SKILL SETS REQUIRED FOR ENVIRONMENTAL ENGINEERING AND WHERE THEY ARE LEARNED

By

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DEDICATION

This book is dedicated in memory of my parents, William and Jacqueline Warren and my grandmother, Wilma "Peggy" Reed.

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SKILL SETS REQUIRED FOR ENVIRONMENTAL ENGINEERING AND WHERE THEY ARE LEARNED

Abstract

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2010

The purpose of this study was to investigate the knowledge, skills, abilities and traits environmental engineers need. Two questions were asked: what skills are considered important, and where are they learned? Dreyfus and Dreyfus' novice-to-expert model, which describes a progressive, five-step process of skill development that occurs over time on the job and through practical application, was used to frame this study. This study extended prior research by including data on professional skills and seeking the input of working professionals: in this case, the technical staff at the California Department of Toxic Substances Control. Quantitative methodology and descriptive statistics were used for data collection and analysis.

Results showed that experienced professionals agree that professional or soft skills are essential are essential in the workplace. Many technical skills are learned over time, through practice and meaningful application on the job that builds on principles learned through formal training. Professional skills are developed through a combination of formal training and experiential learning from work, or through life experiences. The implications for higher education are twofold. Environmental engineering programs would benefit by integrating professional skills development with existing curricula, and by giving students opportunities to develop experiential knowledge in the workplace. Results indicated that environmental engineering professionals with higher levels of education and more experience believed that science and mathematics were most appropriately learned in school, while engineering, skills in technology and other technical areas were best developed through a combination of formal education with experiential learning. The more experienced people also believed that life experiences, rather than work or school, were the best way to develop professional skills. These findings confirm the Dreyfus & Dreyfus model, which indicates that individuals move from novice to expert based on experience. Environmental engineers would benefit through continuing education and in-service training. Collaborative initiatives between higher education and practitioners in environmental engineering may prove mutually effective and beneficial to students, workers, educational institutions and employers.

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CHAPTER I

INTRODUCTION

Scientific progress and technological innovation have been the cornerstone of American national security, economic prosperity, and the economic and social well being of individuals and communities throughout the United States since the Industrial Age (Goldin & Katz, 2008).

National leaders continue to recognize the vital role science and technology play in modern society. During his 2006 State of the Union message, then-President George W. Bush announced the *American Competitiveness Initiative*, the goal of which is to continue this nation's "economic and technological leadership in the world" (Bush, 2006). The Initiative pledged new investments in education and research in science, technology, engineering and math (STEM) as the "gateway to opportunity and the foundation of a knowledge-based, innovation-driven economy" to generate scientific and technological advances and "help ensure that future generations have an even brighter future" (Bush, 2006). In making this three-way connection between education, the futures of individual workers and national competitiveness, Bush invoked a version of John Kennedy's frequently-quoted assertion that a "rising tide lifts all boats" (Kennedy, 1963). To counter assertions that his tax cuts would disproportionately benefit the wealthiest individuals, Kennedy used this statement to argue that securing America's position in the globalized economy would also ensure meaningful life chances for individuals at multiple socioeconomic levels (Kennedy, 1963).

Later, in an executive order calling for scientific integrity in Federal policies, President Barack Obama wrote that "the scientific process must… guide decisions of my Administration on… issues including improvement of public health, protection of the environment, increased efficiency in the use of energy… and protection of national security" (Obama, 2009).

Conversely, national reports have provided warning about the opposite: without lifting boats, the tide cannot rise. In other words, unless the number of Americans who secure their economic futures through education in general and effective STEM training in particular is increased, the national economy is likely to stagnate (Goldin & Katz, 2008). The link between economic competitiveness and individual prosperity has been the subject of many national reports in the past two decades, including *A Nation at Risk: The Imperative for Educational Reform* (National Commission on Excellence in Education, 1983) and *American's Choice: High Skills or Low Wages* (National Center on Education and the Economy, 1990).

More recent reports explicitly link deficient STEM skills to deficiencies in the national well being, using the metaphor of stormy disturbances to the nation's economy. In its 2005 report titled *Rising Above the Gathering Storm: Energizing and Employing Americans for a Brighter Economic Future*, the National Academy of Sciences decried the erosion of U.S. advantages in the globalized marketplace because of inadequate STEM education. The report warns that the U.S. is on a "losing path" in global economic competition and that drastic improvements in STEM education would be necessary to reverse this trend (Augustine, Vagelos & Wulf, 2005). On the other hand, policymakers have repeatedly linked improved STEM education with national competitiveness and economic security for individuals (National Center on Education and the Economy, 1990).

On these grounds, concerns about technical abilities and global competence among American students and workers have increased in the first part of the 21st century, with advances in technology, globalization and increased levels of education among students in other countries (Richter & Paretti, 2009). As students and workers in other countries become better-educated, American students need to also develop advanced skills in science, technology, math and engineering in order for the United States to retain its role as a leader in worldwide scientific and technical innovation and economic development (Augustine, Vagelos & Wulf, 2005). Recognition of the need for improved STEM education has led to increased calls for educational reforms in both K-12 and higher education to ensure that the United States continues to train a highly-skilled, competitive workforce (Kirsch, Braun, Yamamoto & Sum, 2007).

The demand for educational reform has been a salient issue for STEM education in the United States since the latter part of the 20th century. Concerns about the development of a highly-skilled workforce in the United States include a growing awareness of the need to align education and training with employer requirements. Due to factors such as globalization, researchers now acknowledge that students in scientific programs of study need to develop competency in both technical abilities and professional skills (Goldin & Katz, 2008; Richter & Paretti, 2009). In other words, American students and workers need both skills in performing job-oriented tasks and the ability to get along well with colleagues, customers and others in order to be able to compete globally and collaborate with clients and colleagues from around the world.

Evaluating the need for improved cultural competency and technical abilities may be done by exploring these areas in a discipline that has meaning for workers in the United States. This study used environmental engineering, an emerging specialty in the field of engineering, to examine the knowledge, skills, abilities and traits, or the competencies practitioners need for success in this profession. Some elements of the skill development process focused on the competencies students develop through formal training. However, research indicates that experienced professionals who are already in the field may serve as an even richer and more valuable source of information for students considering environmental engineering as a career option (Finch & Crunkilton, 1999).

Problem Statement

Higher education and professional training are particularly effective when the knowledge, skills, abilities and traits developed by employees are consistent with workplace requirements (Gilleard & Gilleard, 2002). Employees also benefit by gaining familiarity with organizational culture and by learning skills through on-the-job training. Those with effective interpersonal, communication, teamwork and other professional skills considered essential in the workplace may also be able to master the technical competencies they need (Goldin & Katz, 2008).

Employees with the ability to engage in lifelong learning may also be more adaptable to changes in field work or the profession, and may find it easier to remain current in the technical requirements of their field (Mulder, 2006). The need to adapt has led to a realization in the field of engineering that an interdisciplinary focus in both formal training programs and transition to the workplace is essential for the development of employees who can collaborate effectively with clients, colleagues and other stakeholders; synthesize technical competencies with important professional skills; and continue learning over a professional lifetime (Becker, 2006; Hecker, 1997; Jones, Merritt & Palmer, 1999; Mulder, 2006).

Research addresses the skills engineers in different specialties need in order to perform effectively (Accreditation Board of Engineering and Technology, 2008; Mulder, 2006). Existing studies have focused on technical rather than professional skills, and have emphasized skills developed primarily through formal education, rather than on the job (Becker, 2006). Finally, the majority of studies conducted on skill sets required in engineering specialties have collected and analyzed data from students and instructors (Richter & Paretti, 2009). Few studies on this topic have used data collected from working professionals in the field.

Purpose Statement

The purpose of this study was to investigate the knowledge, skills, abilities and traits required of environmental engineers, and to learn where these skills are developed, based on the views of experts in the profession.

Importance of this Study

The importance of this study is that its findings may be used to inform the content of curriculum in STEM programs among community colleges, four-year universities and professional associations by adding aspects of the requisite knowledge, skills, abilities and traits from experienced professionals in the field – a source of information that has been traditionally overlooked (Finch & Crunkilton, 1999). This study can also help develop a broader understanding of the needs leaders in STEM education have by helping them better understand the competencies required by employers (Goldin & Katz, 2008). In addition, both educators and employers may benefit from the additional insights generated as part of this study as they seek to achieve an appropriate balance of technical and professional skills among environmental engineers (Ayers, Miller-Dyce, & Carlone, 2008). Finally, this research can inform policymakers as they design legislation and funding mechanisms to establish training programs for students considering careers in environmental engineering, and to incorporate the role of experiential learning in addition to formal education (Accreditation Board of Engineering and Technology, 2008).

Research Questions

This study addresses two research questions:

RQ1: What knowledge, skills, abilities and traits do experienced professionals view as necessary for a successful career in environmental engineering?

RQ2: Where do experienced professionals in the field of environmental engineering believe they learned the skill sets they use in their work?

Definitions

The following definitions are provided to promote a common understanding of the terms used in this study:

Career ladder: The term used to refer to upward mobility in a specific field or profession, usually through earned promotion or development of greater areas of professional responsibility (Dynan, Cate & Rhee, 2008).

Emotional intelligence: This term refers to the ability to accurately identify, understand and manage one's own emotional state, particularly in reference to personal and professional relationships (Goleman, Boyatzis & McKee, 2002).

Engineering: A discipline concerned with applying "the principles of science and mathematics to develop economical solutions to technical problems. The work of engineers links scientific discoveries with practical or commercial application" (United States Bureau of Labor Statistics, 2009, p. 1).

Environmental engineering: A specialty of engineering that focuses on solving environmental problems by focused application of the principles of sciences such as biology, chemistry, geology and physics (United States Bureau of Labor Statistics, 2009).

Generalizability: A process that uses statistical probability to predict that data gathered from a sample concerning a particular social phenomenon can be applied to a larger population of individuals similar to those in the sample (Creswell, 2008).

Leadership development: This is the process of building and improving the quality of leadership within an organization, through strategic hiring, formal training programs and/or activities such as mentoring (Harris & Cullen, 2009; Markes, 2006).

Lifelong learning: Originally used to describe specialized education for older adults, the definition of this term has expanded to refer to continuing education, self-directed learning, and on-the-job training for graduates embarking upon their careers (Dynan, Cate & Rhee, 2008; Hecker, 1997).

Professional skills (also, life skills, interpersonal skills or soft skills): The ability to interact, collaborate, and communicate effectively with other people. These skills encompass areas that include critical thinking, intellectual curiosity, an ability to engage in lifelong learning, integrity, empathy, emotional and social intelligence. In the context of higher education or the workplace, soft skills may include effective collaboration teamwork, negotiation, persuasion and an ability to view an issue from the client's point of view (Lohmann, Rollins & Joey, 2006).

Self-directed learning: Formal or informal training where learning is initiated by the learner (Dynan, Cate & Rhee, 2008)

Skill sets: The knowledge, skills, abilities and traits workers are expected to have in order to perform their jobs effectively.

Succession planning: The process of developing effective leaders from within the ranks of organizations over time. The goal is to ensure continuity of leadership and a reasonably smooth transition when senior leaders leave (Goleman, Boyatzis & McKee, 2002; Harris & Cullen, 2003).

Technical skills (also, hard skills): The abilities required to perform the tasks needed for a specific occupation or profession (Bezdek, Wendling & DiPerna, 2006).

Summary

Scientific progress and technological innovation play a key role in the economic and social well being of individuals, communities and society. Continued progress in scientific fields requires a fully functional, innovative and competitive workforce with proficiency in science, technology, engineering and mathematics (STEM). There is also a growing recognition in the profession of engineering of the need to integrate soft skills, also known as professional skills, with technical, task-oriented competencies. Furthermore, working professionals in engineering disciplines can provide valuable insights into the importance of integrating training in technical and professional skills. This information can be used to inform the development of STEM curricula. However, the overwhelming majority of existing research draws on the experience of formal training, rather than on the perspective of experienced professionals.

For these reasons, the purpose of this study was to investigate the knowledge, skills, abilities and traits required of environmental engineers. Two questions were asked: what knowledge, skills, abilities and traits are considered important, and where are these skills learned. This study focused upon environmental engineering, and extended existing research by analyzing the importance of professional skills in addition to technical competencies, and by using data collected from working professionals who have learned at least part of their skills through practice and application. The literature used to support the development of this study was discussed in Chapter II.

CHAPTER II

REVIEW OF THE LITERATURE

The purpose of this study was to investigate the knowledge, skills, abilities and traits required of environmental engineers, and to learn where these skills are developed, based on the views of experts in the profession. The viewpoints of environmental engineers in government service were sought, because state and federal agencies establish and enforce acceptable policies, protocols and practice in the specialty of environmental engineering. For example, California state agencies are legally mandated to regulate environmental projects, oversee remediation and ensure that engineering professionals meet standards specified by licensing laws (California Department of Consumer Affairs, 2009). For these reasons, state and federal agencies involved with environmental issues need to consider how their decisions affect their communities and other professionals. Their regulations and policies set the standards followed by other professionals working for local governments and in private industry (United States Bureau of Labor Statistics, 2009). This research study focused on the skills considered important by a sample of skilled environmental engineering professionals employed at one California state agency involved in remediation, regulation, and policy development.

This chapter provides a review of the literature covering the profession of environmental engineering: the technical skills required for professional competency and licensure, the professional or soft skills required, an interdisciplinary approach to formal study, the benefits and challenges of lifelong learning, and on-the-job or experiential learning.

Environmental engineers

According to the United States Bureau of Labor Statistics (2009), "engineers apply the principles of science and mathematics to develop economical solutions to technical problems… to meet societal and consumer needs" (p. 1). As a specialty field within the larger discipline, environmental engineering applies scientific and mathematical principles to protect human health and the environment from environmental degradation. Professionals in the field work to protect and improve environmental quality by participating in the prevention and remediation of water, air and soil pollution, brownfields restoration, development of regulations to ensure environmental quality improvement and pollution control, evaluation of the economic and efficiency of applied environmental protocols, public education of the impact of hazardous substances and the analysis of environmental impacts of projects such as the construction of roads, buildings or housing projects (AAEE Working Group, 2008; Bureau of Labor Statistics, 2009).

Increased environmental awareness and public demands for remediation of existing hazards have made environmental engineering the fastest-growing specialty in the field of engineering. The number of professionals in this discipline is expected to grow to 68,000 by 2016, one-fifth of whom will be employed by government agencies (United States Bureau of Labor Statistics, 2009). Environmental engineering is one of the newer specialties in the discipline. However, its principles and practices overlap with other specialties. For example, many current practitioners began their careers as civil or chemical engineers (Accreditation Board of Engineering and Technology, 2008). Like practitioners in other engineering specialties, environmental engineers are faced with increased expectations that they will master both technical and interpersonal skills, and that they will remain current in their field through self-directed and lifelong learning (AAEE Working Group, 2008).

Technical skills

Like other engineering professionals, environmental engineers are required to master a rigorous set of scientific and technical skills in order to be licensed (Bezdek, Wendling & DiPerna, 2006). The knowledge, skills and abilities required for environmental engineers overlaps with those required for professionals in other specialties such as civil engineering (Accreditation Board of Engineering and Technology, 2008). According to the Accreditation Board of Engineering and Technology (ABET), the organization responsible for accrediting baccalaureate and graduate-level engineering programs in the United States, all engineering programs (including environmental engineering specialties) need to ensure that their students and graduates meet rigorous standards, including a solid understanding of the physical sciences and competency in solving mathematical, technical and engineering problems. Students are expected to demonstrate global competency and commitment to professional and ethical standards (Accreditation Board of Engineering and Technology, 2008).

Because decisions made and actions taken by environmental engineers can have significant and long-range consequences for the environment and the public, these rigorous criteria are deemed necessary for the protection of public health and safety (Becker, 2006). Consequently, state agencies responsible for licensing professional engineers also include specific levels of education in established principles and proper application of mathematics, science and engineering. As a condition of licensure and practice, engineers also need to demonstrate familiarity with state and federal laws that govern their profession and graduate from accredited programs (California Board for Professional Engineers and Land Surveyors, 2009).

The rigorous skill set required by accreditation boards and state licensing agencies has resulted in a heavy concentration of math, science, technology and engineering skills in the curriculum for both undergraduate and graduate-level programs at accredited institutions (California Institute of Technology, 2009). Students are required to meet rigorous criteria for successful completion of their environmental engineering programs. However, while these programs have found it necessary to focus on developing student competency in science, math and engineering (Ahern, 2007; Becker, 2006), there is growing recognition that environmental engineers also need communication, teamwork and other interpersonal skills to interact with and respond appropriately to the concerns of internal and external stakeholders (Richter & Paretti, 2009; Tansel, 2008). Thus, it appears that an interdisciplinary focus, with emphasis on balancing scientific rigor with the development of soft skills, may prove beneficial to the study and application of environmental engineering (Mulder, 2006).

Requirements for soft skills

Programs in environmental engineering and other technical disciplines have not traditionally focused on developing the skills in human relations that are routinely taught to students majoring in business, liberal arts, social sciences and the humanities (Richter & Paretti, 2009). Historically, engineering programs have emphasized the highly-complex, specialized skills in mathematics and science that engineers in the workplace require in order to perform their jobs according to the rigorous standards of their chosen fields (Costlow, 2000; Richter & Paretti, 2009). Furthermore, while earlier practitioners in engineering disciplines might have performed satisfactorily in isolation, today's engineers are expected to communicate effectively with internal and external stakeholders, collaborate as members of teams to ensure maximum efficiency, remain competitive in the global marketplace and move into positions of leadership within their organizations as their predecessors retire or otherwise leave the field (Hecker, 1997; Pulko & Parikh, 2008).

Stakeholder relations

The public has demonstrated a high level of interest in issues like global warming and the mitigation of hazardous substances, making environmental engineering an emerging specialty within the field of engineering (Accreditation Board of Engineering and Technology, 2008; Richter & Paretti, 2009). Environmental engineers need to develop the skills to communicate effectively with the media and the public. Furthermore, since external stakeholders may not understand technical jargon or complicated scientific concepts (Becker, 2006), environmental engineers need to have the ability to understand their audiences and translate their work into everyday language (Tansel, 2008).

Furthermore, interaction between environmental engineers and the public frequently involves controversial subjects, such as vapor intrusion, defined as the contamination of indoor air by toxic gases from neighboring sites (Department of Toxic Substances Control, 2009b). If environmental engineering professionals rely heavily on technical jargon, fail to listen to public input or act without sensitivity and regard for the concerns of the people whose communities are affected, their failure to communicate with effectiveness and empathy will undermine their credibility and impede their ability to perform their jobs (Department of Toxic Substances Control, 2009a).

As licensed professionals, environmental engineers also operate in a complex legal and political environment because of government regulations in the United States and elsewhere. This may present a conflict for them because the precise nature of engineering does not always mesh with the ambiguous and occasionally confusing issues involved in environmental law or global politics (Hammer, 1999). Environmental engineers may be called as witnesses in criminal or civil court proceedings, or required to act in an advisory capacity to government officials ranging from local council members to heads of state (Becker, 2006; Costlow, 2000). The legal, social, economic and political ramifications of environmental engineering add to the complexity of working conditions and requirements for practitioners (Becker, 2006; Hammer, 1999).

Local to global collaboration

The complex nature of environmental engineering means many projects are now completed by teams from one or more organizations rather than by individuals (Richter & Paretti, 2009). For this reason, environmental engineering professionals need to collaborate with other engineers, consultants and other professionals who may be located in the same building or on the other side of the world, and with geologists, accountants, administrative assistants and other colleagues who operate from different perspectives but whose input and cooperation are just as important to each project (Lohmann, Rollins & Joey, 2006). Environmental engineers need to know when and how to delegate specific tasks, making teamwork another important area of skill development (Rohlander, 1999).

The value of integrity

Environmental engineers make decisions that carry significant potential consequences because their work can impact public policy, private practice and public health and safety in communities (Markes, 2006; United States Bureau of Labor Statistics, 2009). Practitioners are expected to follow a high standard of integrity, "evident when organizational principles of communication, ethical decision-making, and humility are… demonstrated consistently" (Bavier, 2009). At times, adherence to rigorous scientific principles and standards of professional integrity places environmental engineers in conflict with the demands of employers, clients, elected officials, political advocacy groups or others who may not understand or agree with the rationale they use in their decisions (Markes, 2006). Because of this pressure, critical thinking abilities, adaptability and conflict management are also valuable skills in the practice of environmental engineering (Paretti, 2003).

Acquiring proficiency in technical and professional skills

Employers and professional associations are incorporating interpersonal or soft skills into workplace expectations for professional engineers. For example, the Accreditation Board of Engineering and Technology (ABET) includes ethical behavior, commitment to quality, a commitment to continual improvement and lifelong learning, an understanding of global concerns and other professional competencies for environmental engineering graduates in their accreditation standards (Accreditation Board of Engineering and Technology, 2008). Careful attention to the standards and changing demands of their field are also included as part of leadership development and succession planning for environmental engineers and the organizations that employ them (Richter & Paretti, 2009).

Developing leadership

Leadership capability is a matter of concern for organizations in both the public and private sectors (Kouzes & Pozner, 2002). One way organizations can be managed is through a resonant style of leadership that fosters a sense of responsibility for the greater good and the social and emotional intelligence to work effectively with internal and external stakeholders (Goleman, Boyatzis & McKee, 2002). In addition, succession planning is a salient concern for state and federal agencies: as senior employees retire and take with them their technical and professional skills acquired through their training and decades of practice (Sanchez-Manzanares, Rico & Gil, 2008), it is important for graduates of environmental engineering programs to have a basic understanding of teamwork, interpersonal skills and emotional intelligence, in addition to advanced technical skills in mathematics, science and engineering (Markes, 2006; Palethorpe, 2006). However, expanding requirements for technical, interpersonal skills and global social competence may present a conflict for all engineering education programs as they are faced with increasing demand by employers in all sectors to prioritize and balance teaching a wide array of technically-sophisticated abilities with training in the professional skills and global competence graduates will need for success in the workplace (Harris & Cullen, 2009; Lohmann, Rollins & Joey, 2006).

Differences between the theories and principles developed in formal training with the realities of the workplace may also lead to conflict. Novice environmental engineers may face tension between the inherently precise nature of engineering and the ambiguity they will face as they collaborate with others from different organizations and cultures (Gilleard & Gilleard, 2002). For environmental engineering professionals, developing skills in identifying and managing ambiguity in real-life situations will likely depend on a combination of interdisciplinary principles learned in college with professional skills developed through experiential and lifelong learning (Mansilla & Duraising, 2007; Mulder, 2006).

