DIFFERENCES IN EDUCATIONAL GOALS WITHIN THE FIELD OF ELECTRICAL ENGINEERING

A Dissertation Presented to the
Faculty of the College of Education
University of Houston

In Partial Fulfillment
of the Requirements for the Degree

Doctor of Education

by

Diana G. de la Rosa-Pohl

December, 2011

ACKNOWLEDGMENTS

I would like to thank all of the people that supported me through these many years of academic pursuit. However, there are entirely too many people to explicitly mention in two short pages. So I apologize to anyone whose name is absent from this list. Please be assured that you are not absent from my thoughts.

I must first thank my committee who has guided me all along the process of this dissertation. I chose wisely and have learned much from their expertise and wisdom. Dr. Bernard Robin was the first person that I spoke with about trying to craft a doctorate around engineering and education. He was also the only one who agreed to attempt it. I am forever grateful for his courage (and ultimately his patience, as it took me eight years to complete this).

Dr. John Gaa opened my eyes to the wonderful world of educational psychology and showed me that the material was just as fun as it was fascinating. It was also in his class that I met the amazing Dr. Diane Jerome. My girls' lunches with Diane these past years have been invaluable and were the sole reason that I was able to keep my sanity throughout the dissertation process. Dr. Gaa also introduced me to Dr. Richard Olenchak. I am very grateful to have had him as my methodologist and I look forward to picking apart the engineering mind with him in the future.

And the last and newest member of my committee was Dr. Stuart Long. He had the most important job of all: keeping me employed long enough to finish this! I cannot thank him enough for all his patience over these years and for all of the wonderful opportunities that he, Dr. Fritz Claydon, and Dr. Dave Shattuck have brought my way. I have been very blessed to be able to take part in some wonderful educational adventures in the Cullen College of Engineering.

I also need to thank my hometown team from south Texas: Esther Farías, Laura Kaechele, and Patricia Edelstein. They kept me going through the hard times and helped me to find the strength to dust myself off and get my rear back in graduate school. There's not a better bunch of cheerleaders anywhere. We did it ladies! And although my two little blonde babies with fur (Joe Cocker and Güera) won't be with me on graduation day, I know that they will be watching from somewhere with wagging tails and those beautiful big brown eyes that get me every time.

There is absolutely no way that I could have completed a project of this magnitude—with all of the emotional and financial sacrifices required of it—without the infinite support of my husband Federico. He has cheered me on more nights than I can count, especially when I just didn't think that I could stay up to study one more minute. He has always believed in me more than I could believe in myself, and he has loved me more than I ever thought that I deserved to be. I am the richest woman in the world because he has chosen to share his life with me.

And lastly, I thank my parents Cale and Julie de la Rosa, who raised a little girl from the Rio Grande Valley to dream big and believe that she could do anything. Every good thing that I have done is because they taught me to always believe. Believe in God and believe in myself. I love them more than words could ever express. This is for them.

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de la Rosa-Pohl, Diana G. “Differences in Educational Goals within the Field of Electrical Engineering.” Unpublished Doctor of Education Dissertation, University of Houston, December, 2011.

Abstract

The knowledge capital that a nation's population of engineers brings to a society has great economic and cultural impact. Electrical engineers in particular are responsible for many innovations that we now take for granted in everyday life. Therefore, preparation of electrical engineers for careers in this field becomes an important national issue, especially since engineers are expected to continue being global leaders in high-technology innovation. The issue of properly educating these engineers to address the highly complex and technical issues of the modern world is more important now than ever. In order to design electrical engineering programs that train these engineers to be successful and excel in the workforce, their potential major employers and developers of engineering curricula must work together to ensure that societal and individual needs are being met. However, before this work can truly be productive, it is important to understand the needs of each group. If the intentions of academia differ from the needs of industry, then the work of preparing a new generation of electrical engineers that is capable of solving society's most challenging problems will be stifled. The purpose of this study was to investigate, through interviews, the opinions of practicing engineers in both industry and academia to determine if a misalignment of needs and educational goals between the two groups exists. Thus, the guiding research question for this study is: “How do electrical engineers in industry and academia differ in their conceptions of the goals of engineering education?”

To answer this question, six electrical engineers currently practicing in the field were chosen to provide feedback regarding educational outcomes through interview data. In selecting the six respondents to be included in this study, the following criteria were applied: 1) respondents must have been working in their field for a minimum of seven years, and 2) industry respondents must have obtained at least a bachelors degree in electrical engineering, and faculty respondents must have been actively teaching in an electrical engineering program. Based on these criteria, three respondents were selected from industry and three respondents were selected from academia. Semi-structured interviews were conducted and comparisons of comments made regarding student outcomes were made between the two respondent groups.

Study data showed that there was disagreement in some but not all of the educational outcomes. In fact, there was surprising agreement on approximately half of the student outcomes that emerged from the interview data. Overall there were very few comments regarding outcomes that respondents felt were not important. Only five outcomes elicited unfavorable remarks. Interestingly, all of the unfavorable remarks from industry respondents dealt with technical outcomes. There were only two unfavorable comments from academia and they pertained to a single non-technical outcome (ethics/morality). Also, there were some instances of disagreement on importance of educational goals within the groups. These instances were mainly within the industry group and related to technical outcomes.

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I. Introduction

There is growing evidence in the engineering education literature of a school-work gap in the electrical engineering field. The National Academy of Engineering (NAE) reports that over time "a disconnect between engineers in practice and engineers in academe has developed and grown" (2005, pp. 20-21). This disconnect seems to have contributed to differences in what skills are taught in electrical engineering departments and skills valued by both employers and recent electrical engineering graduates. Unfortunately, this is not a problem unique to the electrical engineering discipline. In a recent survey of U.S. employers spanning a large number of fields, it was found that school training did not always match the most pressing needs of the workplace. From 4-year colleges, 17.4% of respondents rated the preparation level of new entrants as deficient (Casner-Lotto, Rosenblum, & Wright, 2009). However, with the recent concern of a lack of sufficient engineers to provide the United States with the innovation and scientific knowledge that will allow it to keep its current global economic position (Committee on Prospering in the Global Economy of the 21st Century, National Academy of Sciences, National Academy of Engineering, & Institute of Medicine, 2007), this matter takes on even greater importance in the electrical engineering field.

Although there is little in the current research which addresses these issues in the electrical engineering discipline specifically, the literature does provide evidence of a mismatch between employers' needs and what is being in taught generally in engineering colleges and universities. From the literature, it appears that many academic courses ignore the development of skills needed by employers in industry (Jones, 2002, p. 35/1). In a 2001 report titled "Curriculum development guidelines, new ICT curricula for the

21^{st} century” it is stated that the relationship between academia and industry has long been a relationship of “mutual suspicion” (Career Space, p. 17). Companies believed that academia did not prepare students for their actual needs because the programs focused too much on concepts and theory and not enough on application. In turn, academia criticized industry for not focusing enough on citizenship and personal development, which they considered as the core of their mission. Industry representatives now believe this disconnect to be the reason that engineering students are not adequately prepared to enter today's workforce (National Academy of Engineering, 2005, p. 21). One Chairman of Motorola has even been reported as saying that 64% of employers polled said that existing courses did not provide the type of engineering graduates required (Jones, 2002, p. 35/1). Employers feel that engineering graduates are not arriving at work equipped with the skills needed to be immediately productive in the industry work environment.

Other evidence of the school-work gap lies with the recent graduates themselves. Often, engineers in industry do not perceive their college training to be relevant to their current occupation. A survey of science and engineering graduates found that only about 40 percent of bachelor's degree holders felt that their job required skills that were "closely related" to their college major (Lowell & Salzman, 2007, p. 33). Many feel that the skills that they have learned in their technical programs are not being utilized on the job (Muhammad, Aurangzeb, & Tarique, 2009, p. 64). Traits that are in demand in industry (such as the non-technical skills, or “soft skills”) often come into conflict with the actual training that engineers acquire during their degree programs, while the math and design skills that are emphasized in school remain underutilized.

However, when practicing engineers in industry want to update their skills for their jobs by continuing their education, they find low real-world and applied content in university courses (Paton, 2002, p. 7) and are therefore unable to obtain the instruction to match their skills to their jobs. One way educators can increase the perceived relevance of instruction is to place more emphasis on tying theory to practice. At the Carnegie Foundation for the Advancement of Teaching, Sheppard, Macatangay, Colby, and Sullivan conducted a multi-year study in which engineering programs across the United States were evaluated through field work (2009).They recommend that colleges do a better job of integrating knowledge and practice and also developed a set of guiding principles to address the issue.

There also seem to be stark differences between industry and academia in work and learning cultures. Teamwork and cooperation are not often highly valued and rewarded in academia in the ways that they are in industry.

> "The culture of academia for students is characterized by competition. Students are placed in large classrooms with curved grading systems that discourage collaboration and information sharing…This contrast in cultures, from academia where students are viewed as receivers of information from faculty and collaboration is discouraged by the competitive culture and few opportunities for formal interaction exist, to corporations, where employees utilize each others' knowledge base extensively for information, provides insight into the less than optimal educational methods presently implemented in academia." (Brown, Flick, & Williamson, 2005, pp. 11-12)

Students who enter industry after graduation find that the problems they are solving in the workplace are more complex and ambiguous than the problems they solved in school. The new workplace culture is unfamiliar and many find that they are working with larger, more diverse teams than they experienced in school (Atman, et al., 2010, p. 5). Whereas new hires are used to working on short school projects through the entire life-cycle, industry projects can run for years and even decades and some engineers may never see a project to completion. These major differences in the engineering process and culture inevitably add to the time it takes an industry engineer to become fully productive in the workplace and likely add to the school-work gap perceived by both employers and employees.

However, before reforms are implemented, the causes of such major differences between the work and school experience should be investigated. Perhaps the cause is (or is related to) differences in perceived goals of the engineering profession. There is evidence that engineers in academia have a different view from industry of what the engineering practice actually is. One engineer in academia noted that many faculty members viewed the primary role of the engineer as a developer of new knowledge rather than one who applies known knowledge, and yet he found the general view in industry to be just the opposite (Conner, 2002, p. 1). He also noted that many faculty members based their view of the future of the field on their past activities in their own research field. Many had little or no significant industry experience that could serve as the basis for preparing students to be practicing engineers in industry. In fact, the great majority of engineering faculty have no industry experience (National Academy of Engineering, 2005, p. 21) even though the NAE states that "if engineering faculty, as a group, are to adequately prepare students for practice, then some population within that group must have credible experience in the world of non-academic practice" (p. 54). Therefore, because most engineering faculty members do not have experience working in industry, they will not likely gear their instruction towards the needs of industry jobs if those needs differ from the needs in their field of research.

These differences in opinion regarding the profession itself could be one cause of the perceived school-work gap. If faculty members have a very different view of what engineering is than industry representatives, then it stands to reason that faculty would (at least on some factors) design engineering curriculum that is out of alignment with what industry wants and needs, because their conceptions of the goals of an education in engineering would be different.

It is the purpose of this study to investigate, through qualitative measures, the opinions of practicing engineers in both industry and academia to determine if there is a misalignment of goals of education. The hope is that this will be merely the first step in addressing the issue of educational gaps perceived in industry, and also that this will aid in building better university-industry relations for the future. Only through an open discourse among representatives from both industry and academia can the engineering field be assured of alignment of the goals of education and practice for each career path in engineering. However, academia and industry must work together to share information and keep an open mind about the goals and needs of the other.

Research Question

Despite the wealth of literature concerning the impact of teachers' beliefs on their teaching practices, we know very little about the general beliefs held by engineering faculty members regarding the goals of an undergraduate education. Because beliefs are tied to behavior, we would expect that faculty conceptions significantly influence the course and program curricula that they develop. The focus on technical knowledge in engineering programs continues to be the norm even after the publication of many engineering education reports which recommend a greater emphasis on soft skills such as design, creativity, and multi-disciplinary work. Sheppard et al. note that “although the 1740 undergraduate engineering programs in the United States vary in their emphasis and serve diverse student populations, they are remarkably consistent in their goal: U.S. engineering education is primarily focused on the acquisition of technical knowledge” (2009, p. 11). They add that “although engineering schools aim to prepare students for the profession, they are heavily influenced by academic traditions that do not always support the profession’s needs” (p. 1).

Findings such as those presented by Sheppard et al. are completely understandable if industry engineers and university instructors do not share the same beliefs and values pertaining to engineering education. After a review of the literature in engineering education, it appears these two groups may not share the same goals for undergraduate education, yet a formal study investigating this matter is lacking. For this reason, before any sweeping changes are made in electrical engineering education, one should establish whether there truly are fundamental differences in conceptions of the goals of an electrical engineering undergraduate degree between the two groups. Thus, the research question guiding this study is: “How do electrical engineers in industry and academia differ in their conceptions of the goals of engineering education?”

Significance of Study

> "All who have meditated on the art of governing mankind, have been convinced that the fate of empires depends on the education of the youth." –Aristotle

United States social and economic conditions. If the United States is to remain a global economic leader, it is critical that science and engineering students be better prepared with the motivation, competence, and critical thinking skills required to solve problems and generate technological breakthroughs (Atman, et al., 2010). However, in recent years there has been concern that our undergraduates are not keeping up with those in other nations (Committee on Prospering in the Global Economy of the 21st Century, et al., 2007, p. 163). President Barack Obama has warned us that countries that out-teach us today will outcompete us tomorrow (Rising Above the Gathering Storm Committee, 2010, p. 73). However, due to the growing national debt and severe state budget shortfalls, many lawmakers are faced with cutting educational funding at a time when our nation can least afford it.

The Rising Above the Gathering Storm report warned in 2007 that "a weakening of science and technology in the United States would inevitably degrade its social and economic conditions and in particular erode the ability of its citizens to compete for high-quality jobs" (p. ix). The committee members who authored that report were deeply concerned that the scientific and technological building blocks critical to economic leadership were eroding at a time when many other nations were gathering strength. They felt that the United States must compete by optimizing its knowledge-based resources. In a follow-up 2010 report, the committee stressed innovation in the nation's workforce (largely derived from advances in science and engineering) as a primary driver of the future economy and job creation. They also noted that although only four percent of the nation's workforce is involved in engineering and science, they create jobs for the other 96 percent (Rising Above the Gathering Storm Committee, pp. 2-3). Others go even farther and declare engineering prowess as the key to the progress of civilization (Sheppard, et al., 2009, p. xviii).

Clearly, engineering and science education is worth our national attention and financial investment. Those who believe that this is the time to limit our spending on education because of the current economic situation may want to consider the words of Professor Eric Hanushek when he stated that “[a]n investment in education, designed to improve and increase students' skills, is the best and most effective strategy for stimulating economic recovery (Rising Above the Gathering Storm Committee, 2010, p. 75).

This nation requires, and will require in the future, individuals who are highly educated and well-skilled in STEM (science, technology, engineering, and mathematics) fields if it is to continue to have a strong economy and remain globally competitive (Committee on Prospering in the Global Economy of the 21st Century, et al., 2007, p. ix).

Student preparedness. Fueled by alarming reports such as Rising Above the Gathering Storm, many studies have been conducted to determine just how prepared the current engineering graduates really are to face the challenges of a 21st century world (e.g., Casner-Lotto & Barrington, 2006; Casner-Lotto, et al., 2009). The concern over the preparedness of the current and future engineering workforce and the perceived importance of their role in the future global economy has prompted many calls not just for changes in the engineering curriculum but major educational reforms (e.g., Sheppard, et al., 2009).

Employers expect young people to arrive in the workplace with a set of basic and applied skills. The Workforce Readiness Report Card produced in the study "Are They Really Ready to Work?" makes it clear that the reality is not matching expectations (Casner-Lotto & Barrington, 2006). Employers reported that many of the new entrants (from all educational levels) lacked the skills essential to job success (p. 10). The hugely successful venture capitalist and founder of Nanosys, Inc., Larry Bock states, “I find myself hiring talent for my companies abroad, not because I want to but because I can't find qualified engineers and scientists in America” (Members of the 2005 "Rising Above the Gathering Storm" Committee, 2010, p. 76).

