have to think where some of the philosophical thinking is not narrow minded. This the engineering.

This faculty member described the realization that rather than detracting from the engineering education, the liberal arts courses broadened a student's engineering training.

When describing this requirement in their self-study that one department aligned it with the ABET student outcomes f-j[3] stating that it give students a broad education to help define their social and professional responsibilities. Describing the curricular structure in their self-study, that same department stated that the two years of arts and sciences training are a unique strength designed to provide an "unparalleled foundation for engineering students to function in the workforce," emphasizing the broad set of Twenty-First Century Skills that faculty described.

Half of the faculty interviewed made explicitly reference to the liberal arts requirements while others spoke to institutional culture in a way that alluded to this requirement even if they did not explicitly mention it by name through comments such as, "we're convinced that our students are getting as good of a technical education as any place in the country. But we also think that non-technical aspect is much better than most engineers would have." Faculty had varied responses to the requirement itself, ranging from strong support to criticisms that these courses take students away from their core competencies in engineering, but faculty were in agreement that the requirement has a profound influence on the skills Oxbow students develop as part of their undergraduate education.

---

[3] As a reminder, those outcomes are (f) An understanding of professional and ethical responsibility; (g) An ability to communicate effectively; (h) The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context; (i) A recognition of the need for, and an ability to engage in, life-long learning; and (j) A knowledge of contemporary issues.

Mission and vision statements. The third school-level context faculty at Oxbow described – and one I found surprisingly promising – was the influence of the Oxbow College mission and vision statements on how faculty conceived and implemented the student learning outcomes they emphasized in their teaching of undergraduate engineering courses. Sentiments about college and university mission statements are mixed, with perceptions ranging from an important aspect of institutional success to "rhetorical pyrotechnics" of no consequence (Morphew & Hartley, 2006, p. 456), and yet faculty repeatedly pointed towards the Oxbow College mission and vision statements (revised within the last five years) as a guiding principle for the school. As one faculty member described, "in a very succinct matter [it] captures the motivation and captures the reason to do this. Not how do you do it, but why do you do it" These statements have created impact across the curricular and co-curricular experience. Therefore, while this may not be common across institutions, the mission and vision of Oxbow College was a predominant aspect of school culture referenced by faculty. The mission and vision statements of Oxbow College are found in a number of prominent locations: they are featured extensively on the School's website, they have routinely been the themes of presentations by members of the Dean's Office staff – including the Dean – on campus and on the road, and Oxbow launched a series of faculty talks focused around the main concepts contained within the mission and vision statements. There is a significant amount of recognition at Oxbow of the mission and visions statements as a component of the school milieu.

The Oxbow College mission and vision have two predominant themes: empowering students to become tomorrow's technology leaders and a commitment to

graduating engineering leaders who will do good in the world. The first part, empowering students to become tomorrow's technology leaders, expresses a vision that incorporates the kind of diverse skills faculty describe as the purpose of their teaching. Many faculty referred to the mission and/or the vision as a guiding principle for their own set of student outcomes saying it succinctly captures the motivation of their work – not how they do it but why they do it. Faculty appreciated that this vision stemmed from the leadership of the school and was resonant throughout the institution, in both curricular and co-curricular opportunities and priorities. The second theme of Oxbow College's mission and vision statements - a commitment to graduating engineering leaders who will do good in the world – expresses something faculty describe as a driving force behind their own intended learning outcomes. As one faculty member described, Oxbow has branded itself with the vision that engineers work for the greater good – an echo of what faculty described as how to identify a problem worth solving. The School's website states an optimistic vision for the role of engineering in society to address the challenges facing the world. There is a sense within the faculty that the ship is being steered from the very top in a specific direction, one faculty have expressed a commitment to support through their teaching within individual courses and across the curriculum.

Summary of school-level context. The literature on engineering education described the common curricular structure, including the historic inclusion of foundational math and science as well as the more recent addition of a first year cornerstone experience. While describing the student learning outcomes they intend of their teaching of undergraduate engineering students, faculty at Oxbow College referenced both of these features as well as the school mission/vision as impacting their

work in teaching towards these outcomes. The prevalence of attention to these school-level contexts by engineering faculty and their recognition of how the larger school context contributes to the student learning outcomes described in Pattern A show an environment that faculty perceive as complementary to their teaching towards those broad student learning outcomes.

National-level context/ABET. As described in Chapter II, the modern higher education landscape is seeing increased emphasis on assessment and accreditation. (Chapter II also specifically discussed the development of engineering accreditation and the recent shift in response to various critiques.) Therefore, it is not surprising that ABET, the accrediting body for engineering and technology programs, was a common topic of conversation during interviews. What was noteworthy was that these conversations extended beyond the common narrative of faculty expressing frustration with the mechanics and process of an accreditation review. Instead, the faculty of Oxbow shared insights into how the ABET 11 student learning outcomes included in Criterion 3 compared and contrasted with their own conceptions of the important student learning outcomes (those described in Pattern A of this chapter). As discussed in Chapter II, it has become increasingly possible for faculty to critique ABET and the ability of Oxbow faculty to comment on the ABET Criterion 3 outcomes in this way reflects the privileged position of Oxbow as a top engineering school.[4] When considering ABET's outcomes in conversation with their own ideas about the Twenty-First Century Skills, there were three

---

[4] I noted in Chapter II that the faculty of EECS at Berkeley went so far as to not pursue ABET reaccreditation – an option I believe reflects the same faculty agency seen here exhibited by the Oxbow faculty resulting from the privileged position of both institutions.

general themes: 1) the ABET outcomes are too general; 2) the ABET outcomes represent a minimum standard rather than an aspirational goal; and 3) the ABET outcomes represent skills and competencies faculty were emphasizing regardless.

Too general. The first type of observation faculty provided within the ABET theme was that while faculty did not typically disagree with the ABET 11 outcomes themselves, ABET's outcomes were viewed as too general when compared with faculty's conceptions of the outcomes they believed were important. Faculty repeatedly described the ABET outcomes as "vague," and "generic." Faculty were not dismissive of the outcomes, but rather expressed that the outcomes did not go far enough.

Some faculty expressed their concern about the generic nature of the ABET 11 by commenting that the standards were not disciplinary specific. For example, the outcomes call for knowledge of math and science, but do not specify what kinds of math and science. Similarly, there were comments that the ABET 11 list is intentionally broad enough to apply to all engineering disciplines and therefore excludes the specific technical competencies within that major – for example in my discipline of chemical engineering all students would be expected to know thermodynamics, but ABET's list generally calls for the ability to apply knowledge of mathematics, science, and engineering without specifying the kind of math, science, and engineering skill a student should possess. Instead, the ABET outcome could have said "an ability to apply knowledge of mathematics, science, and engineering to the relevant problems of the discipline" but without such a clarification it leaves the type of knowledge required vague.

Other faculty commented that the ABET list was vague enough that it was not even necessarily specific to engineering, but that these competencies largely could – and perhaps should – be applicable to any college graduate. When describing the ABET 11 outcomes, one faculty member said, “they shouldn’t be unique to engineers.” Faculty also critiqued that the generality of the items made them appear redundant (making it noteworthy that for the year after Oxbow’s review ABET revised and condensed their list seven outcomes).

One faculty member did note that the generality of ABET’s list made it easier for the program to respond during reaccreditation. Faculty felt they were better able to demonstrate to ABET that they were addressing these criteria than if ABET had been more specific in their requirements. Multiple faculty members stated the ABET 11 were not necessarily at the forefront of their minds when developing their curriculum, but that the ABET outcomes were both aligned enough with what Oxbow faculty valued and simultaneously broad enough that connections could be shown even if those connections were not the result of ABET impacting a faculty member’s decisions about what they conceived of as the outcomes of their teaching. One faculty member stated that Oxbow has found an efficient way of satisfying the criteria in part because the ABET 11 were sufficiently general so that “none of them are so offensive to [Oxbow faculty] in terms of educational outcomes that [they] are opposed to them.”

Faculty members stated definitively that they found the ABET 11 outcomes too general in comparison to their own expectations. They did not take issue with the ABET outcomes, but rather expressed they would prefer the ABET outcomes be more specific or they felt their own specific outcomes superseded those from ABET in a way that

rendered the ABET outcomes unnecessary. Importantly, this generality of the ABET outcomes, with more specific versions originating from the faculty in this study, did allow for the faculty's outcomes to appear to respond to the ABET outcomes during the accreditation review because they were generally aligned, even if the Oxbow perspective was more specific.

Minimum standards. The second type of comment faculty provided within the ABET theme was that ABET's list reflected a set of minimum standards rather than an aspirational goal. A handful of faculty – and perhaps it is noteworthy that these were some of the most senior faculty who participate in the study and those with extensive accreditation involvement – noted this was largely their view of accreditation: the process was designed to ensure everyone participating met the minimum standard for accreditation, but accreditation was not designed to elevate beyond that threshold. Admittedly, ABET itself describes the value of accreditation as "proof that a collegiate program has met standards" and describing those graduates as having "a solid educational foundation." As discussed in Chapter II, accreditation today is frequently spoken of in conversation with accountability and assessment – though the three are seen as having very different intentions. The quotation cited earlier in this dissertation from Roger Peters in *Accountability and the End(s) of Higher Education* referenced those differences: "The spirit of assessment requires a diligent search for bad news, but accountability encourages the opposite" (Peters, 1994, p. 23 cited in Volkwein, 2010, p. 4). The comments from these faculty reflect a view that the ABET standards existed at a level for which they were simply avoiding bad news rather than striving for good news.

Faculty understood the need for ABET to ensure a common level of competency and uniformity across engineering schools nationally, but felt that holding up this list as the student outcomes without emphasizing a desire to go beyond was insufficient compared to their own perception of what Oxbow graduates should be equipped to do. Instead, ABET was seen as existing to enforce the minimum standards. While this function provided ABET the ability to tell industry that they are enforcing a level of uniformity across engineering programs, it does not serve a school like Oxbow College where faculty believe the institutional expectations surpass those of ABET.

The faculty at Oxbow, perhaps recognizing the privileged place of being a top-tier engineering school, expressed a belief that more should be expected not just of them as faculty but of their students.

> There's nothing wrong with ABETs student outcomes. I think this more tends to be...the lowest common denominator, right? This is the minimum of what's expected. But, that's the fallacy of accreditation. It's meant to be a minimum standard. Not necessarily an aspirational goal. There's no leadership qualities on here, there's no independence on here. Our students…want to identify the world's problems [and] solve those problems…

Faculty understood the purpose of ABET and accreditation to ensure that programs across schools are achieving a minimum standard, but for faculty who had demonstrated their commitment not just in teaching the undergraduate curriculum, but through extensive involvement with the Oxbow ABET accreditation, they sought higher level incentives than the enforcement of minimum standards.

"We're doing it anyway." Finally, the third type of comment within the ABET theme describes how faculty at Oxbow expressed they would be emphasizing the same important outcomes regardless of the ABET list and in essence they were doing this

anyway. In some cases, faculty referenced other reasons they emphasize specific outcomes – feedback from employers, their own educational experience, their conception of what engineering is, or the institutional culture of Oxbow – but that alignment with ABET was unintentional. This does not mean the faculty were dismissive of ABET or their outcomes, but rather found the overlaps benignly serendipitous.

Half the faculty in the study expressed that the list of ABET outcomes reflected things they were doing anyway and would be doing without the added burden of the ABET process; interestingly only one faculty member described the ABET outcomes as both minimum standards and something they were doing anyway, meaning these two groups combined represent a strong majority of the participants. The two concepts appear aligned, but have an important, but nuanced difference: the claim that ABET outcomes are a minimum standard (as with the claim that the ABET 11 outcomes are too general) is a critique of how the outcomes were conceptualized – it is a critique of the scope and scale of the outcomes (although I have noted not a rejection of the ABET 11 outcomes themselves; they are not wrong, but simply insufficient). In contrast, the faculty perception that the ABET 11 outcomes are things they would are doing anyway is an evaluation of the impact – or lack of impact – the ABET outcomes had on the faculty conceptions. In the first claim faculty stated the ABET outcomes were too general with their own outcomes being more specific and in the second claim the faculty labeled the ABET outcomes as minimum standards with their own outcomes surpassing ABET's; in this claim the faculty are describing the inconsequentiality of the ABET outcomes to their endeavors.