The benefits and challenges of lifelong learning

Lifelong learning is a term originally associated with formal education for senior citizens (Miller & Beard, 2008). However, in a broader context, lifelong learning may also describe the continued education, self-directed experiential learning and on-the-job training students and working professionals experience as they make the transition from college to the workplace (Dynan, Cate & Rhee, 2008; Hecker, 1997). While a good deal of information exists on undergraduate and graduate training for engineers, currently, there is no known literature that specifically addresses lifelong learning for environmental engineers. However, the benefits of cooperative, continuous learning for civil engineers have been discussed. Ahern (2007) found that civil engineering students in cooperative programs benefitted from working together in teams, under conditions similar to those they would face in the field: this process may continue as graduates transition into the workplace. Lifelong learning and on-the-job training may also be used to help environmental engineering graduates develop global competence and gain proficiency in the technical, social and professional competencies they will need in order to work effectively with other people and make a successful transition into their careers (Harris & Cullen, 2009; Lohmann, Rollins & Joey, 2006).

Experiential learning

Advances in technology and changes in other factors influence the requisite tasks and working conditions faced by employees. Generally, employers also have their own policies, protocols and procedures for completing tasks (Ayers, Miller-Dyce, & Carlone, 2008). Scientific discovery and changes in the environment may also render some skills learned in college obsolete (Becker, 2006). In addition, experiential learning also helps new employees develop competencies related to their career goals, apply classroom knowledge in real-world situations, and take responsibility for their own learning (Mulder, 2006). While preparation for future employment is a top priority in higher education, the diverse set of learning opportunities in experiential learning offers a unique and valuable avenue of skill development for environmental engineers (Aamodt & Havnes, 2008; Townsend & Shelley, 2008).

In the workplace, experiential learning on the job takes multiple forms, such as internships, cooperative training, apprenticeships and mentoring (United States Department of Labor, 2009). Many employers view on-the-job training favorably for several reasons: It is generally conducted on-site and relies on real-world events rather than simulations, making it more relevant and efficient for training and development (Benner, 2004). New employees may also develop effective technical and professional skills informally by collaborating with experienced colleagues who know the organization's culture, job-specific requirements, and the expectations of clients and management (Ayers, Miller-Dyce, & Carlone, 2008; Mulder, 2006; Townsend & Shelley, 2008). Thus, novice engineers may expect to engage in experiential and on-the-job training as they move up the career ladder.

Career ladders and upward mobility

Environmental engineers can expect to work with a diverse array of stakeholders during their careers and will face complex legal, political, cultural and socioeconomic environments (Accreditation Board of Engineering and Technology, 2008). Graduates moving into the workplace have the task of continually refining both their technical and professional skill sets in order to remain in the field and move up the career ladder into senior-level engineering and managerial positions (Richter & Paretti, 2009). Moreover, employers benefit by ensuring that new employees either have both technical and professional competencies or can develop them. These skills may be developed through continuing education and through mentoring by experienced colleagues (Accreditation Board of Engineering and Technology, 2008; Gilleard & Gilleard, 2002; Hecker, 1997). The insights of skilled, experienced environmental engineers may also provide additional insights for curriculum development in accredited environmental engineering programs.

Framework for this Study

Any study involving human social phenomena would benefit from the use of a theoretical or conceptual framework: a model that can be used to guide and inform the study. For the purpose of this study, Dreyfus' novice-to-expert model detailing the process of skill acquisition was used as a conceptual lens that was suitable for informing the study and through which the data collected from experienced professionals in the field of environmental engineering could be viewed (Dreyfus & Dreyfus, 1986).

Dreyfus' novice-to expert model is a sequential, five-stage process (Table 1) that explains how an individual develops in his or her field of expertise through experiential learning (Benner, 2004; Dreyfus & Dreyfus, 1986). It posits that experiential learning forms the foundation of expert wisdom, sound practice and good professional judgment. These qualities are developed over time, through regular practice and engagement with concrete learning experiences as the individual develops his or her expertise in the profession. He or she learns to recognize situations as they develop and respond appropriately based on concrete situations and prior experiences (Benner, 2004).

This process of skill development begins with the novice stage, when an individual begins performing routine tasks in areas where he or she might have studied, but lacks experience on which to base any understanding of the work. In this stage, the novice works under the close supervision of a more experienced colleague or supervisor (Benner, 2004). As the novice gains confidence in his or her own ability to perform these tasks, he or she is gradually given more responsibility and progresses to the advanced beginner stage, in which they are given new, more complex responsibilities and more autonomy in their work (Dreyfus & Dreyfus, 1986). The individual gradually gains confidence with this new level of responsibility and autonomy and learns from his or her mistakes. He or she continues to pay close attention to the practice of more experienced colleagues and supervisors, relying on them for support and feedback. Gradually, the individual reaches the competent stage, where the individual analyzes and plans his or her own work, makes decisions based on past experiences and relies on colleagues for encouragement when things don't go as planned (Benner, 2004, Dreyfus & Dreyfus, 1986).

Table 1: Five stages of the Dreyfus & Dreyfus novice-to-expert model

Stage	Description	Decision-Level
Stage 1: Novice	Employee performs routine tasks in areas for which he or she has trained, but has little or no experience.	Employee works under close supervision by a manager or more experienced peer.
Stage 2: Advanced Beginner	Employee gains confidence in own ability to perform the job and begins synthesizing experiential knowledge with formal training.	Employee receives more complex responsibilities and autonomy in work performed; still relies on supervisors and peers for support and feedback.
Stage 3: Competent	Employee makes decisions based on past experiences, and synthesizes training and experience.	Employee analyzes and plans own work; relies on colleagues for encouragement instead of direction.
Stage 4: Practitioner	Employee/practitioner develops a new relationship with work and colleagues; makes judgments based on a combination of knowledge learned in school with that acquired on the job.	Has an excellent grasp of each unique situation; anxiety is minimal or nonexistent; works with supervisors as equals and as collaborative partners.
Stage 5: Expert	Expert is completely attuned to his or her work and can readily adapt to unique circumstances as needed.	Expert uses practical wisdom in making decisions, and may teach others.

Sources: Benner (2004), Dreyfus & Dreyfus (1986)

Application of the Dreyfus model to environmental engineering

The evolving nature of environmental engineering and progressive, practice-based skill development make Dreyfus' novice-to-expert model an appropriate conceptual lens through which to view data collected from experienced practitioners on the need for specific skills in environmental engineering and where these skills are learned.

Summary of the Literature Review

This chapter provided a review of the literature covering the profession of environmental engineering, the fastest-growing specialty in the field of engineering. The literature covered for this study included research on the technical skills required for professional competency and licensure, the professional or soft skills required, interdisciplinarity, the benefits and challenges of lifelong learning, and on-the-job or experiential learning. State and federal agencies tasked with environmental management have to address the impacts their decisions have on others, because their policies set the standards followed by other professionals. This research study focused on the skills considered important by a sample of skilled environmental engineering professionals employed at one public agency involved in environmental remediation, regulation, and policy development.

This study focused on the need for and development of skills from the perspective of working professionals. Much of the time, progress in skill development begins with a foundation of principles learned through formal study and continues with the application of these principles through real-world experiences in the workplace. These factors make Dreyfus' novice-to-expert model a suitable conceptual framework for the study. The methodology used for the collection, analysis and reporting of data in this study was presented and discussed in Chapter III.

CHAPTER III

METHODOLOGY

The purpose of this study was to identify the knowledge, skills, abilities and traits needed by environmental engineers as well as their perceptions about where skills are learned in this specialty, based on data collected from experienced professionals. This chapter covers the methodology used in this study and the nature of the study. It includes a description of the quantitative methodology and an explanation of descriptive statistics, the sampling frame, sample validity and transferability, the data collection process and procedures, the handling and analysis of survey data, and assumptions and limitations.

Nature of the Study

This research study involved quantitative methods of inquiry to answer research questions about the perceptions of experienced professionals concerning the knowledge, skills, abilities and traits environmental engineers need to perform their jobs successfully. Appropriate methods of data collection and analysis were needed to identify the knowledge, skills, abilities and traits required for success in environmental engineering. Therefore, this study employed descriptive statistics, mathematical "procedures used for classifying and summarizing, or describing, [numerical] data" (Hinkle, Wiersma & Jurs, 2003). For this study, the descriptive statistics computed and analyzed included frequency distributions for respondent choices, or points on an ordinal scale where scores are located (Gall, Gall & Borg, 2007).

Study Population and Sample

For this study, it was important to locate a sufficient number of experienced professionals with understanding of the knowledge, skills, abilities and traits required for environmental engineering, as well as where respondents believe they learned those skills. For this reason, the sampling frame consisted of the technical staff from the California Department of Toxic Substances Control, or DTSC, a California state agency involved in the regulation and oversight of environmental protection and hazardous materials remediation. Investigation revealed that approximately 483 employees, or 47% of DTSC's 1,019 full-time employees, qualified as technical staff directly engaged in occupational activities related to environmental engineering (Department of Toxic Substances Control, 2009). Thus, they were qualified to participate in this study

The 483 technical staff at DTSC contacted for this study have been employed in one of three classifications: hazardous substances engineers, engineering geologists, and hazardous substances scientists. As part of their regular duties, employees in all three classifications interpret and enforce state and federal environmental regulations, make site visits and evaluations, write recommendations to local agencies and the public, identify sites that are contaminated by hazardous materials, and then collaborate with other internal and external stakeholders to remedy environmental contamination (Ramanujam, 2009). Technical employees at DTSC are also employed at three levels: technical staff who perform routine tasks of average complexity, senior staff who perform tasks of greater complexity, and supervisors (Department of Toxic Substances Control, 2009a).

For the technical staff at DTSC, the tasks involved with environmental management and hazardous materials remediation follow a seven-stage process, known as the cycle of hazardous materials remediation, which begins once a site for environmental remediation is identified, The unique nature of hazardous materials remediation and other work completed by DTSC employees make it necessary for engineers, scientists and geologists to collaborate during the critical early stages of the hazardous materials remediation cycle (Ramanujam, 2009). While hazardous substances engineers have the primary responsibility for regulation and oversight of activities later in the process, collaboration between hazardous substances engineers, engineering geologists and hazardous substances scientists for the duration of the cycle is standard practice (Ramanujam, 2009). Therefore, the viewpoints of technical staff of all three classifications are valid for this study, and the findings may be applicable to other public agencies and private firms that employ engineers, scientists and geologists for the purpose of protecting the environment.

In order to determine whether the results of this study may be applied in similar situations, it was also important to establish sample validity (Babbie, 2000).

Sample Validity

Establishing the credibility of a study requires sample validity, defined as the extent to which the results of a survey from a given sample are generalizable or transferable to a larger population (Gall, Gall & Borg, 2007). It is impossible to know the exact, definitive number of what constitutes a sufficient sample size (Hinkle, Wiersma & Jurs, 2003). To achieve sample validity, the sample size, meaning the number of study respondents or observations, need to be large enough to reduce the likelihood that significant differences will exist between the sample and the study population. Depending on the nature of the study, an adequate sample size for quantitative research may include as few as 100 people (Creswell, 2008). For this study, a sample size of 100 survey respondents was deemed sufficient to minimize the possibility of sampling error (Hinkle, Wiersma & Jurs, 2003).

Data Collection

The data for this study was collected using a survey instrument. A survey "provides a quantitative or numeric descriptions, attitudes or opinions of a population by studying a sample" (Creswell, 2008). Because this study used a purposeful sample, in this case respondents who were available at the time this study was conducted, the results may not be generalizable to a larger population (Babbie, 1990). However, they may be transferable (Creswell, 2008). That is, the findings of this study may be applicable to environmental engineering professionals in other locations, those employed by other organizations, or to engineers in other specialties.

To expedite the collection of survey data from the group of environmental engineering professionals at DTSC, an electronic questionnaire was designed using Survey Monkey, an online survey subscription service that enables users to quickly create encrypted, web-based surveys and distribute links to them via websites or email (Creswell, 2008). It was important to test the survey prior to collecting data from the main study sample (Babbie, 2000). For that reason, a pilot study (an exploratory version of the survey) was conducted to refine the questions (Creswell, 2008). The pilot study group consisted of a group of 20 individuals at DTSC invited to participate in and provide feedback for a draft of the survey prior to the deployment of the final version to the rest of the study population sample. Of this group, 16 (80%) completed the survey and provided feedback. As part of the pilot study process, this group was asked the same questions intended for the entire study panel (Appendix A). In addition, four questions specifically designed to generate feedback about the actual survey were presented only to the pilot study group. These four questions addressed the survey's effectiveness, ease of use, strengths and weaknesses, and the amount of time required for completion. A two-week period was allocated for completion of the pilot study, after which feedback given by respondents in the pilot study was used to guide changes to the survey.

Following appropriate revisions to the survey instrument, an invitation email (Appendix B) was sent to the study population sample (n=483). In order to comply with DTSC's request that it be made clear that participation was voluntary, study respondents were asked to "opt-in" with an affirmative reply to the invitation email and were given two weeks to do so; one week after the initial invitation to participate was sent, a follow-up reminder was sent by email to respondents who had not initially replied (Appendix C). A total of 131 employees responded affirmatively, and were sent an email with the link to the survey (Appendix D). One week later a reminder email with another link to the survey was sent (Appendix E). According to Babbie (2000), follow-up contacts are important for maximizing study participation. The follow-up emails for both the initial invitation and the survey itself were consistent with this standard procedure. Ultimately, 112 DTSC employees (for a response rate of 23%) participated in the survey. The survey included twelve multiple choice questions: six demographic questions, and an additional six questions about respondents' work-related experience, academic or professional training, and military service. Ten sets of Likert-scale type questions, ranging from "Strongly Disagree" to "Strongly Agree" focused on respondents' opinions about specific skills (five sets covered technical competencies and five addressed personal, soft or professional skills).. For each of these questions, study respondents were given the option of checking "Not Applicable" if they believed a specific skill did not apply to their profession (Babbie, 2000). A companion multiple-choice question asking where the respondent believed he or she learned specific skills accompanied each Likert-scale question. Respondents were given the following choices: in college, at work, both, neither or not applicable.

In the full study, respondents were given four additional short answer questions concerning advice they would give someone considering their profession, the best development they felt they had, their desire to move up the career ladder, and any other areas they felt may have been overlooked in the survey. These last four questions allowed respondents to provide additional insights about their experience and its relevance to training and skill development in environmental engineering. Respondents were also given the opportunity to request a summary of aggregated survey results.

Handling and Analysis of Survey Data

Measures of central tendency, including median or mean scores, are typically not used with survey questions where answers are ranked on an ordinal scale (Babbie, 1990). Instead, the use of frequency distributions made it possible to effectively identify typical responses to questions on the survey (Gall, Gall & Borg, 2007). Statistical analysis of the data from this study included an ordinal distribution along opinion-based categories of "Disagree," "Neutral" and "Agree" in response to the first research question, which asked about the need for specific skills. Ordinal distribution of responses to the questions concerning where specific skills were learned was also used to answer the second research question, which focused on where skills were learned.

Demographic Variables Used in this Study

The demographic data in the survey may not directly answer the two research questions. However, its inclusion in this study is important because people define themselves by their personal and professional characteristics such as gender, ethnicity, length of time in service, occupational status and educational level (Goidel, et al, 2008; Tatum, 2000). Because people form opinions and interpret or filter experiences and circumstances through their own unique perspectives (Babbie, 2000; Creswell, 2008), collecting and analyzing demographic data played a vital role in this study.

In this study, collecting data on every possible demographic variable was not practical. For example, it was unlikely that factors such chronological age, marital status or number of children would influence respondent responses to questions about technical or professional skills. Based on the results of the literature review and pilot study, it was considered appropriate to collect data on the characteristics viewed as most likely to influence the opinions of study respondents (Babbie, 2000). Therefore, questions designed to gather data on seven demographic variables were included in the survey. These variables were: gender; ethnicity; years of service; highest educational level attained; occupational status; attendance at community college, and military service.

Gender and ethnicity

Gender may be viewed as a construct that includes self-identification, recognition by others and, in many cases, assignment of social and professional roles based on an individual's status as either male or female (Caricini & Lindquist-Wong, 2009). In the discipline of engineering and its specialties, little information is available on the percentage of women versus men currently employed in the field of environmental engineering. However, a number of studies have noted that women are substantially underrepresented in engineering and related scientific and technical specialties (Caricini & Wong, 2009; de Cohen & Deterding, 2009).

A review of data collected by the National Center on Education Statistics (NCES) for the 2007-2008 academic year also indicates that men completed the majority of degrees in environmental engineering granted by programs at 73 schools in the U.S (National Center for Educational Statistics, 2009). In the specialty of environmental engineering, men received 58% of bachelor's degrees, 56% of master's degrees, and 66% of doctorates. At DTSC, the gender composition of the sampling frame was unknown. However, the first demographic question asked respondents to specify their gender, and 67% indicated they were male, while 32% were female and 1% declined to state. This is consistent with data on engineering degree attainment reported by NCES. As was the case with gender, the precise ethnicity and national origin of all technical staff at DTSC was unknown. For the second demographic question, 65% indicated that they were Caucasian. This was followed by 10% who indicated they were Asian-American, 8% who reported mixed ethnicity, 6% Hispanic, 5% African American. The remaining 6% were divided among other ethnic groups and nationalities.

Time in service

Other demographic variables besides gender and ethnicity appeared to influence responses. One possible reason for this may be the fact that knowledge, skills, abilities and traits in the workplace are developed over time in a given profession (Dreyfus & Dreyfus, 1986). Therefore, in this study the choices made in the survey may reflect respondents' seniority and full-time experience. The results of the study revealed that respondents ranged from less than one year to 37 years of full-time or full-time equivalent service, with a mean time in service of 15.98 years. Among respondents, 57% had 15 or more years of experience. The greatest number (21%) had at least 20 but fewer than 25 years of experience, while 20% had more than 25 years of experience (Table 2)

Table 2: Respondents by years in full-time/FTE government service

Years of full-time/FTE service	Frequency	Percent
Less than 5 years	20	17.86%
5 to 9.99 years	19	16.96%
10 to 14.99 years	9	8.04%
15 to 19.99 years	18	16.07%
20 to 24.99 years	24	21.43%
25 years or longer	22	19.64%
Total	112	100.0%

Occupational classification and level

Another demographic question asked respondents about their occupational status. The occupations of respondents are grouped in three classifications experienced with environmental engineering are represented in the sample at DTSC: hazardous substances engineers (environmental engineers); hazardous substances scientists (environmental scientists), and engineering geologists. Respondents are also employed at three different levels or ranks within these classifications: technical, senior, and supervisory (Table 2). Supervisors are employed at the highest level and oversee the work of others; senior-level staff are mid-level and perform more advanced tasks, while technical staff are responsible for completing tasks of average to high complexity (Department of Toxic Substances Control, 2009a).

Table 3: Occupational status of respondents by classification and level

		Frequency	Percent
Classification	Hazardous Substances Engineer	41	36.61%
	Hazardous Substances Scientist	40	35.71%
	Engineering Geologist	31	27.68%
	Total	112	100%
Level	Technical	63	56.25%
	Senior	28	25.00%
	Supervisory (I, II)	21	18.75%
	Total	112	100%

Postsecondary education and community college attendance

Postsecondary education may also influence on respondent choices. When asked about their highest level of postsecondary education, 52% reported earning a master's degree or doctorate (Table 4). Because environmental engineering professionals are required to have at least a bachelor's degree for employment at federal and state agencies

Table 4: Highest level of postsecondary education completed

	Degree Level	Frequency	Percent
Valid	Bachelor's degree (B.S.)	54	48.21%
	Master's degree (M.S.)	51	45.54%
	Doctorate (Ph.D.)	7	6.25%
	Total	112	100%

including DTSC (Ramanujam, 2009), the two-year or associates' degree was not included in the question concerning the highest level of postsecondary educational attained by study respondents. However, in order to determine the extent to which respondents completed at least some of their lower-division coursework at a community college, a question was asked about community college attendance. Of the sample, 52% of respondents reported that they attended community college (Table 5).

Table 5: Respondent rates of community college attendance

		Frequency	Percent
Valid	Attended community college	58	51.79%
	Did not attend community college	54	48.21%
	Total	112	100%

Military service

Comments in the pilot study suggested that military service might be a salient factor in respondent opinion. However, in the actual survey the number of respondents with military service was low. Only 18% reported military service (Table 6). Of those, 68% indicated that the military had provided at least part of their postsecondary education (either directly or by providing financial aid after completion of their service).

Table 6: Respondents with military service and service-based educational benefits

Service in the military?		Frequency	Percent
Valid $N = 112$	Yes	20	17.9
	No	92	82.1
	Total	112	100.0
Educational benefits provided or paid for by the military?		Frequency	Percent
Valid $N = 19$	Yes	13	68.42%
	No	6	31.58%
	Total	19	100%
	Missing (No response)	1	

By reviewing the results of the pilot study and collecting demographic data as part of the survey, it was possible to identify factors that might have influenced responses. It appears that time in service, employment factors (level and classification) and highest level of education may have had the most influence on respondent choices. The role played by respondent characteristics were explored more fully in Chapter IV. However, it is not possible to control for every possible variable that might influence respondent opinions (Babbie, 2000). Therefore, for the purposes of this study, it was important to acknowledge the assumptions and limitations of quantitative research methodology in general and this study in particular (Gall, Gall & Borg, 2007).

Assumptions and Limitations of this Study

Four assumptions existed in the quantitative methodology used for this study. The first assumption is that study respondents share similarities with other environmental engineering professionals. Second, each observation is assumed to be independent. That is, responses to questions from individuals were not influenced by the answers given by other study respondents (Gall, Gall & Borg, 2007). Third, it was assumed that study respondents provided truthful responses. That is, they did not intentionally deceive the researcher. Finally, it may be assumed that the information provided by study respondents accurately reflects their experiences (Creswell, 2008), which underscores the value of independent observations.

It is also important to consider the limitations of quantitative research methods in general, and this study in particular. First, in any study one or more respondents may provide responses that do not accurately reflect their experiences (Hinkle, Wiersma &

Jurs, 2003). Second, the survey method is a snapshot method because it only collects data at a single point in time (Babbie, 2000). Furthermore, a survey does not address all facets of the complex nature of any social phenomenon. Thus, capturing a complete range of experiences of any population through a survey is virtually impossible (Creswell, 2008, Gall, Gall and Borg, 2007). In spite of the limitations cited, the results of this study may be used to inform curriculum development and practice, because the data were collected from respondents whose experiences may be typical of environmental engineering professionals (Babbie, 2000).