At the videogame maker Electronic Arts Inc., the executive vice president of human resources, Gabrielle Toledano, speaks of a gap between the skill requirements the company posts and the experience of the people who apply (Light, 2011). David Arkless, president of corporate and government affairs for the Milwaukee-based staffing firm Manpower Incorporated says that they are seeing a problem of “companies unable to find the right skills in the right place"(Light, 2011).

Survey results from industry indicate that many young people are inadequately prepared to be successful in the workplace. When surveyed about the general preparedness of new hires entering the workforce in the United States, almost nine percent considered the employees to be deficient in their preparation. Noted deficiencies were writing in English, written communications, and leadership (Casner-Lotto & Barrington, 2006, pp. 11-14).

Lattuca et. al. (2006) surveyed employers about their perception of preparedness of engineering hires. Although 92% felt that new hires were adequately or well prepared in their use of math, science and technical skills, only around half felt that they understood how to work within contexts and constraints (a major component of engineering work), and a quarter of respondents felt that they were not adequately prepared to communicate and work in teams (p. 12).

From the student perspective, many engineering graduates also do not feel that they have learned enough to work in industry. A 2010 survey of engineering graduate students reported that the students felt themselves to be ill-prepared in many soft skills, such as time management, leadership, sensitivity to cultural differences, and the ability to work in a global marketplace (Mohan, Merle, Jackson, Lannin, & Nair, 2010, p. 568). It is this lack of global perspective in our engineering students that prompted Roman (2004) to state that "[t]herein lies our greatest failure. We have educated 'flat-earthers' for a multidimensional world."

It is the responsibility of the engineering education community to discover these deficiencies and address them in the curriculum, but only after defining clear goals from both academia and industry. Unfortunately, these communities have not spoken in a clear and unified voice about what the goals of engineering education should be. Should the goal be theoretical knowledge? Practical application? There appear to be some differences in opinions.

> "With these disconnects, it's no surprise that there has been little progress in moving the needle on the issue of workforce readiness." (Casner-Lotto, et al., 2009, p. 21)

Preparedness and retention. The issue of preparedness is not a minor one for either students or employers. Students in the United States and their families make enormous sacrifices to obtain a college education. In fact, the increase in cost of higher education in America has substantially surpassed the growth in family income in recent decades. The result is that current and former students in this country have amassed $633 billion in student loan debt (Members of the 2005 "Rising Above the Gathering Storm" Committee, 2010, p. 10). Students need the best training for their money so that they can quickly begin to experience professional and financial success and begin to pay down that debt.

The high costs of recruiting and training new engineers also makes alignment of educational goals to industry needs an important issue for companies. It takes six to 12 months to hire and orient an engineer with a cost of $20,000 to $80,000, excluding recruiting fees. Also, because of the fast pace at which technology changes within the field of engineering, continuing education is a must for any engineer for the duration of their career. To deliver 100 hours of in-house continuing education costs between $5,000 and $10,000, and the half-life of engineering knowledge now stands at just two years (Paton, 2002, p. 7).

With such high hiring and training costs, it is important for companies to retain the engineers that eventually get hired. However, engineering as a field experiences very high attrition rates. Not only have the science and engineering (S&E) fields traditionally lost a significant number of students to other fields right out of college, but throughout the 1990's there was a total attrition of 65 percent just one to two years after graduation (20 percent of S&E bachelor degree holders were in school but not in S&E studies, while another 45 percent were working but in non-S&E employment) (Lowell & Salzman, 2007, pp. 31-34). In a recent study (Atman, et al., 2010, p. 66) it was found that even of the seniors who were intending to finish an engineering degree, 20% of them were either turning away from the engineering profession or remained unsure about their future plans.

Even after new engineering hires are situated in the workplace, preparedness has an impact on retention among those engineers. In a study among new engineering graduates in Singapore, a positive correlation between task mastery and job satisfaction (r=.40) was found. Task mastery was also tied to intention to quit through a negative correlation (r=-.20). And not surprisingly, there was a negative correlation between job satisfaction and intention to quit (r=-.74) (Kowtha, 2008, p. 73).

Dan (2010) obtained similar findings. Technical competence was found to be positively correlated with job satisfaction (r=.246) and negatively correlated with the intention to quit (r=-.329) Again, there was a negative correlation between job satisfaction and intention to quit (r=-.533) (pp. 501-503). It is then important to companies that new engineers perceive themselves to be adequately prepared for their new jobs as this perception may improve job satisfaction and hence, retention.

The analysis of differences in educational goals between practitioner groups in electrical engineering can be the beginning of a process whereby common values are found within the profession and academia can begin to better align engineering education to those common values. This alignment should better prepare electrical engineering students to enter the workforce with the necessary skills to be successful in their careers and remain in a profession that holds so much promise for this country's future.

II. Review of Related Literature

> Controversy in educational discourse most often reflects a basic conflict in priorities concerning the form and content of curriculum and the goals toward which schools should strive. (Eisner & Vallance, 1974, pp. 1-2)

In reviewing the literature for this study, the researcher sought to find sources in which both electrical engineers working as university faculty members and electrical engineers practicing in industry were questioned about their views concerning the goals of undergraduate engineering education. Because of the limited amount of sources in the literature pertaining to electrical engineers specifically, the search was broadened to include all engineering disciplines. The researcher is making the assumption that attitudes across engineering disciplines do not vary significantly and that conclusions made from research of the literature for the general field can be applied to the discipline of electrical engineering in particular.

There are very few formal research studies concerning engineers' beliefs and attitudes regarding educational goals and how they relate to curriculum development. What emerged were papers representing mostly two major areas: instructional practices and curriculum design. For example, Kane, Sandretto, and Heath (2002) performed an extensive meta-analysis of the literature on post-secondary faculty beliefs related to teaching practices. The study outlined many useful resources and provided a wealth of data concerning faculty conceptions, but provided almost no resources regarding conceptions of educational goals. Although the question of best instructional practices is an important one to investigate, it assumes that the educational goals and curricula have already been decided. Therefore, those articles related to instructional methods were omitted from the literature review.

Literature Concerning Curriculum Design

The second major portion of the literature dealt with the selection of engineering curriculum content. Although educational goals are very closely related to the curriculum content, they are not the same. There is a causal relationship between the two. Educational goals should *define* curriculum content, and subsequently student outcomes. In addressing curriculum development, many articles describe the activity in one of two ways: curriculum design by committee opinion, and curriculum design by scientific methods.

Curriculum design by committee. When designing curriculum by committee, researchers solicit feedback from a group of stakeholders consisting either solely of a single group (e.g., faculty members, industry engineers, or business leaders) or from a combined group. The hope is that, by having groups rank the importance of various engineering topics through surveys or discussions, a consensus can be formed and a curriculum that best serves the interests of the students can be crafted.

For example, McGettrick, Theys, Soldan, and Srimani (2003) discuss the use of a task force of presumably academics to look at trends and areas of future development in computer engineering. Although details are lacking on the specific process used, they do outline specific principles employed in guiding their process. The result was a list of knowledge areas, technology trends, and important emerging technical areas that "define the body of knowledge that constitutes computer engineering" (p. 457) These topics would then be used to guide course development.

At times, the "committee" was simply the authors themselves. The authors would study the current trends in engineering and try to make predictions about what the face of the profession would look like years into the future. Using those predictions, they would try to design a curriculum that addressed anticipated needs and then would often provide a sample curriculum reflecting their conclusions (e.g., Evans, Goodnick, & Roedel, 2003).

Curriculum design by scientific methods. A second method of curriculum design encountered in the literature was curriculum design by scientific methods. One example of this method is the concept mapping technique (CMT) used by Toral, Martínez-Torres, Barrero, Gallardo, and Durán (2007). They employ sophisticated mathematical methods to find clusters of relevant and related items. In this case, the relevant items were potential curriculum topics. Feedback on the importance of curriculum topics was obtained from both industry and academia and then statistical methods were employed to refine the original list to produce the final optimized curriculum. The authors argue that this systematic and scientific approach is the ideal approach to developing curricula.

Whichever method one utilizes to develop curriculum, one should not embark on this task until the educational goals of the program have been clearly defined. Although the educational goals should be inherent in the curriculum if all stakeholders are consulted in the design, the goals need to be an important aspect of feedback and the design process. Too often educators address the issue of curriculum content before clarifying overall educational goals.

National Reports

There are a number of national reports that have been published in recent years addressing the issue of engineering education. The reports are usually produced by committees which consist of members from both academia and industry. As such, they represent a more balanced opinion of the most pressing reforms needed in engineering education and the characteristics required of successful engineering graduates in the near future. Examples of these are a series of reports published from 2004 to 2010 through the National Academies in Washington, D.C. (Committee on Prospering in the Global Economy of the 21st Century, et al., 2007; National Academy of Engineering, 2004, 2005; Rising Above the Gathering Storm Committee, 2010).

The 2004 report from the NAE (pp. 53-56) makes very clear what the committee believes to be the key attributes of the engineer of 2020. They are strong analytical skills, practical ingenuity, creativity, good communication, mastery of the principles of business and management, strong leadership ability, acknowledgment of significance and importance of public service, high ethical standards, and a strong sense of professionalism. They go on to say that boldness, courage, dynamism, agility, resilience, flexibility, and lifelong learning will support these attributes in a successful engineering career.

The report concludes with a discussion of traits for the ideal 2020 engineer, stating that the successful engineer of 2020 will “aspire to have the ingenuity of Lillian Gilbreth, the problem-solving capabilities of Gordon Moore, the scientific insight of Albert Einstein, the creativity of Pablo Picasso, the determination of the Wright brothers, the leadership abilities of Bill Gates, the conscience of Eleanor Roosevelt, the vision of

Martin Luther King, and the curiosity and wonder of our grandchildren” (p. 57). These are very inspiring words indeed, but the hard work starts when one tries to envision the curriculum that will produce such a person.

These reports paint a very broad picture of engineering education for the future, also emphasizing the engineer's role in society:

> “Within the context of the changing national and global landscape, the Phase I committee enunciated a set of aspirations for engineers in 2020...At their core they call for us to educate technically proficient engineers who are broadly educated, see themselves as global citizens, can be leaders in business and public service, and who are ethically grounded.” (Rising Above the Gathering Storm Committee, 2010, p. 51)

In an effort to produce some sense of consistency in engineering programs based on academia and industry input, ABET, Inc. developed a set of accreditation criteria for engineering programs. In 1997 they made a dramatic shift in the focus of their criteria and changed their emphasis from what was being taught in engineering programs to student capabilities upon completion. What follows is the current version of the well-known "a-k" engineering outcomes provided by ABET, Inc:

Criterion 3. Program Outcomes:

Engineering programs must demonstrate that their students attain the following outcomes:

(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. (ABET Engineering Accreditation Commission, 2009, p. 3)

Again, one sees a very broad picture of the ideal engineer in these outcomes. ABET intended for this list to be used as a guideline in developing curriculum to ensure that every engineering graduate has at least this core set of attributes. What is not apparent from "a-k" is the relative importance of these outcomes. An emphasis on outcome (b) would suggest a curriculum bias towards a career in academic research whereas a curricular emphasis on outcome (c) could be seen as preparing a student more for a career in industry. Engineers in industry are more likely to do design work on large projects with many different types of system constraints and requirements.

Formal Studies

Industry only. In an early study, consisting of interviews of electrical engineers from industry, the overall finding was that industry desired graduates who were technically enhanced, able to manipulate applications software or electrical engineering design tools via software on a work station or PC, able to participate fully in a team approach to solutions, and able to present work verbally and in writing in an excellent manner (Bates & Conner, 1994, p. 242). No information on relative importance of these attributes was reported. When asked about the future of electrical engineering work, the industry engineers referenced computers/software/automated processes 96 times, teamwork/working with people/verbal and written communications 41 times, fiber optics/optics 25 times, conservation/environmental concerns 24 times, and the need for a foreign language 21 times (Bates & Conner, 1994, p. 242).

It is interesting to note that technical skills were mentioned over twice as many times as any other topic listed in the study. This seems to be at odds with many newer publications which imply an industry bias towards soft skills in new graduates. For example, Casner-Lotto and Barrington (2006) surveyed over 400 employers across the United States regarding which skills they considered to be "very important" for four-year institution graduates (across all disciplines). Every skill with a response rate of 90% or higher (oral communications, teamwork/collaboration, professionalism/work ethic, written communications, and critical thinking/problem-solving) would be considered a soft skill. In fact, for all educational levels (high school, two-year institutions, and four-year institutions), soft skills tended to rate higher than basic knowledge and non-soft skills (p. 9).

In addition, a 2006 survey of 444 engineering company representatives rated three soft skills as the top three skills desired by employers (Spinks, Silburn, & Birchall, 2006, p. 53). In fact, practical application was rated as the most important skill on the list. This result correlates well with the opinions expressed in the literature by industry authors. Technical breadth and theoretical understanding ranked fourth and fifth.

In a separate 2006 survey rating the ABET outcomes, employers rated the application of math, science, and engineering (the closest outcome to technical and theoretical understanding) as third (Lattuca, et al., p. 11). Although far from the 11th and last spot, it still ranked beneath communications and problem-solving, though not by much. Nineteen percent considered it to be only moderately important.

Employers in industry appear to be asking not necessarily for a less technically educated individual, but a better-rounded individual. They want people who are exceptionally good at handling pressure situations and presentation skills. They stress factors like being able to work at a systems level (Waks & Frank, 2000, p. 350) and business skills such as conflict resolution, human resource management, and budgeting (Muhammad, et al., 2009, p. 64) and they appear to voice this with a higher frequency and emphasis than those in academia.

It is sometimes possible to notice differences in values between academia and industry simply by polling practitioners in industry on self-efficacy. By looking at perceived abilities of engineers just out of school and comparing them to those who have been practicing in the profession for some time, one begins to construct a picture of values in each environment. A high rating of a particular ability of those recently graduated would suggest a heavy emphasis and hence a high value placed on that skill in school. Of course, a low rating would suggest the opposite. Looking at how those abilities change over time through professional practice in industry, one can deduce a value system for industry as a whole.

One such study was recently conducted in Lebanon. Baytiyeh and Naja (2010) surveyed 188 engineers across multiple disciplines. Respondents were asked to assess themselves on technical, inter-personal, and personal skills both before and after practicing engineering using a five-point Likert scale. According to their perceived abilities of technical skills before starting their engineering practice they rated "learn a new subject on your own" and "possessing computational skills" highest while rating "creativity and innovation skills" and "transforming knowledge to product" lowest (Table 1). They were then asked to rate their perception of current abilities having practiced engineering for a relatively short time (most, less than five years). They once again rated "learn a new subject on your own" as the highest ability followed by "solving engineering problems." The two lowest rated abilities were "theoretical knowledge" and "conduct experiment on your own" implying that these two aspects of their knowledge were not being greatly utilized on the job and therefore not highly valued in industry. The two greatest positive gains from school to the workplace were seen in "creativity and innovation skills" and "transforming knowledge to product" showing an emphasis on the more design-related and applied skills on the job (p. 3).

Table 1

Ranking of Technical Skills from Batiyeh and Naja 2010 Study

	Ranking	
Technical Skill	Before Starting Career	After Practicing Engineering
Learn a new subject on your own	1	1
Possessing computational skills	2	6
Solving engineering problems	3	2
Theoretical knowledge	4	9
Model and formulate problems	5	3
Conduct experiment on your own	6	8
Using technological tools	7	7
Transforming knowledge to product	8	5
Creativity and innovation skills	9	4

These results are consistent with the responses to the open-ended questions of the same survey where industry representatives expressed “the need for more practice and less theory in school” (p. 5). They desired that more practical courses with real-life problem-solving situations be implemented in the engineering program. Regarding perceived ability levels of personal skills upon graduation, "ability to work under pressure" and "preparedness for continued learning" rated highest. "Knowledge of business and public policies" and "leadership and managerial skills" rated lowest.

It is interesting that these skills should rank so low considering that they are often cited as being important attributes by industry managers. In fact, it is on these two factors that the highest gains were seen after practicing in the field, pointing to perhaps a low value of these attributes in academia and a high value in industry. This discrepancy suggests that there may in fact be a difference in conceptions of educational goals in the field.