As with the sentiment that the minimum standards of ABET were not sufficient encouragement for faculty, those faculty who would be doing this anyway did not feel the ABET list – minimum standards or not – provided any motivation if one was not already committed to these goals. Compared with those who felt ABET reflected minimum standard, those who said they would be doing this anyway were less likely to express displeasure with ABET's list, but similarly seemed to find it irrelevant to choices for their work. Faculty descriptions of the overlap between the outcomes they would be focused on anyway with those desired by ABET suggested it little more than a fortuitous alignment. One faculty member provided an analogy that the ABET outcomes were like a stair railing in that it helps one to get up a staircase you were planning to climb anyway, but is not the reason you are climbing the stairs. Similarly, the ABET outcomes were compared to weight loss advice, in that someone only pays attention to it if they are already committed to reaching the outcome:

> if you were going to lose weight, you might want to have some rules up on the wall to help you. And if you don't want to lose weight, or you don't need to lose weight, you won't pay much attention to it. Or if you episodically decide to lose weight, you can look on the wall and see what it says to do, and do it for a couple of weeks, and it's better than nothing.

This comment relates to the faculty feedback that the standards are too general and minimum standards as well as the feedback that faculty would do this anyway, because in all three cases faculty believe that Oxbow was already so consciously committed to developing these kinds of skills in their students that the ABET standards were not an influencing factor. The common refrain from faculty regarding the ABET outcomes simply that they were doing this anyway.

Summary of national context. The literature on accreditation paints a picture of faculty frustrated by a burdensome process. While the faculty at Oxbow College did express some of that perception, they also provided commentary on the ABET 11 student learning outcomes themselves, emphasizing that compared with their own outcomes as codified in Pattern A of this chapter, the ABET 11 were: 1) too general; 2) minimum standards; and 3) what they were doing anyway. This insight into the outcomes themselves rather than the process provides an important perspective on the objectives of accreditation rather than the process of complying.

Proposition B: faculty describe student learning outcomes within a set of department, school, and national contexts that impact their conceptions of important student outcomes in a variety of ways. The faculty members in this study described a variety of contexts that impact the development of Twenty-First Century Skills through the teaching of undergraduate engineering courses. The contexts included those at the department, school, and national levels. It was especially noteworthy that the responses to ABET did not emphasize the commonly accepted narrative of faculty distain for accreditation, but rather reflected a thoughtful response to the process as well as the details of the ABET student outcomes codified in Criterion 3.

Chapter Summary

This chapter presented the findings of this study summarized within two patterns that included the set of Twenty-First Century Skills faculty described as intended outcomes of their teaching and the descriptions of the contexts that impacted these outcomes. These findings are situated in conversation with the literature on engineering

education described in Chapter II. In Chapter V, I present the implications of these findings for theory, practice, and future research.

V – GOING BEYOND: THE IMPLICATIONS OF TEACHING TOWARDS THE VOCATION OF LIFE

Chapter Overview

In Chapter I, I stated that the aim of this study was to contribute to an understanding of purpose in engineering higher education by examining the various intended outcomes for undergraduate engineering courses through a case study of one engineering school at the completion of an accreditation cycle. Next Chapter II set up the landscape within which this work occurred and highlighted the current gap in understanding how engineering faculty on the front lines of teaching undergraduates conceptualized the student learning outcomes for their teaching. In Chapter III, I described the single-site case study at Oxbow College where I investigated how these ideas were shaped for one group of faculty and the resulting student learning outcomes they specifically valued as well as the contexts that shaped those conceptions. Finally Chapter IV presented the findings of that study as closely as possible to the actual data

towards two propositions: Proposition A postulates that faculty describe intended outcomes of their teaching undergraduate engineering students in a way that includes a set of skills including technical, professional, and personal skills that covers the breadth of Twenty-First Century Skills; Proposition B puts forth the set of contexts faculty describe for doing this work, including department-level, school-level, and national-level effects.

In this concluding chapter, Chapter V, I take a step back to discuss how meaning can be made of those findings by situating them side-by-side with the issues of higher education, and specifically those of engineering education, presented throughout this dissertation. Firstly, I situate the findings in the context of Oxbow College and then I addresses three specific areas of implications: theory, practice, and further research.

Findings in the Context of Oxbow College

The United States has a STEM education attainment problem. Engineering education specifically faces three major challenges: 1) student interest in an engineering education; 2) persistence in engineering education for all students; 3) attainment of engineering degrees by a diverse set of students representing the broader national population. My study will not magically fix these problems; there are deep-seated issues of academic culture that will require substantial efforts to change. However, what my study has done is highlight an example of an institution that is operating differently from the perception of engineering schools described in the literature review and from that individual experience we can take away lessons and opportunities to begin changing engineering and STEM education in the United States. Most noteworthy, the faculty at

Oxbow College speak directly to a set of student learning outcomes including technical and non-technical (professional and personal) skills they are teaching towards in their disciplinary engineering courses. In doing so, they are expanding the idea of what an engineering education does and what it intends to do. The purpose of an undergraduate engineering education at Oxbow College, as described by its faculty, is to prepare students for all aspects of their lives after graduation. I believe this to be noteworthy because it provides insight into what these engineering faculty perceive as important in their courses; I believe this to be meaningful for engineering education and higher education more broadly because these faculty are demonstrating a shift away from the historical divide between professional and liberal education, because these faculty are an example of the broadening of student learning outcomes that has implications for how we calculate the return on investment of a college education, and because by emphasizing more than just their disciplinary content these faculty are illustrating a larger societal change regarding the role and purpose of higher education.

The Specific Case of Oxbow College

There are a number of commonly accepted narratives about engineers and engineering education to which the data shows the faculty of Oxbow College do not conform. First and foremost, these faculty value a broad set of student learning outcomes – technical, professional, and personal – as the product of their teaching. They are not dismissive of non-technical competencies, they are not acknowledging professional and personal skills but relegating them to other parts of the curriculum, and they are not accepting these skills as important but insisting they be the purview of liberal arts faculty;

rather the Oxbow College faculty described technical, professional, and personal skills that they themselves value as student learning outcomes of their teaching and ideas that they are teaching towards within subject-matter focused undergraduate engineering courses. At the crux of this dissertation's findings is a group of faculty who are unequivocally furthering two views of engineering education: (1) an engineering education is more than a vocational preparation for engineering jobs exclusively; and (2) an engineering education prepares graduates to work in service of improving the world for society through whatever profession they enter. These two objectives are being addressed not in the engineering curriculum overall, but within the disciplinary teaching; it might have been interesting enough if the faculty of Oxbow College described their graduates as being prepared for a broader set of vocations because of things that had been added beyond the disciplinary education, but beyond that they have sought ways to integrate these ideas into the very center of an engineering education – the disciplinary courses. The Oxbow College faculty have outlined a variety of outcomes – ranging from problem solving to communication to confidence – which they aim to install in their students not just at the end of a four-year engineering degree but as a valuable component of subject matter learning in the engineering disciplines. These findings, here situated within the larger landscape of engineering education in the United States, also provide implications for theory, practice, and research.

Student Interest in Engineering Education

The first broader theme to put these findings into perspective is student interest in pursuing an engineering education. Multiple surveys of the broader population

demonstrate the disconnection between the perception of engineering held by the general population and what is described by engineers themselves, illustrating a need to better communicate the reality of an engineering education in today's world. A 2016 poll found 90 percent of parents of children under 18 would encourage their children to pursue a STEM career with engineering being the top desired career, even edging out medicine (ASQ, 2016). A Microsoft (2011) study a few years earlier found similar sentiments regarding the perceived importance of STEM to parents and students, but also found a significant gender gap in the motivation of students for pursuing a STEM degree: "male students were more likely to pursue STEM because they have always enjoyed playing with games and toys, reading books, and participating in clubs focused on their chosen subject areas (51 percent versus 35 percent of females)" while "female students were more likely to say they chose STEM to make a difference (49 percent versus 34 percent of males)" (Microsoft, 2011, para. 22-23). This finding becomes increasingly concerning for engineering education in light of survey findings that the most common reasoning physicians give for pursuing medicine is that they wanted to help people while an engineer's most common response is an aptitude or affinity for math and science – "it is easy to see why many young people don't see a future in a profession perceived as isolating and lacking in social relevance. Indeed, in engineering disciplines where social relevance is manifest, such an environmental or biomedical, women are well-represented" (Grasso, 2002, p. 76). If women pursuing an engineering degree are specifically seeking that social relevance, and potentially only perceiving it in specific engineering disciplines, it is possible this disconnect is contributing to the disproportionate leakage of women in the engineering pipeline. By better communicating

the social relevance of engineering, something the Oxbow faculty spoke of repeatedly, there is both an opportunity to increase the retention of students who begin engineering degrees and to reach additional potential engineers.

During my time with the Oxbow faculty, I gained two insights that I related to issues of engineering interest: 1) vision setting at schools of engineering needs to include technical competencies beyond engineering industry outcomes and 2) the need to further the movement to integrate engineering thinking into primary and secondary education. I spoke at length in Chapter IV about the mission and vision statements of Oxbow College and particularly how faculty pointed to those as guiding beacons for their conceptions of the student learning outcomes they valued in their teaching of undergraduate engineers. I also gave a nod to the literature broadly that has raised questions about the impact and influence of mission statements in higher education, but at this institution the finding was clear that an aspirational vision can unify the faculty behind such a motivation. My perception was that the vision statement at Oxbow was not empty rhetoric, but a call to arms for the faculty to educate technological leaders who would do good in the world – exactly the vision of engineering that needs to be conveyed. I found it particularly noteworthy that the program objectives I encountered across Oxbow's departments included the goal of educating students for success in industry as engineers or in graduate engineering study, but also explicitly noted the objective of training students to utilize their engineering education even in fields outside the discipline of their degree.

Secondly, although it ultimately was outside the scope of this dissertation, I learned through my conversations with faculty about the efforts at Oxbow to integrate engineering design and entrepreneurship into K-12 education. My conversations with

faculty about engineering as centrally about identifying and solving problems along with learning about the programs at Oxbow to connect the resources of this leading engineering school to local K-12 schools highlighted a faculty committed to this education for their students and they broader community. The statements Oxbow faculty made about living in a world in which we are surrounded by the products of engineers underlines the importance of expanding understanding of engineering to students of all ages. The social relevance and societal benefit of an engineering degree seems so obvious to the faculty of Oxbow College. Communicating that vision of engineering and engineering education to the broader population, and particularly to the High School students making decisions about their future degrees and careers, is imperative to developing the technical workforce of this country. Even if those students ultimately undertake careers outside engineering, this education will have produced a workforce that is broadly more technically competent and better able to address the new challenges related to technology.

Persistence in Engineering Education

The second broad theme for engineering education as one of the STEM disciplines is that of persistence for the students who do enroll in such degree programs. Merely increasing the retention of STEM majors from 40% to 50% would generate three quarters of the targeted 1 million additional STEM degrees President Obama's commission called for in 2012. This has resulted in more attention recently to the introductory level courses in STEM – those that have traditionally been thought of as the gatekeeper or weed-out courses (Chubin, May, & Babco, 2005). These introductory

courses typically occur in the first year of college, a transition point when students are more likely to either change their major or leave higher education; improving the experience in these courses specifically experience could make a substantial difference in persistence. As evidence of this importance, the NSF has undertaken initiatives specifically focused on introductory STEM courses but there is vast recognition that changing such deep-seated academic culture will require substantial efforts. Faculty still perceive research to be valued over teaching with few incentives for excellence in the classroom (Mervis, 2009). There has been movement to counterbalance the weight given to research versus teaching with efforts like those at NSF, which requires funding proposals for the CAREER Award to indicate not just how the award would advance the faculty member's research agenda but also how the faculty member utilize the award for their teaching; these efforts reflect a perception that faculty should be rewarded for both contributing to cutting-edge research and the development of the STEM workforce through enhanced teaching. However, faculty are mindful of what is valued, particularly within the tenure review process of higher education.

In Chapter IV the curricular structures of Oxbow College were shown to impact the student learning outcomes faculty emphasized in their teaching. In particular two aspects of Oxbow's curriculum may help address issues of persistence: 1) the cornerstone design course and 2) the integration of the liberal arts requirements. Many schools of engineering have adopted the cornerstone course to begin integrating an actual practice of engineering earlier in a student's experience. Many years ago, I read Marshall Lih's "The Parable of Baseball Engineering" and it has stuck with me; in essence it provided an analogy wherein spring training was an engineering curriculum and so for six weeks the

players learned the fundamentals of batting and fielding before suddenly being asked to play full baseball games to demonstrate the culmination of all their foundational knowledge. If anything resembling the practice of engineering that students found interesting is held until their final two semesters, it is no wonder students are changing their major long before that.