Summary of the Methodology

The purpose of this study was to identify the knowledge, skills, abilities and traits needed by environmental engineers as well as their perceptions about where they learned these skills, based on data collected from experienced professionals. This research study involves quantitative methods of inquiry to answer research questions about the perceptions of experienced professionals concerning the knowledge, skills, abilities and traits environmental engineers need to perform their jobs successfully. Descriptive statistical methods of analysis were used to identify the knowledge, skills, abilities and traits students in environmental engineering programs need for success in this profession. Specifically, frequency distributions were used.

The survey was distributed to technical employees from the California Department of Toxic Substances Control (DTSC). Respondents were identified as belonging to one of three employment classifications (hazardous substances engineer, hazardous substances scientist, and engineering geologist) and three employment levels (technical, senior, and supervisory). Their work materially involves participation in the cycle of hazardous materials remediation. Data for this study were collected using an electronic survey instrument that was first tested using a pilot study instrument that was initially sent to a group of 20 DTSC employees. Their recommendations supported and informed the final version of the survey sent to the sample.

For the actual survey, questions were asked about the importance of specific skills, accompanied by questions about where these skills were developed. The survey also included four optional, open-ended questions where respondents could provide detailed information. Demographic data were also collected to identify respondent characteristics: gender, ethnicity, occupational status, education, and military service. Ultimately, participation in military service was low and it was subsequently excluded as a demographic variable.

Assumptions of this study include similarities between the respondents in this study and other practitioners, independent observations, truthful responses from respondents, and responses that accurately reflect their experiences in the profession of environmental engineering. Limitations of this study include the possibility that one or more responses may not accurately reflect respondent experiences, the collection of data at a single point, the inability of a survey to address all facets of complex social phenomena, and the specialized language routinely used by study respondents in their work. Because this study used a purposeful sample, the findings may not be generalizable. However, they may be transferable, meaning they can be applied in similar situations. Findings of the study, including the data used to answer both of the research questions, were presented in Chapter IV.

CHAPTER IV

FINDINGS

The purpose of this study was to investigate the knowledge, skills, abilities and traits required of environmental engineers, and to learn where these skills are developed, based on the perspectives of experts in the profession. This was a non-experimental study, and the survey method was used to collect data. This chapter presents the findings related to the questions of the study. It also reports the perspectives of working professionals in areas related to environmental engineering, both of the need for specific technical and professional skills and where these skills are most appropriately developed. In each section of the analysis of this data, the term "experienced professionals" refers to individuals with working knowledge of the skill sets required for environmental engineering. In this case, "experienced professionals" included the hazardous substances engineers, hazardous substances scientists, and engineering geologists at the California Department of Toxic Substances Control (DTSC)

For the purpose of this study, the term "technical skills" was used to define specific, task-oriented competencies (those skills that are considered essential to the practice of environmental engineering). The term "professional skills" referenced personal traits, also known as the "soft skills" commonly required in the workplace. These include the ability to communicate, work in groups and demonstrate qualities such as ethical behavior, global competence, social and emotional intelligence and the ability to engage in lifelong learning (Richter & Paretti, 2009).

Two questions were asked. The first question of this research was the broadest:

What knowledge, skills, abilities and traits do experienced professionals view as necessary for a successful career in environmental engineering

The second question of this research asked where experienced professionals believed specific technical and professional skills were learned.

In this chapter, the data collected for the first question are analyzed and discussed. This is followed by a detailed analysis and discussion of the responses that pertain to the second research question. To answer the first research question, respondents were asked to provide their perspectives about the importance of multiple skills, which were grouped into technical and professional skill sets. Each skill set contained a series of questions that could be answered using a series of Likert-scale type choices, ranging from the value of "1" for "Strongly Disagree" to "5" for "Strongly Agree." Ordinal data, defined as those that fall into distinctive and ordered categories (Hinkle, Wiersma & Jurs, 2003) are collected through these types of questions.

For ordinal scales, measures of central tendency and standard deviations are not generally calculated: instead, frequency distributions are used (Babbie, 1995; Hinkle, Wiersma & Jurs, 2003). For the purpose of this study, data are analyzed for skill sets, defined as the categories encompassing specific skills. Examples include task-related or technical competencies such as engineering, or professional skills considered essential to workplace relationships such as communication. Data are then analyzed for individual skills located within each skill set, with the results landing on a continuum between 1 (Strongly Disagree) to 5 (Strongly Agree). The data for skill sets are analyzed first, using frequency distributions to determine the importance study respondents place upon specific sets of skills.

To calculate the frequency amounts and percentages for each skill set, the sum of scores for all respondents (X) are calculated for each question within the skill set. The sum (Σ) is then divided by the number of respondents (N) to obtain the mean for each skill. The frequencies for each skill set and category are then added together, and the sum is then divided by the number of questions per skill set (n). The result is then divided by N for the percentage (Figure 1).

$$\text{Frequency} = \frac{\Sigma(X_1, X_2 \ldots X_N)/\, n}{N}$$

Figure 1: Formula for calculating frequency distribution per skill set

For example, to calculate the mean for Scientific Skills, the means for the individual skills ($X_1 \ldots X_n$) are added together, divided by n (in this case, 5) to obtain the raw scores for the skill set, and then divided by N (the valid number of responses) to calculate the percentages that are then entered into the distribution table for Technical Competencies. A second distribution table has been calculated for Professional Skills.

Technical skills

Respondents were asked to rate specific technical skills. Data from their responses were used to calculate the scores in general for technical skill sets (Table 7). Survey respondents had high agreement on the importance of other technical areas, defined as the task-related body of skills not covered in other skill sets. Examples of other technical areas include knowledge in dealing with groundwater contamination or vapor intrusion.

Table 7: Respondent perspectives of skill sets: Technical skills

Technical Competency/ Skill Set	Valid *N*	Strongly Disagree/ Disagree	Neutral	Agree/ Strongly Agree
Other technical areas	111	0.45%	5.86%	93.69%
Technical skills	111	2.71%	10.11%	87.18%
Scientific skills	111	4.70%	15.19%	80.11%
Mathematics	109	7.19%	23.70%	69.11%
Engineering	106	13.32%	30.09%	56.58%

An overwhelming majority of respondents (94%) agreed or strongly agreed that knowledge and skills in other technical areas were important in performing their tasks. A strong majority of respondents also agreed about the importance of technical competencies (87%) and knowledge developed in scientific disciplines (80%). However, a smaller majority of respondents agreed or strongly agreed about the importance of mathematics (69%) and engineering (57%), while they indicated 30% neutrality for engineering, followed by mathematics (24%), scientific skills (15%), technical skills (10%), and other technical areas (6%). Disagreement was indicated at low levels for all skills in technical competencies. Engineering (13%) showed the highest level of disagreement, followed by mathematics (7%), scientific skills (5%), technical skills (3%), and other technical areas (<1%).

The dispersion of responses throughout the frequency distribution for skill sets in technical competencies reflects the diversity in responses respondents provided for questions pertaining to individual skills. In particular, the lower percentage of respondents who indicated that they agree or disagree overall with the importance of engineering reflects unusually low ratings respondents provided for two specialties: structural and mechanical engineering.

Professional skills

Respondents were also asked their opinions about professional skills. Data from their responses were used to calculate the general scores for professional skill sets (Table 8). Survey respondents had high agreement on the importance of all five professional skill sets. An overwhelming majority of respondents (97%) agreed or strongly agreed that communication was important in the performance of their professional responsibilities. This was followed by social and emotional skills (93%), professional qualities (92%), teamwork (92%), and intellectual traits (92%). The clustering of responses at the top of the scale in the frequency distribution reflects the importance indicated by respondents in response to questions pertaining to professional skills.

Table 8: Respondent perspectives of skill sets: Professional skills

Professional Skill Set	Valid *N*	Strongly Disagree/ Disagree	Neutral	Agree/ Strongly Agree
Communication	110	0.65%	1.95%	97.40%
Social and emotional skills	109	0.23%	6.41%	93.36%
Professional qualities	110	0.82%	7.01%	92.17%
Teamwork	110	0.26%	7.42%	91.93%
Intellectual traits	109	0.92%	7.33%	91.76%

What frequency distributions represent

For both technical competency and professional skill sets, the frequency distributions of the skill sets provide a useful barometer of the opinions experienced professionals in the field of environmental engineering generally have about the importance of technical competencies and professional skills. To analyze their opinions about specific skills, it is appropriate and useful to look at how respondent responses are distributed for each skill. Thus, for the individual competencies within each skill set, frequency distributions are also developed to determine response percentages for "Disagree," "Neutral" and "Agree." The first group presents each of the five sets of technical competencies. This is followed by frequency distributions for each of the five professional skills.

Respondent Opinions about Specific Technical Skills

Scientific skills

Respondents were asked to rate the importance of knowledge about specific scientific disciplines, including environmental science, geology, biology, chemistry and physics. Survey respondents had high agreement on two areas of science (Table 11). An overwhelming majority of respondents (95%) agreed or strongly agreed that skills in chemistry were important in performing their tasks, as did 90% of respondents about the importance of geology. For both of these scientific disciplines, there was little neutrality or disagreement.

A smaller majority of respondents agreed or strongly agreed about the importance of biology (77%), environmental science (72%), or physics (68%). Physics also had the highest neutral rating at 26%, followed by global environmental science (21%) and biology (16%). Respondents indicated disagreement with the importance of global environmental science (7%), biology (7%), and physics (6%). The variation in responses is reflected in the dispersion of responses throughout the frequency distribution (Table 9).

Table 9: Respondent perspectives of individual skills: Science

Scientific Discipline	*N*	Strongly Disagree/ Disagree	Neutral	Agree/ Strongly Agree
Chemistry	110	0.91%	4.55%	94.55%
Geology	111	1.80%	8.11%	90.09%
Biology	111	7.21%	16.22%	76.58%
Environmental Science	110	7.27%	20.91%	71.82%
Physics	111	6.31%	26.13%	67.57%

Skills in technology

Respondents were next asked to rate the importance of skills in technology, including the ability to evaluate environmental impacts, read and interpret maps and diagrams, perform quality assurance and control (QA/QC) checks, create accurate maps, diagrams and other graphics, and use industry-standard technology (Table 10). Survey respondents had high agreement on three types of technical skills. The overwhelming majority (97%) agreed that environmental engineers needed to be able to evaluate environmental impacts and have the ability to read and interpret maps, diagrams and

Table 10: Respondent perspectives of individual skills: Technology

Technological Skill/Ability	*N*	Strongly Disagree/ Disagree	Neutral	Agree/ Strongly Agree
Evaluate environmental impacts	111	0.90%	1.80%	97.30%
Read, interpret maps, diagrams and graphics	111	0.90%	1.80%	97.30%
Perform quality assurance/quality control (QA/QC) checks	111	2.70%	7.21%	90.09%
Create accurate maps, diagrams and graphics	110	2.73%	20.91%	76.36%
Use industry-standard technology	111	6.31%	18.92%	74.77%

other graphics, and 90% of respondents agreed about the importance of quality assurance and control.

For all three of the most agreed-upon areas, there was little neutrality or disagreement. A smaller majority of respondents agreed or strongly agreed about the importance of creating accurate maps, diagrams and other graphics (76%), or using industry-standard technology (75%). The ability to create graphics also had the highest neutral rating (21%), followed by industry-standard technology (19%), which also had the highest percentage of disagree responses (6%). The variation in responses is reflected in the dispersion of responses throughout the frequency distribution.

Engineering skills

Engineering was the third set of technical competencies respondents were asked to rate. Respondents rated engineering disciplines for importance to their profession, including environmental engineering, mechanical engineering, civil engineering, structural engineering, chemical engineering and engineering geology (Table 11).

Table 11: Respondent perspectives of individual skills: Engineering

Engineering Specialties	*N*	Strongly Disagree/ Disagree	Neutral	Agree/ Strongly Agree
Environmental engineering	108	1.85%	13.89%	84.26%
Engineering geology	109	5.50%	17.43%	77.06%
Civil engineering	109	9.17%	25.69%	65.14%
Chemical engineering	98	3.96%	35.64%	60.40%
Mechanical engineering	107	26.17%	45.79%	28.04%
Structural engineering	107	32.71%	44.86%	22.43%

Survey respondents agreed on the importance of four of the six areas of engineering skills analyzed as part of this study. A strong majority (84%) agreed that developing skill in environmental engineering was important to their profession, as did 77% of respondents concerning the importance of engineering geology.

A smaller majority agreed on the importance of civil engineering (65%) and chemical engineering (60%), while a minority of respondents agreed or strongly agreed about the importance of mechanical engineering (28%) and structural engineering (22%). Engineering also showed higher levels of neutrality than the other technical skill sets, with the two highest neutral scores for mechanical engineering (46%) and structural engineering (45%). These were followed by neutral scores for chemical engineering (36%), civil engineering (26%), engineering geology (17%) and environmental engineering (17%).

Skills in mathematics

As part of this study, respondents were asked to rate the importance of six mathematical skills, including statistics, modeling, algebra, geometry, trigonometry and calculus Survey respondents had high agreement on three areas of mathematical skill A strong majority (86%) agreed that the application of statistics was important in performing their tasks, as did 78% of respondents about the importance of statistical modeling (either process or groundwater), and algebra (76%). For all three of these mathematical skills, there were lower percentages of neutrality or disagreement.

On the other hand, a smaller majority of respondents agreed or strongly agreed about the importance of geometry (70%) or trigonometry (60%), while a minority of respondents agreed about the importance of calculus (45%). Calculus also had the highest neutral rating (40%), followed by trigonometry (29%), geometry (25%), modeling (19%), and algebra (19%). Calculus also had the highest negative rating (15%), followed by trigonometry (11%), geometry and algebra (both at 5%). The variation in responses is reflected in the dispersion of percentages through the frequency distribution (Table 12).

Table 12: Respondent perspectives of individual skills: Mathematics

Mathematical Skill	*N*	Strongly Disagree/ Disagree	Neutral	Agree/ Strongly Agree
Statistics	111	3.60%	9.91%	86.49%
Modeling	103	2.91%	19.42%	77.67%
Algebra	111	5.41%	18.92%	75.69%
Geometry	110	5.45%	24.55%	70.00%
Trigonometry	109	11.01%	29.36%	59.63%
Calculus	110	14.55%	40.00%	45.45%

Other technical areas

Respondents were asked to rate the importance of skills in six other areas related to environmental engineering, including groundwater contamination, chemical fate and transport, hazardous materials remediation, public health and safety, vapor intrusion, and workplace health and safety. Survey respondents had high agreement in all six skills encompassing other technical areas. The overwhelming majority (96%) agreed that an understanding of vapor intrusion was important in performing their tasks, as did 96% of respondents about the importance of chemical fate and transport. These were followed by knowledge of and skills in hazardous materials remediation (95%), public health and safety (93%), vapor intrusion (92%), and workplace health and safety (89%).

In all of these areas, there was little disagreement. Respondents indicated disagreement with only three skills: chemical fate and transport, public health and safety, and workplace health and safety. For all three skills, the scores indicating disagreement came to less than 1% of the response (Table 13). Neutrality was also minimal. Only three skills had responses for neutrality in excess of 5%: workplace health and safety (10%), vapor intrusion (8%), and public health and safety (6%). The high agreement indicated by respondents is reflected in the clustering of responses at the high end of the scale for all six questions.

Table 13: Respondent perspectives of individual skills: Other technical areas

Other technical area	*N*	Strongly Disagree/ Disagree	Neutral	Agree/ Strongly Agree
Groundwater contamination	111	0.00%	3.60%	96.40%
Chemical fate and transport	111	0.90%	2.70%	96.40%
Hazmat remediation	111	0.00%	4.50%	95.50%
Public health and safety	111	0.90%	6.31%	92.79%
Vapor intrusion	111	0.00%	8.11%	91.89%
Workplace health and safety	111	0.90%	9.91%	89.19%

Analysis of the technical skill sets and individual competencies within these areas revealed that a majority of respondents agreed or strongly agreed about the importance of nearly all of the specific skills listed. The few exceptions appear to be for skills that may not be directly related to environmental engineering, such as structural and mechanical engineering. Respondents may have also assigned lower levels of importance to technical skills that they may have developed prior to college, such as trigonometry and calculus. Meanwhile, an overwhelming majority of respondents agreed about skill areas that they apparently use on a regular basis. These include scientific competencies such as chemistry and other technical skills like chemical fate and transport.

In addition to the five areas of technical competency that were examined, this study also looked at five professional skill sets considered common to workers in a diverse set of skill areas including environmental engineering.

Respondent Opinions about Specific Professional Skills

Communication

Respondents were asked to rate the importance of seven communication skills, including interviewing, speaking with another (person-to-person), group communication, public speaking, effective writing, correct use of grammar, and the use of evidence to support writing (Table 14). Survey respondents had high agreement on all seven areas.

Table 14: Respondent perspectives of individual skills: Communication

Communication Skill	*N*	Strongly Disagree/ Disagree	Neutral	Agree/ Strongly Agree
Group communication	109	0.00%	0.00%	100.00%
Effective writing	110	0.00%	0.00%	100.00%
Supporting with evidence	110	0.00%	0.00%	100.00%
Speaking with another	110	0.00%	0.91%	99.09%
Using correct grammar	110	0.00%	0.91%	99.09%
Public speaking	110	0.91%	5.45%	93.64%
Interviewing	109	3.67%	6.42%	89.91%

The overwhelming majority (100%) agreed or strongly agreed that group communication, effective writing, and supporting writing with evidence were important in performing their tasks, as did 99% of respondents about the importance of being able to speak with other individuals and the use of correct grammar. This was followed by public speaking (94%) and interviewing (90%).

For all of these communication skills, there was little neutrality. Respondents indicated neutrality at or above 5% for only two skills: interviewing (6%), followed by public speaking (5%). Disagreement was indicated for only two skills: public speaking (<1%) and interviewing (5%). Speaking with another person and correct grammar each received less than 1% of respondent choices for neutrality. The variation in responses is reflected in the dispersion of responses throughout the frequency distribution.

Teamwork

Respondents were also asked to rate the importance of eight skills related to teamwork, including the ability to share key ideas, acknowledge the work of others, listen patiently, support consensus, share credit, seek help to identify and achieve goals, solve problems collaboratively and keep colleagues informed (Table 15). Survey respondents had high agreement on seven areas of teamwork. The majority (97%) agreed that the ability to share key ideas was important, as did 96% of respondents about the importance of keeping colleagues informed and current on developments. These two skills were followed by the ability to listen patiently (95%), seek help to identify and achieve goals (95%), acknowledge the work of others (95%), and solve problems collaboratively (93%). For these seven teamwork skills, there was little neutrality or disagreement.

Table 15: Respondent perspectives of individual skills: Teamwork

Teamwork-related skill	*N*	Strongly Disagree/ Disagree	Neutral	Agree/ Strongly Agree
Share key ideas	110	0.00%	2.73%	97.27%
Keep colleagues informed	110	0.00%	3.64%	96.36%
Listen patiently	110	0.00%	4.55%	95.45%
Seek help with goals	110	0.00%	4.55%	95.45%
Acknowledge others' work	110	0.91%	4.55%	94.55%
Solve problems collaboratively	110	0.00%	7.27%	92.73%
Share credit for ideas	108	0.00%	6.48%	92.59%
Support consensus	110	2.73%	20.91%	76.36%

A smaller majority of respondents agreed or strongly agreed about the importance of supporting consensus (76%). This skill also had a 21% neutral response rate and 3% disagreement. The minimal variation in responses is reflected in the clustering of responses at the top of the scale in the frequency distribution.

Professional qualities

Respondents were asked to rate the importance of professional qualities that impact both their working and interpersonal relationships, including integrity, the ability to plan ahead, the ability to learn from others, work ethic, flexibility, resourcefulness, concern for others, empathy, and a sense of humor. Survey respondents had high agreement on six out of the nine areas encompassing professional qualities. The overwhelming majority (100%) agreed that integrity and the ability to plan ahead are important qualities in their work, as did 98% of respondents about the importance of the ability to learn from others and a work ethic, followed by flexibility (97%) and resourcefulness (96%). For all of these professional qualities, there was little or no neutrality or disagreement.

A smaller majority of respondents agreed or strongly agreed about the importance of concern for others (88%), empathy (87%), and a sense of humor (80%). A sense of humor also had the highest neutral rating at 16%, followed by concern for others (12%), empathy (12%), resourcefulness (4%), flexibility (3%), the ability to learn from others (2%) and work ethic (<1%). Respondents indicated disagreement with the importance of only three of the nine skills in professional qualities including a sense of humor (4%), while less than 1% of respondents indicated disagreement with empathy and work ethic (Table 16). The variation in responses accounts for the differences in frequencies and percentages for these nine questions, even though many of the responses were grouped at the top of the scale in the frequency distribution.

Table 16: Respondent perspectives of individual skills: Professional qualities

Professional Quality	*N*	Strongly Disagree/ Disagree	Neutral	Agree/ Strongly Agree
Integrity	110	0.00%	0.00%	100.00%
The ability to plan ahead	110	0.00%	0.00%	100.00%
The ability to learn from others	110	0.00%	1.82%	98.18%
Work ethic	110	0.91%	0.91%	98.18%
Flexibility	110	0.00%	2.73%	97.27%
Resourcefulness	110	0.00%	3.64%	96.36%
Concern for others	109	0.00%	11.93%	88.07%
Empathy	110	0.91%	11.82%	87.27%
A sense of humor	110	3.64%	16.36%	80.00%

Social and emotional skills

Respondents were asked to rate the importance of social and emotional skills, including the ability to manage one's own emotions, read and understand others' moods, influence others and respond effectively (Table 17). Survey respondents had high agreement on three of the four areas of social and emotional skills. An overwhelming majority (97%) agreed that the ability to manage one's own emotions was important in performing their tasks, as did 96% of respondents about the importance of responding effectively, followed by 93% for appropriate influence. For all three of these social and emotional skills, there was very little neutrality or disagreement.

For social and emotional skills, a smaller majority of respondents agreed or strongly agreed about the importance of understanding others' moods (87%). The ability to understand others' moods also received less than 1% of "Disagree" responses, and 12% of "Neutral" responses. Low levels of neutrality were also indicated for the ability to influence others appropriately (7%), respond effectively (4%), and manage one's own emotions (3%). The minimal variation in respondent responses is reflected in the clustering of responses at the top of the scale in the frequency distribution.

Table 17: Respondent perspectives of individual skills: Social and emotional skills

Social and emotional skill	*N*	Strongly Disagree/ Disagree	Neutral	Agree/ Strongly Agree
Manage own emotions	110	0.00%	2.73%	97.27%
Respond effectively	109	0.00%	3.67%	96.33%
Influence others appropriately	110	0.00%	7.41%	92.59%
Understand others' moods	110	0.91%	11.82%	87.27%

Intellectual traits

Respondents were asked to rate the importance of six intellectual traits that may impact their work: critical thinking, independent learning, lifelong learning, intellectual curiosity, professional growth and assimilation (the ability to synthesize new information with existing knowledge). Survey respondents had high agreement on five of these six intellectual traits. The overwhelming majority (98%) agreed that critical thinking was important in their work, as did 95% of respondents about the importance of independent learning. These were followed by: lifelong learning (94%), intellectual curiosity (93%), and professional growth (91%).