Academia only. The views from academia seem to lean towards a different emphasis. In a study using only faculty respondents, "the basic body of knowledge in the domain" was rated highest, followed by "knowledge needed for professional work." "Methods of research in the domain" and "contribution of academic discipline to humanity" scored lowest (Hativa, 1997, p. 23).

Franklin and Theall (1992) took a slightly different approach in obtaining faculty conceptions of educational goals. Faculty respondents were surveyed about the relative emphasis placed on various objectives in their classes and then were compared across disciplines. For this study, engineering, math, and science (EMS) were considered a single area. The findings showed that the EMS faculty group placed a higher emphasis on gaining factual knowledge, learning fundamental principles, problem-solving, and psychomotor skills than the humanities and business faculty groups. The EMS group also rated written communication skills, oral communication skills, creativity, leadership, groupwork, and self-knowledge lower than either the humanities or business groups (p. 10).

Industry and academia combined. In the only formal study found that compared differences between industry and academia, Eskandari, Sala-Diakanda, Furterer, Rabelo, Crumpton-Young, and Williams (2007) surveyed faculty and industry professionals across the United States regarding desired characteristics of graduates and curriculum topics in industrial engineering (IE). Regarding desired characteristics of IE graduates, teamwork skills were found to be the most important desired characteristics from the industry respondents surveyed, and there was considerable difference between the academic and industry perspective. The authors were able to find some statistically significant differences between the industry group and the faculty group on responses. The industry respondents placed more emphasis than faculty on teamwork skills and the human dimension of management. Faculty respondents placed more emphasis on technical writing, the global perspective, and programming. Faculty also put more emphasis, but not by a statistically significant amount, than industry on general engineering and diversity sensitivity. Once responses from both groups had been combined, adaptable problem-solving skills were found to be the most important overall, followed by process evaluation/analyses and quantitative/analytical abilities, respectively. There was a very strong correlation between the desired characteristics of future IE graduates found in this study and the key attributes of engineers in 2020 reported by the NAE (2004).

Regarding important *topics* to be included in IE curriculum, project management was found to be the most important topic, followed by performance measurement/management, ethical behavior, and leadership, respectively (from combined faculty/industry responses). Again, sufficient evidence was provided to indicate a statistically significant difference between the industry and academic perspective on a few topics. Industry respondents put statistically significant more emphasis than faculty on team building facilitation, financial engineering, organizational behavior, customer relationship management, negotiation and conflict resolution, and data mining. Faculty put more emphasis than industry on semantic web technologies. From this study, it would appear that industry favors the soft skills over the more technical skills which were rated higher by faculty. However, through surveys and interviews of industry executives and managers, industry-savvy government leaders, and academic leaders from around the world, Hissey (2000) found a *consensus* on the importance of soft skills and the understanding of their value in being "career enhancing" in today's economy.

Opinion Pieces

Beyond looking at formal studies, one also can find evidence of conceptions of educational goals by reviewing opinion pieces in the literature. There is an ongoing discussion in the engineering journals which includes representatives from both industry and academia. Both sides seem to be calling for major reforms in engineering education, citing that the methods for educating engineers have not changed in decades. The calls for reform have not changed much over the past few decades either.

If one is seeking evidence of educational goal differences between the two career paths, one must consider these data with a grain of salt. These authors are self-selected. Their opinions do not come from a random sampling of practitioners but from those who already have some very strong opinions about the state of engineering education today. Nonetheless, these are voices from the trenches of the profession on both sides, and their writings still provide important insight into the values and belief systems within the profession.

Industry. Although industry representatives are less likely to write articles in peer-reviewed academic journals, there is still a good amount of information about industry conceptions of educational goals in the literature. It should come as no surprise that industry would have many opinions as to how to reform and improve engineering education. In fact, most authors have very specific recommendations for the engineering curriculum. For example, Cavin, Joyner, and Wiggins (2003) propose the following ten principles as a curriculum guide to be used in connecting the graduates of today with the engineering careers of tomorrow:

1. Keep a strong laboratory component in ECE education.
2. Teach the fundamentals of science and mathematics.
3. Encourage students to learn to communicate effectively.
4. Instill wealth creation as a noble enterprise.
5. Emphasize the importance of professional ethics.
6. Instill a love for learning in ECE students.
7. Target future as well as current needs.
8. Recognize the value of industry and government internships.
9. Encourage cross-disciplinary exposure.
10. Value mentoring and teaching.

The details of achieving these goals in the curriculum are still left to those in academia, but the principles do give one a sense of what employers in industry hold as important.

Many of the writings from industry stress the importance of soft skills in the engineering profession, warning that a failure to acquire them "can limit opportunities" in the workplace (Rainey, 2002). "Although technical skills may aid an engineering graduate in getting a job offer, other capabilities frequently determine career success" (p. 4). This last statement is supported by the fact that job descriptions are very detailed in technical requirements even though industry representatives, when questioned, focus on soft skills as most important for success. Raymond Yeh (2002, p. 3) adds that "engineers cannot be merely 'nerds,' because they will encounter a multitude of technical, human, cultural, and organization challenges along their career. We need to provide them with leadership skills, and we need to educate them on being professional with high ethical standards." Particular soft skills that are often stressed by industry authors are critical thinking and adaptability, since they are skills that can be generally applied across disciplines and occupations and do not become obsolete as do the "transient technological facts" (Rainey, p. 4).

Other sources show evidence of industry representatives essentially viewing engineering fundamentals and soft skills with equal importance in the curriculum (e.g., Hissey, 2000, p. 1368; Jones, 2002, p. 35/1). (Engineering fundamentals are defined by the researcher in this study as all technical courses excluding mathematics and science.) Probably no one would argue that both are not absolutely necessary for a successful career in engineering. The question is the relative emphasis of these skills in the curriculum and whether those in industry believe that the engineering curriculum needs to be modified to increase the emphasis of one or the other.

The literature from industry also often speaks of the engineer as a responsible citizen and the role of the engineer in society. It has been suggested that one educate the *whole* engineer through approaches such as "subject integration" (which blends both technical and nontechnical aspects of a problem into a choice that has real value to society) (Roman, 2004, p. 88), injecting more liberal arts courses into the curriculum (Heinig, 2005, p. 88), and convincing students of the importance of lifelong learning (Rainey, 2002, p. 4). There does seem to be a difference in the writings between industry and academia with regard to what the engineer's role in society actually is. Industry authors are more likely to write of the impact of an engineer's work on society and the role of the engineer in economic development. There is a heavier emphasis on the environmental and commercial context within which the engineer works. "Engineers are citizens of their community and the globe, and must be sensitive to the societal impacts of the technologies they create" (Rainey, 2002, p. 4).

The following section outlines the important issues from the perspective of academia from a review of opinion pieces authored by people working in higher education.

Academia. Although there is not as much emphasis from faculty authors on the engineer's role in society in the literature, one occasionally finds comments stressing the importance of this issue. For example, the faculty of one mechanical engineering department mention wanting students to be socially responsible as a goal of the undergraduate curriculum (Quinlan, 2002, p. 47).

Hu (2003) writes of a holistic approach to education and sees engineering programs as having a higher responsibility to produce good citizens. He writes that electrical and computer engineering (ECE) graduates must be well-rounded citizens and that engineering education must be more than just about engineering. He also encourages active social-political involvement. However, throughout the literature, the emphasis on the social responsibility of the engineer is less in academic writings than in industry writings.

Although authors from academia propose a curriculum that broadly educates students and one that teaches through design (e.g., Aylor, 2009, p. 96) similar to the industry view, it seems to mean something different. Academia places a heavier emphasis on the theoretical fundamentals, or what is often called the engineering fundamentals. For example, Hu encourages hands-on, problem-solving, and design in the curriculum just as many industry authors do, but he is also a strong proponent of providing students with a strong set of fundamental knowledge and skills through what he terms a "technology-independent high-level of abstraction" (pp. 445-451). He goes on to say:

> It is more important to have a curriculum that teaches knowledge and skills that are long lasting and can be applied in new situations than one that teaches cutting-edge technology that may become obsolete in a few years. (p. 444)

Although many industry voices mirror these sentiments, the skills that they are often referring to are not the technical skills but the soft skills.

However, even though the soft skills are not emphasized as often in academic writings as they are in industry writings, faculty do see the value of attaining these skills. Communicating well verbally and in writing were mentioned in the literature, as well as leadership, initiative, adaptability, knowledge integration, teamwork, and lifelong learning (e.g., Metrolho, Costa, & Silva, 2005, p. 14; Quinlan, 2002, p. 47; Teixeira, da Silva, & Flores, 2007). Business knowledge and entrepreneurship are also mentioned as desirable attributes (Teixeira, et al.).

Another difference seen in the literature is that faculty authors are also more likely to argue the merits of a liberal arts education (Moore & Voltmer, 2003, p. 453). The difficulty in achieving this is acknowledged, however, since the engineering curriculum is normally already very crowded, with little room for non-technical courses. Nonetheless, some authors argue for room to be left for subjects such as economics and humanities (Lee & Messerschmitt, 1998, p. 84). Hu even argues that liberal studies have a positive impact on non-technical studies. He suggests that "[a] liberal education provides a context for all knowledge" (Hu, 2003, p. 446).

This opinion within academia is not unanimous, however. Sobol has a very different view of what the engineering curriculum should look like. In fact he argues for *no* electives, not more electives, and less emphasis on liberal arts.

> During the past several years engineering schools have been pressured by certain segments of the industry to place more, not less, emphasis on liberal arts…many universities are already instituting an increased liberal arts curriculum at the expense of technical courses! Can we in the engineering community stand by and let this happen? I say no! The time has come to rally forces to put this sham to rest. This is a time when engineering students need more technical education, not less. (Sobol, 1990, p. 28)

Unfortunately for Sobol, most engineering programs have moved more towards a liberal arts emphasis, at least within their honors programs. This may be because some are beginning to see the undergraduate engineering degree as a sort of "pre-engineering" degree that is a stepping stone to other professions (e.g., Berry, DiPiazza, & Sauer, 2003, p. 471; Quinlan, 2002, p. 47). In fact, the NAE recommends that the engineering baccalaureate degree be recognized as the "pre-engineering" degree that includes a “liberal” engineering education to those students who wish to use it a springboard to other professions. They state that adequate depth in a specialized area of engineering is not even possible in the baccalaureate degree and that the masters degree should be the first professional degree in engineering (2005, p. 52).

Although a lot of important information can be mined from opinion pieces, what one does not get is a sense of relative importance of the characteristics and skills discussed. Overall, there is a sense of valuing more breadth in the curriculum than what is currently present. This academic emphasis on less depth and more breadth contradicts an earlier study conducted by the author (de la Rosa-Pohl, 2011) in which faculty and industry respondents differed most on the issue of "knowledge of one subject in depth." Although results were not found to be statistically significant, the largest rating difference of all engineering educational goals appeared from faculty respondents rating this particular goal much more important (mean = 1.67, s.d. = 0.58) than industry respondents (mean = 3.00, s.d. = 0.00) on a five-point Likert scale. Because of contradictions such as this, it is felt that further investigation into the conceptions of these two groups in electrical engineering be pursued. That is the purpose of this study.

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III. Methods

Data

To address the research question, the researcher used interview data from both electrical engineering practitioners in industry and electrical engineering faculty members employed at a four-year university. These two groups were used because they were specifically mentioned as comparison groups in the research question for this study. Conceptions of educational goals regarding undergraduate electrical engineering education was obtained from each participant and was used to identify patterns among the groups.

Participants

When employing interview methods, the amount of data collected from participants can be substantial. Therefore, in order to keep the amount of data preparation and analysis manageable for a single researcher, the sample size for this study was kept relatively small (N = 6). The breadth of a large study was sacrificed to obtain depth in the small number of interviews. Three electrical engineers from industry and three electrical engineers from academia were interviewed by the researcher. All interviews were recorded and were approximately one hour in length. They were conducted in person at a private location selected by the respondents.

The collective respondent group was a judgmental sample. The researcher selected these individuals based on characteristics that in her judgment made them best suited for the study. All respondents had at least seven years experience in their field. Industry respondents were required to have at least a bachelor's degree in electrical engineering. Faculty respondents were required to be currently active in teaching undergraduate courses in electrical engineering. The group was chosen to include individuals that varied in age, gender, title, field of expertise, and experience to avoid bias towards any single participant characteristic. All faculty respondents were from a single public academic institution, and all industry respondents were from large business organizations in a single metropolitan area. Only large organizations were drawn from since they were more likely be involved in a significant amount of hiring of electrical engineers. The overall group included both female and male respondents.

Because respondents were chosen based on their ability to provide insight into the importance of student outcomes in serving the needs of industry, industry respondents were chosen based on their involvement in hiring decisions at their respective organizations. It was assumed that individuals involved in the hiring process would have more knowledge as to what skills and attitudes companies were seeking in the emerging classes of engineers. Having been in this process, one was more likely to have reflected on any noticeable performance gaps and to have thought more deeply about what direction engineering education should take.

As for university respondents, it was assumed that any faculty member who had been required to teach courses (presumably all faculty members) would have been involved in curriculum development and therefore would have had experience in this area. Therefore, faculty member participation was limited only by years of experience and level of involvement in teaching electrical engineering courses. In addition, to provide a “big picture” perspective, one faculty respondent was chosen who had also worked as an administrator. All respondents were from a single geographical region for convenience in arranging interviews at locations accessible to the researcher.

Procedures

Data collection. In conducting the interviews, the researcher used a variation of Seidman's three-interview series (Seidman, 2006). The series consisted of three stages: 1) life history, 2) contemporary experience, and 3) reflection. The aim of the first stage in this series (life history) was to set the historical context for the respondent's conceptions. The questions focused on *how* respondents arrived at their current position, as opposed to *why*. The second stage (contemporary experience) included questions that guided the respondent in painting the current picture of their professional life. This was particularly important in this study because the goal was to compare two different professional groups in the same engineering discipline. Similarities and differences of the two branches of electrical engineering emerged as respondents described their day-to-day activities and responsibilities. The final stage, reflection, was the heart of the study, where the respondents made meaning of their life story and, in light of that meaning, described their conceptions of engineering and the goals of engineering education.

Because it was not logistically possible to arrange three interviews with each respondent, the original three-interview series was reduced to a single three-stage interview. There is evidence of successful use of Seidman's full three-interview method in the existing literature (e.g., Jones Sr., 2010; Parot-Juraska, 2009). Although this study used a contracted version of the full three-series method with some acknowledged loss of depth, all three required stages of the Seidman method were present in the interviews, allowing this modified method to nevertheless produce meaningful data. Approximately equal time of 20 minutes was spent on each stage of the interview including life history, contemporary experience, and reflection. The reflection stage stood to lose the most from reducing the number of interviews to one since respondents had very little time to reflect on the whole experience. However, it was felt that *any* amount of time spent on reflection added value to the process and produced meaningful data because “[t]he very process of putting experience into language is a meaning-making process” (Vygotsky, 1987 in Seidman, 2006).

The interview process was chosen as the data collection method because it allowed respondents to develop their own personal meanings in their own words. There were no quantitative variables to limit their personal interpretations as would be the case with a survey. This study sought to identify broad themes and patterns in the related conceptions of the interviews. By adhering to the modified three-interview structure, the researcher obtained common information from each respondent. Only broad general questions were laid out in advance in order to give the respondents more opportunities to develop themes. The researcher acknowledges that this resulted in different information being obtained from each respondent and also that this made comparisons slightly more difficult, but this was an acceptable tradeoff for the opportunity for ideas to emerge freely. Furthermore, there was a single interviewer for all respondents, thereby minimizing the chance of significantly different interviewing experiences across the sample.

This interviewing method was a good fit for the proposed research question because this study sought to uncover conceptions. Interviewing allowed the researcher to peer into the respondents’ everyday experience to unearth beliefs and values that surveys and observations would have otherwise left obscured.

Data analysis. The analysis process was not a separate activity apart from the interview itself but was instead a "continuation of the conversation" that involved "developing the meanings of the interviews, bringing the subjects' own understanding into the light" (Kvale & Brinkmann, 2009, pp. 195-196). For this study, the process used was one based on the methods described by Miles and Huberman (1994).