Oxbow College does follow the general curricular structure of many engineering schools at which the majority of the first and second year curriculum is focused on math and science courses in preparation for engineering coursework during the final two years. However, what I found especially noteworthy at Oxbow College was the attention paid to these courses by engineering faculty. The cornerstone course at Oxbow has made efforts to build a more cohesive engineering cohort for the school of engineering from the first year before students split into disciplinary cliques, and the attention by Oxbow faculty to what happens elsewhere during a student's first and second years was reassuring to me that things may be changing. While students in my day may have felt disconnected from their school, the faculty at Oxbow are taking seriously the experience of students even when those students are enrolled in courses outside the department or even the engineering school. I believe more can be done to foster greater connection between those foundational courses and their applications in engineering contexts at Oxbow and at most engineering schools, but the first step is the engineering faculty recognizing that all aspects of their student's education – both in their own disciplinary courses but also in the supplementary coursework students take in other departments – is part of a cohesive experience. I mentioned multiple times in Chapter IV how surprising but important it was to see Oxbow College faculty take seriously the teaching of professional and personal

outcomes in their disciplinary courses; the flip side of that coin is also their individually taking seriously the preparation for technical, professional, and personal outcomes that happens before the student's reach their departmental courses. If students are feeling a greater connection to their discipline, their faculty, and engineering broadly earlier in the curriculum, it may combat some of the symptoms that cause a student not to persist in their engineering program.

Attainment Demographics

The final theme for engineering education broadly within which the findings from Oxbow College should be considered focuses on who attains an engineering degree. Beyond overall student interest and persistence, the demographics of who persists and competes an engineering degree remain an additional point of concern. Baccalaureate degree attainment demographics differences are not limited to engineering or STEM; there are larger societal concerns about the role of higher education in this country that extend beyond the scope of this study. However, within the bound of what I aimed to understand about engineering education, many of those societal concerns are visible and deserve specific attention. White undergraduates enter college with an intention to major in STEM at the same rate as Black and Latino peers but are much more likely to earn their degree in these fields (Chang, Sharkness, Hurtado, & Newman, 2014). Additionally, while the presentation of women in STEM programs has grown, they are still concentrated in particular disciplines with other areas of engineering seeing less representation (Bossart & Bharti, 2017). Educating an engineering population that better represents the broader population of this country certainly has social benefits, but also if

women, racial minorities, and those with disabilities were present in the U.S. STEM workforce in ratio with their percentages in the total workforce, the shortage of domestic workers with science, technology, engineering, and mathematics skills would largely be filled (May & Chubin, 2003).

There are also striking statistics about where underrepresented populations are succeeding in STEM. Black and Hispanic students who do persist and complete a STEM degree disproportionately do so by graduating from a minority-serving institution (MSI) including Historically Black Colleges and Universities (HBCUs) or schools in areas with high populations of underrepresented minorities (Chubin, May, & Babco, 2005). For example, while 22% of all bachelor's degrees earned by Black students are granted from a HBCU, these schools award 30% of STEM degrees earned by Black students (Hurtado, Eagan, Tran, Newman, Chang, & Velasco, 2011). Why are underrepresented minority students more successful in persisting and graduating from STEM programs at minority serving institutions? One noteworthy finding in the "culture of science" (Hurtado et al., 2011, p. 557) was that Black students at HBCUs reported more support and more interaction with their faculty than students at highly selective institutions. However, that necessitates improving the pipeline leaks of these populations specifically and for engineering broadly.

Reiterating from the discussion of engineering persistence above, earlier connections for students to the faculty and the discipline of engineering impact retention; Oxbow College, and its university broadly, report second year retention percentages well above the national average. Oxbow College is in the privileged position of being a leading engineering school at a selective university, which in many ways contributes to

this statistic. As a school within an elite university, Oxbow College also has a student population that is more diverse than the national population of engineering students (Yoder, 2015). Prestige contributes greatly to that; however, I would also argue that Oxbow has taken measures that contribute to student persistence and success. The curricular structures that increase faculty-student interaction and/or underscore the social relevance of engineering benefit the broader student body, but the literature suggests they may be especially impactful for particular demographic groups of students within the population.

At various points throughout this dissertation journey I restated (to myself and others) that this was not a dissertation about diversity in STEM, however as a female graduate of an engineering program I am aware of the demographic trends – and thrilled to see them trending in the right direction. These trends matter for the pipeline of engineering students because most of the college-age population is not a white male; if women and underrepresented minorities are not entering engineering programs, even if more students who do enter persist in programs, the starting population will be limited. And while this dissertation may not be focused on it, diversity in STEM matters. Engineering prides itself on being a meritocratic doorway to the middle class and diversifying STEM is not about ignoring merit but rather supporting the talent that has not previously been cultivated (Gibbs, 2014). Oxbow faculty spoke about the importance of teamwork to engineering and ABET calls for the ability to work on multi-disciplinary teams, but there is also substantial value to those teams reflecting a broad set of viewpoints. So much engineering progress is the result of teams and those teams will be better equipped to solve complex problems if they include multiple perspectives.

Maintaining that meritocratic ideal of engineering necessitates supporting the best and brightest students from whatever background that talent originates.

Implications for Theory: Reflecting on My Conceptual Framework

Chapter II concluded with a description of Vocation of Life modified with the conception of Twenty-First Century Skills to frame this study. Through this study, the understanding of those theories has changed. In the following sections I describe the changes in my understanding of Vocation of Life (the conceptual framework of this study) and Twenty-First Century Skills (its modifier).

Vocation of Life

Vocation of Life as described in Chapter II emphasized Dewey's assertion that education, even if primarily intended as work preparation, must be paired with objectives for the student's social, community, and personal life. In that spirit, the findings in Chapter IV were categorized into three themes of student learning outcomes – technical, professional, and personal. As in Dewey's conception, the faculty of Oxbow College believed that an engineering education (which has historically been categorized as vocational) must include learning that is designed to improve a student's post-graduation life outside of work as well. Within the technical skills theme these faculty described student learning outcomes directly related to the disciplinary practice of engineering while in the professional skills they described student learning outcomes that could be instrumental in engineering or in another field. Although both are important for career

preparation, the distinction between technical and professional is nuanced but relevant for considering "Vocation of Life" in engineering.

The dictionary definitions I used in Chapter I[1] when defining key terminology highlighted that vocational is typically used in reference to training for an occupation while professional is chosen to refer to the practice of the occupation, but their use has perpetuated a hierarchy between trades and careers, placing value judgements on the different roles. I have found myself wondering if this study would feel profoundly different if I had called the frame "Profession of Life" or "Occupation of Life" rather than vocation. Yet, I feel there is merit not just in retaining Dewey's terminology, but in elevating vocation from the perception that it is second-class to liberal education. I noted when introducing Twenty-First Century Skills (which will be addressed next) that there was overlap between the hallmark characteristics of a liberal education and the student learning outcomes emphasized by the Oxbow Faculty, including within the technical theme. The faculty at Oxbow College are teaching engineering, but that technical education – that vocational training – is inextricably linked with the non-technical skills that complement their engineering preparation.

I keep returning to the promising realization that not only are these faculty acknowledging the importance of professional and personal skills for their students, but they are embracing those student learning outcomes within their disciplinary teaching of engineering. Not only are they following Dewey's vision that all education should

---

[1] In Chapter I, I wrote that "Webster's College Dictionary (1992) defines vocational as 'of, pertaining to, or providing instruction or training in an occupation or trade' while defining professional as 'following an occupation as a means of livelihood.'"

include preparation for career and non-career outcomes, but they are integrating all aspects of a student's post-graduation life – technical, professional, and personal – into one comprehensive disciplinary education for the Vocation of Life.

Twenty-First Century Skills

Twenty-First Century Skills as described from theory in Chapter II and from findings in Chapter IV encompassed three themes – technical, professional, and personal. However, the larger cluster of Twenty-First Century Skills, and especially the interplay between skills within and across these themes was an important aspect of the descriptions from Oxbow College. Faculty were perpetually making connections not just between the outcomes and their teaching, but highlighting how the outcomes that they defined distinctly were influencing their ideas of other outcomes and also how to operationalize these outcomes for their students within and beyond the classroom. Thus, while the individual skills were important, so was the whole of Twenty-First Century Skills.

Therefore while the literature provided many versions of the skills list that could be included within Twenty-First Century Skills, one important change to this framing lens is the need for the list of skills to be conceptualized also as a single cohesive unit – faculty are teaching towards these individual skills as student learning outcomes, but as with the integration of the themes above within Vocation of Life, faculty are also teaching towards a comprehensive integration of these skills in a student's technical, professional, and personal life. For example, while faculty felt communication skills were important, that skill should also be thought of in conversation with other Twenty-First Century Skills: how does a student learn to communicate as a leader or how does a

student learn to adapt their communication for technical and non-technical needs. Each of the skills Oxbow faculty highlighted are important, but moving beyond the theory as it was conceived at the start of this study, there is also a great value in considering how those skills are melded together to create not just a set of Twenty-First Century Skills (emphasis on the plural), but an education towards a unified, comprehensive, and integrated Twenty-First Century Skill.

Implications for Practice

I presented a picture of the current landscape within which the faculty of Oxbow College teach undergraduate engineering students as part of the literature review in Chapter II of this dissertation. The findings of this study in Chapter IV included not just the specific skills faculty were emphasizing as their student learning outcomes, but a second pattern of the contextual factors that influenced their conceptions. That pattern in particular has implications for the three levels of contexts – the department, the school, and the nation contexts.

Department Level: For Faculty

This study illuminated the pedagogical practices of engineering faculty at Oxbow teaching towards not just a knowledge of subject matter, but a broad set of Twenty-First Skills they sought to develop in their students. Many of these faculty reflected on feeling as if they might be the exception for emphasizing these ideas, even at an exemplary institution like Oxbow that was selected because of its reputation for emphasizing these ideas. While Chapter II referred to the perception that there is a perpetuating cycle of

faculty teaching like they were taught, the faculty of Oxbow demonstrate that department culture can have a profound influence on the values of faculty. A number of junior faculty in this study pointed to the example of their senior colleagues as an influence in their perception of the student outcomes to value and their decision, particular with regard to professional and personal skills.

These examples of faculty taking seriously the teaching of not just technical competency, but also professional and personal skills can serve to guide the next generation of engineering professors. Research on undergraduate STEM education has noted that "personal endorsement of classroom innovations by colleagues who are esteemed for their research standing" serve as effective means of influencing the institutional culture around pedagogical practice (Foertsch et al., 1997, as cited in Seymour, 2006). These conversations happen formally at department or curricular meetings, through formal guidance from senior faculty to junior faculty who are undertaking new courses, and informally through the example of established and respected faculty. The departments at Oxbow have set up various mechanisms to ensure these conversations are happening and these conversations – in all their forms – are important to the careers of new faculty and have a clear impact on the students in the classrooms. When speaking about their students, a number of faculty in the study referred to leading by example and demonstrating the skills they wished to instill in their students. It is important to recognize the importance of these efforts as Oxbow faculty are simultaneously sharing that example with colleagues as well as with graduate students who will be the next generation of engineering faculty.

School Level: For Academic Leaders and Administration

At the beginning of this chapter, I situated this dissertation's findings in context to address three concerning issues for engineering education: interest, persistence, and demographics. Many of the findings from Oxbow that responded to those challenges were based on the school-level contexts: first year cornerstone, liberal arts requirements, and mission/vision statement. Beyond those, I have one further implication specifically for academic leaders and administrators at schools of engineering: connect your faculty to the resources on your camps and connect those supporting offices directly to your faculty. The faculty at Oxbow referenced a number of initiatives on the campus that supported their efforts to teach towards the student learning outcomes, but they also routinely expressed they were not sure how widespread use of those were across the faculty. One faculty member mentioned working with a professional development office housed at the university's business school, although it turns out that office is part of Oxbow College's administration; the resources colleges are developing to support the academic mission, faculty, and students are valuable but need to be conceived and rolled out thoughtfully so they can operate most effectively. That includes open channels of communication between the school and its faculty. I found the Oxbow faculty to be engaging thought-partners around the purpose of the work they do, and I believe those insights would be valuable for the academic leadership and administration of Oxbow College. The partnership between faculty and the school leadership is key to the continued advancement of these ideas in higher education.