For all of these intellectual traits, there was little or no neutrality or disagreement (Table 18). A smaller majority of respondents agreed or strongly agreed about the importance of assimilation (80%). For this skill, 17% of respondents indicated neutrality and 3% indicated disagreement. Disagreement was indicated at less than 1% for only three other skills: professional growth, intellectual curiosity, and critical thinking. Respondents also indicated lower levels of neutrality for professional growth (8%), intellectual curiosity (6%), lifelong learning (6%), independent learning (5%), and critical thinking (<1%). The variation in responses accounts for differences among these six questions, even though many of the responses were grouped at the top of the scale in the frequency distribution.

Table 18: Respondent perspectives of individual skills: Intellectual traits

Intellectual Trait	*N*	Strongly Disagree/ Disagree	Neutral	Agree/ Strongly Agree
Critical thinking	110	0.91%	0.91%	98.18%
Independent learning	110	0.00%	5.45%	94.55%
Lifelong learning	110	0.00%	6.36%	93.64%
Intellectual curiosity	110	0.91%	6.36%	92.73%
Professional growth	110	0.91%	8.18%	90.91%
Assimilation	105	2.86%	17.14%	80.00%

Individual professional skills

Analysis of the professional skill sets and individual competencies within these five areas revealed that an even stronger majority of respondents agreed or strongly agreed about the importance of "soft" skills. In some cases, responses favored specific competencies, while a few areas of neutrality or disagreement existed. Comparing responses based on respondent characteristics may yield insights into the pattern of responses within the frequency distributions for both technical and professional skills.

Perspectives on Specific Skills by Respondent Characteristics

Because human beings base their perspectives on their unique experiences, respondent responses may be influenced by individual characteristics (Babbie, 2000). For the purposes of this study, crosstabulation (the calculation of percentages of responses by skill set and respondent characteristics) is a useful method of determining the extent to which respondent responses may be influenced by personal or professional traits (Creswell, 2008). To calculate crosstabulations, the sum of scores (Σ) for all respondents by characteristics (X) are compared by skill set (Y). This is divided by the number of respondents (*N*). The frequencies for each skill set and category are then added together, and the result is divided by the number of questions per skill set (*n*). Percentages for categories are then obtained by dividing the result by *N* (Figure 2). These percentages are compared with the frequency distribution for each skill set.

$$\text{Crosstabulation} = \frac{\Sigma(XY_1, XY_2 \ldots XY_N)/n}{N}$$

Figure 2: Formula for calculating crosstabulations

For the purposes of this study, crosstabulations were performed on the characteristics of respondents considered most likely to influence their choices: employment status (level and classification); education (highest educational level achieved and community college attendance), and years of service. Only crosstabulations that deviated from the frequency distribution by at least 10% were reported in this chapter. A complete set of crosstabulations for the first research question appears in Appendix F

Respondent responses and the importance of technical skills

Crosstabulation of employment status by technical skills indicates that engineering was the only technical skill set where this characteristic made a significant difference in the responses given by respondents. The importance study respondents assigned to the engineering skill set by level and classification revealed substantial differences in crosstabulated scores between employee classifications and the frequency distribution for the entire skill set. The largest difference was for hazardous substances engineers (HSE), who agreed overwhelmingly with the importance of engineering as a required skill set: 73%, compared with 57% for all scores in the frequency distribution (Table 19).

Table 19: Respondent perspectives on the importance of engineering by level and classification

		Level			Classification		
N = 112	Distribution	Tech	Senior	Supervisor	HSE	HSS	EG
Disagree	13.32%	12.18%	18.01%	10.48%	11.11%	13.14%	16.67%
Neutral	30.09%	28.61%	32.92%	30.65%	16.24%	40.25%	35.12%
Agree	56.58%	59.21%	49.07%	58.87%	72.65%	46.61%	48.21%

Only 48% of engineering geologists (EG) and 47% of hazardous substances scientists (HSS) agreed with the importance of engineering as a skill set. For the level of seniority reported by respondents, the percentages in the crosstabulation were more closely aligned with the frequency distribution: 59% of respondents who identified themselves as being at both the technical and supervisory levels, and 49% of respondents at the senior level indicated agreement.

For the crosstabulation of education by technology, percentages by community college attendance were also consistent with those found in the frequency distribution for all study respondents (Table 20). Among respondents who reported attendance at a community college, 87% agreed with the importance of technology as a skill set for environmental engineers, while 88% who did not attend indicated agreement, making the results for this group consistent with the frequency distribution for all study respondents. With educational level, the responses were more varied. Crosstabulating the highest educational level and the scientific skill set revealed that a strong majority of respondents with bachelor's degrees (89%) agreed with the importance of technology, compared with 88% respondents with master's degrees and 71% of those with doctorates.

Table 20: Respondent perspectives on the importance of technology by educational level and community college attendance

		Highest educational level			Community college	
	Distribution	BS/BA	MS/MA	Ph.D.	Yes	No
Disagree	2.71%	2.65%	1.18%	14.29%	3.11%	2.26%
Neutral	10.11%	8.33%	11.37%	14.29%	9.34%	10.94%
Agree	87.18%	89.02%	87.45%	71.43%	87.54%	86.79%

Crosstabulation of educational level with the mathematics skill set also reveals variations in respondent responses according to the highest educational level attained

(Table 21). Compared with 69% of all respondents reported in the frequency distribution, 88% of respondents with doctorates agreed that mathematics was an important skill set for environmental engineers. On the other hand, the percentages for respondents without doctoral degrees were more consistent with the frequency distribution: 70% of respondents with master's degrees and 65% of those with bachelor's degrees reported agreement with the importance of mathematics. Crosstabulated percentages for community college attendance were more closely aligned with the frequency distribution: 68% of respondents who reported community college attendance and 70% of those who did not indicated they agreed with the importance of mathematics.

Table 21: Respondent perspectives on the importance of mathematics by educational level and community college attendance

		Highest educational level			Community college	
	Distribution	BS/BA	MS/MA	Ph.D.	Yes	No
Disagree	7.19%	6.09%	8.97%	2.44%	7.99%	6.33%
Neutral	23.70%	28.53%	20.60%	9.76%	23.96%	23.42%
Agree	69.11%	65.38%	70.43%	87.80%	68.05%	70.25%

For years of full-time/FTE experience in government service, engineering is the only skill set showing a significant difference between the frequency distribution and any of the groups representing years of service. Compared with 57% of all respondents who expressed agreement with the importance of this skill set, as represented by the frequency distribution, 46% of respondents with 15-19.99 years of service indicated agreement, as did 70% of those with less than five years. Only 15% of respondents with less than 5 years of experience and 17% of those with 10-14.99 years reported neutrality about the importance of engineering, compared with 30% of all respondents as indicated by the frequency distribution (Table 22). In contrast, 27% of respondents with 10-14.99 years of service disagreed, compared with 13% of all respondents.

Table 22: Respondent perspectives on the importance of engineering by years of full-time/FTE government service.

	Distribution	Years of Full-Time/FTE Government Service					
Disagree	13.32%	15.45%	9.65%	26.92%	12.00%	14.18%	9.38%
Neutral	30.09%	14.55%	39.47%	17.31%	42.00%	25.37%	35.94%
Agree	56.58%	70.00%	50.88%	55.77%	46.00%	60.45%	54.69%

Summary of respondent opinions by characteristic

Crosstabulation of the need for professional skill sets indicated consistency with the frequency distribution for all professional skill sets across all respondent characteristics. All crosstabulation scores deviated less than 10% from the frequency distribution. For this reason, any deviation from the frequency distribution was considered not significant. The fact that crosstabulated results for the first research question deviated substantially from the frequency distributions for only a few of the technical skill sets and none of the professional skills is significant. Its significance lies in the indication that although observations for this study were independent of each other, there is general agreement among study respondents about the importance of different technical and professional skill sets.

Where Skills Are Learned: Technical Skills

The second research question asked where skills are learned. Respondents were first asked for their opinion about the areas of learning for technical competencies considered relevant to environmental engineering. These areas of learning exist in five skill sets: science, technology, engineering, mathematics and other technical areas. Respondents were given four choices: in college, on the job, both in college and on the job ("Both"), and neither college nor on the job ("Neither").

Where skills in science are learned

Science was the first skill set where respondents were asked to choose where skills were developed. Frequency distributions were calculated to determine the highest percentages in favor of areas of learning (Table 23). For three of the five skills in the scientific skill set: geology at 62%, environmental science at 61%, and chemistry at 55%, a majority of respondents indicated that they believed skills were most appropriately developed both in college and on the job. On the other hand, an overwhelming majority of respondents indicated that physics (76%) and biology (65%) were most likely to be learned in college. For all five disciplines in the Scientific skill set, there were few responses for "Neither." Both chemistry and geology had zero responses, biology and physics each had only 2%, and environmental science just 4%.

Table 23: Respondent perspectives on where scientific skills are developed

Scientific Skill	*N*	College	On the job	Both	Neither
Geology	111	27.03%	10.81%	62.16%	0.00%
Environmental Science	111	26.13%	12.61%	61.26%	4.50%
Chemistry	111	44.14%	0.90%	54.95%	0.00%
Biology	111	64.86%	3.60%	29.73%	1.80%
Physics	105	76.19%	1.90%	20.00%	1.90%

Where skills in technology are developed

To answer the second research question, respondents were also asked to choose where technical skills were learned. The choices made available in the survey were college, on the job, both or neither. Frequency distributions were calculated to determine the percentages in favor of specific areas for learning (Table 24). For three of the five skills in the technical skill set, a majority of respondents indicated that the ability to create accurate maps, diagrams and graphics (70%), the ability to read and interpret maps, diagrams and graphics (69%) and the ability to evaluate environmental impacts (59%) were most likely to be developed through a combination of formal college education and on the job training. Meanwhile, a smaller majority indicated that skills in performing quality assurance and control checks (61%) and using industry-standard technology (52%) were best learned on the job alone. There were few responses of "Neither" to the five questions presented for technical skills. The highest response for "Neither" was 5% for the ability to use industry-standard technology.

Table 24: Respondent perspectives on where skills in technology are developed

Technological Skill	*N*	College	On the job	Both	Neither
Create accurate maps, diagrams and graphics	111	14.41%	13.51%	70.27%	1.80%
Read, interpret maps, diagrams and graphics	111	17.12%	10.81%	69.37%	2.70%
Evaluate environmental impacts	110	0.91%	39.09%	59.09%	0.91%
Use industry-standard technology	111	5.41%	52.25%	36.94%	5.41%
Quality assurance and control (QA/QC)	111	2.70%	61.26%	34.23%	1.80%

Where engineering skills are learned

In response to the second research question, respondents were asked their opinions about where specific disciplines in the field of engineering were learned, and a frequency distribution was calculated for these six questions (Table 25). A majority of respondents indicated that they believed a combination of college and on the job training was appropriate for two of the six engineering disciplines: environmental engineering (69%) and engineering geology (64%). This was followed by civil and mechanical engineering, both at 48% for combined college and on the job training, structural engineering (29%) and mechanical engineering (27%). On the other hand, a majority of respondents indicated that mechanical engineering (54%) and structural engineering (53%) were most likely to be learned primarily or exclusively through formal training. Mechanical and structural engineering also received the highest percentages of responses for "Neither" (15% and 16%, respectively).

Table 25: Respondent perspectives on where skills in engineering are developed

Engineering Discipline	*N*	College	On the job	Both	Neither
Environmental	110	18.18%	10.91%	69.09%	1.82%
Engineering geology	107	26.17%	8.41%	64.49%	1.87%
Civil	110	46.36%	3.64%	48.18%	1.82%
Chemical	103	42.72%	3.88%	47.57%	5.83%
Structural	108	52.78%	4.63%	28.70%	13.89%
Mechanical	109	54.13%	4.59%	26.61%	14.68%

Where mathematical skills are learned

In response to the second research question, respondents were also asked to choose where mathematical skills were learned. The choices made available in the survey were college, on the job, both or neither. Frequency distributions were calculated to determine the highest percentages in favor of specific venues for learning (Table 26). For four of the six competencies in the area of mathematics, a majority of respondents indicated these skills were most likely to be learned only through college training:

calculus (91%), trigonometry (90%), geometry (89%) and algebra (88%). A smaller majority of respondents chose a combination of college and on the job training as the venue for the development of skills in statistics (53%) and statistical modeling (57%). With on the job training, statistical modeling was chosen by 25% of respondents.

Table 26: Respondent perspectives on where mathematical skills are developed

Mathematical Skill	*N*	College	On the job	Both	Neither
Calculus	106	90.57%	0.00%	6.60%	2.83%
Trigonometry	108	89.81%	0.00%	5.56%	4.63%
Geometry	108	88.89%	0.00%	6.48%	4.63%
Algebra	109	88.07%	0.00%	6.42%	5.50%
Statistics	110	46.36%	0.91%	52.73%	0.00%
Modeling	102	16.67%	25.49%	56.86%	0.98%

Where other technical, task-related skills are learned

For skills in other technical areas, respondents were asked to choose where they are best learned. As with all technical skill sets, the available choices were college, on the job, both or neither. Frequency distributions were calculated to determine the highest percentages in favor of specific settings where skills were developed (Table 27). Most responses reflected a preference for either on the job training or a combination of college education and on the job skill development.

Table 27: Respondent perspectives on where skills in other technical areas are developed

Other Technical Area	*N*	College	On the job	Both	Neither
Chemical fate & transport	111	7.21%	21.62%	71.17%	0.00%
Groundwater contamination	111	5.41%	30.63%	63.96%	0.00%
Vapor intrusion	111	3.60%	46.85%	49.55%	0.00%
Public health & safety	111	2.70%	15.32%	44.14%	1.80%
Hazardous materials remediation	111	3.60%	53.15%	43.24%	0.00%
Workplace health & safety	111	1.80%	67.57%	29.73%	0.90%

For two of the six skills in other technical areas, a majority of respondents indicated that they believed skills were most appropriately developed both in college and on the job: chemical fate and transport (71%) and groundwater contamination (64%). This was followed by vapor intrusion (50%), public health and safety (44%), hazardous materials remediation (43%), and workplace health and safety (30%). However, a majority of respondents indicated that only two of the skills were most likely to be learned on the job alone: workplace health and safety (68%) and hazardous materials remediation (54%). There were few responses in favor of college training alone: the highest percentage was for chemical fate and transport (7). There were also very few responses for "Neither." Public health and safety had only 2% of the responses for "Neither," followed by workplace health and safety (1%), and the remaining four task-related competencies had zero responses.

Summary of where technical skills are learned

The second research question asked where the knowledge, skills, abilities and traits required for environmental engineers are learned or developed. For technical skill sets, frequency distributions were used to determine the overall areas of learning that respondents believed skills were learned. Respondents were given the choice of college, on the job, both or neither. The results indicate that the majority of respondents indicate that skills in other technical areas are most appropriately developed either on the job or through a combination of employment and formal training. Similar results were found for technological skills. On the other hand, a majority of respondents indicated that scientific and mathematical skills were best developed through formal study in college. The results for engineering disciplines were more ambiguous. While most respondents indicated that engineering geology, environmental civil and chemical engineering were best developed either on the job or through both college and on the job training, a small majority chose college only for structural and mechanical engineering.

The results for competencies in the five professional skill sets were also analyzed to determine where they were most likely to be learned.

Where Skills Are Learned: Professional Skills

The second research question asked where relevant professional skills and traits are learned. Five skill sets were analyzed: communication, teamwork, professional qualities, social and emotional skills, and intellectual traits. As was the case with the questions related to technical skills, respondents could choose college, on the job, both or neither. However, in response to feedback provided by the pilot study, respondents were also given the choice of "life experiences" as another area where professional skills could be developed.

Communication

In response to the second research question, respondents were asked to choose where communication skills were learned. Frequency distributions were calculated to determine the highest percentages in favor of specific areas for learning communication skills (Table 28). For four of the seven skills in the communication skill set: supporting writing with evidence (74%), effective writing (64%), group communication (62%), and public speaking (55%), a majority of respondents indicated that they believed communication skills were most likely to be developed both in college and on the job. A minority of respondents indicated that the use of correct grammar (47%), the ability to speak with another person (41%), and interviewing (31%) were most likely to be learned through both training and work experience.

Table 28: Respondent perspectives on where communication skills are developed

Communication skill	*N*	College	On the job	Both	Neither	Life exp.
Supporting with evidence	108	10.19%	12.96%	74.07%	0.00%	2.78%
Effective writing	109	11.01%	21.10%	64.22%	0.00%	3.67%
Group communication	110	5.45%	12.73%	61.82%	0.00%	20.00%
Public speaking	109	6.42%	23.85%	55.05%	0.00%	14.68%
Correct grammar	109	43.64%	2.73%	47.27%	0.91%	5.45%
Speaking with another	110	2.73%	8.18%	40.91%	0.00%	48.18%
Interviewing	108	1.85%	45.37%	31.48%	5.56%	15.74%

With communication skills, the responses for college, on the job training, neither, or life experience as the most appropriate areas for learning were more widely dispersed. For example, speaking with another person (48%) received the highest percentage of responses for life experiences, while correct grammar (44%) was considered most likely to be learned in college. Interviewing had the highest percentage for on-the-job training alone (45%), and neither (6%).

Teamwork

In response to the second research question, respondents were also asked to choose where teamwork-related skills were learned. The choices made available in the survey were college, on the job, both, neither or life experiences. Frequency distributions were calculated to determine percentages in favor of specific venues for learning. For the ability to solve problems collaboratively (54%), a small majority of respondents indicated they believed this skill was most appropriately developed through a combination of college with on the job training (Table 29). This was followed by sharing key ideas (46%), seeking help to identify and achieve goals (45%), sharing credit with others (36%), acknowledging others' work (35%), keeping others informed (31%), supporting consensus (30%), and patient listening (23%).

Table 29: Respondent perspectives on where skills in teamwork are developed.

Teamwork skill	*N*	College	On the job	Both	Neither	Life exp.
Solve problems collaboratively	110	1.82%	26.36%	53.64%	0.91%	17.27%
Share key ideas	109	5.50%	23.85%	45.87%	1.83%	22.94%
Seek help to identify and achieve goals	109	2.75%	26.61%	44.95%	0.92%	24.77%
Share credit	110	2.73%	24.55%	36.36%	1.82%	34.55%
Acknowledge others' work	110	0.91%	30.00%	35.45%	0.91%	32.73%
Keep colleagues informed	108	0.93%	42.59%	31.48%	1.85%	23.15%
Support consensus	110	0.91%	30.91%	30.00%	8.18%	30.00%
Listen patiently	110	0.91%	28.18%	22.73%	0.91%	47.27%

Among the teamwork skills, there was no clear majority that favored college by itself, on-the-job training only, neither, or life experience. This indicates a lack of consensus about where skills in teamwork are best developed. The highest score for life experience was patient listening (47%). At 43%, the ability to keep colleagues informed was the skill respondents indicated was most likely to be learned solely on the job. The ability to share key ideas (6%) was the top score for college only, and supporting consensus received 8% of "Neither" responses.

Professional qualities

In response to the second research question, respondents were also asked to choose where they believed professional qualities were developed. The choices made available in the survey were college, on the job, both, neither or life experience. Frequency distributions were calculated to determine the highest percentages in favor of specific venues for learning (Table 30).

Table 30: Respondent perspectives on where professional qualities are developed

Professional quality and skill	*N*	College	On the job	Both	Neither	Life exp.
Concern for others	110	0.91%	5.45%	15.45%	8.18%	70.00%
A sense of humor	109	0.92%	3.67%	15.60%	11.01%	68.81%
Empathy	110	0.91%	6.36%	16.36%	8.18%	68.18%
Integrity	110	1.82%	3.64%	28.18%	4.55%	61.82%
Work ethic	109	3.67%	8.26%	29.36%	7.34%	51.38%
Flexibility	110	0.91%	10.00%	31.82%	7.27%	50.00%
Resourcefulness	109	1.83%	8.26%	33.94%	9.17%	46.79%
Ability to learn from others	110	1.82%	10.00%	37.27%	5.45%	45.45%
Ability to plan ahead	110	3.64%	10.91%	51.82%	2.73%	30.91%

For five of the nine skills in professional qualities: concern for others (70%), a sense of humor (69%), empathy (68%), integrity (62%) and work ethic (51%), a majority of respondents indicated that they believed professional qualities were most appropriately developed through life experiences. Fewer respondents indicated that flexibility (50%), resourcefulness (47%), the ability to learn from others (45%) and the ability to plan ahead (31%) were learned through life experiences.

Social and emotional competencies

In response to the second research question, respondents were also asked to choose where social and emotional management skills were learned. The choices made available in the survey were college, on the job, both, neither or life experience.

Frequency distributions were calculated to determine the highest percentages in favor of specific venues for learning (Table 31).

Table 31: Respondent perspectives on where social and emotional skills are developed

Social and emotional management skill	*N*	College	On the job	Both	Neither	Life exp.
Manage one's emotions	110	3.64%	2.73%	17.27%	4.55%	71.82%
Understand others' moods	110	3.64%	4.55%	19.09%	8.18%	64.55%
Influence others appropriately	109	3.67%	17.43%	25.69%	2.75%	50.46%
Respond effectively	110	1.82%	15.45%	30.91%	3.64%	48.18%

For two of the four competencies in the social and emotional management skill set: the ability to manage one's own emotions (72%), understanding others' moods (65%), a majority of respondents indicated that they believed these skills were most appropriately developed through life experiences. Only 50% of respondents indicated that the ability to influence others appropriately was learned through life experiences. This was followed by the life experience score for responding effectively (48%). Scores indicating where respondents believe social and emotional competencies used in their jobs were developed were more widely dispersed throughout the distribution.

Intellectual traits

Respondents were also asked to choose where they believed intellectual traits were developed (Table 32). A small majority favoring both college and on the job training was found for critical thinking (52%), followed by independent learning (39%), assimilation (39%), professional growth (36%), lifelong learning (29%), and intellectual curiosity (24%). On the other hand, most respondents believed that two intellectual traits were best developed through life experiences: lifelong learning (54%) and intellectual curiosity (51%). These were followed by assimilation (35%), independent learning (35%), critical thinking (17%) and professional growth (16%).