Initially, all interviews were completely transcribed by the interviewer from audio recordings. The qualitative research software NVivo 9 was used to complete the transcribing, track coded data, and collect notes. NVivo allowed for all interview data and annotations to be organized easily in one file location. Once an interview was transcribed, the researcher reviewed each transcription for accuracy. The transcription and review process were actually the first phase of analysis. As ideas about patterns and connections within the data were observed by the researcher, memos were written and collected for further analysis.

After each interview was transcribed and reviewed completely, a contact summary sheet was created for the study participant. The contact sheet allowed the researcher to reflect on the interview soon after completion while the interview experience was still fresh. Reflections concerning what things went well and what things could be improved upon for future interviews were noted for each participant and appropriate changes to future interviews were then implemented. For example, an early interview was conducted in a public setting that did not control for noise. The resulting audio file was very difficult to transcribe. Therefore subsequent interviews were conducted in private and quiet settings. Also, it was noted after the first couple of interviews that too much time was spent discussing the participant's personal history as opposed to the study's unit of analysis (educational goals). The researcher then took measures to ensure that the remaining interviews were segmented more carefully to allow for proper time allocation to all three Seidman stages. Care was taken to not change the interview process in significant ways that might affect the validity of the study. The contact summary sheets also documented the main issues and themes from the interviews for later reference, since these are things that may have easily been forgotten by the time that formal analysis was eventually conducted.

Once all of the interviews were correctly transcribed, all of the text was analyzed for passages of interest that provided insight into this study's unit of analysis: goals of electrical engineering education. Each passage of interest was then analyzed to determine a topic that best described it. The passage was then coded to that topic and the topic was added to a master list of educational goals to be used for further coding. As other salient topics emerged while analyzing the transcribed data, those topics were added to the master coding list and also used in the remaining analysis.

After all of the coding had been performed, the researcher sorted coded segments into their respective topics. The coded segments for each topic were then reviewed to ensure that appropriate coding had been performed for each segment included in that topic. Where more detail was required, new coding topics were included. Where two topics proved to be similar, the coding topics were merged. This was an iterative process which continued until the researcher felt that the master coding list accurately represented all evidence of the unit of analysis in the interview data.

Once interview data had been thoroughly sorted by topic to the researcher's satisfaction, data were further sorted within each topic in two different ways. First, data were sorted by study group (i.e., industry v. academia). Next, data were sorted by context of statements. Respondents referenced educational goals when reflecting on their own work activities and also in the context of what electrical engineering students should be learning in their programs. This resulted in four subcategories. The quantity and quality of the interview segments for each subcategory was then compiled into a table for each topic and used in analysis. From each table, patterns between groups were observed and reported in the findings chapter. The researcher then looked for the emergence of patterns from the perspective of the overall outcomes list and reported those findings as well.

IV. Findings

Introduction

The purpose of this study was to determine if major differences exist between industry and academic practitioners in electrical engineering regarding undergraduate educational goals. The industry component of this study collected and summarized the perceptions of three industry practitioners in electrical engineering who had been involved in the hiring of entry-level engineers. The faculty component collected and summarized the perceptions of three faculty practitioners in electrical engineering who had been involved in curriculum development within the discipline. All study participants had been working in the field for a minimum of seven years. These six participant interviews collected information on the perceived importance of electrical engineering undergraduate educational outcomes from each group.

Interview data were analyzed for evidence of participant value systems as they pertained to the study unit of analysis—undergraduate electrical engineering student outcomes. Evidence was found in two contexts: 1) participant work activities and 2) participant discussions of student outcomes. This chapter presents findings resulting from analysis of study data that related to 13 educational outcomes which emerged from participant interviews.

Educational Outcomes

Emerging themes. Throughout the six practitioner interviews in this study, 19 educational outcomes emerged from the transcribed data (see Table 2). Of these 19 outcomes, 5 were technical outcomes and 14 were non-technical outcomes. The outcomes were coded throughout the interviews as respondents discussed their own work activities and as they discussed desirable characteristics in electrical engineers just entering the workforce (i.e., students who recently graduated). For this particular analysis, all comments were included whether they were favorable (respondents implied that an outcome was important) or unfavorable (respondents implied that an outcome was not important).

Table 2

Educational Outcomes Emerging from Interview Data

	Total Number of Comments (Favorable and Unfavorable)		
Educational Outcomes	Industry	Academia	Combined
Technical Outcomes			
Engineering Fundamentals	14	6	20
Science	3	7	10
General/Unspecified Theory	6	2	8
Mathematics	2	5	7
Practical Applications	3	3	6
Non-Technical Outcomes			
Systems Modeling and Design	2	12	14
Broad Education	10	3	13
Business Knowledge	9	4	13
Problem-Solving	7	6	13
Communications	4	8	12
Ethics/Morality	5	7	12
Learn to Learn/Lifelong Learning	8	2	10
Creativity	7	0	7
Service	1	3	4
Research Skills	1	2	3
Pride	0	2	2
Leadership	1	0	1
Teamwork	1	0	1
Time Management	1	0	1

Overall, respondents talked most about engineering fundamentals—particularly the industry group. Engineering fundamentals cover a wide range of engineering topics in the curriculum and include technical course content that is not included in mathematics and natural sciences. Topics such as programming and electronics are considered to fall under the umbrella of engineering fundamentals. Twenty comments from the two groups were coded under the outcome of engineering fundamentals—twice as many comments as the next highest rated technical outcome of science. The technical outcome that respondents spoke least about was the practical application of knowledge. Each group tallied only three comments on this topic.

In the non-technical outcomes list, there were quite a few outcomes with ten or more total comments. In fact, ten or more comments were coded for half of the non-technical outcomes. Systems modeling and design topped the list with 14 comments, but a broad educational background, business knowledge, and problem-solving came in as very close seconds. Tied for the least talked about outcomes were leadership, teamwork, and time management.

Technical outcomes.

Theoretical knowledge in mathematics. Although one assumes that electrical engineers need to be highly proficient in mathematics upon graduating from college, industry respondents had surprisingly little to say about the value of this outcome with new graduates. As Table 3 shows, only one of the three industry respondents mentioned the need for students to understand mathematics.

Table 3

Group Comments Related to Theoretical Knowledge in Mathematics

	Industry		Academia			
Role/Responses	+	—	+	—	△ (I-A)	Total
Job	0	1	0	0	1	1
		Never had to apply knowledge on the job				
Student	1	0	5(2)	0	-4	6
	There is a need to understand it		Math is the language of EEs; Must be highly skilled so that focus can then turn to context of EE problem; Cannot be a good engineer w/o solid skills; (GAPS: Students do not believe they need math; Students need more math in curriculum)			

Note: Respondents include: I = Industry, A = Academia
Types of responses: + = favorable , — = unfavorable
( ) = Gap: Number of comments pertaining to learning gaps in mathematics

Faculty respondents, however, placed a much higher emphasis on this outcome as is evidenced by the following statement:

> Every good engineering student has to have solid mathematical skills. It's absolutely impossible to produce a good engineer without mathematical skills that allow him to handle problems.

Faculty referred to mathematics as the "language we speak." They called attention to what they perceived weaknesses in the electrical engineering student body and suggested more emphasis be placed on mathematics in the curriculum. Faculty comments imply that this weakness may be related to student perception of a low level of importance of advanced mathematics in their career. The data also suggest that this perception may follow students into their careers in industry, as only one industry respondent mentioned mathematics in relation to their job. That single industry response merely acknowledged never applying mathematical concepts such as Fourier and Laplace transforms (two concepts heavily emphasized in the electrical engineering curriculum).

Theoretical knowledge in science. Of the six electrical engineering respondents, only two (one from each—industry and academia) commented on the importance of understanding science as a student outcome. The single industry respondent addressed the importance of understanding physics, while the single faculty respondent addressed the need for a basic understanding of chemistry (Table 4). Although the faculty respondent conceded that chemistry theory is not needed on a daily basis by electrical engineers on the job, data showed that a basic understanding was indeed seen as important for seeing the big picture of engineering problems.

Table 4

Group Comments Related to Theoretical Knowledge in Science

	Industry		Academia			
Role/Responses	+	—	+	—	△ (I-A)	Total
Job	0	2	3(1)	0	-1	5
		Chemistry is not used on the job.	EEs need chemistry, especially in semi-conductor fields; Predicting chemical processes and reaction rates.			
Student	1	0	4	0	-3	5
	Need to understand Physics		Chemistry teaches important ideas that are helpful later in curriculum; Chemistry is needed to see “big picture” in engineering problems.			

Note: Respondents include: I = Industry, A = Academia
Types of responses: + = favorable , — = unfavorable

Two of the three industry respondents pointed out that an understanding of chemistry was not helpful in their current occupation. One expanded on the function of chemistry, saying that it might aid in understanding current events discussed in the news, but was not useful on the job. Two of the three faculty respondents, however, stated that they did in fact use chemistry theory in their current work. One even regretted not having a stronger background in chemistry.

Chemistry and physics were the only two science subjects mentioned, most likely due to the fact that they are typically the only pure science courses required in electrical engineering programs. Courses in life sciences, such as biology, are not usually required elements in the electrical engineering curriculum.

Theoretical knowledge in engineering fundamentals. Perhaps not surprisingly, the topic of engineering fundamentals elicited the greatest number of comments from respondents (20 comments total) of all student outcomes discussed. As illustrated in Table 5, respondents were particularly specific in their comments when discussing both student outcomes and work activities. With no other outcome were respondents so specific in their discussion of engineering outcomes. Comments covered a wide range of topics. Within these topics, circuit theory and signals and systems theory emerged most often across both groups.

When discussing engineering fundamentals as a student outcome, industry respondents felt that it was important for students to have a basic foundation and mentioned a wide range of engineering topics specifically. Faculty respondents did not mention as many specific skills. They mentioned a need for students to have overall good technical skills, and mostly emphasized the need for a strong understanding of signals and systems theory. One faculty respondent felt that students currently in the program were very weak in signals and systems, arguing that being able to "come up with a simple model…and understand its frequency response are the key abilities of electrical

Table 5

Group Comments Related to Understanding of Engineering Fundamentals

	Industry		Academia			
Role/Responses	+	—	+	—	△ (I-A)	Total
Job	7(2)	2	2	0	7	11
	Programming various languages; Statics and dynamics; Signals and systems theory; Circuit theory; (GAPS: Weak in circuit theory; Lacking VLSI experience)	Circuit theory, Solid state physics, VLSI and control systems theory never applied on job	Signals and systems; Programming			
Student	5	0	4(1)	0	1	9
	Circuit theory; Network theory; Computer Architecture; RF Theory; Signal Processing; Digital logic		Signals and systems; Overall good technical skills; (GAP: Signals and systems)			

Note: Respondents include: I = Industry, A = Academia
Types of responses: + = favorable, — = unfavorable
( ) = Gap: Number of comments pertaining to learning gaps in engineering fundamentals

engineers." Signals and systems theory was the only knowledge gap mentioned by either of the two groups. This theory was also mentioned as being important in academic work by the faculty group. But perhaps the most interesting finding to emerge from these data was that, even though there were many specific topics mentioned overall, there was absolutely no overlap of important student outcomes discussed between the two groups. However, there was some agreement between the groups in that neither listed any subjects as being unnecessary or useless in the context of student outcomes.

Several topics, however, were mentioned by industry respondents as being unnecessary or unused on the job, even though there was some disagreement within the group. Of the three industry respondents, one perceived a personal weakness in circuit theory knowledge and expressed a desire for more training in this area, while another acknowledged never using this theory on the job at all. The third had argued that a good understanding of circuit theory was "the most important thing" that students needed to be learning in the electrical engineering undergraduate program, but failed to mention its relevance or importance on the job.

There was also disagreement on the subject of VLSI within the industry group. One respondent regretted not taking a VLSI course in school after landing a job in the semiconductor industry, while another respondent in a completely different field acknowledged never using VLSI theory in the workplace. There was, however, agreement between the two groups regarding the usefulness of programming skills on the job, although neither group addressed this skill when discussing important student outcomes.

Interestingly, only one respondent from industry discussed the benefits at work of taking courses from another engineering discipline. In this case, the courses were from the mechanical engineering department.

General/unspecified theoretical knowledge. Respondents did not always specify the type of theory being referred to, or at times were referring to all theory taught at the undergraduate level. These comments have been categorized under the outcome of general or unspecified theoretical knowledge. When participants spoke of theoretical knowledge in general terms, respondents described this outcome as a basis for new learning or as the foundation for logical thinking and problem-solving skills (Table 6).

Both groups were in close agreement on the importance of this outcome. In fact, there were no negative comments regarding theoretical knowledge as a student outcome across any of the theory outcomes (mathematics, science, engineering fundamentals, and general/unspecified). The only negative comments came when discussing the importance of theory by industry practitioners on the job. Regarding general or unspecified theoretical knowledge, two industry respondents remarked that only 10% or less of this knowledge was used in their current position. These data are in stark contrast to their views concerning the importance of this outcome with electrical engineering undergraduates. Faculty respondents provided no negative comments regarding theoretical knowledge (Table 3 – Table 6).

Table 6

Group Comments Related to General/Unspecified Theoretical Knowledge

	Industry		Academia			
Role/Responses	+	–	+	–	△ (I-A)	Total
Job	0	2	0	0	2	2
		Using 10% or less in current position - both comments quote same percentage				
Student	4	0	2	0	2	6
	Needed to develop logical thinking and problem-solving; Needed as base for new knowledge		Understanding of fundamental concepts is most important thing for students to take away; Needed to develop problem-solving; Needed as base for new knowledge			

Note: Respondents include: I = Industry, A = Academia
Types of responses: + = favorable, — = unfavorable

Practical applications experience. When respondents spoke of the need for practical application experience (Table **7**), faculty respondents expressed concern over the danger of injecting too much practical application into the curriculum and hence becoming a vocational program as opposed to an engineering program:

> FACULTY RESPONDENT: As long as you favor practical knowledge, you're producing a technician instead of an engineer. As long as you favor the theoretical knowledge, you're producing a scientist and not an engineer. So you have to balance this to have an engineer, because reality has to be modeled through some kind of meaningful approach. That's what the good engineer is…[Theory] cannot be neglected. Believe me, you pay.

Another faculty respondent discussed practical application not as a valued outcome per se, but as an important teaching tool for motivating students and providing a context for deeper theoretical learning.

Industry respondents did not share the same views and concerns as those from academia. The data imply that industry respondents tend to favor practical skills over theoretical knowledge. One respondent spoke of the need for more real-world projects in the electrical engineering curriculum, even at the expense of the theory currently taught in classes.

> INDUSTRY RESPONDENT: I would sacrifice some theory to provide that real-world experience. More of the real-world experience. Make sure that you're getting that in there somehow. Whether it's a project or whether as part of teaching that theory you have hands-on lab experience with it or you have some way of demonstrating how that theory is applied in real-world applications.

Table 7

Group Comments Related to Practical Application Experience

	Industry		Academia			
Role/Responses	+	–	+	–	△ (I-A)	Total
Job	1(1)	0	0	0	1	1
	(Lacking hands-on experience with circuit theory)					
Student	2(1)	0	3	0	-1	5
	Practical Skills are Important; (GAPS: Real world connection to coursework; Projects; Hands-on lab experience)		Practical/ theoretical knowledge balance; Application provides motivation and context for learning			
Total	3		3		0	6

Note: Respondents include: I = Industry, A = Academia
Types of responses: + = favorable, – = unfavorable
( ) = Gap: Number of comments pertaining to learning gaps in practical application

The data imply that industry respondents see theory as a necessary foundation for the more relevant and practical skills needed on the job, which contrasts with one faculty respondent's view that practical applications are the motivational foundation for theoretical learning.

All respondents had little to say regarding the on-the-job benefits of their experience with practical applications in school. Only one comment was made by a single industry respondent who expressed a gap in personal experience with hands-on learning activities in school. Data from this respondent indicate that hands-on design experiences in circuits and electronics courses would have been beneficial in their current position.

No negative comments concerning practical applications were made by either group.

Non-technical outcomes.

Leadership, teamwork, and time management. Respondents had little to say about three particular outcomes that apply greatly to managerial duties: leadership, teamwork, and time management (see Table 8, Table 9, and Table 10). Statements from one industry respondent suggested that good time management and strong leadership abilities were highly valued in industry. Another remarked that teamwork skills learned in school had proven to be beneficial in the workplace. No other comments were made regarding these outcomes, meaning that faculty respondents made no mention of them with regards to personal work activities or student educational goals.