National Level: For ABET

The final theme in the dissertation's findings described the faculty perception of ABET's student learning outcomes from the most recent reaccreditation cycle, the ABET 11. As I noted while describing those findings, ABET has revised the student outcomes from Criterion 3 since Oxbow's reaccreditation cycle and the 11 outcomes are now 7. I am not privy to the factors that prompted that decision, but I would imagine it was similar feedback to what I heard from the Oxbow faculty. Reiterating a point for Chapter II, faculty engagement is essential for real impact on the education of students; the perception of program assessment as existing somewhere between a necessary evil and a real impediment to improvement obstructs that faculty engagement and limits the impact of the process. Therefore, I strongly hope that ABET will continue to discuss the student learning outcomes they codify with faculty in the classrooms. A formal assessment of faculty perception of the new student learning outcomes after the 2020-2021 accreditation cycle could be a useful mechanism for evaluating the impact of the change. Changing the perception of accreditation to be an aspirational goal rather than the minimum standards, particularly for institutions like Oxbow College is important to achieving that faculty engagement. It is common for us as educators to describe needing to meet students where they are – similarly, ABET needs to meet Oxbow and all schools where they are to better serve both the national and institutional needs.

Implications for Further Research

The findings in Chapter IV suggest a variety of areas for further research on this topic. In particular, recognition of the lack of generalizability beyond this case study highlights potential research opportunities for a longitudinal study to look at the impact of this type of engineering education as well as opportunities for additional research at other types of engineering schools or in other disciplines beyond engineering.

Longitudinal Study of the Twenty-First Century Skills and Vocation of Life

The post-graduation paths of engineering students have changed. An engineering degree no longer means a 40-year career at Bell Labs, but instead could include everything from medicine to finance to law to education. While faculty describe a milieu of engineering education that is looking to embrace this new frontier, this case study is the tip of the iceberg in understanding how these broad Twenty-First Century Skills for engineering students are utilized in their lives personally and professionally after graduation. One potential research avenue is a longitudinal study of engineering graduates as they take this Twenty-First Century engineering education into Twenty-First Century society. I spoke with faculty about the objectives of their teaching, but a study of how students perceive the purpose of their education – at graduation and over a longer term – would provide valuable data on how these skills are put into practice in the lives of engineering graduates across a variety of industries professionally and considering a broad set of personal circumstances.

Twenty-First Century Skill and Vocation of Life at Other Types of Engineering Schools

Oxbow College was selected for this case study because it is an exemplar institution and has a strong record of commitment to developing not just engineering leaders but leaders of society. The faculty of Oxbow College pointed to a number of department and school level contexts as shaping the work they do and the perception they hold. There are two particular aspects of this case that lead me to suggest a similar study at other engineering schools for comparison: 1) Oxbow College is a relatively small undergraduate population within a university with a large liberal arts undergraduate student body and strong liberal arts tradition and 2) Oxbow College is a highly-ranked engineering school in the country.

In describing the selection of this case, I emphasized that Oxbow College is one school within a larger research university and that approximately 20% of undergraduates are engineering students compared with 80% in the liberal arts. Faculty pointed to a number of school-context that are strongly influenced by the resources available at the broader university. Specifically, the liberal arts curriculum available to Oxbow students may not be an option for students at other engineering schools. Further, the strength of that liberal arts college may influence what the Oxbow faculty conceive of as their own student learning outcomes.

I have also noted at various points that Oxbow College is in a privileged position as an elite engineering school. That has impacted who is on the faculty, who is in the classroom, and the resources available to them. It also impacts the reputation of Oxbow graduates in a way that might influence the post-graduation career opportunities available

to them. A number of faculty in the study spoke about what makes Oxbow distinct from other schools, but some also made reference to the broader set of elite schools who are in a fortunate position where they can diverge from the pack – whether that is Oxbow's liberal arts requirement or the UC Berkeley EECS faculty voting not to renew their ABET accreditation. For engineering schools without the reputation of Oxbow or Berkeley these types of decisions may not be an option and the student learning outcomes their faculty value may reflect such differences.

Therefore, further research on how faculty at other types of engineering schools – at flagship public colleges, at resource-constrained institutions, and at STEM only institutions or a university primarily known for its STEM education – may provide different understandings about student outcomes that are valued and the contextual factors that influence those faculty beliefs.

Twenty-First Century Skills and Vocation of Life in Other Disciplines

Engineering remains a unique undergraduate degree within STEM because of its vocational tradition and within professional education because of the recognition that an engineering bachelors degree is sufficient to enter the practice of engineering. Perhaps faculty in engineering departments are especially mindful of professional outcomes because they have historically trained students for practice. This may have contributed to the perception about what engineering graduates should do after graduation in a way that sets it apart from other undergraduate majors – it would be rare to hear a political science major chastised for not becoming a professional political scientist but I have lost count of the number of times my decision not to become a professional chemical engineer has

been questioned. Additionally, because engineering accreditation occurs at the program level, there are potential differences in the level of attention placed on conceiving student learning outcomes in departments where they are not asked to regularly account for what they teach and why they teach it. Dewey called for an education that prepares students for the Vocation of Life, but in programs that pride themselves on being inherently non-vocational what would that mean? How then would the findings of this study differ in other STEM disciplines or in non-STEM disciplines? Further research about how faculty in other subject areas conceive of the important student outcomes they teach towards within disciplinary courses would serve as an interesting comparison to those found in this study.

Concluding Thoughts

As stated at the beginning of this chapter the popular images of engineers and engineering education represent an inaccurate picture of what can be found at Oxbow College where highly engaged faculty across department and professorial rank gave thoughtful consideration to the outcomes of their undergraduate teaching. It is quite likely that many others at Oxbow, as well as in other places, already are or would give these ideas their attention and efforts. Engineering's role is the world is changing and engineering education is changing to address those needs. The intersection of engineering and education is profoundly important for the technical workforce of the United States. Engineering graduates in technical and non-technical fields have weathered the claims that they are not using their degrees – or not using them correctly – because they are not using them in the ways people outside engineering expected them to; more than 100 years

ago John Dewey (2008, p. 268) wrote “the dominant vocation of all human beings at all times is living – intellectual and moral growth,” and these engineering faculty and the engineering graduates they teach are living up to that supreme vocation and hopefully will change those outdated perceptions to align with the Twenty-First Century conception of engineering on display at Oxbow College.

REFERENCES

ABET (n.d.). *Accreditation Policy and Procedure Manual, 2018-2019*. https://www.abet.org/accreditation/accreditation-criteria/accreditation-policy-and-procedure-manual-appm-2018-2019/

Adelman, C. (1998). *Women and Men of the Engineering Path: A Model for Analyses of Undergraduate Careers.* US Government Printing Office, Superintendent of Documents, Mail Stop: SSOP, Washington, DC 20402-9328.

Alexander, F. K. (2000). The Changing Face of Accountability: Monitoring and Assessing Institutional Performance in Higher Education. *The Journal of Higher Education, 71*(4), 411–431.

Allen, W. (1992). The color of success: African-American college student outcomes at predominantly White and historically Black public colleges and universities. *Harvard Educational Review, 62*(1), 26-45.

American Council on Education. Office of Women in Higher Education. (2005). *An agenda for excellence: Creating flexibility in tenure-track faculty careers.* American Council on Education.

Arum, R., & Roksa, J. (2011). *Academically adrift: Limited learning on college campuses.* University of Chicago Press.

ASQ (2016). *Parents, Educators Inclined to Steer Children Away from STEM Teaching Careers: ASQ Survey.* http://asq.org/newsroom/news-releases/2016/20160217-asq-survey.html

Azzam, A. M. (2007). Why students drop out. *Educational Leadership, 64*(7), 91-93.

Baez, B. (2000). Agency, structure, and power: An inquiry into racism and resistance for education. *Studies in Philosophy and Education, 19*(4), 329-348.

Baldwin, R. G. (2009). The climate for undergraduate teaching and learning in STEM fields. *New Directions for Teaching and learning, 2009*(117), 9-17.

Banta, T. W., & Blaich, C. (2010). Closing the assessment loop. *Change: The Magazine of Higher Learning, 43*(1), 22-27.

Belzer, A., & Ryan, S. (2013). Defining the Problem of Practice Dissertation: Where's the Practice, What's the Problem?. *Planning & Changing, 44.*

Besterfield-Sacre, M., Atman, C. J., & Shuman, L. J. (1997). Characteristics of freshman engineering students: Models for determining student attrition in engineering. *Journal of Engineering Education, 86*(2), 139-149.

Besterfield-Sacre, M., Shuman, L. J., Wolfe, H., Atman, C. J., McGourty, J., Miller, R. L., Olds, B. M., & Rogers, G. M. (2000). Defining the outcomes: A framework for EC-2000. *IEEE Transactions on Education, 43*(2), 100-110.

Black, I. (2006). The presentation of interpretivist research. *Qualitative Market Research: An International Journal, 9*(4), 319-324.

Bogdan, R., & Biklen, S. (1998). Introduction to qualitative research in education. England: Pearson.

Bordogna, J., Fromm, E., & Ernst, E. W. (1993). Engineering Education: Innovation Through Integration. *Journal of Engineering Education, 82*(1), 3-8.

Bossart, J. & Bharti, N (2017). Women In Engineering: Insight Into Why Some Engineering Departments Have More Success In Recruiting And Graduating Women. *American Journal of Engineering Education, 8*(2), 127-140.

Boyer, E. L. (1990). *Scholarship reconsidered: Priorities of the professoriate.* Princeton University Press, Lawrenceville, NJ.

Bransford, J. D., Brown, A. L, & Cocking, R.R., (2000). *How people learn: Brain, mind, experience, and school* (expanded edition). National Academy Press.

Britt, H. (2016) *Can we agree to stop calling them "soft skills"?* Procurious. https://www.procurious.com/procurement-news/stop-calling-soft-skills

Campbell, C, M. (2012). *Faculty agency: Departmental contexts that matter in faculty careers.* [Doctoral dissertation, University of Maryland, College Park].

Carnegie Classifications (2014). *Institution lookup*. https://carnegieclassifications .iu.edu/lookup/lookup.php

Carson, D., Gilmore, A., Perry, C., & Gronhaug, K. (2001). *Qualitative marketing research.* Sage.

Cassidy, S. (2006). Developing employability skills: peer assessment in higher education. *Education + Training, 48*(7), 508–517.

Catalano, G. D., & Catalano, K. (1999). Transformation: From teacher-centered to student-centered engineering education. *Journal of Engineering Education, 88*(1), 59-64.

Chaney Jones, S. (2014). *Outputs vs. outcomes and why it matters.* Measurement Resources. http://measurementresourcesco.com/outputs-vs-outcomes-matters/

Chang, M. J., Sharkness, J., Hurtado, S., & Newman, C. B. (2014). What matters in college for retaining aspiring scientists and engineers from underrepresented racial groups. *Journal of Research in Science Teaching, 51*(5), 555-580.

Chubin, D. E., May, G. S., & Babco, E. L. (2005). Diversifying the engineering workforce. *Journal of Engineering Education, 94(*1), 73-86.

City, E. A., Elmore, R. F., Fiarman, S. E., & Teitel, L. (2009). *Instructional rounds in education.* Cambridge, MA: Harvard Education Press.

Creswell, J. W. (2007). *Qualitative inquiry and research design: Choosing among five traditions* (2nd ed.). Sage Publications, Inc.

Creswell, J. W. (2012). *Educational research: Planning, conducting, and evaluating quantitative and qualitative research.* Boston, MA: Pearson Education.

Crowe, S., Cresswell, K., Robertson, A., Huby, G., Avery, A., & Sheikh, A. (2011). The case study approach. *BMC Medical Research Methodology, 11*(1), 100.

Darke, P., Shanks, G., & Broadbent, M. (1998). Successfully completing case study research: combining rigour, relevance and pragmatism. *Information Systems Journal, 8*(4), 273-289.

Delucchi, M. (1997). "Liberal Arts" Colleges and the Myth of Uniqueness. *Journal of Higher Education, 68*(4), 414-426.

Demmel, J. (2017, October 23). *ABET letter to everyone*. https://eecs.berkeley.edu/sites/default/files/abet_letter_to_everyone_rev7.pdf

Dennedy, M., Fox, J., & Finneran, T. (2014). *The privacy engineer's manifesto: Getting from policy to code to QA to value.* Apress.