Table 32: Respondent perspectives on where intellectual traits are developed

Intellectual trait	*N*	College	On the job	Both	Neither	Life exp.
Critical thinking	109	19.27%	11.01%	52.29%	0.92%	16.51%
Independent learning	110	12.73%	10.00%	39.09%	3.64%	34.55%
Assimilation	110	6.36%	7.27%	39.09%	11.82%	35.45%
Professional growth	110	0.91%	41.82%	36.36%	4.55%	16.36%
Lifelong learning	108	1.85%	11.11%	28.70%	4.63%	53.70%
Intellectual curiosity	110	7.27%	5.45%	26.36%	5.45%	55.45%

For intellectual traits, the highest percentage of responses indicating a belief in favor of on-the-job training alone was for professional growth (42%), followed by lifelong learning (11%), critical thinking (11%), independent learning (10%), assimilation (7%), and intellectual curiosity (5%). College received a smaller percentage of responses: the highest was for critical thinking (19%), followed by independent learning (13%), intellectual curiosity (7%), assimilation (6%) and professional growth (< 1%).

Summary of where professional skills are learned

The second research question asked where the knowledge, skills, abilities and traits required for environmental engineers are learned or developed. As with technical skills, frequency distributions were used to determine the overall areas of learning that respondents believed skills were learned. Respondents were given the choice of college, on the job, both, neither and life experiences.

The results for professional skills reflect ambiguity in respondent opinions about where communication and teamwork skills are learned. This is most apparent in the intellectual traits skill set, where the results for two of the individual skills were divided between both college and on the job and life experiences. Both college and on the job was preferred for critical thinking, while most respondents chose on the job training for professional growth and life experiences for lifelong learning and intellectual curiosity. For communication, a majority favored both college and on the job training among six of the seven competencies in this skill set. The exception was the ability to speak with another person, for which most respondents chose life experiences as the area of learning. Life experience was also the preferred area of learning for patient listening, part of the teamwork skill set, while a majority of respondents chose either on the job training or a combination of on the job training with college education for other skills related to teamwork. A majority of respondents chose life experience as the area of learning for eight of the nine skills in the professional qualities skill set. The exception was the ability to plan ahead, where most respondents chose both college and on the job training. The majority of respondents also indicated that life experience was the area of learning for all skills in social and emotional management.

These types of responses may have been influenced by respondent characteristics. Gaining additional insight into the effects of personal and professional perspectives on respondent opinions would add an additional layer of understanding to both the need for specific technical and professional skills and where these skills are most appropriately developed.

Perspectives on Where Specific Skills are Learned by Respondent Characteristics

For the first research question, crosstabulation of the need for specific skills revealed few areas where the results differed significantly from the frequency distribution. In contrast, for the second research question the crosstabulation of where skills are developed ("Areas of Learning") by respondent characteristic revealed a greater number of areas where respondent responses based on their characteristics differed significantly from the frequency distribution.

Characteristics most likely to influence respondent choice

As with the first research question, crosstabulations were performed on the characteristics of respondents that were considered most likely to influence their choices. The results for any characteristic were considered significant and reported in this chapter if the difference between crosstabulated percentages and those calculated as part of the frequency distribution for a specific skill set was equal to or greater than 10%. A complete set of crosstabulations for the second research question appears in Appendix G.

Respondent Perspectives by Employment: Technical Skills

Crosstabulations were performed on technical skill sets to determine the extent to which respondent characteristics influenced their choices. The characteristics included employment (level and classification), education (highest educational attainment and community college attendance), and years of service. Crosstabulation of employment with technical skills revealed only two technical skill sets where the results deviated significantly from the frequency distribution: mathematics and other technical areas.

For mathematics, the most significant difference was found in classification, where 62% of engineering geologists (EG) indicated that mathematics was learned both in college and on the job, compared with 50% of all respondents (Table 33). Among this group 32% selected college only, compared with 42% of all respondents. Crosstabulated results for other classifications and all levels were more consistent with the frequency distribution.

Table 33: Respondent perspectives on areas of learning by employment level and classification: Mathematics

		Level			Classification		
	Distribution	Technical	Senior	Sup	HSE	HSS	EG
Both	50.16%	48.84%	51.32%	52.59%	43.50%	48.00%	62.20%
In college	42.16%	42.44%	44.08%	38.79%	50.22%	41.78%	31.71%
On the job	6.37%	7.85%	1.32%	8.62%	4.93%	9.78%	3.66%
Neither	1.31%	0.87%	3.29%	0.00%	1.35%	0.44%	2.44%

In the skill set titled "Other technical areas," hazardous substances scientists (HSS) were the respondents most likely to choose both college and on the job training as most suitable for developing skills in other technical areas related to environmental engineering: 63% compared to 51% for all respondents (Table 34). Engineering geologists were most likely to choose on the job training: 56% compared to 45% for all respondents. Only 34% of hazardous substances scientists indicated that skills in other technical areas were best learned on the job. Crosstabulated results for all levels were more consistent with the frequency distribution.

Table 34: Respondent perspectives on areas of learning by employment level and classification: Other technical areas

		Level			Classification		
	Distribution	Technical	Senior	Sup	HSE	HSS	EG
Both	50.53%	50.29%	58.55%	62.93%	43.93%	63.33%	42.39%
On the job	45.40%	51.45%	48.03%	43.97%	48.95%	33.75%	55.98%
In college	4.07%	5.52%	3.95%	1.72%	7.11%	2.92%	1.63%
Neither	0%	0%	0%	0%	0%	0%	0%

Respondent Perspectives by Employment: Professional Skills

Employment characteristics were also crosstabulated with professional skills for areas of learning. None of the results deviated substantially from the frequency distribution for any of the five professional skill sets. This means that there were no differences equal to or greater than 10% between the crosstabulated results and the frequency distribution. The lack of difference indicates general agreement about areas of learning for professional skills, regardless of employment status.

Respondent Perspectives by Education: Technical Skills

When education was crosstabulated with technical skills for areas of learning, significant differences from the frequency distribution were found in three of the five skill sets: science, mathematics and other technical areas. For science, the most substantial difference was among respondents with earned doctorates. Among respondents who attained this educational level, 70% indicated that skills in science was most likely learned in college compared to 47% of all respondents (Table 35). Only 21% believed skills in science were most likely to be developed both in college and on the job, compared with 46% of all respondents. For science, crosstabulated results among other educational levels and by community college attendance were more consistent with the frequency distribution.

Table 35: Respondent perspectives on areas of learning by highest educational level and community college attendance: Science

		Highest educational level			Community college	
	Distribution	BS/BA	MS/MA	Ph.D.	Yes	No
In college	46.88%	41.22%	49.80%	69.70%	47.54%	46.15%
Both	46.32%	52.67%	42.97%	21.21%	44.01%	48.85%
On the job	6.07%	4.58%	7.23%	9.09%	7.04%	5.00%
Neither	0.74%	1.53%	0.00%	0.00%	1.41%	0.00%

For mathematics, crosstabulated results among respondents with doctorates also deviated to a greater extent from the percentages reported in the frequency distribution (Table 36). Among respondents with doctorates, 60% selected college as the area of learning for mathematics compared with 71% of all respondents, while 33% chose both college and on the job training, compared with 22% of all respondents. The results among other educational levels and by community college attendance were more closely aligned with the frequency distribution for the mathematics skill set.

Table 36: Respondent perspectives on areas of learning by highest educational level and community college attendance: Mathematics

		Highest educational level			Community college	
	Distribution	BS/BA	MS/MA	Ph.D.	Yes	No
Both	22.31%	20.97%	22.34%	32.50%	22.32%	22.29%
In college	70.67%	71.29%	71.48%	60.00%	70.34%	71.02%
On the job	4.21%	5.48%	3.44%	0.00%	3.98%	4.46%
Neither	2.81%	2.26%	2.75%	7.50%	3.36%	2.23%

In "Other Technical Areas," 64% of respondents with doctorates noted that skills were most likely to be learned both in college and on the job, compared with 51% of all respondents. A minority (17%) chose on the job, compared with 45% of all respondents and 19% chose college attendance compared with 4% of all respondents. The results among other educational levels and by community college attendance were more closely aligned with the frequency distribution for the mathematics skill set (Table 37).

Table 37: Respondent perspectives on areas of learning by highest educational level and community college attendance: Other technical areas

		Highest educational level			Community college	
	Distribution	BS/BA	MS/MA	Ph.D.	Yes	No
Both	50.53%	47.15%	52.13%	64.29%	47.40%	53.94%
On the job	45.40%	50.63%	43.93%	16.67%	50.00%	40.38%
In college	4.07%	2.22%	3.93%	19.05%	2.60%	5.68%
Neither	0%	0%	0%	0%	0%	0%

Respondent Perspectives by Education: Professional Skills

Significant differences between the crosstabulated results and the frequency distributions regarding skill development were also found in three of the five professional skill sets: professional qualities, social and emotional skills, and intellectual traits. For professional qualities, the frequency distribution for all respondents showed that 55% chose life experiences as the most likely area of learning, while 29% indicated skill development through a combination of college and on the job training (Table 38).

Conversely, only 38% of respondents with doctorates chose life experiences, while 44% chose both college and on the job. The results among other educational levels and by community college attendance were more closely aligned with the frequency distribution.

Table 38: Respondent perspectives on areas of learning by highest educational level and community college attendance: Professional qualities

		Highest educational level			Community college	
	Distribution	BS/BA	MS/MA	Ph.D.	Yes	No
Life experience	54.87%	52.21%	60.04%	38.10%	50.77%	59.44%
Both	28.90%	31.79%	23.66%	44.44%	27.88%	30.04%
On the job	7.40%	5.47%	9.60%	6.35%	7.69%	7.08%
Neither	7.00%	9.89%	4.69%	1.59%	12.31%	1.07%
In college	1.83%	0.63%	2.01%	9.52%	1.35%	2.36%

Among social and emotional skills, the crosstabulated results for respondents with doctorates again differed substantially from the frequency distribution for all respondents (Table 39). Respondents with doctorates were more likely to choose both college and on the job: 54% compared with 23% for all respondents. Respondents with doctorates were also less likely to choose life experiences: 32% compared with 59% for all respondents. The results for all other educational levels, community college and areas of skill development were more closely aligned with the results of the frequency distribution.

Table 39: Respondent perspectives on areas of learning by highest educational level and community college attendance: Social and emotional skills

		Highest educational level			Community college	
	Distribution	BS/BA	MS/MA	Ph.D.	Yes	No
Life experience	58.77%	62.26%	58.79%	32.14%	59.48%	57.97%
Both	23.23%	20.28%	22.11%	53.57%	19.83%	27.05%
On the job	10.02%	9.91%	10.05%	10.71%	7.33%	13.04%
Neither	4.78%	5.66%	4.52%	0.00%	7.76%	1.45%
In college	3.19%	1.89%	4.52%	3.57%	5.60%	0.48%

For intellectual traits 52% of respondents with doctorates chose both college and on the job as the best area of learning for intellectual traits and 21% chose life experiences (Table 40). Meanwhile, 37% of all respondents chose college and on the job, while 36% indicated that life experiences as the best area of learning. Results for all other educational levels and community college were more closely aligned with the results of the frequency distribution.

Table 40: Respondent perspectives on areas of learning by highest educational level and community college attendance: Intellectual traits

	Distribution	Highest educational level			Community college	
		BS/BA	MS/MA	Ph.D.	Yes	No
Both	37.33%	38.54%	33.90%	52.38%	36.15%	38.64%
Life experience	35.64%	37.90%	35.25%	21.43%	35.57%	35.71%
On the job	14.59%	11.46%	17.63%	16.67%	13.70%	15.58%
In college	8.14%	7.32%	9.15%	7.14%	7.29%	9.09%
Neither	4.30%	4.78%	4.07%	2.38%	7.29%	0.97%

Respondent Perspectives by Length of Service: Technical Skills

Crosstabulation of length of full-time/full-time equivalent (FTE) service by skill set also indicated that length of service influenced respondent responses among three of the five technical skill sets: science, engineering and other technical areas. For science, while 46% of all respondents indicated both college and on the job as the area of choice for skill development, only 34% of respondents with less than five years of experience made the same choice (Table 41). Results for all other time-of-service groups and areas of learning were more closely aligned with the results of the frequency distribution.

Table 41: Respondent perspectives on areas of learning by highest educational level and community college attendance: Science

	Distribution	Years of Full-Time/FTE Experience in Government Service					
		< 5	5-9.99	10-14.99	15-19.99	20-24.99	> 25
College	46.88%	55.67%	51.09%	54.55%	43.37%	44.54%	37.61%
Both	46.32%	34.02%	44.57%	38.64%	51.81%	50.42%	53.21%
On the job	6.07%	9.28%	4.35%	2.27%	4.82%	4.20%	9.17%
Neither	0.74%	1.03%	0%	4.55%	0%	0.84%	0%

For engineering, the frequency distribution indicated that 50% of all respondents chose both areas of learning, while only 38% of respondents who had been there 15 to

19.99 years did so (Table 42). Respondents with greater than 25 years of full-time/FTE service chose college (33%), compared with 42% for the frequency distribution.

Table 42: Respondent perspectives on areas of learning by years of full-time/ FTE experience in government service: Engineering

	Distribution	Years of Full-Time/FTE Experience in Government Service					
		< 5	5-9.99	10-14.99	15-19.99	20-24.99	> 25
Both	50.16%	50.91%	54.13%	53.33%	38.30%	49.62%	54.47%
College	42.16%	45.45%	39.45%	42.22%	48.94%	45.80%	32.52%
On the job	6.37%	3.64%	6.42%	0%	9.57%	3.82%	11.38%
Neither	1.31%	0%	0%	4.44%	3.19%	0.76%	1.63%

In "Other Technical areas," the frequency distribution indicated that 51% of respondents chose both college and on the job, 45% chose on the job, and 4% chose college only (Table 43). Experience may have been a factor in opinions about where skills in other technical areas were learned, as 38% of respondents with less than five years of full-time/FTE government experience chose on the job training. On the job training was also selected by 65% of respondents with between 10 and 14.99 years of service. For both engineering and other technical areas, results for all other time-of-service groups and areas of learning were more closely aligned with the results of the frequency distribution.

Table 43: Respondent perspectives on areas of learning by years of full-time/ FTE experience in government service: Other technical areas

	Distribution	Years of Full-Time/FTE Experience in Government Service					
		< 5	5-9.99	10-14.99	15-19.99	20-24.99	> 25
Both	50.53%	38.14%	48.25%	64.81%	50.50%	54.86%	53.03%
On the job	45.40%	51.69%	51.75%	35.19%	43.56%	40.28%	45.45%
College	4.07%	10.17%	0%	0%	5.94%	4.86%	1.52%
Neither	0%	0%	0%	0%	0%	0%	0%

Respondent Perspectives by Length of Service: Professional Skills

Crosstabulations were also done for years of full-time/FTE service by professional skills. The results showed significant differences among four of the five professional skill sets: teamwork, professional qualities, social and emotional skills, and intellectual traits. For teamwork, the largest deviation from the frequency distribution was for respondents with 10 to 14.99 years of experience (Table 44). The crosstabulated score for college combined with on the job among this group was 47%, compared with 38% for the frequency distribution and 19% for on the job only, compared with 29% for the frequency distribution. The only other respondents showing a significant difference in any area of learning were those with over 25 years of experience. Crosstabulation of this group's scores with the areas of learning indicate that 42% consider teamwork most likely to be developed on the job only, compared with 29% of all respondents. The crosstabulated results for all other time-of-service groups and areas of learning were more closely aligned with the results of the frequency distribution.

Table 44: Respondent perspectives on areas of learning by years of full-time/ FTE experience in government service: Teamwork

		Years of Full-Time/FTE Experience in Government Service					
	Distribution	< 5 yrs	5-9.99	10-14.99	15-19.99	20-24.99	25+
Both	37.77%	47.47%	42.11%	47.22%	35.56%	26.67%	34.48%
On the job	29.28%	26.58%	21.71%	19.44%	22.22%	35.00%	41.95%
Life experience	29.28%	20.25%	36.18%	31.94%	31.85%	38.33%	18.97%
College	2.07%	3.80%	0%	0%	2.96%	0.00%	4.60%
Neither	1.61%	1.90%	0%	1.39%	7.41%	0.00%	0.00%

Crosstabulation of professional qualities by years of service indicate that the only significant difference was for respondents in the 10-14.99 year range (Table 45). Of this group, 40% chose both college and on the job, compared with 29% of all respondents. On the other hand, only 21% of respondents in the 10-24.99 year range chose both college and on the job. Among respondents with less than 5 years of experience, 18% chose "Neither college nor on the job" compared with 7% of all respondents. The crosstabulated results for all other time-of-service groups and areas of learning were more closely aligned with the results of the frequency distribution.

Table 45: Respondent perspectives on areas of learning by years of full-time/ FTE experience in government service: Professional qualities

		Years of Full-Time/FTE Experience in Government Service					
	Distribution	<5	5-9.99	10-14.99	15-19.99	20-24.99	>25
Life experience	54.87%	46.67%	61.99%	46.91%	60.26%	62.32%	47.45%
Both	28.90%	27.78%	29.82%	39.51%	25.17%	20.29%	36.73%
On the job	7.40%	5.56%	2.92%	13.58%	4.64%	4.35%	15.82%
Neither	7.00%	17.78%	1.75%	0.00%	5.30%	12.56%	0.00%
College	1.83%	2.22%	3.51%	0.00%	4.64%	0.48%	0.00%

For the skill set titled "Social and emotional skills," 71% of respondents with 5 to 9.99 years of experience chose "Life experience," compared with 59% of all respondents (Table 46). Only 49% of respondents with over 25 years of experience chose this area of learning, while 39% of respondents in the same group chose both college and on the job, compared with 23% of all respondents.

Table 46: Respondent perspectives on areas of learning by years of full-time/ FTE experience in government service: Social and emotional skills

	Distribution	Years of Full-Time/FTE Experience in Government Service					
		<5	5-9.99	10-14.99	15-19.99	20-24.99	>25
Life experience	58.77%	55.00%	70.67%	61.11%	57.35%	61.96%	48.86%
Both	23.23%	18.75%	18.67%	27.78%	22.06%	15.22%	38.64%
On the job	10.02%	15.00%	4.00%	0.00%	10.29%	11.96%	12.50%
Neither	4.78%	6.25%	2.67%	0.00%	5.88%	10.87%	0.00%
College	3.19%	5.00%	4.00%	11.11%	4.41%	0.00%	0.00%

Respondents with over 25 years of experience were also more likely to consider both college and on the job as the best area of learning for intellectual traits (Table 47): 53%, compared with 37% for all respondents. For both social and emotional skills and intellectual traits, results for all other time-of-service groups and areas of learning were more closely aligned with the results of the frequency distribution

Table 47: Respondent perspectives on areas of learning by years of full-time/ FTE experience in government service: Intellectual traits

	Distribution	Years of Full-Time/FTE Experience in Government Service					
		< 5 yrs	5-9.99	10-14.99	15-19.99	20-24.99	25+
Both	37.33%	35.29%	39.64%	33.96%	29.70%	29.20%	53.08%
Life experience	35.64%	26.05%	33.33%	43.40%	43.56%	45.26%	26.92%
On the job	14.59%	15.97%	13.51%	16.98%	12.87%	11.68%	17.69%
College	8.14%	15.13%	11.71%	5.66%	6.93%	6.57%	2.31%
Neither	4.30%	7.56%	1.80%	0.00%	6.93%	7.30%	0.00%

Summary of Findings

The findings of this study indicate that experienced professionals consider technical skills important for success in the field of environmental engineering. However, it also appears that experienced professionals prioritize certain technical skills. Rates of "Agree/Strongly Agree" responses were highest for other technical areas, followed by skills in technology, science and mathematics. Engineering had the lowest rate of "Agree/Strongly Agree" responses.

It also appears that experienced professionals consider professional skills even more important than technical skills. The percentage of "Agree/Strongly Agree" responses was even higher for professional skill sets than for technical skills. Communication had the highest percentage among all professional skills, indeed, for all skill sets. This was followed by social and emotional skills, professional qualities, teamwork, and intellectual traits.

Furthermore, it appears that respondent characteristics may have a moderating effect on the opinions of respondents regarding the importance of certain skills. For technical skills, there were significant differences in crosstabulated percentages between specific groups of respondents and the frequency distribution for all respondents in four areas: employment status with engineering; education with technology; education with mathematics, and time of service with engineering. On the other hand, crosstabulation of respondent characteristics with professional skills indicate a closer alignment between responses by group and the frequency distribution.

For the second research question, areas of learning for technical skills were more or less evenly divided between college, on the job training, and both areas. While a greater percentage of respondents favored on the job training for the development of skills in other technical areas and in technology, this was balanced with a higher percentage of respondents who chose college only as the area of learning for scientific and mathematic skills. Again, the results for engineering were mixed, depending on the specialty.

Comparison of the results for both technical and professional skill sets by respondent characteristics shows greater numbers of instances where percentages deviate from the frequency distributions for all respondents. Employment status, particularly classification, was found to significantly influence respondent responses in regards to areas of learning for mathematics and other technical areas, while education affected respondent opinions about where skills in science, mathematics and other technical areas are developed.

Employment status (e.g. level) was not a significant factor in respondent opinions about professional skills. However, education did affect the responses given for questions related to professional qualities, social and emotional skills, and intellectual traits. The number of years of service also influenced respondent responses concerning the areas of learning for science, engineering, other technical areas, and all professional skill sets with the exception of communication.

The significance of these findings, implications for research and practice, and recommendations for further study were presented in Chapter V.

CHAPTER V

ANALYSIS

Introduction

The purpose of this study was to investigate the knowledge, skills, abilities and traits required of environmental engineers, and to learn where these skills are developed. To that end, this study examined the opinions of skilled, experienced professionals in the field of environmental engineering by examining data provided in response to two research questions:

RQ1: What knowledge, skills, abilities and traits do experienced professionals view as necessary for a successful career in environmental engineering?

RQ2: Where do experienced professionals in the field of environmental engineering believe they learned the skill sets they use in their work?

This chapter presents an analysis of the results of this study. At the end of this chapter, implications for research and practice and recommendations for future studies will be presented.

The Results of this Study and the Research

Confirming and extending the research

This study extended existing research on the development of skills for environmental engineers in two ways: by including data on professional or "soft" skills as well as on technical skills, and by drawing upon the perspective of individuals who are already employed in the field - some for decades. As noted earlier, the findings of this study can inform curriculum development in STEM programs among community colleges, four-year universities and professional associations by adding aspects of the requisite knowledge, skills, abilities and traits from experienced professionals in the field of environmental engineering. Professionals with experience in their areas of expertise generally have a different perspective on the need for specific knowledge, skills, abilities and traits than do academics.