Table 8

Group Comments Related to Leadership

	Industry		Academia			
Role/Responses	+	—	+	—	△ (I-A)	Total
Job	0	0	0	0	0	0
Student	1	0	0	0	1	1
	Demonstrating good leadership					

Note: Respondents include: I = Industry, A = Academia
Types of responses: + = favorable, — = unfavorable

Table 9

Group Comments Related to Teamwork

	Industry		Academia			
Role/Responses	+	—	+	—	△ (I-A)	Total
Job	1	0	0	0	1	1
	Learning to work w/difficult people					
Student	0	0	0	0	0	0

Note: Respondents include: I = Industry, A = Academia
Types of responses: + = favorable, — = unfavorable

Table 10

Group Comments Related to Time Management

	Industry		Academia			
Role/Responses	+	—	+	—	△ (I-A)	Total
Job	0	0	0	0	0	0
Student	1	0	0	0	1	1
	Demonstrating good time management					

Note: Respondents include: I = Industry, A = Academia
Types of responses: + = favorable, — = unfavorable

Pride. Pride is not a concept that is commonly associated with educational goals in electrical engineering. However, in this study pride did emerge as a relevant topic during the interviews. One industry respondent felt that pride in one's work was part of what defined the success of an electrical engineer:

> INDUSTRY RESPONDENT: My success is being happy in what I do. Feeling like, you know, going around and showing people I did this. That's pride in your work.

One member of the faculty group also discussed a personal sense of pride on the job, however, in this case related to the quality of education received at their school:

> FACULTY RESPONDENT: I'm so proud of [my school] because it gave me the knowledge necessary to survive the highest competition.

Although other respondents did speak of certain aspects of their job as being personally rewarding, there were no other comments made by either group regarding pride in one's work or school.

In one comment from academia, pride in one's school was directly tied to the job duties of an electrical engineering professor:

> FACULTY RESPONDENT: I have no problem saying to anybody that I graduated from [my school] because I know how good of a school it is…So as long as our graduates, after a certain number of years in industry, have this opinion, I think we are doing a great job…The common good is that our students get the job, they excel, and tomorrow they are proud of what they have learned.

This respondent speaks of pride, not as a *learnable* outcome, but as a direct result of an education that allows one to compete at the highest levels in the field. The statement emphasizes the great responsibility of the faculty to create a culture that fosters this level of pride after graduation.

Overall, there were four comments recorded regarding pride from respondents (see Table 11). Although both groups mentioned pride, only one respondent from academia discussed pride as an important educational outcome for students.

Research methods. With regards to research methods, only one respondent from each group stated that such skills were useful on the job (Table 12). However, most faculty members in

Table 11

Group Comments Related to Pride

	Industry		Academia			
Role/Responses	+	—	+	—	△ (I-A)	Total
Job	1	0	1	0	0	2
	Pride in work tied to definition of success		Pride in one's school			
Student	0	0	2	0	-2	2
			Pride in what they have learned; pride in one's school			

Note: Respondents include: I = Industry, A = Academia
Types of responses: + = favorable, — = unfavorable

tenured or tenure-track positions are expected to be productive in the three areas of teaching, scholarship (research), and service. All three faculty respondents in this study have achieved tenure and therefore strong research skills would have been vital during some point in their career. Even so, only one faculty respondent explicitly mentioned research skills as being part of their current job duties.

Only one industry respondent addressed research activities when discussing current job duties. Overall there were three comments pertaining to this topic. Research skills were not discussed as a student outcome by either group.

Table 12

Group Comments Related to Research Skills

	Industry		Academia			
Role/Responses	+	—	+	—	△ (I-A)	Total
Job	1	0	2	0	-1	3
	Researching patents		Research expectations with faculty appointment			
Student	0	0	0	0	0	0

Note: Respondents include: I = Industry, A = Academia
Types of responses: + = favorable, — = unfavorable

Service and social duty or responsibility. An appreciation for service and a sense of responsibility towards society also emerged as minor topics. There were four comments total pertaining to this outcome (see Table 13). All comments were positive and only one comment came from the industry group. The single industry respondent who commented merely stated that community service was something desirable for new graduates to have listed on a résumé, as it helps to distinguish applicants from others with similar academic achievement.

Service was also briefly mentioned by a faculty respondent as an important workplace activity in academia. Service is used as one of the three major performance metrics for tenured and tenure-track faculty, the other two being scholarship and teaching. The remaining two faculty respondents in this study would have also been

Table 13

Group Comments Related to Service and Social Responsibility

	Industry		Academia			
Role/Responses	+	—	+	—	△ (I-A)	Total
Job	0	0	1	0	-1	1
			Service activities expected with faculty appointment			
Student	1	0	2	0	-1	3
	Community involvement		Obligation to society; Behavior reflects on society; Awareness of role in society			

Note: Respondents include: I = Industry, A = Academia
Types of responses: + = favorable, — = unfavorable

expected to be involved in service activities since they were also tenured faculty members, however they did not explicitly mention service in their interviews.

There were only two additional faculty respondent comments which addressed social responsibility. The respondent stated that electrical engineers must be aware of their role in society. It was argued that electrical engineers must understand not just how to be good engineers, but also good citizens since their work affects so many people in society. This respondent also argued that electrical engineers had an obligation to society, although the specifics of this obligation were never stated during the interview.

Creativity. All of the seven comments related to creativity (Table 14) came from industry respondents (although most from a single source). Comments expressed a desire for new graduates to be able to be creative and explained how hiring managers look for demonstration of creativity on résumés of potential new hires. Data show that industry finds value in an applicant's ability to develop novel approaches to problems, and creativity is perceived to be correlated with that ability. One respondent, however, added that electrical engineering graduates were currently lacking in creativity due to a lack of creative opportunities in laboratory courses in school. A desire for fewer sequenced activities and more unstructured creative opportunities was expressed. One interesting note regarding these data is that they imply a belief that creativity can be taught in schools, or at least be positively influenced through a well-designed curriculum.

The data also show that industry respondents viewed creativity as an asset in the workplace. Creativity was mentioned in the data as being helpful in technical activities such as software development, but was also discussed as having possible secondary effects on coworkers. One respondent stated how one creative coworker's ability to generate many new ideas in meetings was highly motivating to the group. Therefore, creativity was seen as not just having technical benefits, but also non-technical benefits as well.

There were no interview comments concerning creativity from the faculty group.

Table 14

Group Comments Related to Creativity

Role/Responses	Industry +	Industry —	Academia +	Academia —	△ (I-A)	Total
Job	2	0	0	0	2	2
	Creativity in solving technical problems; Creativity as means of motivating others					
Student	5(2)	0	0	0	5	5
	Develop Novel approaches to problems; (GAP: lacking in school lab assignments)					

Note: Respondents include: I = Industry, A = Academia
Types of responses: + = favorable, — = unfavorable
( ) = Gap: Number of comments pertaining to learning gaps in creativity

Learning to learn and lifelong learning. The field of electrical engineering continues to change rapidly. It is vital that practitioners continue to acquire new knowledge and skills throughout their careers. Therefore, it is not surprising that respondents from both industry and academia discussed the importance of students continuing to learn after they leave school. However, industry respondents placed more emphasis on learning than did faculty respondents (Table 15). Also, industry respondents discussed the benefits of having the discipline to continue learning on the job while faculty respondents did not discuss learning in the context of their work.

Comments from both groups were very general in nature and there were no comments from either group implying a negative perception of continued learning.

Table 15

Group Comments Related to Learning to Learn and Lifelong Learning

	Industry		Academia			
Role/Responses	+	—	+	—	△ (I-A)	Total
Job	2	0	0	0	2	2
	Good study habits; Ability to learn; Learning how to learn					
Student	6	0	2	0	4	8
	Knowing how to get needed information; desire to learn; Learning how learn; Ability To learn many/ new things well		Learning how to learn something specific; Ability to learn and adapt			

Note: Respondents include: I = Industry, A = Academia
Types of responses: + = favorable, — = unfavorable

Communications. Respondents from both the industry and academia groups had only favorable remarks when discussing communications skills. One industry respondent addressed the need for students to come to work with good oral communications skills and be able to teach others what they know. One faculty respondent addressed the need for students to know how to act professionally with clients and also be able to convey technical ideas to non-technical people (Table 16). One comment from the faculty group suggested that students were currently weak in written communications.

Although faculty respondents commented twice as much as their industry counterparts, most of the faculty comments pertained to good communications skills in the context of their own job activities. This is not surprising considering that two of the three major components of a tenure-track faculty position require good oral communications skills (teaching) and written communications skills (research). There were only two comments from the industry group pertaining to communications skills on the job which concerned networking and customer relations. These data suggest that faculty practitioners are making slightly greater use of their communications skills on the job than industry practitioners, and in particular their writing skills.

Ethics and morality. Most comments from both groups regarding ethics and morality were positive and had to do with student outcomes (Table 17). Interestingly, there were almost no comments regarding the importance of ethical behavior or morality on the job. Only one comment came from the industry group concerning ethics on the job, and it was with regards to working hard and "doing what it takes to get the job done."

Table 16

Group Comments Related to Communication Skills

	Industry		Academia			
Role/Responses	+	—	+	—	△ (I-A)	Total
Job	2	0	5	0	-3	7
	Networking; Dealing with customers		Teaching; Managing/ mentoring students; Scholarly writing; Grant writing			
Student	2	0	3(1)	0	-1	5
	Oral communcation; Ability to teach others		Communicate technical ideas non-technical people; Interface with clients; (GAP: Currently weak in writing)			

Note: Respondents include: I = Industry, A = Academia
Types of responses: + = favorable, — = unfavorable
( ) = Gap: Number of comments pertaining to learning gaps in communication skills

In fact, all comments from industry related to ethics had to do with strong work ethics, and all but one were in the context of desired student outcomes. Aside from work ethics, no other type of ethical behavior or morality was discussed by the industry group. Although a majority of comments in this category were related to strong work ethics, there was only one faculty respondent comment that explicitly expressed a high regard

Table 17

Group Comments Related to Ethical Behavior or Morality

	Industry		Academia			
Role/Responses	+	—	+	—	△ (I-A)	Total
Job	1	0	0	0	1	1
	Getting the job done whatever it takes – strong work ethic					
Student	4	0	5	2	-3	11
	Getting the job done whatever it takes – strong work ethic; Hard work; Extra effort		Doing the right thing; Behaving ethically, with values; Being a good person; Not being a monster; Hard work	Ethics are objective of parents, not school; More important to be competent engineer		

Note: Respondents include: I = Industry, A = Academia
Types of responses: + = favorable, — = unfavorable

for hard work in electrical engineering:

> FACULTY RESPONDENT: Work is the essence of success…So basically, as long as they understand that engineering is about hard work, that's the main thing.

The remaining faculty comments related to other types of ethical behavior and morality. In fact, the faculty group was the only group to address these issues.

Most faculty respondents felt that it was very important that students leave the program with more than just a good understanding of technical issues:

> FACULTY RESPONDENT: You cannot emphasize only being a good engineer…That's not the point. It's the whole package.

One faculty respondent even ranked this outcome above technical outcomes:

> FACULTY RESPONDENT: I think it's more important to create good people than technical people...I think we should, and I think we do, encourage ethical behavior. Appropriate behavior. Behavior with values. I think that's an important part of what we need to do, and I think that's an aspect of being a good engineer.

However, there was major disagreement on this issue within the faculty group, as another respondent warned of the dangers of the curriculum focusing too much on non-technical outcomes:

> FACULTY RESPONDENT: So you're asking yourself, what is the outcome of the bachelor's degree? Is it someone who has these skills very well developed? Or is it to make a good human being?...And the answer is no. That's not our objective. That's your parents' objective…If students are leaving the curriculum without good technical skills, it doesn't do you any good to have five more lectures on ethics, because they're going to screw things up…even if they're very ethical about it...It's not that there is anything wrong with ethics, but they've got to be able to do the other stuff first. That's my view.

It is interesting to note that this previous comment was the only negative comment that emerged from either group regarding any of the non-technical outcomes. It is also interesting that there were no industry comments regarding any ethics or morality issues other than hard work.

Broad educational background. In this section, differences between perceptions of broad educational backgrounds and technical specialization were investigated. Discussions concerning a liberal arts education and multi-disciplinary education were both included in this outcome because they both relate to having a broad educational background beyond the required technical electrical engineering courses.

Both industry and faculty respondents agreed that exposure to courses outside of electrical engineering provided them with broader experiences which were valuable in their professional practice. One faculty respondent commented that this broad background blurred the borders of the different disciplines and opened up a wide range of employment and research opportunities:

> FACULTY RESPONDENT: I diversified so much. That's why I have difficulty defining what I'm doing, because I'm not doing a narrow field of research. It's very broad. If I worked in physics then I could say I was a physicist. If I were in chemical engineering then I would fit perfectly fine there. Now I'm in electrical engineering. It doesn't matter. I don't see borders.

One industry respondent carried the coursework for two different engineering disciplines through most of their undergraduate career. Later it was found that having this multi-disciplinary background had its advantages in a large multi-national company. It provided a "broad base." In total, three respondents spoke of their own exposure to outside courses and how this exposure benefited them on the job.

Both groups also agreed that students would benefit from a broad educational background although the specific ways in which such a broad education was beneficial were never discussed. One industry respondent stated:

> INDUSTRY RESPONDENT: I think broad experiences in other areas are always going to make you well-rounded and better at what you do.

It appears from the data that large companies are particularly looking for incoming graduates to have a broad background because the company may place them in any of a large number of different technical fields and expects to train them in industry-specific skills when they arrive. It may also be the case that a project that someone is hired for encompasses many different disciplines. Therefore a large company may need "someone that is more of a generalist. A person that understands a lot of different things."

Interestingly, there was some concern from both sides that the curriculum may become imbalanced, although the concerns were at polar opposites. As expressed by one industry respondent, the concern was that if there were too much emphasis on the technical side of the curriculum then the program would become a vocational school:

> INDUSTRY RESPONDENT: Then you would be going strictly to a technical school...It's like a vocational school then. You do need to broaden your horizons and to experience other things.

However, one faculty respondent expressed concern over the possibility of the pendulum swinging too far in the other direction:

> FACULTY RESPONDENT: I think people who are more well-balanced tend to be better engineers in general because they've seen more things. There's more

> experience. It's richer. It's better. But to cut out fundamental engineering concepts so that you can replace them with these other softer skills just doesn't make sense to me.

The concern was that students would sacrifice too much technical knowledge for breadth of knowledge and emerge from the program ill-prepared as engineers.

Overall industry respondents spoke much more than faculty respondents (10 comments versus 3) concerning this outcome (Table 18).

Business knowledge and experience. During the course of the interviews, industry referenced business knowledge almost twice as much as faculty. Surprisingly, there were only three comments from industry regarding business knowledge which might give the impression that it is not a valued outcome in industry. However, when speaking of their own professional practice, they had a bit more to say. There were six comments total from industry relating to professional practice (Table 19). All three industry respondents contributed in this area. Their comments most concerned managing teams and projects. All three faculty respondents also referenced business knowledge in their interviews. However their references were very brief and mostly concerned management skills in the context of the supervision of graduate students. Only one faculty member mentioned program management as part of their job duties.

Most industry comments regarding their own professional experience had to do with a perceived gap in their own business knowledge at the time they entered the workforce.

Table 18

Group Comments Related to Broad Educational Background

	Industry		Academia			
Role/Responses	+	—	+	—	△ (I-A)	Total
Job	3	0	1	0	2	4
	Liberal arts courses; Courses in other eng. disciplines		Multi-disciplinary background			
Student	7	0	2	0	5	9
	Broadening of horizons; Broad experiences; Liberal arts courses; Well-rounded or broad education; Fine arts exposure; Without non-tech courses EE becomes a vocational degree		Foreign languages; Well-balanced background; More/richer experiences			

Note: Respondents include: I = Industry, A = Academia
Types of responses: + = favorable, — = unfavorable

Table 19

Group Comments Related to Business Knowledge

Role/Responses	Industry +	Industry –	Academia +	Academia –	△ (I-A)	Total
Job	6(4)	0	4	0	2	10
	Project & people management; (GAPS: Supervising/ Managing people; Training; Product development; Business operations; Project Management)		Supervising/ managing people; Program management			
Student	3	0	0	0	3	3
	Business experience; Co-op/ internship; Understanding of work & business environment; Early industry exposure					

Note: Respondents include: I = Industry, A = Academia
Types of responses: + = favorable, — = unfavorable
( ) = Gap: Number of comments pertaining to learning gaps in business knowledge

> INDUSTRY RESPONDENT: You have to understand the business. You have to understand the work environment and sometimes that's something they don't teach in school.