Dewey, J. (2008). *Democracy and education: An educational classic*. Radvord, VA: Wilder Publications.

Dictionary.com (n.d.). *Definition of purpose*. https://www.dictionary.com/browse/purpose

Dobson, P. J. (1999). *Approaches to theory use in interpretive case studies – a critical realist perspective.* Australasian Conference on Information System, Wellington, New Zealand. https://www.researchgate.net/profile/Philip_Dobson/publication/228509820_Approaches_to_Theory_Use_in_Interpretive_Case_Studies--a_Critical_Realist_Perspective/links/54b659ee0cf2e68eb27e7cbe.pdf

Douglas, J., Iversen, E., & Kalyandurg, C. (2004). Engineering in the K-12 classroom: An analysis of current practices and guidelines for the future. *ASEE Engineering K12 Center*.

Dow, J. 2002. The new vocationalism: A deweyan analysis. [Doctoral dissertation, University of Florida].

Duderstadt, J. J. (2008). Engineering for a changing world: A roadmap to the future of American engineering practice, research, and education. In Grasso, D (ed.) *Engineering education for the 21st century: A holistic approach to meet complex challenges.*

Dudovskiy, J. (2018). Pragmatism research philosophy. *Research Methodology.* https://research-methodology.net/research-philosophy/pragmatism-research-philosophy/

Dym, C. L. (1999). Learning engineering: Design, languages, and experiences. *Journal of Engineering Education, 88*(2), 145.

Dym, C. L., Agogino, A. M., Eris, O., Frey, D. D., & Leifer, L. J. (2005). Engineering design thinking, teaching, and learning. *Journal of Engineering Education, 94*(1), 103-120.

Edirisingha, P. (2012). Interpretivism and positivism (ontological and epistemological perspectives). https://prabash78.wordpress.com/2012/03/14/interpretivism-and-postivism-ontological-and-epistemological-perspectives/

Elliott, R., Strenta, A. C., Adair, R., Matier, M., & Scott, J. (1996). The role of ethnicity in choosing and leaving science in highly selective institutions. *Research in Higher Education, 37*(6), 681-709.

Erving, E. (2006). For engineering dean Mort Friedman, 50 is a prime number. *Engineering News.* http://www.columbia.edu/cu/news/06/11/friedman.html

Ewell, P. T. (2002). An emerging scholarship: A brief history of assessment. In Banta & Associates (eds) *Building a scholarship of assessment*. San Fancisco: Jossey-Bass, 3-25.

Ewell, P. T. (2009). *Assessment, accountability, and improvement: Revisiting the tension (NILOA Occasional Paper No. 1).* Urbana, IL: University of Illinois and Indian University. National Institute for Learning Outcomes Assessment (NILOA).

Felder, R. M. (1982). *Does Engineering Education Have Anything to Do with Either One?: Toward a Systems Approach to Training Engineers.* School of Engineering, North Carolina State University at Raleigh.

Felder, R. M., & Brent, R. (2003). Designing and teaching courses to satisfy the ABET engineering criteria. *Journal of Engineering Education, 92*(1), 7-25.

Felder, R. M., & Brent, R. (2007). Cooperative learning. In *Active learning: Models from the analytical sciences, ACS Symposium Series, 970*, 34-53.

Felder, R. M., Felder, G. N., & Dietz, E. J. (1998). A longitudinal study of engineering student performance and retention. V. Comparisons with traditionally-taught students. *Journal of Engineering Education, 87*(4), 469-480.

Felder, R. M., Woods, D. R., Stice, J. E. & Rugarcia, A. (2000). The Future of Engineering Education – II. Teaching Methods That Work. *Chemical Engineering Education. 34*(1), 26-39.

Ferrare, J. (2013). Why We're Still Talking About Leaving STEM Majors. [Invited Talk] Teachers College, Columbia University. November 25, 2013.

Flyvbjerg, B. (2006). Five misunderstandings about case-study research. *Qualitative Inquiry, 12*(2), 219-245.

Fox, N. J. (2003). Practice-based evidence: Towards collaborative and transgressive research. *Sociology, 37*(1), 81-102.

Gandara, P., & Maxwell-Jolly, J. (1999). *Priming the pump: A review of programs that aim to increase the achievement of underrepresented minority undergraduates.* New York: College Board.

Garrison, H. H. (1987). Undergraduate science and engineering education for Blacks and Native Americans. In *Minorities: Their underrepresentation and career differentials in science and engineering: Proceedings of a workshop*, 234-255.

Garvin, D. A., Wagonfeld, A. B., & Kind, L. (2013). Google's Project Oxygen: Do Managers Matter?. Harvard Business School Case. 313-110, Tech. Rep., 01 2013. Harvard Business School Publishing Corporation.

Gibbs, K. (2014). Diversity in STEM: What It Is and Why It Matters. *Scientific American: Voices*. https://blogs.scientificamerican.com/voices/diversity-in-stem-what-it-is-and-why-it-matters/

Glaser, B. G. (1965). The Constant Comparative Method of Qualitative Analysis. *Social Problems, 12*(4), 436–445. https://doi.org/10.2307/798843

Grasso, D. (2002). Engineering a Liberal Education. *ASEE Prism, 12*(3), 76.

Gray, D. E. (2013). Theoretical perspectives and research methodology. In *Doing research in the real world* (3rd ed.). (pp. 14-38). Los Angeles, CA: Sage.

Grubb, W. N., & Lazerson, M. (2005). Vocationalism in higher education: The triumph of the education gospel. *The Journal of Higher Education, 76*(1), 1-25.

Gurin, P., Nagda, B. R. A., & Lopez, G. E. (2004). The benefits of diversity in education for democratic citizenship. *Journal of Social Issues, 60*(1), 17-34.

Harden, R. M. (2002). Learning outcomes and instructional objectives: is there a difference?. *Medical Teacher, 24*(2), 151-155.

Harling, K. (2002) An Overview of Case Study. *Agricultural Economics, 4*, 1-7.

Harrington, R. (2016). *There's one big problem that's causing the US to fall behind in math and science.* Business Insider. http://www.businessinsider.com/americans-lag-behind-in-science-2015-12

Hartman, H., & Hartman, M. (2006). Leaving engineering: Lessons from Rowan University's college of engineering. *Journal of Engineering Education, 95*(1), 49-61.

Huba, M. E. & Freed, J. E. (2000). *Learner-centered assessment on college campuses: Shifting the focus from teaching to learning.* Boston, MA: Allyn & Bacon.

Hudson, L. A., & Ozanne, J. L. (1988). Alternative ways of seeking knowledge in consumer research. *Journal of Consumer Research, 14*(4), 508-521.

Hursh, D., & Wall, A. F. (2011). Repoliticizing higher education assessment within neoliberal globalization. *Policy Futures in Education, 9*(5), 560-572.

Hurtado, S., Eagan, M. K., Tran, M. C., Newman, C. B., Chang, M. J., & Velasco, P. (2011). "We Do Science Here": Underrepresented Students' Interactions with Faculty in Different College Contexts. *Journal of Social Issues. 67*(3), 553-579.

Impraise Blog (n.d.). Project Oxygen: 8 Ways Google Resuscitated Management. https://blog.impraise.com/360-feedback/project-oxygen-8-ways-google-resuscitated-management

Judd, T., & Keith, B. (2011). Student learning outcomes assessment at the program and institutional levels. In Secolsky, C., & Denison, D. B. (Eds.). (2012). *Handbook on measurement, assessment, and evaluation in higher education.* Routledge.

Kazerounian, K., & Foley, S. (2007). Barriers to creativity in engineering education: A study of instructors and students perceptions. *Journal of Mechanical Design, 129*(7), 761-768.

Kerr, B., Colangelo, N., Maxey, J., & Christensen, P. (1992). Characteristics of academically talented minority students. *Journal of Counseling & Development, 70*(5), 606-609.

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

Kurshan, B. (2017). *Teaching 21st century skills for 21st century success requires an ecosystem approach.* Forbes. https://www.forbes.com/sites/barbarakurshan/2017/07/18/teaching-21st-century-skills-for-21st-century-success-requires-an-ecosystem-approach/#3835e0f53fe6

Kvale, S. (1996). *Interviews: An introduction to qualitative research interviewing.* Thousand Oaks, CA: Sage Publications.

Kvale, S. & Brinkmann, S. (2009). InterViews: *Learning the craft of qualitative research interviewing* (2nd ed.). Los Angeles, CA: Sage.

Labaree, D. F. (2006). Mutual subversion: A short history of the liberal and the professional in American higher education. *History of Education Quarterly, 46*(1), 1-15.

Levine, D. N. (2006). *Powers of the Mind: The Reinvention of Liberal Learning in America.* Chicago, IL: University of Chicago Press.

Lewis, T. (1994). Bridging the liberal/vocational divide: An examination of recent British and American versions of an old debate. *Oxford Review of Education, 20*(2), 199-217.

Lewis, T. (1997). Towards a liberal vocational education. *Journal of Philosophy of Education, 31*(3), 477-489.

Lewis, T. (1998). Vocational education as general education. *Curriculum Inquiry, 28*(3), 283-309.

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

Lundgreen, P. (1990). Engineering education in Europe and the USA, 1750–1930: The rise to dominance of school culture and the engineering professions. *Annals of Science, 47*(1), 33-75.

Lynton, E. A. (1991). New concepts of professional expertise: Liberal learning as part of career-oriented education. *The Journal of General Education*, 11-23.

Mann, C. R. (1918). *A study of engineering education*. Boston: The Merrymount Press.

Marshall, V. W. (2005). Agency, events, and structure at the end of the life course. *Advances in Life Course Research*, *10*, 57-91.

Maton, K. I., Hrabowski III, F. A., & Schmitt, C. L. (2000). African American college students excelling in the sciences: College and postcollege outcomes in the Meyerhoff Scholars Program. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching, 37*(7), 629-654.

Maxwell, J. A. (2012). *Qualitative research design: An interactive approach*. Sage Publications.

May, G. S., & Chubin, D. E. (2003). A retrospective on undergraduate engineering success for underrepresented minority students. *Journal of Engineering Education, 92*(1), 27-39.

Menges, R.J., & Austin, A.E. (2001). Teaching in higher education. In V. Richardson (Ed.), *Handbook of research on teaching* (4th ed.) (pp.1122-1156). Washington D.C.: American Education Research Association.

Merriam, S. B. (1988). *Case study research in education.* San Francisco, CA: Jossey-Bass Publishers.

Merriam, S. B. (2001). *Qualitative research and case study applications in education: Revised and expanded from case study research in education*. San Francisco, CA: Jossey-Bass Publishers.

Merriam-Webster (n.d.). Definition of context. https://www.merriam-webster.com /dictionary/context

Mervis, J. (2004). Perceptions and Realities of the Workplace. *Science, 304*(5675), 1285.

Mervis, J. (2009). *Universities begin to rethink first-year biology courses.* Science, 325(5940), 527. https://doi.org/10.1126/science.325_527a

Microsoft (2011). *Microsoft releases national survey findings on how to inspire the next generation of doctors, scientists, software developers and engineers.* Microsoft News Center. September 7, 2011. https://news.microsoft.com/2011/09 /07/microsoft-releases-national-survey-findings-on-how-to-inspire-the-next-generation-of-doctors-scientists-software-developers-and-engineers/

Mills, J. E. & Treagust, D. F. (2003) Engineering Education – Is Problem-based or Project-based Learning the Answer? *Australasian Journal of Engineering Education*. *3*(2), 2-16.

Mills, A. J., Durepos, G., & Wiebe, E. (Eds.). (2009). *Encyclopedia of case study research*. Sage Publications.

Mills-Scofield, D. (2012). It's not just semantics: managing outcomes vs outputs. *Harvard Business Review, 26.*

Min, T. L., & Christian, W. (Eds.). (2017). *Handbook of the Management of Creativity and Innovation: theory and practice.* World Scientific Publishing Company.

Morphew, C. C., & Hartley, M. (2006). Mission statements: A thematic analysis of rhetoric across institutional type. *The Journal of Higher Education, 77*(3), 456-471.