In this study, the opinions expressed by study respondents through their responses to questions presented in the survey emphasized the importance of developing technical skills through both formal training and experience on the job. Respondents indicated it was important for engineers to begin with a strong foundation of science, mathematics, engineering skills, and other technical skills such as hazardous materials remediation and chemical fate and transport. They would then build upon that foundation by developing additional task-related competencies and remaining current with changes in technology related to engineering, project management, and geology.

According to study respondents, professional skills are even more important in their work than are technical competencies. Certainly, skills in science, technology, engineering, mathematics and other technical areas are essential for completing tasks routinely associated with environmental engineering. However, the ability to deal with ambiguity, communicate, collaborate with others, think critically, consider the greater good, act with decency and integrity, and build effective working relationships make it possible for technical staff to succeed in their chosen profession. And, the ability to develop through non-traditional methods, synthesize new knowledge with existing skills, and learn throughout one's lifetime and career enables environmental engineering professionals to remain current with their field as they continually develop and refine both their technical and professional skills.

The ideas working professionals have about where skills are developed also vary from those expressed in formal training programs. Their opinions are based on years or even decades of experience in field work and through interaction with other professionals, and may change with the passage of time and acquisition of further experience. The insights they contributed indicate that the acquisition and refinement of technical skills is not a unitary process. There is not one single protocol for learning technical skills. Rather, the development of technical skill sets begins with a foundation of basic instruction in science and mathematics starting with grammar school. A solid understanding of technical skills evolves over time, through additional training and experience.

The role of professional or what are sometimes called "soft" skills played a pivotal role in this study. This can be attributed to the importance of effective communication, teamwork, intellectual curiosity, social skills and personality characteristics that make it possible for new employees to "fit" into the workplace and establish themselves as bona fide working professionals who can work well with their peers and others in the workplace. Since many tasks and projects are now completed on a multinational scale, further research on global competence may yield additional insights into the need for professional skill development among environmental engineers.

Finally, this study supports the use of Dreyfus and Dreyfus' novice-to-expert model by confirming that many of the skills required in environmental engineering are developed through the progression of time and practice on the job. Engineers in all specialties usually begin their careers with a good understanding of the principles of their discipline, developed through their training (Richter & Paretti, 2009). For the rest of their careers, they build a more comprehensive and dynamic base of knowledge through the routine practical application of these principles on the job (Dreyfus & Dreyfus, 1986). A more detailed exploration of the ways the results of this study may apply to a more thorough application of the Dreyfus & Dreyfus novice-to-expert model may yield additional insights into how this model may be confirmed and extended for further application in the profession of environmental engineering or in other disciplines.

Extending the Dreyfus & Dreyfus Model: Introduction

Each working professional brings a unique perspective to the job. This individual perspective is based on a number of factors, including education, personal characteristics and previous experiences. Individuals socially construct their professional identities from personal situations as well as experiences that occur in the context of the workplace and pre-employment circumstances (Blumer, 1968). Therefore, any or all of these factors may provide a lens through which the practitioner views his or her work. These factors may affect performance, the ability to learn technical skills, and the ability to form effective working relationships with colleagues, clients and other stakeholders. Therefore, an individual's perspective may affect the rate of progress among the novice-to-expert continuum. This rate of progress may also be reflected in the opinions working professionals express about specific technical and professional skill sets.

For the purpose of this study, three respondent characteristics were examined to determine the extent to which their opinions of technical and professional skills corresponded to the Dreyfus & Dreyfus novice-to-expert model. The first was level of employment (technical, senior and supervisor). The level of education completed (bachelor's, master's and doctorate) was also examined. Finally, three brackets in length of full-time/FTE service were examined. Early career included respondents who had been in the profession full-time or FTE for five years or less. Mid-career respondents, or those between 15-20 years of service were also analyzed. Late career encompassed respondents with 25 years or more of experience.

Level of Employment and the Novice-to-Expert Model

Technical skills were considered important by all respondents, and were ranked highest by those employed at the technical level at the time of the survey. The importance of technical skills decreased slightly for senior-level professionals, and then rose slightly for those at the supervisory level. According to Dreyfus & Dreyfus (1986), skill develop operates on a continuum that begins with the novice following strict, prescribed rules for completing clearly-defined tasks and ends with the expert's instinctive integration of new and existing information. Thus, a trend toward decreased importance on technical skills by senior-level staff followed by an increased emphasis on these skills by supervisors may seem inconsistent with Dreyfus' novice-to-expert model. However, it makes sense when considering that professionals who become supervisors may face new responsibilities such as training new employees. Thus, they may need to develop new skills as they move from task-oriented functions to managerial roles.

This shift in responsibilities as environmental engineering professionals move up the career ladder may also influence their opinions about where skills are learned. In this study, most respondents indicated that four of the five technical skill sets were developed through a combination of college with on the job training. There was also a direct correlation between employment level and the percentage of responses favoring both college and on the job training, with the highest percentages among supervisors, followed by senior staff. The only exception to this was for the engineering skill set, for which college was the favored area of learning across the board. Even so, the percentage of responses favoring college decreased as engineering professionals rose through the ranks. Both these trends indicate that skill development and the perception of where technical skills are developed may change over time as a result of experience on the job combined with employment status. This is consistent with the novice-to-expert model, which specifies that an individual's knowledge base, autonomy and sense of responsibility for their actions increase with time and experience (Dreyfus & Dreyfus, 1986).

Respondent opinions about the value of professional skills also corresponded with an increase in employment level among respondents. The importance of communication, teamwork and professional qualities increased slightly, from technical to senior, with the highest percentage of "Agree" responses among respondents in supervisory roles. Intellectual traits and social and emotional skills were also high at all levels, but dipped slightly among senior-level staff before moving back up among supervisors.

Among the professional skill sets, communication was unique in that a majority of respondents across the board indicated that this skill was most appropriately developed through a combination of college with on the job training. This combination was also the learning area of choice for teamwork by technical level staff. However, on-the-job training was preferred by senior-level staff, and life experience was chosen by a majority of supervisory-level staff. Life experience was the favored area of learning for professional qualities, social and emotional skills, and intellectual traits. To a certain extent, these trends concur with Dreyfus' novice-to-expert model, which assumes a progressive development of skills throughout a practitioner's career. However, it may also indicate that the five-stage process of career development begins another cycle as a practitioner experiences changes in types and level of responsibilities required for moving up to another level. These career changes may coincide with major events that are occurring outside of the scope of employment. Social reality, including employment, is socially constructed and people's attitudes about their work and personal lives may be affected by their experiences in both areas (Blumer, 1968). Therefore, one area of a practitioner's life may influence their opinions of and performance in other areas, despite efforts to separate personal concerns from work-related issues.

How the highest level of education achieved affected respondent perspectives

The highest level of education achieved was then examined to determine the extent to which opinions affected by respondents at different degree levels corresponded with the novice-to-expert model. The results showed that technical skills considered more likely to be learned in college rather than on the job or through a combination of the two were considered most important by respondents with doctoral degrees. On the other hand, skills considered more likely to be learned on the job or through a combination of college with on the job training received more "Agree" responses from respondents with baccalaureate degrees. For these skills, the percentage of "Agree" responses decreased as educational level increased. These trends may indicate two things: environmental engineering professionals with lower levels of formal training place a higher emphasis on skills developed through time, on the job training and experiential learning, and skill sets that require higher amounts of time spent in the classroom are more salient to professionals with higher levels of education because they have taken more coursework in these areas and who may use these skills more frequently in their daily work than do their colleagues without advanced degrees.

While the novice-to-expert model focuses on the skills that practitioners develop through time and practice on the job, it is worth noting that in many occupations for which postsecondary degrees are required, skill development begins with a foundation of principles, theories and basic skills learned through formal training (Benner, 2004). Practitioners subsequently expand their knowledge base through time and practical application, and they master new skills on the job. Therefore, it appears this trend expands on the novice-to-expert model by bringing the element of formal education back into the domain of progressive skill development over time and through practice (Aamodt & Havnes, 2008).

This suggests that extension of the novice-to-expert model to include factors that include levels of formal education may expand its utility as a conceptual model for progressive skill development. Several aspects of the relationship between formal education and on-the-job training have not been discussed in the original novice-to-expert model. One important variable that has not yet been addressed concerns the phenomenon of formal training acquired after practitioners begin their careers. For example, an environmental engineer who accepts a full-time position while holding a bachelor's degree and then later earns a master's degree while working may have opinions about the importance of specific technical skills and where they are developed that differ substantially from those held by colleagues who enter the profession with graduate degrees, as well as from those who progress through their careers without continuing their formal education. Further study of professionals in environmental engineering or other professions who seek advanced training in their field might extend Dreyfus' model through a detailed and progressive examination of skills developed through practice meshed with knowledge developed through advanced education completed after professionals have advanced to the later stages of the model: competency, proficiency or expertise (Dreyfus & Dreyfus, 1986).

As was the case with technical skills, the perceived importance of professional skill sets was also contingent on the highest level of completed education reported by respondents and where they were learned. The importance of communication and teamwork, both considered most likely to be learned through a combination of college with on the job training, rose in importance between respondents with bachelor's degrees and those with master's degrees. These two skill sets then decreased slightly in importance for those with doctorates. The importance of professional qualities, social and emotional skills and intellectual traits, all skill sets considered most likely to be developed through life experiences prior to college, actually declined slightly as educational level increased. These trends may indicate that the perceived importance of specific professional skills changes with educational level. Another possibility is that the development and refinement of professional skills through practice at work makes them more salient to practitioners over time and with additional training.

Full-time experience and skill development along the continuum

The value of technical skills for practitioners in the early stages of their careers was reinforced by the high percentage of respondents with five years or less who indicated their agreement with the importance of all five technical skill sets. This importance of technical skills decreased among respondents who had between 15 and 20 years of experience, then rose again for those who had worked in the profession for 25 years or more. Rather than contradicting the novice-to-expert model, this phenomenon coincides with similar changes between technical, senior and supervisory levels and may reflect a mid-level career plateau, or decisions made by practitioners with several years of experience to move into senior-level or supervisory positions. Consistency with the Dreyfus & Dreyfus novice-to-expert model may mean that, at least in the population sampled for this study, most practice-based skill development at the first level has occurred in the first ten or fifteen years in the profession. In order to move into higher levels of employment, practitioners may find it necessary to integrate existing skill sets with new ones and find themselves at the second level of skill development ("Advanced Beginner") in their new set of skills while operating at the fifth level ("Expertise") when assuming older, more familiar roles. This indicates that in reality, the five-stage progression of skill development outlined by Dreyfus & Dreyfus (1986) may be more fluid and less finite than what was originally presented in the model. Acknowledging that skill development may occur simultaneously at two or more stages may also reflect the dynamic and changing nature of environmental engineering and other professions, as experienced workers go through multiple iterations of skill development to remain current in their career paths.

The tendency of skill importance to level off or decrease for mid-career professionals in environmental engineering, and then rise again for those in the later stages of their careers also remained consistent for two of the professional skill sets:

teamwork and intellectual traits. In contrast, levels of importance for social and emotional skills and for communication, which had overwhelmingly high rates of "Agree" responses to begin with, were highest for professionals at the mid-career stage. Levels of importance for professional qualities rose steadily with time in the field. These trends may reflect greater emphasis on specific professional skills at later career stages, consistent with the Dreyfus & Dreyfus novice-to-expert model, which specifies that as practitioners move through the five stages of skill development they automatically become more selective about the skills developed and used. This automatic selection process is contextual and depends on the salience of certain skills to the type of work performed (Dreyfus & Dreyfus, 1986). For example, some tasks associated with environmental engineering may emphasize the need for strong intellectual traits and skills in written communication, while others prioritize teamwork. It is also useful to examine how this study contradicts the research, including areas that were overlooked in development of the novice-to-expert model.

How this study contradicts the research

One surprising area of learning professional skills is the role of life experiences in the development of professional skills. As noted in the methodology, the results of the pilot study led to the inclusion of life experiences as an avenue for skill development for this study. The high rate of "Agree/Strongly Agree" responses for a number of the professional skills listed in the survey indicate that further research needs to be done on the knowledge, skills, abilities and traits students acquire through their experiences prior to college. Research on learning suggests that student success at all educational levels –

from preschool through graduate school – may be shaped by experiences that begin in early childhood and continue throughout the lifespan (Dynan, Cate & Rhee, 2008).

In addition, it is also useful to consider areas that have not been covered by the Dreyfus & Dreyfus model. Looking at situations that fell outside the scope of this study may also yield useful information. Examining these external circumstances may simultaneously contradict the research and provide insights that may be used to extend the novice-to-expert model. They may also provide rich areas for future research in the area of skill development.

Areas not covered under the model or through this study

Several factors that exist beyond the focus of this study and outside the scope of the current novice-to-expert model may have also influenced respondent opinions about both the importance of certain skill sets and where they are developed. For example, generational status was not covered in this study, nor is it addressed in the Dreyfus to Dreyfus model. However, in any group of educated people there is a good possibility that at least some of them were the first in their families to attend or graduate from college (Lubrano, 2004). Several possible explanations exist for why the opinions of respondents who were first-generation college students may have varied from those whose parents had graduated from college. First-generation students from working-class backgrounds are more likely than their continuing-generation peers to have acquired practical experience prior to graduating from college, frequently through gainful employment in areas unrelated to their programs of study (Ishitani, 2006). Thus, first-generation students may consider on the job training especially important as they move from college to career. They may also have different ideas about what is involved in making this transition than colleagues who did not need to juggle college with work responsibilities, and may have to adapt the practical skills they learned elsewhere to the circumstances they face in their new employment (Lubrano, 2004). In addition, environmental engineers who are the first in their families to graduate from college may rely more heavily on life experiences, on-the-job training, mentoring and 'trial-and-error' in developing both their technical and professional skills than do their continuing-generation peers. Thus, they may experience greater levels of tension between achieving their professional goals and managing the duality between who they are and what they do (Lam, Srivatsan & Doverspike, et al, 2005).

Generational status is just one factor in skill development and career progress that has fallen outside the scope of this study. Another matter worthy of further consideration is the perspective gained by environmental engineering professionals who have acquired private sector experience in their field prior to entering government service. Similarities do exist between positional responsibilities and requisite skills regardless of sector. However, working in civil service presents circumstances, priorities and rules that differ considerably from what practitioners in private companies and consulting firms are accustomed to (United States Bureau of Labor Statistics, 2009). Thus, in some ways the novice-to-expert progression may begin anew for practitioners who transition from the private sector to government service, or vice-versa. Further investigation in this area may reveal that Dreyfus' novice-to-expert model has evolved into an iterative, recursive learning process rather than a singular, linear sequence of events followed in skill development.

Strengths of this study

One of the strengths of this study involved the collection and analysis of data from professionals with real-world experience in the field of environmental engineering and/or hazardous substances remediation. For respondents, experience in their chosen fields ranged from one to 37 years. The majority of respondents had developed their skills through a combination of training and many years of experience: 57% of the study sample reported 15 years or more of full-time or full-time equivalent (FTE) service in their professions. This level of experience gave the respondents in this study a solid base of first-hand, practical knowledge and experience from which they could express their opinions about the need for specific technical and professional skills and indicate where they believe these skills are most appropriately learned.

The study sample also included respondents from three employment classifications that were distinct, yet related: hazardous substances engineers, hazardous substances scientists, and engineering geologists. At the California Department of Toxic Substances Control (DTSC), professionals in all of these classifications have first-hand knowledge of the field of environmental engineering. Their specialties also make them uniquely qualified to express opinions about the different elements of environmental engineering. The fact that data for this study came from individuals working in these three areas lends a broader perspective to an analysis of the need for and development of specific skills in environmental engineering. It also illustrates the concept that while knowledge in many career paths and fields of study is specialized, there are overlapping areas between disciplines and the value of general, broad-based knowledge cannot be underestimated.

Limitations of this study

The most serious limitation of this study was the small sample size. At the time the survey was administered, 483 professional staff at DTSC were available and invited to participate. Responses were received from 112 respondents, making the sample size too small to generalize the results to either the larger population of working professionals involved with environmental engineering or to other engineering specialties. Data were collected from working professionals at only one government agency involved with environmental remediation.

However, in many cases the findings of this study are transferable, meaning they can be applied to a future study environmental engineering professionals in other locations, those employed by other organizations, or to engineers in other specialties. Furthermore, this study yielded insights that may be used in future studies where data may be collected from larger samples, professionals from multiple public agencies involved with environmental engineering and remediation, or multiple sectors. In addition, the sample size was sufficient to make recommendations for education and training programs for students seeking employment in the field of environmental engineering.

Implications for Higher Education Research and Practice

The findings of this study may be used to inform current and future environmental engineering training, either pre-employment during academic education or professional development after hiring programs. First, there is the value of synthesizing the knowledge gained through formal training with the understanding that can only acquired through on-the-job experience and in other areas. In addition, learning may take place outside of college or the workplace. This is particularly true in the case of professional skills. The importance of life experiences in the development of social and emotional skills, communication, teamwork and professional qualities deserves consideration in both academic and professional venues. Furthermore, the perspectives provided by working professionals based on their experiences of working in the discipline also provide valuable input that can be used in curriculum development.

Most notably, there was the overwhelming response by respondents who agreed or strongly agreed with the need for the development of specific professional skills. This clearly indicates that integrating professional skills such as communication and teamwork into the engineering curriculum is vital, even though doing so may present a logistical challenge for engineering programs because of the many rigorous courses in science, technology, engineering and math required to achieve competency in these areas. Given the heavy technical course load required in engineering disciplines, the worthwhile objective of professional skills training may not easily be met in the context of traditional engineering curricula. Thus, it may be advisable to develop one or several innovative approaches to equipping environmental engineering students with the skills they need to ensure their success within the workplace.

One option might be to supplement traditional courses in engineering with training across the curriculum for professional skills. One example can be seen in the Writing Across the Curriculum (WAC) programs that have been successfully developed at a number of colleges and universities since the late 20th century (Mullin, 2008). WAC programs are based on the premise that the entire academic community is responsible for ensuring that their students develop effective writing skills. All departments in universities with WAC programs are expected to integrate writing into their other courses with the goal of making sure that their students receive continuous writing instruction throughout their undergraduate programs of study. Similar programs to develop other professional skills could be developed, at the undergraduate engineering level, or in the early stages of employment. This type of training might be titled "Professional skills across the Curriculum," and used to develop competency in skill sets like teamwork and communication that will benefit students as they transition from school to the workplace.

Cooperative education, in which engineering students complete one or more semesters acquiring hands-on experience in real work settings, can support the growth of both technical and professional skills. The value of placing students in learning situations that reflect employer needs while allowing students to engage in the practical application of the principles and skills they have learned in school is an idea that has withstood the test of time. It is worth considering for engineering students in all disciplines (Grubb and Badway, 1995). Cooperative education programs form a natural environment for academic faculty, employers and students to collaborate and share technical as well as professional skill needs. This helps students acquire leading-edge skills and ensures that academic programs remain current with the dynamic needs of the workplace.

Training in professional skills for environmental engineers who have completed their formal undergraduate education could also be integrated into the continuing education programs required and/or provided by many employers. Nearly all government agencies offer a specified number of annual hours of continuing education so that employees can remain current in technical skills (Department of Toxic Substances

Control, 2009a). Supplementing course content for both technical and professional skills may enable environmental engineers in civil service to update their current abilities in the use of instruments and scientific applications and acquire or polish the professional skills they need to communicate effectively with others.

Another alternative might involve integrating professional skill development into the lower-division, general education coursework currently required for all baccalaureate students. This may be done at either four-year universities or community colleges. For example, University of the Pacific publicizes that its graduates are "practice ready" (University of the Pacific, 2010). Assuring that students have mastered common professional skills would both raise the image of a baccalaureate degree as well as raise the income potential of college graduates.

Finally, since working professionals in the field of environmental engineering have gained unique and valuable perspectives from their experiences of completing projects and interacting on a daily basis with a diverse set of individuals, higher education may seek the input of these individuals on a regular basis, either through mentoring programs, leadership councils, or workshops where faculty and administrators in engineering programs at colleges and universities are given the opportunity to interact and even collaborate with working professionals – and subsequently take the knowledge they acquire back into the classroom.

Recommendations for Employers

Employers can also play at least three roles in skill development for environmental engineers. The first way is by offering training and development opportunities for new employees, including upper-level students in company professional development, and pairing new employees with experienced mentors who can provide recent graduates with working knowledge of the appropriate professional knowledge, skills, abilities and traits for the job (Harris & Cullen, 2009). For example, an inexperienced engineer whose writing skills need further development might co-author a report with an experienced colleague or seek peer review from veteran staff. Sponsoring cooperative education is another option. Long recognized as an effective practice for integrating both technical and professional skills through real-world experiences, cooperative education is the most highly recognized form of employer engagement in preparing future professionals for the workplace. Its value in exposing students and prospective employees to the situations they will routinely face cannot be underestimated (Schuurman, Pangborn & McClintic, 2008). Cooperative education, mentoring programs and other collaborative efforts that augment formal training with hands-on, real-world experience may also make environmental engineering graduates more valuable and marketable as employers look for professionals who demonstrate that they have both competence in fundamental technical skills and the ability to apply the softer skills they learn through training, employment and life experiences to their relationships with their colleagues and clients (Walters & Zarifa, 2008).

Areas for Future Research

Future research may extend the findings of this study by conducting similar studies at other local, state and federal agencies specifically designated with the responsibility of protecting the environment. Doing so would result in a larger study sample and collect data from respondents working from multiple perspectives. For example, an environmental engineer for a county agency involved in the remediation of hazardous materials might have a different perspective from his or her counterpart at the state or federal level. Additional insights would also be gained by replicating this study with at least three other groups of experienced environmental engineers: those who work for other government agencies that are not specifically designated to perform environmental protection and remediation, but need to address the environmental impacts of carrying out their specified mission, such as the development of infrastructure; those who work for private consulting firms; and those employed by organizations considered directly responsible for doing or fixing? Clarify here environmental hazards such as groundwater contamination.

For scientific and technical disciplines (including engineering) there is a growing recognition that students need a broad-based set of knowledge, skills, abilities and traits that includes at least a basic understanding of communication, teamwork and other professional skills (Richter & Paretti, 2009; Tobias, 1998). A study of this type that draws upon the experiences of working professionals in other engineering specialties might yield valuable insights that could inform the development of new curricula in postsecondary education or in workforce development programs.

Respondents in this study emphasized that life experiences, including those prior to college, are considered pivotal in the development of professional skills. The findings of this study also indicate that many of the fundamental skills in mathematics and science considered necessary for the field of environmental engineering are developed in high school or even earlier. Thus, additional research into the value of early education in math and science for engineers in all specialties might yield valuable insights.