Gaps included a lack of managerial experience and lack of knowledge about product development. All three industry respondents acknowledged a gap but only one explicitly stated that they would have liked to have taken a course in school that addressed business issues.

The industry group was the only group to address the value of cooperative education within the electrical engineering curriculum. All three respondents spoke favorably of the program. One industry respondent expressed a strong desire to have cooperative education required for all students:

> INDUSTRY RESPONDENT: The bottom line is the more experience you get in the workplace, the better. The co-op program is a must for every engineering student or even any non-engineering student. I think it's a must…I think there should be a requirement co-op…You need work experience if you want to do well in work.

No respondents from the faculty group discussed cooperative education during interviews. In fact, faculty respondents never mentioned business knowledge at all when discussing student outcomes.

Problem-solving. An interesting pattern emerged when group comments regarding problem-solving were mapped out. Industry respondents perceived problem-solving skills to be the most important outcome of their own education:

> INDUSTRY RESPONDENT: I would say it's more about the problem solving skills in general. That is what I got out of my undergraduate education.

> INDUSTRY RESPONDENT: It gave me really good problem-solving skills. I think that was the most important thing I learned.

Yet industry respondents had almost nothing to say about the value of these skills when speaking about electrical engineering graduates. Five of the seven industry comments regarding problem-solving pertained to personal values and outcomes.

However, the opposite pattern emerged with the faculty respondent group. There were no comments from this group discussing the importance of problem-solving skills on the job (Table 20), but they had much to say about the importance of students possessing good problem-solving skills.

> FACULTY RESPONDENT: If you don't have the ability to solve the problem then forget about books or anything. You cannot reconnect the facts. That's the problem. So that's what I try to teach the students. To connect the facts so that they can learn to use and activate this knowledge to solve problems through independent ideas and solutions, because that's eventually what defines a good versus a bad engineer.

All six comments from faculty concerning problem-solving pertained to student outcomes.

Overall the number of positive comments from each group was almost equal and there were no negative comments recorded.

Table 20

Group Comments Related to Problem-Solving

	Industry		Academia			
Role/Responses	+	—	+	—	△ (I-A)	Total
Job	6	0	0	0	6	6
	Most useful/ important outcome; Useful in code optimization; Creative problem-solving					
Student	1	0	6	0	-5	7
	Theory courses in curriculum develop problem-solving		Connecting facts from prev. knowledge; Reactivating knowledge; Generating; independent ideas & solns.; Ability to define problem; Converting passive knowledge to active knowledge; Most important aspect of curriculum			

Note: Respondents include: I = Industry, A = Academia
Types of responses: + = favorable, — = unfavorable

Systems modeling and design. This outcome breaks down into two related skills. The first skill has to do with breaking down a large complex system and modeling it with an integrated system of smaller, manageable, and easily understood parts (systems modeling). The second skill is the inverse process of taking a large number of small components and integrating them into a large system which meets predefined constraints (systems design). These two processes together constitute a large portion of what engineers do in practice. It is not surprising then that the largest number of comments for any one outcome emerged from discussions about systems modeling and design. There were 14 comments overall--almost all from the faculty group (Table 21). The high number of comments from academia (12) is in stark contrast with the low number of comments from industry (2). However, all but one of the faculty comments were from a single respondent. This fact may seem to dilute the impact of the faculty comments, but it is worth noting that these comments represent the greatest response (11 comments) from any single respondent on any single outcome. Therefore, although the faculty response is heavily weighted toward a single respondent, this particular respondent was emphatic about the importance of this outcome in electrical engineering students.

One interesting fact to emerge from Table 21 is that only the industry group discussed using the principles of system design on the job. (There was no discussion of using systems modeling on the job by either group.) In fact, those were the only two comments which referenced the application of this outcome on the job. In one comment, an industry respondent described their own activities in designing systems, while in the second comment another industry respondent expressed regret over not having more design opportunities in school.

Table 21

Group Comments Related to Systems Modeling and Design

	Industry		Academia			
Role/Responses	+	—	+	—	△ (I-A)	Total
Job	2(1)	0	0	0	2	2
	Understanding big picture; Interfacing parts in large systems; (GAP: Weak in system design)					
Student	0	0	0	12(1)	-12	12
				Modeling complex systems; Interfacing parts in large system; Modeling large systems; Applying known metaphors; Integrating technologies/ devices; optimizing systems; (GAP: Weak in defining models)		

Note: Respondents include: I = Industry, A = Academia
Types of responses: + = favorable, — = unfavorable
( ) = Gap: Number of comments pertaining to learning gaps in systems modeling and design

In contrast, only the faculty group discussed systems design as an important student outcome. The faculty comments were nearly split between design and modeling. The following are two faculty remarks regarding the importance of students possessing good systems design skills:

> FACULTY RESPONDENT: The engineer's rule is not to develop the basic science, but rather to take complicated systems and combine them to make functional devices. An electrical engineer ought to be very good at defining specifications for devices and understanding how to combine one device with another to make something more sophisticated.

> FACULTY RESPONDENT: A company is looking for someone who can connect all of the different complicated aspects of what they do together.

The last faculty comment is particularly interesting because the faculty respondent perceived good systems design skills to be highly valued by industry when hiring new graduates, yet industry respondents never mentioned it when discussing valued student outcomes.

As for systems modeling, the faculty group was also the only group to discuss it in any context. For example, one faculty respondent stated the following:

> FACULTY RESPONDENT: And so the ability to model things, collect complicated systems and come up with a simple model to describe it are the key abilities of electrical engineers.

Surprisingly, even though one faculty respondent stated that "engineering is all about, especially electrical, measuring correctly and modeling the system," industry respondents never mentioned systems modeling when discussing what outcomes they valued in new hires.

Industry and academia outcome rankings. In the final step of analysis, the total number of positive comments regarding educational student outcomes was used to create a rankings list for each group. For this analysis, only participant comments pertaining to new graduates were included. Table 22 shows these ranking results.

Perhaps the most significant result from Table 22 is the dramatic difference between the rankings of systems modeling and design. The faculty group had it easily topping their list with 12 positive comments while the industry group never addressed this outcome. This outcome also had the most comments of any of the 19 educational outcomes for either group, almost doubling the next highest (broad education in the industry list).

The faculty group also stressed problem-solving a great deal more when discussing student outcomes. Faculty respondents mentioned it six times while industry respondents only mentioned it once. However, the industry group appears to value a broad educational background much more than the faculty group. They recorded seven favorable comments compared to only two from the faculty group. Broad education was also the industry group's top-ranked outcome.

One other interesting fact to emerge from Table 22 is the large difference in the ranking of creativity between the two groups. Creativity tied for 3rd in the industry group with five favorable comments and yet ranked last (tied for 14th) in the faculty group with zero comments. Problem-solving also show large differences in ranking. The faculty group has problem-solving ranked 2nd while for the industry group this outcome tied for 10th. The industry respondents only recorded one comment regarding the importance of problem-solving skills in new graduates.

Table 22

Ranking of Educational Student Outcomes by Group

Rank	Industry Student Outcomes	Number of Favorable Comments (Industry)	Number of Favorable Comments (Academia)	Academia Student Outcomes	Rank
1	Broad Education	7	12	Systems Modeling and Design	1
2	Learn to Learn/Lifelong Learning	6	6	Problem-Solving	2
T3	Creativity/Innovation	5	5	Ethics/Morality	T3
T3	Engineering Fundamentals	5	5	Mathematics	T3
T5	Ethics/Morality	4	4	Engineering Fundamentals	T5
T5	General Theory	4	4	Science	T5
6	Business Knowledge	3	3	Communications	T7
T7	Communications	2	3	Practical Applications	T7
T7	Practical Applications	2	2	Broad Education	T9
T9	Leadership	1	2	General Theory	T9
T9	Mathematics	1	2	Learn to Learn/Lifelong Learning	T9
T9	Problem-Solving	1	2	Pride	T9
T9	Science	1	2	Service	T9
T9	Service	1	0	Business Knowledge	T14
T9	Time Management	1	0	Creativity/Innovation	T14
T15	Pride	0	0	Leadership	T14
T15	Research Skills	0	0	Research Skills	T14
T15	Systems Modeling and Design	0	0	Teamwork	T14
T15	Teamwork	0	0	Time Management	T14

Learning to learn and lifelong learning ranked relatively high (2nd) with the industry group and almost last (tied for 9th) with the faculty group. The industry group had four more favorable comments than the faculty group regarding this outcome. In contrast, the faculty group ranked mathematics knowledge much higher (tied for 3rd) than the industry group ranked it (tied for 10th). Here the industry group had four more favorable comments than the industry group.

Practical applications produced surprisingly similar results for both groups (tied for 8th with industry and tied for 7th with faculty). Even more surprising is that this outcome sits in the middle of the rankings for both groups.

Also surprising and telling is many non-technical skills (soft skills) received no mention by the faculty group and therefore sit at the bottom of the list. Six non-technical skills, including business knowledge, were included in this group. Two outcomes (research skills and teamwork) overlap with those not mentioned by industry when discussing students. Therefore, these outcomes were never mentioned by either group as being important for new graduates. They made the list only because participants mentioned that they themselves used these skills at some point on the job.

Two other outcomes at the bottom of the faculty list were time management and leadership. These two non-technical skills also placed very low in the industry rankings, garnering a mere single comment each from industry. In fact, the only outcomes in the faculty bottom six that rank high with industry were business knowledge and creativity.

Looking at the top five rankings for each group, engineering fundamentals and ethics/morality were the only outcomes to appear high on the list for both groups. Engineering fundamentals tied for 3rd with the industry group and tied for 5th with the faculty group; while conversely, ethics/morality tied for 5th with the industry group and tied for 3rd with the faculty group. Technical skills were spread fairly evenly across the industry rankings. However, within the faculty group, technical outcomes ranked slightly higher. The average ranking for all technical outcomes was 7.2 for the industry group and 5.8 for the faculty group.

V. Conclusion

Summary

The knowledge capital that a nation's population of engineers brings to a society has great economic and cultural impact. Electrical engineers in particular are responsible for many innovations that we now take for granted in everyday life. Therefore, preparation of electrical engineers for careers in this field becomes an important national issue, especially since engineers are expected to continue being global leaders in high-technology innovation. The issue of properly educating these engineers to address the highly complex and technical issues of the modern world is more important now than ever. In order to design electrical engineering programs that train these engineers to be successful and excel in the workforce, their potential employers and developers of engineering curricula must work together to ensure that societal and individual needs are being met. However, before this work can truly be productive, it is important to understand the needs of each group. If the intentions of academia differ from the needs of industry, then the work of preparing a new generation of electrical engineers that is capable of solving society's most challenging problems will be stifled. The purpose of this study was to investigate, through interviews, the opinions of practicing engineers in both industry and academia to determine if a misalignment of needs and educational goals between the two groups exists. Thus, the guiding research question for this study was: “How do electrical engineers in industry and academia differ in their conceptions of the goals of engineering education?”

To answer this question, six electrical engineers currently practicing in the field were chosen to provide feedback regarding educational outcomes through interview data.

In selecting the six respondents to be included in this study, the following criteria were applied: 1) respondents must have been working in their field for a minimum of seven years, and 2) industry respondents must have obtained at least a bachelors degree in electrical engineering, and faculty respondents must have been actively teaching in an electrical engineering program. Based on these criteria, three respondents were selected from industry and three respondents were selected from academia. Semi-structured interviews were conducted and recorded by the researcher at locations chosen by the study participants.

For each recorded audio file obtained through the interviews, the file was transcribed and coded for educational outcomes. Both technical and non-technical outcomes were coded and analyzed. Interview data relating to educational outcomes was then organized into four categories: 1) skills and knowledge used by industry respondents on the job, 2) skills and knowledge used by faculty respondents on the job, 3) industry respondent conceptions of important student outcomes, and 4) faculty respondent conceptions of important student outcomes. Comparisons of student outcomes were made between the two respondent groups. On-the-job skills addressed during interviews were also compared and then used to complement student outcome findings.

Study data showed that there was disagreement in some but not all of the educational outcomes. In fact, there was surprising agreement on approximately half of the student outcomes that emerged from the interview data. Overall there were very few comments regarding outcomes that respondents felt were not important. Only five outcomes were associated with unfavorable remarks. Interestingly, all of the unfavorable remarks from industry respondents dealt with technical outcomes. There were only two unfavorable comments from academia and they pertained to a single non-technical outcome (ethics/morality). Also, there were some instances of disagreement on importance of educational goals within the groups. These instances were mainly within the industry group and related to technical outcomes.

This chapter describes the implications and conclusions drawn from interview data that address the research question stated previously. Specifically, this chapter includes (a) a summary of the study, (b) a discussion of implications of findings, (c) the limitations of this study, and (d) considerations for future research.

Interpretation

Emerging themes. Figure 1 presents a Venn diagram listing all outcomes that emerged from interview data. A complete list of possible electrical engineering outcomes would be immense, and therefore the outcomes listed here are but a subset of those that could have potentially been discussed. Hence, given that study respondents were not provided with a list of pre-defined outcomes to frame their responses, the amount of overlap of referenced outcomes between the two groups is surprisingly high. Of the 19 outcomes discussed in the six practitioner interviews, 14 of these outcomes were addressed by both the industry and academia groups. Although Figure 1 does not take into account perceived level of importance of the outcomes, the fact that almost two thirds of the outcomes merited discussion by both groups is in and of itself a noteworthy result.

Of the 19 educational outcomes mentioned throughout the interviews, 5 were technical outcomes and 14 were non-technical. From the diagram, it appears that both groups placed a much higher emphasis on the non-technical outcomes (or “soft skills”) at

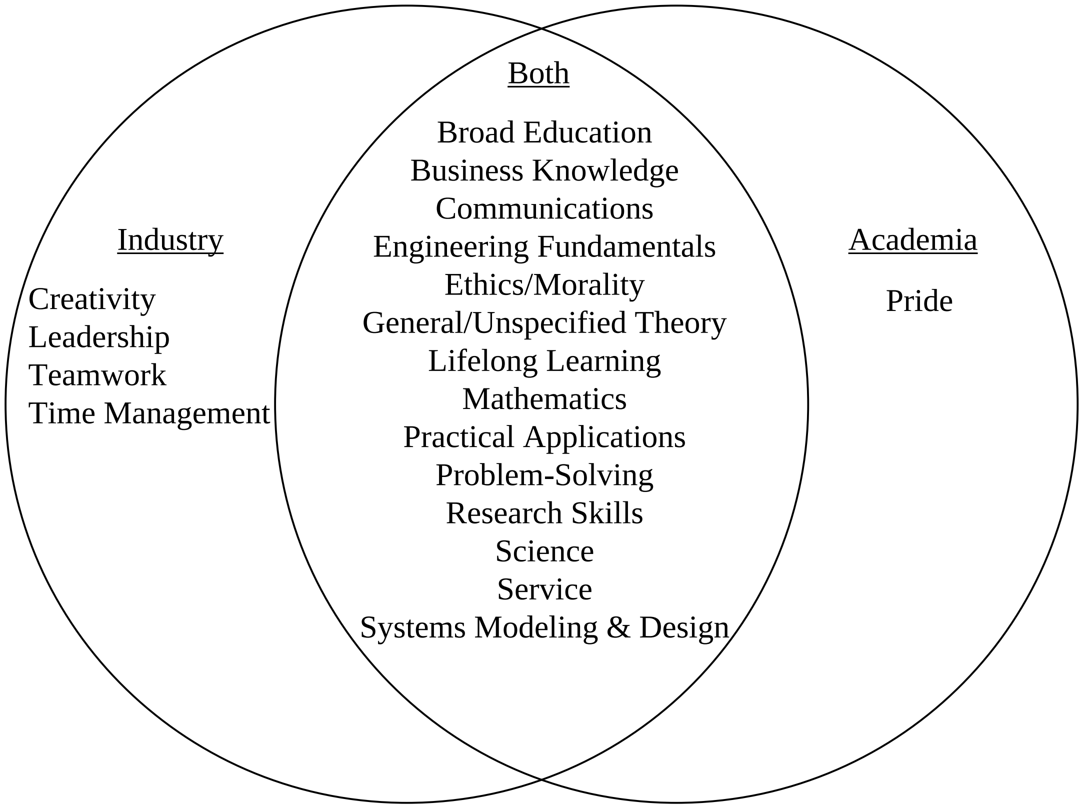

Figure 1. All outcomes discussed by practitioner groups.

least with regards to the total number of outcomes discussed. In light of the research reviewed in chapter two of this study, this finding is not surprising. Many of the opinion pieces pertaining to engineering education called for more emphasis on the non-technical aspects of professional training. However, it is also worth mentioning that all of the technical outcomes, including the purely theoretical ones, were discussed by both groups even though some comments were unfavorable.