National Center for Educational Statistics (2018). *Bachelor's, master's, and doctor's degrees conferred by postsecondary institutions, by field of study: Selected years, 1970-71 through 2016-17*. https://nces.ed.gov/programs/digest/d18/tables /dt18_318.20.asp

National Society of Professional Engineers (2007). *Demonstrating qualifying engineering experience for licensure*. https://www.nspe.org/resources/licensure /resources/demonstrating-qualifying-engineering-experience-licensure

Nettles, M. T. (1988). Factors related to black and white students' college performance. *Toward black undergraduate student equality in American higher education*. Greenwood Press, New York, 17-34.

Neumann, A. Class Notes: The Craft of Interview Research. Spring 2014

Neumann, A., Terosky, A. L., & Schell, J. (2006). Agents of learning: Strategies for assuming agency, for learning, in tenured faculty careers. In S. J. Bracken, J. K. Allen, & D. R. Dean (Eds.), *The balancing act: Gendered perspectives in faculty roles and work-lives* (91-120). Sterling VA: Stylus.

O'Brien, B. (2010) *Faculty Q&A: Feniosky Peña-Mora*. Columbia News. https://archive .news.columbia.edu/research/2183

Ollis, D. F., Neeley, K. A., & Luegenbiehl, H. C. (2004). *Liberal education in twenty-first century engineering: Responses to ABET/EC2000 criteria*. New York: Peter Lang Publishing, Inc.

Olson, S., & Riordan, D. G. (2012). *Engage to excel: Producing one million additional college graduates with degrees in science, technology, engineering, and mathematics. Report to the President.* Executive Office of the President. https://eric.ed.gov/?id=ED541511

O'Meara, K.A. & Campbell, C.M. (2011). Faculty sense of agency in decisions about work and family. *Review of Higher Education*, *35*, 447-476.

O'Meara, K. A., Terosky, A. L. P., & Neumann, A. (2008). Faculty careers and work lives: a professional growth perspective. *ASHE Higher Education Report, 34*(3). San Francisco, CA: Jossey-Bass.

Oxnard College (n.d.). *Student learning outcomes (SLO's).* https://www.oxnardcollege .edu/committees/curriculum-committee/student-learning-outcomes-definition

Patton, M. Q. (1990). *Qualitative evaluation and research methods.* SAGE Publications, Inc.

Peebles, R. C. (2016). Five Dimensions of Quality: A Common Sense Guide to Accreditation and Accountability by Linda Suskie (review). *The Review of Higher Education, 39*(3), 474-476.

Perrenet, J. C., Bouhuijs, P. A. J., & Smits, J. G. M. M. (2000). The suitability of problem-based learning for engineering education: theory and practice. *Teaching in Higher Education, 5*(3), 345-358.

Prados, J. W., Peterson, G. D., & Lattuca, L. R. (2005). Quality assurance of engineering education through accreditation: The impact of Engineering Criteria 2000 and its global influence. *Journal of Engineering Education, 94*(1), 165-184.

Rosser, S. V. (2001). Will EC 2000 make engineering more female friendly?. *Women's Studies Quarterly, 29*(3/4), 164-186.

Rugarcia, A., Felder, R. M., Woods, D. R., & Stice, J. E. (2000). The future of engineering education I. A vision for a new century. *Chemical Engineering Education, 34*(1), 16-25.

Sanderson, M. (1993). Vocational and liberal education: A historian's view. *European Journal of Education, 28*(2), 189-196.

Schuman, H., Steeh, C., Bobo, L., & Krysan, M. (1997). *Racial attitudes in America: Trends and interpretations.* Harvard University Press.

Seidman, I. (1998). *Interviewing as qualitative research: A guide for researchers in education and the social sciences.* New York, NY: Teachers College Press.

Şen, Z. (2013). *Philosophical, logical and scientific perspectives in engineering*. Springer Science & Business Media.

Seymour, E. (2006). *Undergraduate science, math, and engineering education: What's working?*. Hearing Before the Subcommittee on Research, Committee on Science, House of Representatives. March 15, 2006. https://www.govinfo.gov /content/pkg/CHRG-109hhrg26481/html/CHRG-109hhrg26481.htm

Seymour, E., Hewitt, N. M., & Friend, C. M. (1997). *Talking about leaving: Why undergraduates leave the sciences*. Boulder, CO: Westview press.

Shuman, L. J., Besterfield-Sacre, M., & McGourty, J. (2005). The ABET "professional skills"—can they be taught? Can they be assessed?. *Journal of Engineering Education, 94*(1), 41-55.

Simpson, R., & Sastry, S. K. (2013). *Chemical and bioprocess engineering: Fundamental concepts for first-year students.* Springer Science & Business Media.

Smith, K. A., Sheppard, S. D., Johnson, D. W., & Johnson, R. T. (2005). Pedagogies of engagement: Classroom-based practices. *Journal of Engineering Education, 94*(1), 87-101.

Stage, F. K., & Manning, K. (2013). *Research in the college context.* Routledge.

Stake. R. E. (1994). Case Studies. In Denzin, N. K. and Lincoln, Y.S. (eds.) *Handbook of qualitative research.* Thousand Oaks, CA: Sage.

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

Steele, C. M., & Aronson, J. (1995). Stereotype threat and the intellectual test performance of African Americans. *Journal of Personality and Social Psychology, 69*(5), 797.

Steneck, N. H., Olds, B. M., & Neeley, K. A. (2002). Recommendations for liberal education in engineering: A white paper from the Liberal Education Division of the American Society for Engineering Education. In *Proceedings of the 2020 American Society for Engineering Education Annual Conference & Exposition.* American Society for Engineering Education.

Stephan, K. D. (2002). All this and engineering too: a history of accreditation requirements. *Technology and Society Magazine, IEEE, 21*(3), 8-15.

Summers, M. F., & Hrabowski III, F. A. (2006). Preparing minority scientists and engineers. *Institutions, 17*, 18.

Suskie, L. (2009). *Assessing student learning: A common sense guide.* John Wiley & Sons.

Suskie, L. (2015). *Five dimensions of quality: A common sense guide to accreditation and accountability.* John Wiley & Sons

Taningco, M. T. V., Mathew, A. B., & Pachon, H. P. (2008). *STEM professions: Opportunities and challenges for Latinos in science, technology, engineering, and mathematics. A review of literature.* Tomas Rivera Policy Institute.

Terenzini, P. T., Lattuca, L. R., & Harper, B. J. (2007). Special Session – Preparing the Engineers of 2020: A Dialogue. *ASEE/IEEE Frontiers in Education Conference*, Milwaukee, WI: October 10-13, 2007.

Thursby, M. C. (2014). The importance of engineering: Education, employment, and innovation. *The Bridge, 44*(3).

Turner, S. E. & Bowen, W. G. (1999). Choice of Major: The Changing (Unchanging Gender Gap). *Industrial Labor Relations Review, 52*(2), 289-313.

Turns, J., Atman, C. J., & Adams, R. Concept Maps for Engineering Education: A Cognitively Motivated Tool Supporting Varied Assessment Functions. *IEEE Transactions on Education. 43*(2), May 2000.

Turns, J., Eliot, M., Neal, R., & Linse, A. (2007). Investigating the teaching concerns of engineering educators. *Journal of Engineering Education, 96*(4), 295-308.

U.S. Department of Education. *Accreditation in the United States.* https://www2.ed.gov /admins/finaid/accred/accreditation.html#Overview

U.S. Department of Education. *FAQs about accreditation.* https://ope.ed.gov /accreditation/FAQAccr.aspx

US News Rankings. (2018). *Best engineering schools ranked in 2019.* https://www.usnews.com/best-graduate-schools/top-engineering-schools/eng-rankings

Vaz, R. F. (2012). Designing the liberally educated engineer. *Peer Review, 14*(2), 8.

Vest, C. M. (2008). Context and challenge for twenty-first century engineering education. *Journal of Engineering Education, 97*(3), 235-236.

Veysey, L. (1973). "Stability and Experiment in the American Undergraduate Curriculum." In C. Kaysen (ed.) *Content and Context* (pp. 1-63). New York: McGraw-Hill.

Vogt, C. M. (2008). Faculty as a critical juncture in student retention and performance in engineering programs. *Journal of Engineering Education, 97*(1), 27-36.

Vogt, C. M., Hocevar, D., & Hagedorn, L. S. (2007). A social cognitive construct validation: Determining women's and men's success in engineering programs. *The Journal of Higher Education, 78*(3), 337-364.

Volkwein, J. F. (2010). The assessment context: Accreditation, accountability, and performance. *New Directions for Institutional Research*, *2010*, 3–12.

Volkwein, J. F. (2011). *Gaining ground: The role of institutional research in assessing student outcomes and demonstrating institutional effectiveness (NILOA Occasional Paper #11).* National Institute for Learning Outcomes Assessment (NILOA).

Volkwein, J. F., Lattuca, L. R., Harper, B. J., & Domingo, R. J. (2006). Measuring the impact of professional accreditation on student experiences and learning outcomes. *Research in Higher Education, 48*(2), 251–282.

Watkin, J. (2017). *17 Experts Weigh in on the Term "Soft Skills."* https://www.icmi.com/Resources/Learning-and-Development/2017/06/17-Experts-Weigh-in-on-the-Term-Soft-Skills

Webster's College Dictionary (1992). New York: Random House.

Weiss, R. S. (1994). *Learning from strangers.* New York, NY: The Free Press.

When NASA Lost a Spacecraft Due to a Metric Math Mistake. (2017). SimScale. (December 18, 2017). https://www.simscale.com/blog/2017/12/nasa-mars-climate-orbiter-metric/

Williams, J. M. (2001). Transformations in technical communication pedagogy: engineering, writing, and the ABET engineering criteria 2000. *Technical Communication Quarterly, 10*(2), 149-167.

Winslow, L. E. (1996). Programming pedagogy—a psychological overview. *ACM SIGCSE Bulletin, 28*(3), 17-22.

Wulf, W. A. (1998). The Urgency of Engineering Education Reform. *The Bridge, 28*(1), 4-8.

Yin, R. K. (1994). *Case study research: Design and methods.* Thousand Oaks, CA: Sage.

Yin, R. K. (2013). Validity and generalization in future case study evaluations. *Evaluation*, *19*, 321-332.

Yin, R. K. (2018). *Case study research and applications: Design and methods.* Sage publications.

Yoder, B. L. (2015). *Engineering by the Numbers.* American Society for Engineering Education. https://www.asee.org/papers-and-publications/publications/college-profiles/15EngineeringbytheNumbersPart1.pdf

Appendix A: Participants Rights and Informed Consent Form

Teachers College, Columbia University
525 West 120th Street
New York NY 10027
212 678 3000

INFORMED CONSENT

Protocol Title: Teaching Towards the Vocation of Life:
Perspectives on Purpose in Undergraduate Engineering Education
Principal Researcher: Elizabeth Strauss, Teachers College
551-265-2992, ems2123@columbia.edu

INTRODUCTION You are invited to participate in this research study called "Teaching Towards the Vocation of Life: Perspectives on Purpose in Undergraduate Engineering Education." You may qualify to take part in this research study because you are a full-time faculty member at Columbia Engineering. Approximately twenty-five people will participate in this study and it will take 90 minutes of your time to complete over the course of one interview.

WHY IS THIS STUDY BEING DONE? This study is being done to determine conceptions of purpose in undergraduate engineering education. I am especially interested in the development of Twenty First Century Skills through the teaching of academic engineering courses and what your conception of those skills shows about how you have made meaning of the purpose of studying engineering for an undergraduate student.

WHAT WILL I BE ASKED TO DO IF I AGREE TO TAKE PART IN THIS STUDY? If you decide to participate, the primary researcher will individually interview you in your office or another location on/near campus that is mutually convenient.

During the individual interview you will be asked to discuss your career and your teaching and/or your academic responsibilities. The interview will be digitally audio-recorded and transcribed by the interviewer or a professional transcriber who has signed a confidentiality agreement. If you do not wish to be audio-recorded, you will still be able to participate; the researcher will just take hand-notes. The interview will take approximately 90 minutes. You will be given a pseudonym in order to keep your identity confidential.

WHAT POSSIBLE RISKS OR DISCOMFORTS CAN I EXPECT FROM TAKING PART IN THIS STUDY? This is a minimal risk study, which means the harms or discomforts that you may experience are not greater than you would ordinarily encounter in daily life during a conversation with a colleague about career experiences. Risks include the possibility of feeling discomfort that sometimes accompanies discussing personal experiences or some discomfort from being interviewed. Further, it is always possible that someone who knows you well might be able to identify your remarks, although the researcher will mask your identity as much as possible. You do not have to answer any questions or share anything

Teachers College, Columbia University
525 West 120th Street
New York NY 10027
212 678 3000

INFORMED CONSENT

you do not want to talk about. You can stop participating in the study at any time without penalty. Your information will be kept confidential.