Finally, the role of socialization for the development of professionals in all disciplines, and the synthesis of personal experience, formal education and on-the-job training is a potential area of research that is worthy of consideration. The manner in which this can occur effectively, from the perspective of senior professionals, merits further study and may yield significant findings.

Summary and Implications

Looking at the data from the perspective of higher education, specifically schools of engineering, raises the question: What is it that the college could learn from these findings? On one level, faculty and administrators in environmental engineering programs might want to examine the results and the evidence and use them to inform and support changes in curriculum to ensure that students who graduate from their programs are better prepared to enter the workplace. They might be motivated to cultivate effective mentoring relationships with working professionals. For example, alumni of their programs who have worked in the field of environmental engineering for several years, or even decades, would be an extremely valuable resource for both contacts and information as engineering faculty and administrators endeavor to develop or modify coursework or seek to establish cooperative learning opportunities.

From another perspective, leaders of organizations that employ environmental engineers would also benefit from the results of this study. They could use the findings of this study to identify and develop continuing education opportunities and in-service training. In-service training and continuing education would enable current employees to upgrade their technical abilities and develop and refine their professional skills. This could be done in a cost-effective manner. For example, a government agency could identify personnel with good writing skills and provide them with the resources they need to conduct writing workshops for their colleagues.

Finally, it is conceivable that collaborative efforts between higher education and practitioners in environmental engineering, such as cooperative education, could prove to be mutually beneficial for both higher education and the workplace. Current employees could benefit from enhanced training in both technical and professional skills provided by the institution, while students would have increased opportunities for hands-on experiences that will enable them to further develop and refine their skills. This would allow current and future professionals in the field of environmental engineering, and the private and public agencies that employ them, to ensure that they remain competitive and current with scientific innovations, social, economic and political changes that will ultimately affect society and the environment on local, national and global levels.

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APPENDIX A: SELF-REPORTING SURVEY INSTRUMENT

Survey: Required Skill Sets for Environmental Engineering

1. Introduction - ABOUT THE STUDY (Statement/Question 1 of 36):

"REQUIRED SKILL SETS FOR ENVIRONMENTAL ENGINEERING: WHERE SKILLS ARE LEARNED" is a doctoral study currently being conducted through the Benerd School of Education at the University of the Pacific, Stockton, California.

PURPOSE: The purpose of this study is to investigate the knowledge, skills, abilities and traits required of environmental engineers, and to learn where these skills are developed, based on the views of experts in the field.

CONDITIONS AND NATURE OF THIS STUDY: You are invited to participate in this study because of your experience in the profession of environmental engineering as a hazardous substances engineer, engineering geologist, or hazardous substances scientist. Your participation in this study is completely voluntary: at any time, you may choose to withdraw (exit the survey) or to not participate in the study.

BENEFITS OF THIS STUDY: If you choose to participate in this study, the benefit will be that you will have the opportunity to provide input that will be used to improve current and future programs in Science, Technology, Engineering and Mathematics (STEM education) at four-year universities and community colleges. This study can also aid in hiring, training and retention at agencies that employ environmental engineering professionals. In addition, at the end of the survey you will be given the opportunity to request a summary of the findings of this study after it is completed.

RISKS: *There are no known or foreseeable risks at this time from participating in this study.*

ESTIMATED TIME OF COMPLETION: There are 36 questions in this survey. The average time to complete this survey is approximately 20 minutes. Your time may vary.

CONFIDENTIALITY: Records identifying survey participants will be kept confidential as permitted by applicable state and federal laws and regulations and will not be made publicly available. However, federal government regulatory agencies and the Institutional Review Board at University of the Pacific (a committee that reviews and approves research studies involving human subjects) may inspect the records of this survey for quality assurance purposes only. These records may contain private information. This type of inspection is extremely rare.

To ensure confidentiality, all personal identifiers (e.g. names and contact information) will be removed from the data reports prior to analysis. In addition, this survey is encrypted for your protection. Data (responses to the questions) will be aggregated (grouped) for the purpose of statistical analysis and reporting. Identifying information will be separated from the data. All computer-generated disks or printouts containing data from this study will be secured in a locked filing cabinet. All files containing identifying information and raw data will be destroyed on or before June 30, 2011.

FOR FURTHER INFORMATION: If you have questions or need additional information, you may contact Kathaleen Reed, Doctoral Candidate (916-753-6041 or kreed@pacific.edu); Dr. Norena Norton Badway, Doctoral Advisor (209-601-7121 or nbadway@pacific.edu); or Carol Brodie, Research and Graduate Studies Office (209-946-7356 or cbrodie@pacific.edu).

If you understand the above information and are willing to participate in the study, please indicate this in your response to Question #1, below.

Thank you for your participation.

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Survey: Required Skill Sets for Environmental Engineering

1. By typing the word "Yes" in the box below, I indicate that I understand my participation in this study is completely voluntary and will be kept confidential to the extent allowed by law. I know that I may exit the survey and discontinue participation at any time, and I agree to participate in this study.

2. Demographic Information (Questions 2 through 5 of 36):

In this section, you will be asked to provide information about yourself.

2. What is your gender?

- Male
- Female
- Decline to answer

3. What is your ethnicity?

- African American
- Asian American
- Pacific Islander
- Filipino
- Native American
- Other (please specify)
- Hispanic
- Caucasian
- Multi-ethnic
- Decline to answer

4. How many years of full-time or full-time equivalent government service do you have?

Actual number of years:

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Survey: Required Skill Sets for Environmental Engineering

5. What is your job classification?

- ◯ Hazardous Substances Engineer
- ◯ Senior Hazardous Substances Engineer
- ◯ Supervising Hazardous Substances Engineer (I or II)
- ◯ Hazardous Substances Scientist
- ◯ Senior Hazardous Substances Scientist
- ◯ Supervising Hazardous Substances Scientist (I or II)
- ◯ Engineering Geologist
- ◯ Senior Engineering Geologist
- ◯ Supervising Engineering Geologist (I or II)
- ◯ Other (please specify)

3. Education (Questions 6 through 8 of 36):

This section is designed to collect information about your educational background.

6. What is the highest level of post-secondary education you have completed?

- ◯ Bachelor's degree (BS/BA)
- ◯ Master's degree (MS/MA)
- ◯ Doctorate (Ph.D.)
- ◯ Other (please specify)

7. What was your major field of study?

A. Undergraduate

B. Graduate (if applicable)

8. Have you attended a community college?

- ◯ Yes
- ◯ No

4. Military Service (Questions 9 through 11 of 36):

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This section is designed to collect information about any military service you may have had, including any education you may have received as a result of military service.

If you did not serve in the military, you may skip Questions 10 and 11 and press the "Next" button to continue on to Question 12.

9. Have you ever served in the military?

- ○ Yes
- ○ No

10. If you served in the military, in which branch(es) did you serve? Please check all that apply.

- ☐ Not applicable
- ☐ U.S. Army
- ☐ U.S. Navy
- ☐ U.S. Marines
- ☐ U.S. Air Force
- ☐ U.S. National Guard
- ☐ U.S. Coast Guard
- ☐ Reserves
- ☐ Merchant Marine
- ☐ Other (please specify)

11. If your answer to Question #9 was "Yes," did the military provide or pay for any of your postsecondary education?

- ○ Not applicable
- ○ Yes
- ○ No

5. Your opinion about job-related skills (Questions 12 through 21 of 36):

In this section, you will be asked about your opinions of specific knowledge, skills, abilities and traits in science, technology, engineering, mathematics and other areas that may apply to your field, and where you think these skills are learned. Each set of skills has a pair of questions: one asks you to rate specific skills, while the other asks where you think they are learned. Note: You may use "Other" to expand on

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your response.

12. Scientific skills: Knowledge and proficiency in the following scientific areas are critical for technical staff and project managers in this field:

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree	Not applicable
Global environmental science	○	○	○	○	○	○
Geology	○	○	○	○	○	○
Biology	○	○	○	○	○	○
Chemistry	○	○	○	○	○	○
Physics	○	○	○	○	○	○

13. Where the following scientific skills are most likely to be learned:

	In college	On the job	Both	Neither	Not applicable
Global environmental science	○	○	○	○	○
Geology	○	○	○	○	○
Biology	○	○	○	○	○
Chemistry	○	○	○	○	○
Physics	○	○	○	○	○

Other (please specify)

14. Technical skills: It is critical for technical staff and project managers in this field to have the skills needed to perform the following tasks:

	Strongly disagree	Disagree	Neither disagree nor agree	Agree	Strongly agree	Not applicable
Evaluate environmental impacts	○	○	○	○	○	○
Perform routine quality assurance/ quality control checks	○	○	○	○	○	○
Use industry-standard software and hardware	○	○	○	○	○	○
Read and interpret maps, diagrams and other graphics	○	○	○	○	○	○
Create accurate maps, diagrams and other graphics	○	○	○	○	○	○

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15. Where knowledge and skills in the following technical tasks are most likely learned:

	In college	On the job	Both	Neither	Not applicable
Evaluate environmental impacts	○	○	○	○	○
Perform routine quality assurance/ quality control checks	○	○	○	○	○
Use industry-standard software and hardware	○	○	○	○	○
Read and interpret maps, diagrams and other graphics	○	○	○	○	○
Create accurate maps, diagrams and other graphics	○	○	○	○	○

Other (please specify)

16. Engineering skills: Knowledge and proficiency in the following engineering specialties are critical for technical staff and project managers in this field:

	Strongly disagree	Disagree	Neither disagree nor agree	Agree	Strongly agree	Not applicable
Environmental engineering	○	○	○	○	○	○
Mechanical engineering	○	○	○	○	○	○
Civil engineering	○	○	○	○	○	○
Structural engineering	○	○	○	○	○	○
Chemical engineering	○	○	○	○	○	○
Engineering geology	○	○	○	○	○	○

17. Where knowledge and skills in the following engineering specialties are most likely learned:

	In college	On the job	Both	Neither	Not applicable
Environmental engineering	○	○	○	○	○
Mechanical engineering	○	○	○	○	○
Civil engineering	○	○	○	○	○
Structural engineering	○	○	○	○	○
Chemical engineering	○	○	○	○	○
Engineering geology	○	○	○	○	○

Other (please specify)

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Survey: Required Skill Sets for Environmental Engineering

18. Mathematical ability: Knowledge and proficiency in the following mathematical areas are critical for technical staff and project managers in this field:

	Strongly disagree	Disagree	Neither disagree nor agree	Agree	Strongly agree	Not applicable
Statistics	O	O	O	O	O	O
Modeling (e.g. process or groundwater)	O	O	O	O	O	O
Algebra	O	O	O	O	O	O
Geometry	O	O	O	O	O	O
Trigonometry	O	O	O	O	O	O
Calculus	O	O	O	O	O	O

19. Where the following mathematical skills are most likely learned:

	In college	On the job	Both	Neither	Not applicable
Statistics	O	O	O	O	O
Modeling (e.g. process or groundwater)	O	O	O	O	O
Algebra	O	O	O	O	O
Geometry	O	O	O	O	O
Trigonometry	O	O	O	O	O
Calculus	O	O	O	O	O

Other (please specify)

20. Other scientific and technical capabilities: Proficiency in the following additional areas is critical for technical staff and project managers in this field:

	Strongly disagree	Disagree	Neither disagree nor agree	Agree	Strongly agree	Not applicable
Chemical fate and transport	O	O	O	O	O	O
Hazardous materials remediation	O	O	O	O	O	O
Groundwater contamination	O	O	O	O	O	O
Vapor intrusion	O	O	O	O	O	O
Workplace health and safety	O	O	O	O	O	O
Public health and safety	O	O	O	O	O	O

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21. Where knowledge, skills and abilities in the following other areas are most likely to be developed:

	In college	On the job	Both	Neither	Not applicable
Chemical fate and transport	O	O	O	O	O
Hazardous materials remediation	O	O	O	O	O
Groundwater contamination	O	O	O	O	O
Vapor intrusion	O	O	O	O	O
Workplace health and safety	O	O	O	O	O
Public health and safety	O	O	O	O	O

Other (please specify)

6. Your opinion about professional skills (Questions 22 through 31 of 36):

In this section, you will be asked about your opinion of the importance of specific professional skills in your field, and where you think these skills are learned. Each set of skills has a pair of questions: one asks you to rate specific skills, while the other asks where you think they are learned. Note: You may use "Other" to expand on your response.

22. Communication: The ability to perform the following communication tasks is critical for technical staff and project managers in this field:

	Disagree strongly	Disagree	Neither agree nor disagree	Agree	Strongly agree	Not applicable
Interview	O	O	O	O	O	O
Engage in conversation with another person	O	O	O	O	O	O
Communicate in a group setting	O	O	O	O	O	O
Speak in public	O	O	O	O	O	O
Write effective memos and reports	O	O	O	O	O	O
Use correct grammar	O	O	O	O	O	O
Support written reports with evidence	O	O	O	O	O	O

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Survey: Required Skill Sets for Environmental Engineering

23. Where the following communication skills are most likely to be learned:

	In college	On the job	Both	Neither	Life experiences	Not applicable
Interview	O	O	O	O	O	O
Engage in conversation with another person	O	O	O	O	O	O
Communicate in a group setting	O	O	O	O	O	O
Speak in public	O	O	O	O	O	O
Write effective memos and reports	O	O	O	O	O	O
Use correct grammar	O	O	O	O	O	O
Support written reports with evidence	O	O	O	O	O	O

Other (please specify)

24. Teamwork/collaboration: The following teamwork and collaboration skills are critical for technical staff and project managers in this field:

	Disagree strongly	Disagree	Neither agree nor disagree	Agree	Strongly agree	Not applicable
Share key ideas	O	O	O	O	O	O
Acknowledge the work of others	O	O	O	O	O	O
Listen patiently during conflicts	O	O	O	O	O	O
Support consensus even if not in total agreement	O	O	O	O	O	O
Share credit for ideas	O	O	O	O	O	O
Seek help in identifying and achieving goals	O	O	O	O	O	O
Solve problems collaboratively	O	O	O	O	O	O
Keep others informed in a time-conscious manner	O	O	O	O	O	O

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Survey: Required Skill Sets for Environmental Engineering

25. Where the following teamwork and collaboration skills are most likely to be learned:

	In college	On the job	Both	Neither	Life experiences	Not applicable
Share key ideas	○	○	○	○	○	○
Acknowledge the work of others	○	○	○	○	○	○
Listen patiently during conflicts	○	○	○	○	○	○
Support consensus even if not in total agreement	○	○	○	○	○	○
Share credit for ideas	○	○	○	○	○	○
Seek help in identifying and achieving goals	○	○	○	○	○	○
Solve problems collaboratively	○	○	○	○	○	○
Keep others informed in a time-conscious manner	○	○	○	○	○	○

Other (please specify)

26. Professional qualities: The following professional qualities are critical for technical staff and project managers in this field:

	Disagree strongly	Disagree	Neither agree nor disagree	Agree	Strongly agree	Not applicable
Integrity	○	○	○	○	○	○
Empathy	○	○	○	○	○	○
Concern for others	○	○	○	○	○	○
Flexibility	○	○	○	○	○	○
A sense of humor	○	○	○	○	○	○
The ability to plan ahead	○	○	○	○	○	○
The ability to learn from others	○	○	○	○	○	○
Work ethic	○	○	○	○	○	○
Resourcefulness	○	○	○	○	○	○

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27. Where the following professional qualities are most likely to be developed:

	In college	On the job	Both	Neither	Life experiences	Not applicable
Integrity	○	○	○	○	○	○
Empathy	○	○	○	○	○	○
Concern for others	○	○	○	○	○	○
Flexibility	○	○	○	○	○	○
A sense of humor	○	○	○	○	○	○
The ability to plan ahead	○	○	○	○	○	○
The ability to learn from others	○	○	○	○	○	○
Work ethic	○	○	○	○	○	○
Resourcefulness	○	○	○	○	○	○

Other (please specify)

28. Social and emotional skills: The following social and emotional skills are critical for technical staff and project managers in this field:

	Disagree strongly	Disagree	Neither agree nor disagree	Agree	Strongly agree	Not applicable
Managing ones' own emotions	○	○	○	○	○	○
Understanding others' moods	○	○	○	○	○	○
Responding in an effective way	○	○	○	○	○	○
Influencing others appropriately	○	○	○	○	○	○

29. Where the following social and emotional skills are most appropriately developed:

	In college	On the job	Both	Neither	Life experiences	Not applicable
Managing ones' own emotions	○	○	○	○	○	○
Understanding others' moods	○	○	○	○	○	○
Responding in an effective way	○	○	○	○	○	○
Influencing others appropriately	○	○	○	○	○	○

Other (please specify)

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Survey: Required Skill Sets for Environmental Engineering

30. Intellectual abilities and learning skills: The following traits are critical for technical staff and project managers in this field:

	Disagree strongly	Disagree	Neither agree nor disagree	Agree	Strongly agree	Not applicable
Intellectual curiosity	O	O	O	O	O	O
Critical thinking	O	O	O	O	O	O
Assimilation	O	O	O	O	O	O
Professional growth	O	O	O	O	O	O
Independent learning	O	O	O	O	O	O
Lifelong learning	O	O	O	O	O	O

31. Where the following traits are most appropriately developed:

	In college	On the job	Both	Neither	Life experiences	Not applicable
Intellectual curiosity	O	O	O	O	O	O
Critical thinking	O	O	O	O	O	O
Assimilation	O	O	O	O	O	O
Professional growth	O	O	O	O	O	O
Independent learning	O	O	O	O	O	O
Lifelong learning	O	O	O	O	O	O

Other (please specify)

7. Other areas pertaining to your field (Questions 32 through 36 of 36):

In this section, you have the opportunity to provide input in your own words about areas that may not have been covered in the preceding questions.

32. What advice would you give to someone considering your profession as a career choice?

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APPENDIX B: INITIAL SURVEY INVITATION

(Sent via email on October 13, 2009)

Dear ___________,

My name is Kathaleen Reed and I am one of the support staff in the Geologic Services Branch at DTSCs Cal Center office in Sacramento.

Currently, I am also working on my doctorate in Educational Leadership in the Benerd School of Education at University of the Pacific and would like to ask for a few minutes of your time to help me with a survey that will allow me to collect crucial data for my dissertation study, titled *Required Skill Sets for Environmental Engineering: Where Skills Are Learned.* You are invited to participate in my study via a short online questionnaire. I am asking this favor of you because of your familiarity with the profession of environmental engineering, either as a Hazardous Substances Engineer, Engineering Geologist, or Hazardous Substances Scientist. **Please note:** Your participation is voluntary and all responses are confidential.

VERY IMPORTANT: Out of respect for your time and because of the voluntary nature of this study, I ask respondents to **opt-in** and will **ONLY** send the electronic link for the questionnaire to individuals who indicate their willingness to participate as follows: To participate in this study, **please reply to me by email with the word YES in the subject line as soon as possible but no later than C.O.B. Thursday, October 29, 2009.** Once I receive your reply, I will email you a link to a secure, encrypted online survey.

Benefits: The results of this study may aid in skill set development and mentoring for new employees, collaboration, leadership development, succession planning and other matters of importance to you and your colleagues at DTSC. You also have the opportunity to provide input for the improvement of current and future programs in Science, Technology, Engineering and Mathematics (STEM) programs at the universities and community colleges that train your future colleagues. In addition, at the end of the survey you will be given the opportunity to request a summary of the findings of the completed study.

Risks: There are not any known risks associated with participating.
There is no cost to you or to DTSC for participation in this study, and because of the subject matter it is considered work-related.

Thank you in advance for your assistance. I look forward to hearing from you soon. Please feel free to contact me should you have any questions.

APPENDIX C: EMAIL REMINDER TO STUDY RESPONDENTS

October 21, 2009

Dear __________,

As I mentioned in my email on October 13, I'm currently conducting a study for my doctoral dissertation. If you have already responded, thank you. If not, this is a friendly reminder that there's still time to participate. I would like to ask for a few minutes of your time to assist me with a questionnaire that will enable me to collect crucial data for my dissertation study, titled *Required Skill Sets for Environmental Engineering: Where Skills Are Learned.*

The topic deals specifically with the skills students and graduates will need to learn to perform successfully in an agency like DTSC. Because of your expertise in and knowledge of the profession of environmental engineering, either as a Hazardous Substances Engineer, Engineering Geologist, or Hazardous Substances Scientist, you are invited to participate in this study. Completion of the questionnaire takes about 20 minutes. Your participation will be kept confidential and, because of the subject matter, it is work-related.

<u>Reminder</u>: Since this study is voluntary, I am using an **opt-in process** and will **ONLY** send the electronic link for the questionnaire to individuals who indicate willingness to participate by replying to this email with the word "YES" in the subject line no later than **C.O.B. Thursday, October 29**. Once I receive your reply, I cansend you a link to a secure, encrypted online form. Your participation is voluntary and all responses will be kept confidential.

<u>NOTE</u>: If you prefer a paper version of the questionnaire, please let me know and I will send you a hard copy.

Again, thank you for your time and assistance. I look forward to hearing from you soon as your response will be extremely helpful. Please feel free to contact me should you have any questions.

APPENDIX D: EMAIL WITH LINK TO ELECTRONIC SURVEY

October 13, 2009

Dear __________,

Thank you for your positive response to the invitation to participate in my study. As I noted in my earlier message, I am currently collecting data for my dissertation, titled *"Required Skill Sets for Environmental Engineering: Where Skills Are Learned."*

Here is your link to the questionnaire:
https://www.surveymonkey.com/s.aspx?sm=f9N8x_2f095C7CXjQtNdFtbg_3d_3d

If you know anyone else who may be interested in participating, please have them contact me directly. The questionnaire will be available for your completion **until C.O.B. Friday, October 30, 2009**. Participation is voluntary, and it takes an average of 20 minutes to complete the questionnaire: your time may vary.

Again, thank you for your assistance and participation in the study. Please feel free to contact me should you have any questions.

Yours truly,
Kathaleen Reed
Phone: 916-255-6577
Email: kreed@dtsc.ca.gov

Alternate contact information:
Cell: 916-753-6041
Academic email: k_reed@pacific.edu

Opt-Out Notice: If you do not wish to receive further emails from me regarding this study, please click the link below, and you will be automatically removed from the mailing list: https://www.surveymonkey.com/optout.aspx

Note: Should you prefer to complete a hard copy of the questionnaire, a PDF file is attached for your convenience. You may print it out, complete it and return it to me either in person or via interoffice mail. Thank you.