There is some evidence in this list that respondent values are tied to their environment or personal history. Only faculty respondents reference pride in one's training (in particular, school pride). Because faculty members are still in the school environment, they may see the impact of this pride more readily than industry respondents and therefore may be more likely to relate its value as an educational outcome. An interesting follow up activity would be to survey industry respondents on their feelings of the importance of pride in one's school training and how that impacts one's professional success.

Only industry respondents referenced creativity during interviews. Again, this may stem from industry responses influenced by personal experience. If industry practitioners had more creative opportunities in their work through product development activities, then they might be more likely to mention creativity as a relevant outcome. Other outcomes mentioned only by industry were leadership, teamwork, and time management. These have obvious value in both academia and industry, but perhaps are more closely associated with typical day-today activities in industry. So, industry respondents might be more inclined to mention them without prompting.

The educational outcomes listed in Figure 1 were coded from two discussion contexts. First, outcomes were coded from respondent discussions of personal work activities. Second, they were coded from discussions of recent graduates. Even though it became apparent that all of these particular outcomes were perceived as relevant to a career in electrical engineering by these respondents, what remains unclear is which educational outcomes respondents felt should be explicitly addressed in the electrical engineering curriculum. Perhaps respondents felt that these non-technical outcomes could be achieved through means outside of the electrical engineering curriculum. For instance, they may have surmised that these outcomes could be achieved through liberal arts courses, cooperative education, or through informal learning (the means by which students learn things which are not explicitly taught). Whether or not to explicitly address these outcomes in the curriculum is a matter for instructors and other program stakeholders to decide. What this study does provide is a list of important outcomes to use as a reference point during those important discussions involving curriculum evaluation and development.

Job-only outcomes. The data analysis process was expanded to include personal work activity discussions by respondents. Interview data relating to respondent job descriptions and activities were coded for educational outcomes in an effort to capture themes that might have been missed by coding only explicitly stated educational outcomes. There were, in fact, a few outcomes that were overlooked by respondents from both groups when discussing important student outcomes, but appeared in discussions on work activities. Inclusion of the respondent data related to personal work experience provided another dimension for data analysis. The researcher believes that important information relevant to the study would have been missed without this added component. For instance, teamwork and research skills would have both been completely omitted from this study without the additional coding of work discussions. In particular, research skills were never explicitly mentioned as educational goals by either group (see Figure 2). This outcome only emerged through discussions of job-related activities. Although neither group stated that good research skills were important as an educational outcome, the fact that at least one respondent from each group discussed using these skills in their regular work activities suggests this outcome is in fact valued by respondents. Therefore these work-only themes were included in the study analysis. The researcher also assumed that if a respondent described an outcome as an aspect of their regular duties, then that outcome must be important in the practice of electrical engineering which further justified that outcome being included.

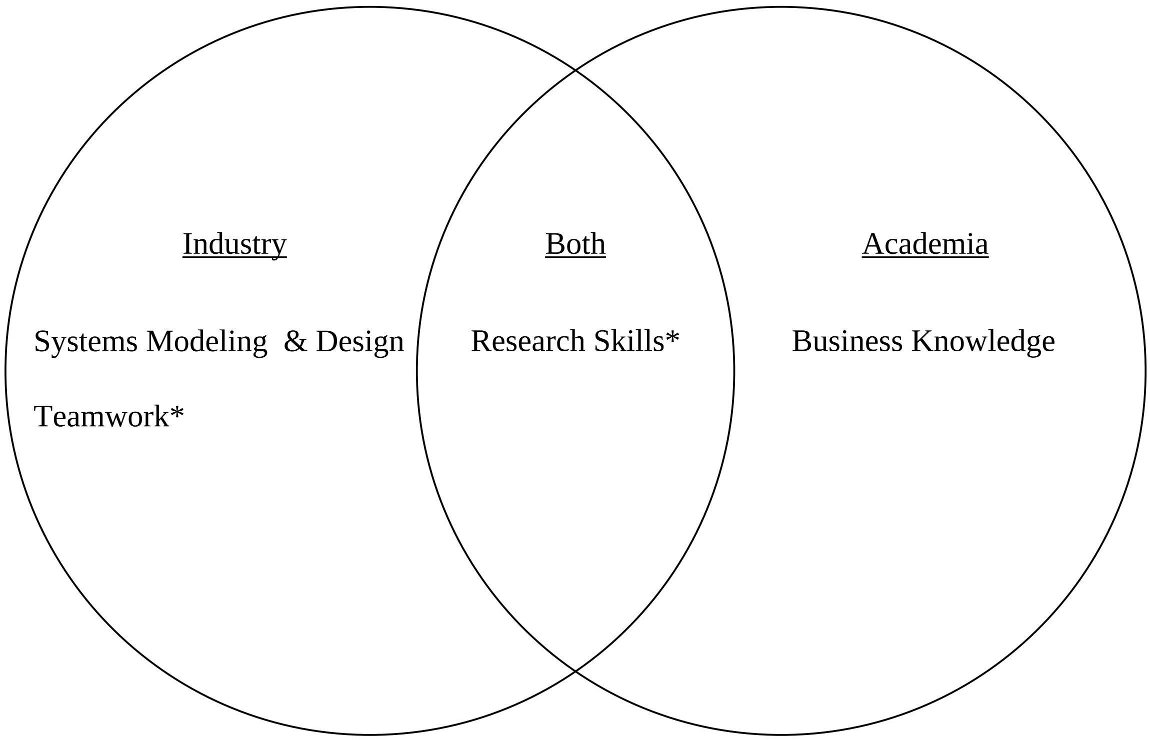

Figure 2. Outcomes discussed only in the context of work activities. (Outcomes marked by asterisks were never discussed as student outcomes by either group.)

The omission of important work skills in student outcome discussions suggests that respondents may take certain skills used in their own work for granted when reflecting on educational outcomes. For instance, research is a major work component for half of the respondents interviewed (two from academia and one from industry), yet none of these respondents spoke of the need for students to be proficient in research skills. There seems to be a slight disconnect between the respondent's perception of the profession as they practice it and the profession as students are being prepared for it. This has important implications for future practitioner studies that employ interview methods. The researcher believes that it is important to include detailed practitioner job descriptions in addition to and as a basis for comparison of practitioner conceptions of educational outcomes. Although this study only coded interview data for descriptive purposes, the relationship between practice and perception will become even more important in inferential type studies.

Comparison with ABET program outcomes. One interesting result from this study is the surprisingly high level of agreement of the study outcomes list with the ABET engineering program outcomes, especially considering that respondents were not prompted on these topics. Respondents in this study addressed 10 of the 11 ABET outcomes shown in Table 23. Only the ABET outcome of "knowledge of contemporary issues" was not addressed in interview data.

Although the ABET program outcomes were not developed specifically for electrical engineering programs, all electrical engineering programs must assess their programs using these outcomes for accreditation. This ABET list of program outcomes (a.k.a., a-k) was developed as a result of feedback from practitioners in both industry and academia. Representatives from the engineering community as a whole came together to develop this list of valued outcomes that could be used to assess individual engineering programs. It stands to reason that these are the outcomes that were most valued by those members who participated in the process. Given that, there were quite a few outcomes from this study that were not included in the ABET program outcomes for engineering. One might then assume that these study outcomes are outliers and would not rate highly on a study of larger scale. But one must be careful not to assume that this implies that the

Table 23

Comparison of ABET Program Outcomes with Study Outcomes

	ABET Outcome	Study Outcome
a.	an ability to apply knowledge of mathematics, science, and engineering	Mathematics, Science Engineering Fundamentals General/Unspecific Theory
b.	an ability to design and conduct experiments, as well as to analyze and interpret data	Research Skills
c.	an ability to design a system, component, or process to meet desired needs within realistic constraints	Systems Modeling and Design
d.	an ability to function on multidisciplinary teams	Teamwork
e.	an ability to identify, formulate, and solve engineering problems	Problem-Solving
f.	an understanding of professional and ethical responsibility	Ethics/Morality
g.	an ability to communicate effectively	Communication
h.	the broad education necessary to understand the impact of engineering solutions	Broad Education
i.	a recognition of the need for, and an ability to engage in lifelong learning	Learn to Learn/Lifelong Learning
j.	a knowledge of contemporary issues	No Study Match
k.	an ability to use the techniques, skills, and eng. tools necessary for eng. practice	Practical Applications
l.	No ABET match	Business Knowledge, Creativity, Service, Pride, Leadership, Time Management

engineering community does not highly value these outcomes simply because they do not appear on the ABET list. One could argue that if these outcomes were truly valued then they likely would have made it to the final ABET list. However, there are other possible explanations for this discrepancy between the two lists.

One explanation may be that ABET and its stakeholders simply did not wish to accredit programs based on these particular outcomes. Looking at the list of outcomes that failed to find a match on the ABET list, one might realize that finding reliable methods of assessment for items such as pride and creativity would be difficult for an electrical engineering department. Practitioners may have valued these outcomes yet felt that the assessment of these outcomes for accreditation was either inappropriate or too difficult to reliably implement.

One other possible explanation is that the ABET respondents felt that these outcomes were part of the informal curriculum at universities. They may have believed these outcomes to be important, but felt that students should be acquiring this knowledge from avenues outside of the formal program curriculum and thus these outcomes should not be included in the accreditation criteria. These uncertainties from data stress why future studies should ask not only if respondents value particular outcomes, but also *how* they feel that students should achieve these outcomes—in other words, whether these outcomes should be addressed in the formal electrical engineering curriculum.

These issues highlight problems when limiting responses in engineering education research studies to the ABET a-k list or, in fact, any other predetermined set of outcomes. As this study shows, important feedback regarding conceptions of educational goals may be missed when this is the case. A list of pre-determined responses such as the ABET outcomes list should only be used when researchers wish to know the *level* of importance of particular outcomes. If one wishes to know *what* is valued by respondents, then less restrictive methods must be employed. Respondents must be allowed to reflect and communicate in their own words what they truly value.

Differences in importance of outcomes.

Favorable comments on student outcomes. Looking only at favorable comments regarding student outcomes, the two groups again showed considerable agreement on most outcomes. Nonetheless, there were some differences worth noting. For instance, the industry group was the only group to suggest that students should possess knowledge about the business world and also demonstrate good leadership and time management skills (Figure 3). However, they made no mention of student achievement on outcomes more closely tied to the technical side of engineering practice, specifically systems modeling and design. The industry group appeared to be more concerned with personal mastery outcomes while the faculty group was more concerned with design outcomes.

Systems modeling and design. Systems modeling and design was also the topic that showed the largest group difference by far on student outcomes. Faculty respondents mentioned the importance of students excelling in this area 12 times during interviews (Table 24). The industry group never mentioned these outcomes as being important for students. This agrees well with industry responses in a previous study (Volkwein, Lattucca, & Terenzini, 2008, p. 202) where industry respondents ranked systems design relatively low. Only 66% of those respondents rated design as highly important or essential, ranking it 7th out of 11 ABET outcomes.

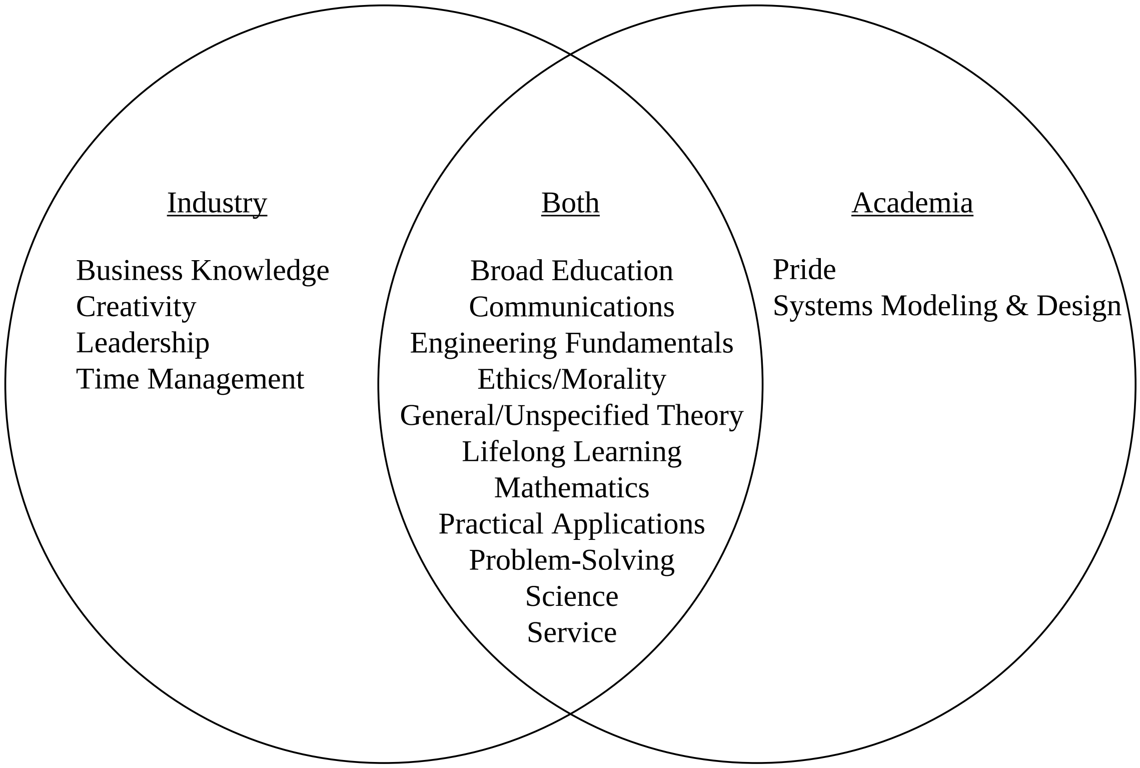

Figure 3. Favorable comments on student learning outcomes only.

From these data, one might interpret this to mean that only the faculty respondents see modeling and design skills as important. However, this interpretation must be rejected once one considers remarks made by industry respondents concerning their own work activities. In the context of work, the industry group was the *only* group to mention systems design. Even though they were not as expressive about the importance of this outcome as the faculty group, it is clear from their responses that they perceive this outcome as an important aspect of their work. Therefore, although Table 24 suggests a significant divide between the two groups on the issue of systems design, further inspection reveals some agreement on this educational goal as well.

Table 24

Ranking of Student Outcomes Based on Favorable Comments Only

Industry		Academia	
Rank	Student Outcome	Student Outcome	Rank
1	Broad Education	Systems Modeling and Design	1
2	Learn to Learn/Lifelong Learning	Problem-Solving	2
T3	Creativity/Innovation	Ethics/Morality	T3
T3	Engineering Fundamentals	Mathematics	T3
T5	Ethics/Morality	Engineering Fundamentals	T5
T5	General Theory	Science	T5
7	Business Knowledge	Communications	T7
T8	Communications	Practical Applications	T7
T8	Practical Applications	Broad Education	T9
T10	Leadership	General Theory	T9
T10	Mathematics	Learn to Learn/Lifelong Learning	T9
T10	Problem-Solving	Pride	T9
T10	Science	Service	T9
T10	Service	Business Knowledge	T14
T10	Time Management	Creativity/Innovation	T14
T16	Pride	Leadership	T14
T16	Research Skills	Research Skills	T14
T16	Systems Modeling and Design	Teamwork	T14
T16	Teamwork	Time Management	T14

Note: T refers to tie in rank (e.g., T3 refers to a tie for 3rd).