The primary researcher is taking precautions to keep your information confidential and prevent anyone from discovering or guessing your identity, such as using a pseudonym instead of your name and keeping all information on a password protected computer and locked in a file drawer.

WHAT POSSIBLE BENEFITS CAN I EXPECT FROM TAKING PART IN THIS STUDY? There is no direct benefit to you for participating in this study. However, this work aims to contribute to the improvement of faculty experiences addressing the EC2000 criteria in their academic teaching and you may find a potential benefit in contributing to that goal.

WILL I BE PAID FOR BEING IN THIS STUDY? You will not be paid to participate.

WHEN IS THE STUDY OVER? CAN I LEAVE THE STUDY BEFORE IT ENDS? The study is over when you have completed the individual interview. However, you can leave the study at any time even if you have not finished.

PROTECTION OF YOUR CONFIDENTIALITY The primary researcher will keep all written materials locked in a desk drawer in a locked office. Any electronic or digital information (including audio recordings) will be stored in an encrypted drive on a computer that is password protected. The file matching your real name with your participant identifier and/or pseudonym will be kept in a separately encrypted file and stored away from other materials.

For quality assurance, the study team, the study sponsor (grant agency), and/or members of the Teachers College Institutional Review Board (IRB) may review the data collected from you as part of this study. Otherwise, all information obtained from your participation in this study will be held strictly confidential and will be disclosed only with your permission or as required by U.S. or State law.

HOW WILL THE RESULTS BE USED? The results of the study will be analyzed for the purpose of writing a dissertation as part of the requirements for the degree of Doctor of Education at Teachers College, Columbia University. Results may also be reported as part of academic/professional presentations and/or publications, such as articles, chapters, and books. Your identity will be removed from any data you provide before publication or use for educational purposes. Your name or any identifying information about you will not be published.

Teachers College, Columbia University
525 West 120th Street
New York NY 10027
212 678 3000

INFORMED CONSENT

CONSENT FOR AUDIO RECORDING Audio recording is part of this research study. You can choose whether to give permission to be recorded. If you decide that you don't wish to be recorded, **you will still be able to participate** in this research study.

_____I give my consent to be recorded _____
Signature

_____I **do not** consent to be recorded _____
Signature

WHO MAY VIEW MY PARTICIPATION IN THIS STUDY
_____I consent to allow written and/or audio-recorded materials to be viewed at an educational setting or at a conference outside of Teachers College, Columbia University

_____
Signature

_____I **do not** consent to allow written and/or audio-recorded materials to be viewed outside of Teachers College, Columbia University

_____
Signature

WHO CAN ANSWER MY QUESTIONS ABOUT THIS STUDY?
If you have any questions about taking part in this research study, you should contact the primary researcher, Elizabeth Strauss, at 551-265-2992 or at ems2123@columbia.edu. You can also contact the faculty advisor, Dr. Corbin Campbell at campbell2@tc.columbia.edu.

If you have questions or concerns about your rights as a research subject, you should contact the Institutional Review Board (IRB) (the human research ethics committee) at 212-678-4105 or email IRB@tc.edu or you can write to the IRB at Teachers College, Columbia University, 525 W. 120th Street, New York, NY 10027, Box 151. The IRB is the committee that oversees human research protection for Teachers College, Columbia University.

Teachers College, Columbia University
525 West 120th Street
New York NY 10027
212 678 3000

INFORMED CONSENT

PARTICIPANT'S RIGHTS

- I have read the Informed Consent Form and have been offered the opportunity to discuss the form with the researcher.
- I have had ample opportunity to ask questions about the purposes, procedures, risks and benefits regarding this research study.
- I understand that my participation is voluntary. I may refuse to participate or withdraw participation at any time without penalty.
- The researcher may withdraw me from the research at their professional discretion.
- If, during the course of the study, significant new information that has been developed becomes available which may relate to my willingness to continue my participation, the researcher will provide this information to me.
- Any information derived from the research study that personally identifies me will not be voluntarily released or disclosed without my separate consent, except as specifically required by law.
- Your data will not be used in further research studies.
- I should receive a copy of the Informed Consent Form document.

My signature means that I agree to participate in this study:

Print name: _____ **Date:** _____

Signature: _____

Appendix B: Recruitment Emails

Faculty Participants

Dear Professor _____,

I am writing to invite you to participate in my doctoral dissertation study entitled, Teaching Towards the Vocation of Life: Perspectives on Purpose in Undergraduate Engineering Education. I am conducting this study as part of my program of work as a doctoral student in the Program in Higher and Postsecondary Education at Teachers College, Columbia University.

The goal of this study is to develop an understanding of the purpose of an undergraduate engineering education in today's world. This research is intended to improve the understanding of how the purpose of an engineering education is conceived by faculty on the front lines of teaching undergraduate students and how you have developed and defined the outcomes you value for your teaching.

Your participation would consist of an interview lasting approximately 90 minutes in your office on campus or another mutually convenient location. In order to better understand your academic work, I will also ask for a copy of your CV, recent course syllabi, or other documents that convey your teaching philosophy.

The privacy of the research participants is very important to me. I will treat the interviews, curriculum vitae, and any other documents provided with the utmost confidentially, and only I would have access to your identity. I would not share your name or the names of any study participants with anyone at the institution or elsewhere. Pseudonyms and other identify-masking techniques will be used in all presentations and writings about the study.

If you would be willing to participate or if you have questions, please reply to this email. Thank you very much for taking the time to consider participation.

Sincerely,
Elizabeth Strauss

Academic Leadership Participants

Dear Professor _____,

I am writing to invite you to participate in my doctoral dissertation study entitled, Teaching Towards the Vocation of Life: Perspectives on Purpose in Undergraduate Engineering Education. I am conducting this study as part of my program of work as a doctoral student in the Program in Higher and Postsecondary Education at Teachers College, Columbia University.

The goal of this study is to develop an understanding of the purpose of an undergraduate engineering education in today's world. This research is intended to improve the understanding of how the purpose of an engineering education is conceived by faculty on the front lines of teaching undergraduate students, especially in light of ABET's EC2000 criteria.

Your participation would consist of an interview lasting approximately 90 minutes in your office on campus or another mutually convenient location. In order to better understand your work, I will also ask for a copy of your CV.

The privacy of the research participants is very important to me. I will treat the interviews, curriculum vitae, and any other documents provided with the utmost confidentially, and only I would have access to your identity. I would not share your name or the names of any study participants with anyone at the institution or elsewhere. Pseudonyms and other identify-masking techniques will be used in all presentations and writings about the study.

If you would be willing to participate or if you have questions, please reply to this email. Thank you very much for taking the time to consider participation.

Sincerely,
Elizabeth Strauss

Appendix C: Protocol for Faculty Interview

Interviewee Code:
Interview Date:
Notes on identifiability issues:

Notes on interview setting:

The goal of this study is to develop an understanding of the purpose of an undergraduate engineering education in today's world. This research is intended to improve the understanding of how the purpose of an engineering education is conceived by faculty on the front lines of teaching undergraduate students and how you have developed and defined the outcomes you value for your teaching.

You received a brief description about the study, but I realize you may have some questions. I would be glad to discuss these with you. **Before we begin, is there anything more you would like to know about the study?**

Our interview will last approximately 90 minutes. Because I want to be as accurate as possible in capturing your thoughts and what we discuss in our conversation, I may take handwritten notes from time to time. I would also like to tape record this interview. Is that okay with you?

Yes _____ No _____

IF YES: If at any time you would like me to turn off the recorder, please let me know and I will pause or turn off the recorder.

IF NO: I'll be happy to take notes by hand only as you speak.

These two sheets [show the consent form and participants' rights] detail what I just told you about this study. You also received the informed consent documents by email. Could I ask you to read these, if you have not yet done so, and sign them at this time. Please let me know if you have any questions.

Pre-Interview Checklist:

- Discuss any questions/concerns
- Request signature on consent form
- Give interviewee a copy of the consent form
- Confirming taping preference, and if allowed turn on the recording device(s)

Background

I reviewed your CV prior to our conversation.

1. Is all of the following correct:

   Your academic title is *[RANK]* in *[PROGRAM/DEPARTMENT]*.

   Your doctoral degree was in *[DISCIPLINE]* and you received this degree from *[INSTITUTION]*.

2. Would you tell me briefly about what you teach? What topics do you teach and what level of students do you teach?

Understanding Your Discipline

As you know, this study is about purpose in undergraduate engineering education. I would like to ask you a few questions about *[DISCIPLINE]* as the subject matter of your teaching and what it means to you to be a scholar of [*DISCIPLINE*] in general.

3. How did you decide to focus on *[DISCIPLINE]*?

4. What do you think is the purpose of *[DISCIPLINE]* as a subject? In other words, what do you think *[DISCIPLINE]* helps us to understand that no other field can?

5. Some education researchers suggest that students need to learn how to "think like" a practitioner of their discipline in order to really grasp the subject matter of the discipline. What do you think that it means to "think" like a *[DISCIPLINE]*?

Teaching Twenty-First Century Skills

I would like to shift to a discussion about your teaching of engineering.

6. You have chosen a career when one typical aspect of your responsibilities is to teach. What do you hope undergraduate engineering students come to know or understand as a result of your class? What do you think is the purpose of your teaching?

7. Thinking about your own teaching, in what ways do you think you teach towards developing these understandings in your students? Could you give me an example of how you have aimed to do so?

8. Taking a step back beyond your classes specifically and thinking about someone's four years here: what do you hope undergraduate engineering students come to know or understand as a result of their education here?

9. I am studying purpose in engineering education. Many different ideas exist about the purpose or the preferred objectives of an engineering degree. What we have been speaking about so far relates to how you see purpose. I have also brought a copy of ABET's 11 outcomes from Criterion 3 for us to discuss as potentially another conception of purpose for an undergraduate engineering degree. [PROVIDE PARTICIPANTS WITH COPY]

    a. How familiar are you with these outcomes?
        i. Optional Probe: If so, where have you seen them discussed?

    b. Do you feel ABET's Criterion reflects your views? Why or why not?
        i. Optional Probe: Are things missing? Would you revise or remove any of ABET's outcomes?

    c. How, if at all, are these outcomes reflected in your teaching? What do you emphasize? What is less represented in your teaching?

10. When considering your engineering teaching, are their other sources (like readings or conference presentations or even your own experience as a student) that you view as having informed your intended outcomes or the purpose of your teaching in engineering?

Institutional Contexts

11. We have now discussed your own perspective and reviewed ABET's conception of purpose for an undergraduate engineering education. If we were to talk about what you perceive of this school as a whole, how similar do you believe the ideas of purpose would be to what we have discussed?
    i. Optional Probe: What aspects of purpose do you see as being emphasized in this school and which are less emphasized?

12. Reflecting on your experience teaching towards these ideas, what would you want administrators or ABET itself to understand about teaching towards this purpose in undergraduate engineering education?

CLOSING:

• I want to thank you very much for your participation in this interview.

• Are there any documents you would be willing to share with me (meeting minutes, emails, syllabi, institutional announcements, articles, etc.) that have influenced your decisions about purpose in your teaching of undergraduate engineering courses? Are there documents that demonstrate your understanding of purpose?

• If snowball sampling is needed: can you please share with me the name(s) of any other individuals that it may be valuable for me to meet with as part of this research study?

• Before closing, I'd like to confirm that I have the right contact information for you *[check front sheet]*.

• I would also like to ask if there is anything in particular that you would like me to keep "off the record" in the final reports of this study.

• Depending on the outcome of my analysis of the interview data, I plan to follow up with some members of the study sample later for member checks to confirm if the results reflect the intentions of participants. Would you be available, willing, and interested in seeing some preliminary analysis? You are under no obligation.

• Again, thank you very much for your time and participation in this study. If anything comes up, please feel free to reach out to me at any time.

Appendix D: Protocol for Academic Leadership Interview

Interviewee Code:
Interview Date:
Notes on identifiability issues:

Notes on interview setting:

The goal of this study is to develop an understanding of the purpose of an undergraduate engineering education in today's world. This research is intended to improve the understanding of how the purpose of an engineering education is conceived by faculty on the front lines of teaching undergraduate students and how you have developed and defined the outcomes you value, including how that is related to the recent ABET reaccreditation cycle.