Creativity v. critical thinking. Looking at the favorable comments on student outcomes, the greatest differences between groups emerged on creativity and the two critical thinking outcomes (problem-solving and systems modeling and design). Of these top three differences, faculty respondents favored the two involving critical thinking (*problem-solving* and *systems modeling and design*) while industry respondents favored creativity. From one perspective, these differences seem rather extreme and polar opposites. Faculty respondents made 18 positive comments regarding the critical thinking outcomes to industry's 1. Surprisingly, industry respondents were the only ones to ever discuss creativity. However, the differences only exist if one considers these outcomes to be different conceptions. The researcher argues that this is in fact the case. Design is merely one *application* of problem-solving, and to do either well requires the *application* of creativity (as well as other cognitive processes such as analysis and synthesis). Based on this argument, these outcomes were coded as three separate items and respondents did in fact split on these outcomes quite neatly. However, it is unclear from study data how tightly or loosely respondents actually perceive these outcomes to be coupled. What is clear from industry responses is that the industry group does see a connection between creativity and critical thinking even if respondents don't perceive them to be equivalent. Most comments from industry regarding creativity associated it with a positive impact on problem-solving and design. One industry respondent even stated that creativity positively impacted one's ability to learn quickly.

These data also suggest that faculty respondents either miss this connection between creativity and critical thinking or simply take the connection for granted since they failed to mention creativity even once. In either case, since faculty members tend to drive the curriculum content, the likely outcome is that opportunities for creative expression are lacking in the electrical engineering curriculum. Since responses suggest that creativity can be cultivated through the curriculum, electrical engineering curriculum designers may want to explore ways to introduce more activities and provide environments that foster creativity within students in order to support the problem-solving and design outcomes that they value so highly.

It is worth pointing out that creativity is not included in ABET's a-k engineering program outcomes. Therefore, one possible explanation for the faculty group not mentioning the importance of creativity as a student outcome is that the faculty group do not value creativity because ABET does not evaluate it. An alternative explanation is that faculty members see creativity as essentially equivalent to design. (See Stouffer, Russell, & Oliva, 2004 for one example of this argument.) However, the responses coded in this study suggest that at least some respondents do differentiate between creativity and critical thinking.

Broad educational background. On the issue of a broad educational background, both groups had only positive things to say, although the industry group placed a much heavier emphasis on this outcome. The fact that this outcome ranked so high with industry is a vote of support for many honors engineering programs which place a high level of emphasis on the liberal arts. Industry respondent data suggest that these honors curricula, with their increased emphasis on ethics, morality, and broad educational experiences, do in fact provide students with added benefits compared to the standard curricula. Faculty responses were also favorable but fewer in numbers. It is perhaps not surprising that this should be the case considering the culture of a research university. One would expect faculty respondents to place more value on specialization, and this assumption is in fact substantiated by survey data obtained from this same study sample (de la Rosa-Pohl, 2011). In that survey, two of the three faculty respondents gave "knowledge of one subject in depth" the highest rating of "very important" while industry respondents unanimously rated this outcome as "not too important." Industry invests heavily in training programs and expects to train new hires for the specifics of a particular job. Faculty respondents, however, have all experienced graduate school which emphasizes mastery of specialization by students. This occurs by increasing levels of specialization all the way through academic preparation including the doctorate level. Therefore, these results correlate well with each group's professional experience. Since most industry hires are at the bachelor level, these findings suggest that undergraduate curricula should provide a well-rounded liberal education and that specialization should be reserved for graduate programs. In a 2005 report, the NAE recommends this approach for engineering education:

> Technical excellence is *the* essential attribute of engineering graduates, but those graduates should also possess team, communication, ethical reasoning, and societal and global contextual analysis skills as well as understand work strategies. Neglecting development in these arenas and learning disciplinary technical subjects to the exclusion of a selection of humanities, economics, political science, language, and/or interdisciplinary technical subjects is not in the best interest of producing engineers able to communicate with the public, able to engage in a global engineering marketplace, or trained to be lifelong learners. (p. 52)

The NAE goes on to say:

> The engineering education establishment must also adopt a broader view of the value of an engineering education to include providing a "liberal" engineering education...Adequate depth in a specialized area of engineering cannot be achieved in the baccalaureate degree. (p. 52)

The NAE suggests that the bachelor degree become a pre-engineering degree leading to the first professional degree, which would be the masters. In light of the concerns regarding student preparedness expressed by the faculty respondents in this study as well as expressed in the reviewed literature, further research involving both academia and industry is absolutely necessary to determine the feasibility and value of such an approach.

Technical outcomes. There was general agreement on technical issues outside of math and science. Both groups placed approximately the same number of positive comments regarding engineering fundamentals, practical applications, and unspecified theory. It was on the science and mathematics outcomes that a divide emerged. The industry group did not perceive this knowledge as relevant to the field as opposed to the faculty group. Again, this is likely due to the career path experiences by each group. Faculty members are more likely to continue to directly use mathematics and science skills far into their careers, whereas each of the industry respondents moved further into management as they progressed through their career. Faculty respondents argued that this knowledge formed the basis of all other technical knowledge and therefore must be heavily emphasized in the curriculum. They also argued that industry engineers simply take for granted how much theory they actually use on the job. With all of the possible educational outcomes to be considered for curriculum inclusion and the limited number of undergraduate hours, this debate must be settled to provide student with the best educational outcomes to support their professional success. The researcher suggests that an in depth task analysis be performed in future studies to determine to what extent members of each group actually apply mathematics and science knowledge on the job. In this way, one would determine whether or not respondent perceptions align with reality, resulting in curriculum decisions made with higher confidence.

Unfavorable comments overall. An interesting finding emerged once the negative comments on student outcomes and job activities were analyzed. Although there were relatively few negative comments overall compared to positive comments, an obvious pattern emerged from the industry group. All unfavorable comments from industry respondents pertained to theoretical outcomes (Table 25). In fact, the negative comments covered *all* of the theoretical outcomes. In contrast, the faulty group had no negative comments regarding any of the theoretical outcomes. The only negative comments from the faculty group were on the topic of ethics and morality. Conversely, the industry group had only favorable things to say about those topics. It is important to note however that on almost all of these outcomes, negative comments by respondents contradicted the other group respondent's comments and in some cases even comments within their own group. Nevertheless, there appears to be complete disagreement between the two groups on what outcomes are *not* important in the undergraduate curriculum. Again, the industry group seems to be in favor of requiring less theory in the curriculum which would provide the needed room for the broader education that they appear to desire.

Table 25

Number of Unfavorable Comments Made by Respondents

Outcomes	Industry	Academia
Engineering Fundamentals	2	0
General Theory	2	0
Science	2	0
Mathematics	1	0
Ethics/Morality	0	2

Educational gaps. One issue discussed in the literature review was the perceived gap between education and practice by many in the engineering field. Therefore, in this last section of interpretations, interview data were analyzed for evidence of these perceived gaps by study respondents. The researcher looked for evidence of differences in perceptions of educational goals between the groups by analyzing comments in the interviews regarding gaps in knowledge.

During interviews, both groups discussed gaps in two different contexts. First, while reflecting on their own work activities, respondents discussed a desire to possess knowledge or skills in a particular area that they believed would benefit them on the job. Secondly, they discussed knowledge and skills that they felt were lacking in students coming out of an electrical engineering program. Considering the amount of literature reviewed in this study alluding to a school-work gap, there were surprisingly only a few comments made related to educational gaps compared to the overall number of coded comments. There were only 17 comments in total related to educational gaps (Table 26).

Table 26

Perceived Educational Gaps in Student and Self Knowledge

Outcomes	Number of GAP Comments			
	Industry		Academia	
	Student	Self	Student	Self
Business Knowledge		4		
Engineering Fundamentals		2	1	
Creativity	2			
Mathematics			2	
Practical Applications	1	1		
Systems Modeling and Design		1	1	
Communications			1	
Science				1
Total	11		6	

Student v. job comments. Although little evidence of a school-work gap emerged from the interview data, there were still some interesting patterns that emerged across the groups. First, the industry group referenced educational gaps almost twice as many times as the faculty group did overall. Second, the faculty group made only one mention of a gap in their own personal knowledge, but made five comments with regards to gaps in student knowledge. By contrast, industry had very little to say about gaps in student knowledge but made more than twice as many comments regarding gaps in their own knowledge. It would be interesting to investigate why industry respondents were more likely to offer comments about their own knowledge shortcomings than the faculty group. One reason could be the difference in level of education between the two groups.

All of the faculty respondents have earned doctorate degrees in engineering and continue to do research in their respective fields, while the highest technical degree obtained by any industry respondent was a masters degree. Faculty respondents may be more likely to perceive themselves as experts in their field and would therefore be less likely to perceive gaps in their own knowledge. Also, faculty respondents may feel more comfortable assessing student performance since that is an integral part of their teaching role. Steps may need to be taken in order to ensure that industry respondents feel more comfortable assessing the performance of new graduates during interviews while faculty respondents may need more prompting for self-reflection. These are issues to consider in future interview studies.

Mathematics and science. Table 26 presents evidence of a possible mismatch in educational goals on two outcomes of particular interest. This mismatch occurs on the outcomes of mathematics and science. Only the faculty group perceived a lack of preparation in students in these areas. The implication is that this perception could result in a decision to include more mathematics and science in the electrical engineering curriculum. Because the curriculum is a zero-sum game, these changes would be at the expense of other subjects in the curriculum. However, industry respondents did not appear to perceive these gaps and instead stated that they would like to see more emphasis placed on the business and practical side of the profession. This potential misalignment of goals between the groups is one reason why it is important to obtain feedback from all stakeholders before significant changes to the electrical engineering curriculum are made.

Agreement on outcome gaps. Even with so few comments regarding gaps from respondents, there was still some agreement between the two groups on outcomes. Two outcomes from Table 26 that overlapped between the two groups were engineering fundamentals and systems modeling and design. Interestingly, the faculty group referenced these two outcomes in the context of student gaps while the industry group referenced these two outcomes in the context of their own work. Because one would expect student knowledge gaps to eventually appear in the workplace, the industry group is essentially validating the faculty group's claims on these two outcomes. Agreement between the groups here suggests two areas worthy of closer inspection in the electrical engineering curriculum. Although all of the gaps mentioned during interviews merit further consideration by curriculum developers, engineering fundamentals and systems modeling and design deserve higher priority since these were the two outcomes on which both groups were in agreement.

Limitations

There were several limitations in this study that limit the extent to which these results may be generalized to larger populations. First, the sample for this study was a convenience sample of only six respondents from electrical engineering. A larger sample size might have captured more evidence of differences between the two groups that were studied.

Second, because of the small sample size, the industry respondent demographics only covered a small portion of the field and career ladder. For instance, there were no electrical engineers whose prime duties included research among the practitioners from industry. Respondents in industry research positions may have felt that new graduates were less prepared for those types of jobs than the non-research positions that study respondents used as a reference. Perhaps for the non-research oriented positions, electrical engineering graduates are better prepared than the literature would suggest. Because the current literature does not distinguish between the two career paths, comparison with previous studies is difficult.

Third, all of the industry respondents in this study were at the lower management level which excluded many other perspectives from up and down the worker hierarchy. It may be that engineers who are involved in more technical work or upper-level managers who see a bigger corporate picture may have a very different assessment of the skills of entry-level engineers.

The final limitations concern the methods used in data collection for this study. The original Seidman 3-interview method was modified in this study and reduced to a single 3-state interview. A relatively short amount of time was allowed for final reflection because the interviewer wanted to minimize the amount of work disruption for respondents as much as possible. The total interview was kept to approximately one hour, and therefore respondents did not have long periods of time to reflect on previous stages of the interview.

Lastly, this type of data collection is best suited for determining a conceptual framework for future studies. Due to the nature of the semi-structured interviews in this study, not all respondents were asked the same questions. Not all respondents addressed every outcome during interviews which makes comparisons between respondents, and hence groups, difficult. Therefore the data must be interpreted with caution.

Suggestions for Future Research

The results of this study have several implications for future research. First, it is likely that some relevant outcomes were missed in this study due to the small sample size. Therefore, a larger study with significantly more respondents should be conducted that would provide a richer description of the perceptions of engineering practitioners. Researchers conducting this study should strive to implement the full 3-interview Seidman method to obtain a rich data set for inferential analysis which was not performed in this study. It is not only important to know what engineers in each group value but also why they might value those things. Inferential analysis which looks at case patterns may reveal some very interesting relationships between variables relevant to curriculum development. There appears to be a lack of these types of studies in engineering education literature.

This study only included feedback from electrical engineers, but the questions and issues addressed here are relevant to all engineering disciplines. Hence, a second recommendation for future research is a study of broader scope that includes respondents from all of the major engineering disciplines.

A third recommendation for future research is to explore differences in perceptions of engineers with respect to their position in the organizational structure. Would project managers respond differently from developers or testers? Would upper management respond differently from lower management? Respondents from this study all work at essentially the same level of management and therefore points of agreement may have occurred due to similar work experiences. It will be important in future research to include multiple perspectives.

A fourth recommendation for future research is to explore difference in perceptions of industry engineers in research-oriented positions with those who are in non-research positions. The skill set required to be successful in a research job would be considerably different from that of a job outside of research. It is likely that industry practitioners involved in research may be more critical of the skills of recent graduate. Therefore it will be important to include these voices in future studies.

Finally, this study produced a list of educational outcomes which have emerged as relevant to electrical engineering practitioners. These outcomes should be merged with ABET outcomes and included in a large-scale quantitative survey study so that statistically significant differences between groups can be measured and reported.

Conclusion

According to this study, one cannot conclude that the school-work gap laid out in the literature review is caused by major differences in conceptions of educational goals between practitioners in industry and academia. Although some differences were found, they do not appear to be large enough to produce this disconnect between the two groups. Larger studies may prove otherwise, but they may also find other causes. The researcher suspects that responses from industry vary greatly depending on the position of the respondent in the corporate structure. Daily work activities are highly dependent on one's work title and industry sector. Therefore one's experience and conceptions will also vary greatly. Along these lines, it is quite possible that differences in practitioner conceptions of educational goals do in fact have a significant impact on the school-work gap reported to exist in this country. It may simply be that these differences exist in varying degrees at different levels of the organization and in different industry sectors. Industry respondents accept the fact that electrical engineers enter the workforce with a broad skill set and require a significant amount of training to become productive in a particular position. It may be that not until later in an engineer's career do educational deficits become apparent. A quick look at job postings for engineers for non-entry-level positions shows that industry very quickly hones in on a formidable list of very specific skills as engineers move even slightly up the career ladder. Hence, a slightly different sample from industry reflecting on non-entry-level electrical engineers might have revealed significantly different results. Years after entering the workforce however, an electrical engineer would have received training from multiple sources which might include corporate training, vendor training, and graduate school in addition to the undergraduate program. The question then becomes who is responsible for what training at what point in an electrical engineer's career. Does then the responsibility of closing the school-work gap fall solely on undergraduate electrical engineering programs or should the responsibility be shared by multiple entities? These are very important questions that hopefully will be investigated in future studies.

On a final note concerning the findings of this study, the researcher was only concerned with uncovering differences between groups of practitioners in the electrical engineering discipline. Although curricula for different disciplines in engineering share a significant portion of course content, each discipline is associated with a specific skill set unique to that discipline. Those skills could be generalized to broader outcomes as in the case of the ABET a-k outcomes and in the case of this study. In that way, one can compare findings across disciplines more easily, but one must be careful in assuming that findings will be the same across different engineering disciplines. The size of the sample in this study was not large enough to merit an argument for generalization of findings to other disciplines. However, previous research has found few differences in employer perceptions of recent graduates' preparation by engineering discipline (Volkwein, et al., 2008), suggesting that findings of this study may be useful when considering curricula outside of electrical engineering.

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