You received a brief description about the study, but I realize you may have some questions. I would be glad to discuss these with you. Before we begin, is there anything more you would like to know about the study?

Our interview will last approximately 90 minutes. Because I want to be as accurate as possible in capturing your thoughts and what we discuss in our conversation, I may take handwritten notes from time to time. I would also like to tape record this interview. Is that okay with you?

Yes _____ No _____

IF YES: If at any time you would like me to turn off the recorder, please let me know and I will pause or turn off the recorder.

IF NO: I'll be happy to take notes by hand only as you speak.

These two sheets [show the consent form and participants' rights] detail what I just told you about this study. You also received the informed consent documents by email. Could I ask you to read these, if you have not yet done so, and sign them at this time. Please let me know if you have any questions.

Pre-Interview Checklist:

- Discuss any questions/concerns
- Request signature on consent form
- Give interviewee a copy of the consent form
- Confirming taping preference, and if allowed turn on the recording device(s)

I reviewed your CV prior to our conversation.

1. Is all of the following correct:

Your administrative title is *[TITLE]*.

You also hold a faculty appointment as *[RANK]* in *[DEPARTMENT]*.

You also have a role elsewhere on campus as *[TITLE]*.

Your doctoral degree was in *[DISCIPLINE]* and you received this degree from *[INSTITUTION]*.

2. Would you tell me briefly about what you teach? What topics do/have you teach/taught and what level of students?

ABET

I am studying purpose in engineering education. Many different ideas exist about the purpose or the preferred objectives of an engineering degree from faculty, students, and industry. One place that we can see a statement of purpose codified is in ABET's criteria for accreditation. Therefore, I would like to speak specifically for a few minutes about accreditation and your experience going through the recent ABET reaccreditation cycle.

3. In your opinion, who were the major stakeholders who contribute to the development of objectives for ABET accredited undergraduate programs during the School's most recent review cycle?

4. Do you have an approach to involve faculty who are teaching undergraduate courses in the ABET review – specifically in the development of the program/school student learning outcomes?

5. As I speak with faculty I have been/plan to share with them the ABET 11 outcomes from Criterion 3 as one potential opinion on the purpose for an undergraduate engineering degree. [PROVIDE PARTICIPANTS WITH COPY].
    a. Do you feel ABET's Criterion reflects your views of purpose in undergraduate engineering? Why or why not?
        i. Optional Probe: Are things missing? Would you revise or remove any of ABET's outcomes?

    b. Do you believe that these outcomes reflect the views of the school as to the purpose of an undergraduate engineering education? Why or why not?
        i. Optional Probe: Are things missing from the way the school views purpose? Would you revise or remove any of ABET's outcomes to may them more aligned with the school's view?

Twenty-First Century Skills

6. Reflecting on ABET's criteria for student outcomes, your own perception of purpose, and what you have heard from your colleagues at the School: how do you think the School fosters the development of these desired qualities in its undergraduate students?

7. How do faculty here learn to teach towards the community's description of purpose? What aspects of purpose do you see as being emphasized in this school and which are less emphasized?

8. How - if at all - does the academic leadership of the programs, departments, and school guide the faculty as a whole to think about purpose in their teaching?

9. To what extent do you believe that it is the responsibility of engineering professors to teach towards broad sense of purpose? And if so, whose idea of purpose – their own, the school's, or ABET's – do you see as being emphasized?

10. Reflecting on your experience teaching and as an academic leader looking towards these ideas, what would you want higher education policymakers, administrators, or professional development staff members to understand about purpose in undergraduate engineering education?

CLOSING:

• I want to thank you very much for your participation in this interview.

• Are there any documents you would be willing to share with me (meeting minutes, emails, institutional announcements, articles, etc.) that have influenced your decisions about purpose in undergraduate engineering? Are there documents that demonstrate the school leadership's perspective on purpose?

• If snowball sampling is needed: can you please share with me the name(s) of any other individuals that it may be valuable for me to meet with as part of this research study?

• Before closing, I'd like to confirm that I have the right contact information for you *[check front sheet]*.

•I'd also like to ask if there's anything in particular that you would like me to kee p "off the record" in final reports of this study?

• Depending on the outcome of my analysis of the interview data, I plan to follow up with some members of the study sample later for member checks to confirm if the results are plausible. Would you be available, willing, and interested in seeing some preliminary analysis? You are under no obligation.

• Again, thank you very much for your time and participation in this study. If anything comes up, please feel free to reach out to me at any time.

Appendix E: Handout for Interviews - ABET Criterion 3 Student Outcomes, 2018-2019

General Criterion 3 Student Outcomes

The program must have documented student outcomes that prepare graduates to attain the program educational objectives. Student outcomes are outcomes (a) through (k) plus any additional outcomes that may be articulated by the program.

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

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

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

(d) an ability to function on multidisciplinary teams

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

(f) an understanding of professional and ethical responsibility

(g) an ability to communicate effectively

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

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

(j) a knowledge of contemporary issues

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

Appendix F: Code Book

Code	# Total Sources	# Individual References	Description	Example	Corresponding Finding
ABET: Agreement with ABET	7	16	Positive feedback on the ABET outcomes or the ABET process.	"I'm supportive of ABET's mission, in the way that they go about doing things. I think the review and the oversight is appropriate."	N/A
ABET: Critique of ABET Process	3	10	Comments on the process of undergoing an ABET accreditation review.	"It's just the documentation part is what's very frustrating."	N/A
ABET: General	11	44	General comments about ABET or the process of undergoing an ABET review.	"I think by and large we do most of this. Actually, I think ABET's mostly useful."	B3
ABET: Minimum Standards	3	5	The student learning outcomes of ABET are designed as minimum standards and not aspirational goals.	"It's almost the lowest common denominator, right? This is the minimum of what's expected."	B3b

ABET: Too Generic	9	16	The a-k student learning outcomes of ABET are too generic.	"I agree with all of this. I would say maybe that some of these… shouldn't be unique to engineers."	B3a
ABET: We Are Doing This Anyway	7	20	The student learning outcomes of ABET are things the faculty or school would do regardless of ABET asking for them.	On hating ABET: "it's like hating a stair railing. I mean it may be a crappy stair railing, but it helps you to get up the stairs…"	B3c
Adaptability	1	1	The quality of being able to adjust to new conditions.	"The idea that things are going to be thrown at you that you've never seen before."	A3a
Alternative Perspectives/Other Schools	5	10	Opinions on how other engineering school differ from or resemble Oxbow College.	"…[in] Europe, where when a student enters an engineering school, from day one until the last day, they only take technical courses."	N/A
Communication	10	27	The sending and receiving of information.	"Obviously the ability to communicate effectively. If only engineers were able to do that, we would live in a very different world."	A2a
Concerns About Engineering Students	4	9	Expressions of worry about undergraduate engineering students.	"It's all very reductionist. They want to know [if] given a problem what formula you have to use."	N/A

Confidence	4	8	The state of feeling certain.	"I hope they come out with that trust. That they trust themselves."	A3b
Liberal Arts Requirements	7	12	Discussion of the required Liberal Arts core Oxbow engineers must take as part of their curriculum.	"The main point is that the [liberal arts requirement] is amazing. It puts your students in a different league."	B2b
First Year Cornerstone	4	15	Discussion of the first year cornerstone engineering course.	"The purpose…is to have them start to view themselves as incipient engineers."	B2b
Creativity	3	3	The use of the imagination or original ideas, especially in the production of an artistic work.	"There's also creative side to it that I don't think they always appreciate…That's not so formulaic."	A3a
Educational Philosophy Broadly	7	28	Descriptions of overarching sentiment regarding education and/or teaching.	"I definitely see my role is that as giving the students the knowledge and the ability to solve real problems."	N/A
Entrepreneurship	1	1	Discussion of student involvement with start-ups or student founded businesses.	"Then, there are many entrepreneurship classes that students can take that are offered in the engineering school, so I think that comes out."	N/A

Ethics	11	22	The code of conduct practiced by a person or group of people.	"They're building their character, they're making their choices, and most times you don't know what they're doing because they're feeling it out."	A2b
Healthy Fear of Being Wrong	3	4	Discussion of student need to acknowledge consequences of their actions and the impact they can have in the world.	"And I think some of it comes from a fear. You have to have fear [that] being wrong will penalize you. If you don't feel there will be any penalty, there's no instinct. There is no reason to build an instinct."	N/A
Identifying the Problem	6	11	Diagnosing a situation in order to understand the root issue rather than symptoms; determining what is known, what is unknown, and what steps must be taken to fill in the necessary unknowns.	"Finding a problem that needs a solution or meeting some need of people…is how engineering is supposed to work."	A1a
Institutional Culture	10	29	Discussion of Oxbow College's institutional culture at the school or department level.	"That's the thing that we can deliver that few other schools can match."	B2

Invent and Optimize	3	5	Engineering has two parts: create or design something that has not existed before and make the best or most effective use of a situation, opportunity, or resource.	"You need just think about two words. One is invention, another one is optimization."	A1c
Judgement and Intuition	6	15	The ability to make considered decisions or come to sensible conclusions coupled with an instinctive feeling.	"Understanding whether a solution makes sense."	A3a
Leadership	3	6	The state or position of being a leader; the art of motivating a group of people to act towards achieving a common goal.	"I think on top of that, we strive to really develop students who are going to be leaders…the kind of engineers, the kind of people that we're graduating are going to be those team leaders."	A2c
Lifelong Learning and Contemporary Issues	6	11	The ongoing, voluntary, and self-motivated pursuit of knowledge for either personal or professional reasons; the knowledge of modern context.	"You have to keep up [with] the latest developments in your field, and try to be ahead of the curve."	A2d

Mathematical Modeling	5	11	Using computational software to develop descriptive or predictive models.	"Nowadays, the computers allow you to model things that are much more complex…but it also means you really need to know how these computational tools work."	A1b
Meaning of Engineering	8	31	How faculty conceptualize of engineering itself.	"I think all of it should sort of center around how things work. But that's a very sort of central concept of engineering."	N/A
Non-Engineering Professions	12	43	Discussion of non-engineering post-graduation plans of students.	"Sometimes I have students who seem really into this...and they come tell us at the end, 'Well, I've taken a job in finance.' And I'm always just kind of surprised."	N/A
Problem Solving	4	12	The process of finding solutions to difficult or complex issues.	"It's always oriented at solving problems, right?...As engineers, we're always teaching them problem solving skills."	A1b
School Mission	3	3	Discussion of Oxbow's School Mission.	"As Engineers we are here to work for the greater good."	B2c

Scientific Method and Engineering Design Thinking	10	20	A method of procedure that has characterized natural science since the 17th century, consisting in systematic observation, measurement, and experiment, and the formulation, testing, and modification of hypotheses; a solution-based approach to solving problems	"I would take the same problem and solve it a different way in class just to teach them there is no one singular solution for everything."	A1c
Senior Design Capstone	6	17	Discussion of the senior design project and final expo, a requirement of Oxbow students.	"The senior design class is really one of the places where you combine the technical knowledge with the motivation."	B1b
Teaching Strategies	11	35	How faculty operationalize their teaching and the actions they take as part of their teaching.	"I try to reach as broad of a group of students as I can. I serve the whole population as well as I can."	N/A

Teaching vs Research Priorities	2	3	Faculty challenges related to balancing teaching and research priorities.	“You’re not called a researcher, you’re called a Professor. So you accept that...you’ve made a commitment that you’re going to come through and teach”	N/A
Teamwork	6	12	The combined action of a group of people, especially when effective and efficient.	“No engineering happens individually anymore. So it’s always a team, even if the team is small.”	A2c
Traditional Objectives	16	36	Discussion of traditional engineering outcomes, which traditionally would be called “technical” outcomes or “hard skills.”	“He’d say, ‘A [] Engineer is an engineer in the [] industry.’ He wanted to assess the value of anything that was offered as it related to something in the [] industry.”	N/A
Twenty-First Century Skills: General	10	29	Any discussion of student outcomes broadly - including technical, professional, and life skills - but not explicitly about a particular skill.	“Success is a big word...they need to make money, they need to be happy, they need to be happy with themselves and others happy with them, and they need to have a foundation laid for something that neither they nor we know is going to be at a given point.”	A

Undergraduate Research	2	2	Discussion of involvement of undergraduate students in faculty research projects.	“I think that there tends to be sometimes a disconnect between what we’re doing today in research and the education.”	B1a