APPENDIX E: REMINDER EMAIL WITH LINK TO ELECTRONIC SURVEY

October 22, 2009

Dear __________,

This is a follow up to the email I sent you on October 13 containing the link to the electronic survey. If you have already completed your survey, thank you. If not, this is a friendly reminder that there's still time to participate. I would like to ask for a few minutes of your time to assist me with an electronic questionnaire that will enable me to collect crucial data for my dissertation study, titled *Required Skill Sets for Environmental Engineering: Where Skills Are Learned.* Here is your link to the questionnaire: https://www.surveymonkey.com/s.aspx?sm=f9N8x_2f095C7CXjQtNdFtbg_3d_3d

The survey will be available until **C.O.B. Friday, October 30, 2009**. Again, your participation is voluntary and it only takes an average of 20 minutes to complete the questionnaire. Your time may vary.

Again, thank you for your assistance and participation in the study. Please feel free to contact me should you have any questions..

Yours truly,
Kathaleen Reed
Phone: 916-255-6577
Email: kreed@dtsc.ca.gov

Alternate contact information:
Cell: 916-753-6041
Academic email: k_reed@pacific.edu

Opt-Out Notice: If you do not wish to receive further emails from me regarding this study, please click the link below, and you will be automatically removed from the mailing list: https://www.surveymonkey.com/optout.aspx

Note: Should you prefer to complete a hard copy of the questionnaire, a PDF file is attached for your convenience. You may print it out, complete it and return it to me either in person or via interoffice mail. Thank you.

APPENDIX F: CROSSTABULATIONS – RESEARCH QUESTION #1

RQ1: Level and classification x technical skills

		Level			Classification		
N = 112	Dist.	Tech	Senior	Supervisor	HSE	HSS	EG
Science							
Disagree	4.70%	5.19%	5.00%	2.86%	3.52%	4.00%	7.14%
Neutral	15.19%	16.23%	18.57%	7.62%	18.59%	13.50%	12.99%
Agree	80.11%	78.57%	76.43%	89.52%	77.89%	82.50%	79.87%
Technology							
Disagree	2.71%	2.59%	4.29%	0.95%	1.50%	4.02%	2.58%
Neutral	10.11%	10.68%	10.71%	7.62%	12.50%	9.55%	7.74%
Agree	87.18%	86.73%	85.00%	91.43%	86.00%	86.43%	89.68%
Engineering							
Disagree	13.32%	12.18%	18.01%	10.48%	11.11%	13.14%	16.67%
Neutral	30.09%	28.61%	32.92%	30.65%	16.24%	40.25%	35.12%
Agree	56.58%	59.21%	49.07%	58.87%	72.65%	46.61%	48.21%
Mathematics							
Disagree	7.19%	6.85%	6.71%	8.80%	8.90%	8.05%	3.85%
Neutral	23.70%	22.74%	28.05%	20.80%	17.80%	29.66%	23.63%
Agree	69.11%	70.41%	65.24%	70.40%	73.31%	62.29%	72.53%
Other							
Disagree	0.45%	0.54%	0%	0.79%	0%	0.42%	1.08%
Neutral	5.86%	4.03%	7.14%	9.52%	7.50%	5.42%	4.30%
Agree	93.69%	95.43%	92.86%	89.68%	92.50%	94.17%	94.62%

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APPENDIX F (Continued)

RQ1: Level and classification x professional skills

		Level			Classification		
N = 112	Dist	Tech	Senior	Supervisor	HSE	HSS	EG
Communication							
Disagree	0.65%	0.46%	0.53%	1.37%	0.37%	0.71%	0.93%
Neutral	1.95%	2.07%	2.66%	0.68%	2.94%	1.07%	1.85%
Agree	97.40	97.47%	96.81%	97.95%	96.69%	98.21%	97.22%
Teamwork							
Disagree	0.65%	0.23%	1.59%	0.68%	0.37%	1.08%	0.46%
Neutral	7.42%	9.95%	3.70%	4.76%	9.52%	3.23%	10.19%
Agree	91.93	89.81%	94.71%	94.56%	90.11%	95.70%	89.35%
Professional qualities							
Disagree	0.61%	0.72%	0.41%	0.53%	0.57%	0.56%	0.72%
Neutral	5.46%	5.91%	5.35%	4.26%	4.86%	4.17%	7.89%
Agree	93.93%	93.37%	94.24%	95.21%	94.57%	95.28%	91.4%
Social and emotional skills							
Disagree	0.23%	0.41%	0.00%	0.00%	0.00%	0.63%	0.00%
Neutral	6.41%	6.10%	11.11%	1.20%	5.84%	5.63%	8.13%
Agree	93.36	93.50%	88.89%	98.80%	94.16%	93.75%	91.87%
Intellectual traits							
Disagree	0.92%	1.63%	0.00%	0.00%	2.15%	0.00%	0.54%
Neutral	7.33%	7.07%	9.88%	4.80%	8.15%	5.88%	8.15%
Agree	91.76	91.30%	90.12%	95.20%	89.70%	94.12%	91.30%

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APPENDIX F (Continued)

RQ1: Education x technical skills

		Highest educational level			Community college	
N = 112	Dist.	BS/BA	MS/MA	Ph.D.	Yes	No
Science						
Disagree	4.70%	6.06%	3.53%	2.94%	6.92%	2.27%
Neutral	15.19%	16.29%	15.29%	5.88%	17.30%	12.88%
Agree	80.11%	77.65%	81.18%	91.18%	75.78%	84.85%
Technology						
Disagree	2.71%	2.65%	1.18%	14.29%	3.11%	2.26%
Neutral	10.11%	8.33%	11.37%	14.29%	9.34%	10.94%
Agree	87.18%	89.02%	87.45%	71.43%	87.54%	86.79%
Engineering						
Disagree	13.32%	15.56%	10.54%	16.67%	15.74%	10.83%
Neutral	30.09%	26.16%	35.37%	21.43%	25.31%	35.03%
Agree	56.58%	58.28%	54.08%	61.90%	58.95%	54.14%
Mathematics						
Disagree	7.19%	6.09%	8.97%	2.44%	7.99%	6.33%
Neutral	23.70%	28.53%	20.60%	9.76%	23.96%	23.42%
Agree	69.11%	65.38%	70.43%	87.80%	68.05%	70.25%
Other technical areas						
Disagree	0.45%	0.63%	33.00%	0.00%	0.86%	0.00%
Neutral	5.86%	4.40%	6.54%	11.90%	5.17%	6.60%
Agree	93.69%	94.97%	93.14%	88.10%	93.97%	93.40%

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APPENDIX F (Continued)

RQ1: Education x professional skills

		Highest educational level			Community college	
N = 112	Dist.	BS/BA	MS/MA	Ph.D.	Yes	No
Communication						
Disagree	0.65%	0.81%	0.57%	0.00%	0.99%	0.28%
Neutral	1.95%	2.16%	1.15%	6.12%	1.23%	2.75%
Agree	97.40%	97.03%	98.28%	93.88%	97.78%	96.97%
Teamwork						
Disagree	0.65%	0.47%	0.57%	2.04%	0.65%	0.55%
Neutral	7.42%	9.95%	3.71%	6.12%	7.34%	6.89%
Agree	91.93%	89.57%	95.71%	91.84%	92.01%	92.56%
Professional qualities						
Disagree	0.61%	1.05%	0.22%	0.00%	0.96%	0.21%
Neutral	5.46%	3.78%	6.89%	7.94%	5.37%	5.56%
Agree	93.93%	95.17%	92.89%	92.06%	93.67%	94.23%
Social and emotional						
Disagree	0.23%	0.00%	0.51%	0.00%	0.44%	0.00%
Neutral	6.41%	5.21%	8.08%	3.57%	9.17%	3.37%
Agree	93.36%	94.79%	91.41%	96.43%	90.39%	96.63%
Intellectual traits						
Disagree	0.92%	0.00%	2.01%	0.00%	0.58%	1.29%
Neutral	7.33%	7.91%	6.04%	12.20%	9.28%	5.16%
Agree	91.76%	92.09%	91.95%	87.80%	90.14%	93.55%

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APPENDIX F (Continued)

RQ1: FTE x technical skills

		Years of Full-Time/FTE Government Service					
N = 112	Dist.	< 5	5-9.99	10-14.99	15-19.99	20-24.99	> 25
Science							
Disagree	4.70%	7.07%	6.32%	4.55%	3.53%	3.33%	3.64%
Neutral	15.19%	14.14%	12.63%	15.91%	17.65%	16.67%	14.55%
Agree	80.11%	78.79%	81.05%	79.55%	78.82%	80.00%	81.82%
Technology							
Disagree	2.71%	1.00%	0%	6.67%	8.24%	1.67%	1.83%
Neutral	10.11%	12.00%	12.63%	6.67%	10.59%	8.33%	9.17%
Agree	87.18%	87.00%	87.37%	86.67%	81.18%	90.00%	88.99%
Engineering							
Disagree	13.32%	15.45%	9.65%	26.92%	12.00%	14.18%	9.38%
Neutral	30.09%	14.55%	39.47%	17.31%	42.00%	25.37%	35.94%
Agree	56.58%	70.00%	50.88%	55.77%	46.00%	60.45%	54.69%
Mathematics							
Disagree	7.19%	5.08%	5.31%	5.56%	8.00%	8.45%	9.45%
Neutral	23.70%	22.88%	26.55%	25.93%	32.00%	19.72%	18.90%
Agree	69.11%	72.03%	68.14%	68.52%	60.00%	71.83%	71.65%
Other Technical Areas							
Disagree	0.45%	1.67%	0%	0%	0%	0%	0.76%
Neutral	5.86%	4.17%	5.26%	0%	7.84%	8.33%	6.06%
Agree	93.69%	94.17%	94.74%	100.00%	92.16%	91.67%	93.18%

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APPENDIX F (Continued)

RQ1: FTE x professional skills

		Years of Full-Time/FTE Government Service					
N = 112	Dist	< 5	5-9.99	10-14.99	15-19.99	20-24.99	>25
Communication							
Disagree	0.65%	0.71%	0.75%	0%	0.84%	0%	1.31%
Neutral	1.95%	2.14%	1.50%	1.61%	0%	4.35%	1.31%
Agree	97.40%	97.14%	97.74%	98.39%	99.16%	95.65%	97.39%
Teamwork							
Disagree	0.57%	0.63%	0.66%	0%	0.74%	0.54%	0.57%
Neutral	6.83%	9.49%	6.58%	15.28%	10.29%	1.63%	6.83%
Agree	92.60%	89.87%	92.76%	84.72%	88.97%	97.83%	92.60%
Professional Qualities							
Disagree	0.61%	1.67%	0.00%	1.23%	0.00%	0.48%	0.61%
Neutral	5.46%	6.67%	7.60%	6.17%	7.24%	2.42%	5.46%
Agree	93.93%	91.67%	92.40%	92.59%	92.76%	97.10%	93.93%
Social and emotional skills							
Disagree	0.23%	0.00%	0.00%	2.86%	0%	0%	0.23%
Neutral	6.41%	8.75%	6.58%	5.71%	5.97%	4.40%	6.41%
Agree	93.36%	91.25%	93.42%	91.43%	94.03%	95.60%	93.36%
Intellectual traits							
Disagree	0.92%	0.00%	0.89%	0%	4.90%	0%	0.92%
Neutral	7.33%	5.83%	3.57%	16.98%	7.84%	8.70%	7.33%
Agree	91.76%	94.17%	95.54%	83.02%	87.25%	91.30%	91.76

APPENDIX G: CROSSTABULATIONS – RESEARCH QUESTION #2

RQ2: Level and classification x technical skills (*N*= *112*)

Skill Set Area of learning	Dist.	Level			Classification		
		Technical	Senior	Super-visor	HSE	HSS	EG
Science							
In college	46.88%	50.00%	46.76%	38.10%	47.69%	45.73%	47.33%
Both	46.32%	40.67%	51.08%	56.19%	41.03%	49.75%	48.67%
On the job	6.07%	8.33%	1.44%	5.71%	10.26%	4.02%	3.33%
Neither	0.74%	1.00%	0.72%	0%	1.03%	0.50%	0.67%
Technology							
Both	54.56%	50.65%	59.71%	59.22%	52.28%	57.36%	53.90%
On the job	35.77%	42.16%	28.06%	27.18%	35.03%	35.53%	37.01%
In college	8.21%	6.86%	11.51%	7.77%	9.14%	6.60%	9.09%
Neither	1.46%	0.33%	0.72%	5.83%	3.55%	0.51%	0.00%
Engineering							
In college	70.67%	72.19%	69.33%	68.03%	72.05%	70.76%	68.75%
Both	22.31%	21.35%	20.86%	22.95%	20.96%	23.31%	22.73%
On the job	4.21%	6.18%	9.20%	8.20%	3.49%	4.66%	4.55%
Neither	2.81%	0.28%	0.61%	0.82%	3.49%	1.27%	3.98%
Mathematics							
Both	50.16%	48.84%	51.32%	52.59%	43.50%	48.00%	62.20%
In college	42.16%	42.44%	44.08%	38.79%	50.22%	41.78%	31.71%
On the job	6.37%	7.85%	1.32%	8.62%	4.93%	9.78%	3.66%
Neither	1.31%	0.87%	3.29%	0.00%	1.35%	0.44%	2.44%
Other technical areas							
Both	50.53%	50.29%	58.55%	62.93%	43.93%	63.33%	42.39%
On the job	45.40%	51.45%	48.03%	43.97%	48.95%	33.75%	55.98%
In college	4.07%	5.52%	3.95%	1.72%	7.11%	2.92%	1.63%
Neither	0%	0%	0%	0%	0%	0%	0%

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APPENDIX G (Continued)

RQ2: Level and classification x professional skills (*N*= *112*)

Skill Set Area of learning	Dist.	Level Technical	Senior	Super-visor	Classification HSE	HSS	EG
Communication							
Both	53.53%	49.88%	57.98%	58.62%	53.70%	53.96%	52.78%
On the job	18.06%	19.95%	19.68%	10.34%	19.63%	16.91%	17.59%
Life exp.	15.84%	16.94%	13.30%	15.86%	16.67%	15.47%	15.28%
In college	11.65%	12.53%	7.45%	14.48%	8.52%	13.31%	13.43%
Neither	0.92%	0.70%	1.60%	0.69%	1.48%	0.36%	0.93%
Teamwork							
Both	37.77%	39.15%	37.09%	34.55%	37.46%	35.74%	40.82%
On the job	29.28%	27.38%	38.50%	23.03%	26.06%	31.97%	29.80%
Life exp.	29.28%	30.83%	23.00%	32.73%	30.62%	30.72%	25.71%
In college	2.07%	1.62%	0.94%	4.85%	2.61%	1.25%	2.45%
Neither	1.61%	1.01%	0.47%	4.85%	3.26%	0.31%	1.22%
Professional qualities							
Life exp.	54.87%	57.45%	43.62%	61.83%	50.00%	57.10%	58.06%
Both	28.90%	23.34%	39.09%	32.26%	27.30%	27.58%	32.62%
On the job	7.40%	10.05%	5.35%	2.15%	9.20%	8.91%	3.23%
Neither	7.00%	6.82%	9.88%	3.76%	12.64%	4.18%	3.58%
In college	1.83%	2.33%	2.06%	0.00%	0.86%	2.23%	2.51%
Social and emotional skills							
Life exp.	58.77%	63.97%	48.15%	57.14%	56.41%	58.75%	61.79%
Both	23.23%	16.60%	32.41%	30.95%	23.72%	18.75%	28.46%
On the job	10.02%	10.93%	10.19%	7.14%	13.46%	12.50%	2.44%
Neither	4.78%	4.05%	6.48%	4.76%	6.41%	3.13%	4.88%
In college	3.19%	4.45%	2.78%	0.00%	0.00%	6.88%	2.44%
Intellectual traits							
Both	37.33%	32.60%	44.10%	42.40%	37.93%	36.71%	37.36%
Life exp.	35.64%	38.08%	27.95%	38.40%	31.47%	36.29%	40.11%
On the job	14.59%	16.44%	14.29%	9.60%	15.52%	17.72%	9.34%
In college	8.14%	9.86%	6.21%	5.60%	7.33%	8.02%	9.34%
Neither	4.30%	3.01%	7.45%	4.00%	7.76%	1.27%	3.85%

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APPENDIX G (Continued)

RQ2: Education x technical skills (*N*= *112*)

Skill Set		Highest educational level			Community college	
Area of learning	Dist.	BS/BA	MS/MA	Ph.D.	Yes	No
Science						
In college	46.88%	41.22%	49.80%	69.70%	47.54%	46.15%
Both	46.32%	52.67%	42.97%	21.21%	44.01%	48.85%
On the job	6.07%	4.58%	7.23%	9.09%	7.04%	5.00%
Neither	0.74%	1.53%	0.00%	0.00%	1.41%	0.00%
Technology						
Both	54.56%	58.30%	49.61%	62.86%	54.23%	54.92%
On the job	35.77%	35.52%	38.98%	14.29%	36.97%	34.47%
In college	8.21%	6.18%	8.27%	22.86%	8.45%	7.95%
Neither	1.46%	0.00%	3.15%	0.00%	0.35%	2.65%
Engineering						
Both	50.16%	49.15%	52.35%	42.86%	46.95%	53.49%
In college	42.16%	43.00%	39.71%	52.38%	44.05%	40.20%
On the job	6.37%	7.85%	5.78%	0%	7.40%	5.32%
Neither	1.31%	0%	2.17%	4.76%	1.61%	1.00%
Mathematics						
Both	50.53%	20.97%	22.34%	32.50%	47.40%	53.94%
On the job	45.40%	5.48%	3.44%	0.00%	50.00%	40.38%
In college	4.07%	71.29%	71.48%	60.00%	2.60%	5.68%
Neither	0%	2.26%	2.75%	7.50%	0%	0%
Other Technical Areas						
Both	50.53%	47.15%	52.13%	64.29%	47.40%	53.94%
On the job	45.40%	50.63%	43.93%	16.67%	50.00%	40.38%
In college	4.07%	2.22%	3.93%	19.05%	2.60%	5.68%
Neither	0%	0%	0%	0%	0%	0%

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APPENDIX G (Continued)

RQ2: Education x professional skills (*N= 112*)

Skill Set Area of learning	Dist.	Highest educational level BS/BA	MS/MA	Ph.D.	Community college Yes	No
Communication						
Both	53.53%	57.61%	47.26%	67.35%	55.09%	51.80%
On the job	18.06%	15.76%	21.61%	10.20%	17.87%	18.28%
Life experiences	15.84%	15.22%	17.58%	8.16%	15.38%	16.34%
In college	11.65%	10.60%	12.68%	12.24%	10.67%	12.74%
Neither	0.92%	0.82%	0.86%	2.04%	0.99%	0.83%
Teamwork						
Both	37.77%	40.14%	33.50%	50.00%	38.78%	36.65%
On the job	29.28%	31.12%	27.92%	25.00%	29.41%	29.13%
Life experiences	29.28%	24.23%	35.28%	25.00%	27.45%	31.31%
In college	2.07%	1.66%	2.79%	0.00%	1.53%	2.67%
Neither	1.61%	2.85%	0.51%	0.00%	2.83%	0.24%
Professional qualities						
Life experiences	54.87%	52.21%	60.04%	38.10%	50.77%	59.44%
Both	28.90%	31.79%	23.66%	44.44%	27.88%	30.04%
On the job	7.40%	5.47%	9.60%	6.35%	7.69%	7.08%
Neither	7.00%	9.89%	4.69%	1.59%	12.31%	1.07%
In college	1.83%	0.63%	2.01%	9.52%	1.35%	2.36%
Social and emotional skills						
Life experiences	58.77%	62.26%	58.79%	32.14%	59.48%	57.97%
Both	23.23%	20.28%	22.11%	53.57%	19.83%	27.05%
On the job	10.02%	9.91%	10.05%	10.71%	7.33%	13.04%
Neither	4.78%	5.66%	4.52%	0.00%	7.76%	1.45%
In college	3.19%	1.89%	4.52%	3.57%	5.60%	0.48%
Intellectual traits						
Both	37.33%	38.54%	33.90%	52.38%	36.15%	38.64%
Life experiences	35.64%	37.90%	35.25%	21.43%	35.57%	35.71%
On the job	14.59%	11.46%	17.63%	16.67%	13.70%	15.58%
In college	8.14%	7.32%	9.15%	7.14%	7.29%	9.09%
Neither	4.30%	4.78%	4.07%	2.38%	7.29%	0.97%

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APPENDIX G (Continued)

RQ2: FTE x technical skills (*N= 112*)

Skill Set Area of learning	< 5	5-9.99	10-14.99	15-19.99	20-24.99	> 25	Distribution
	Years of Full-Time/FTE Experience in Government Service						
Science							
In college	55.67%	51.09%	54.55%	43.37%	44.54%	37.61%	46.88%
Both	34.02%	44.57%	38.64%	51.81%	50.42%	53.21%	46.32%
On the job	9.28%	4.35%	2.27%	4.82%	4.20%	9.17%	6.07%
Neither	1.03%	0%	4.55%	0%	0.84%	0%	0.74%
Technology							
Both	51.00%	61.05%	48.89%	49.40%	61.34%	50.94%	54.56%
On the job	42.00%	33.68%	40%	36.14%	30.25%	35.85%	35.77%
In college	7.00%	4.21%	11.11%	12.05%	8.40%	8.49%	8.21%
Neither	0%	1.05%	0%	2.41%	0%	4.72%	1.46%
Engineering							
Both	50.91%	54.13%	53.33%	38.30%	49.62%	54.47%	50.16%
In college	45.45%	39.45%	42.22%	48.94%	45.80%	32.52%	42.16%
On the job	3.64%	6.42%	0%	9.57%	3.82%	11.38%	6.37%
Neither	0%	0%	4.44%	3.19%	0.76%	1.63%	1.31%
Mathematics							
In college	75.86%	68.47%	73.58%	74.47%	71.13%	63.20%	70.67%
Both	15.52%	26.13%	22.64%	17.02%	22.54%	28.80%	22.31%
On the job	6.03%	2.70%	1.89%	4.26%	4.23%	4.80%	4.21%
Neither	2.59%	2.70%	1.89%	4.26%	2.11%	3.20%	2.81%
Other Technical Areas							
Both	38.14%	48.25%	64.81%	50.50%	54.86%	53.03%	50.53%
On the job	51.69%	51.75%	35.19%	43.56%	40.28%	45.45%	45.40%
In college	10.17%	0%	0%	5.94%	4.86%	1.52%	4.07%
Neither	0%	0%	0%	0%	0%	0%	0%

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APPENDIX G (Continued)

RQ2: FTE x professional skills (*N*= *112*)

Skill Set Area of Learning	Distri-bution	Years of Full-Time/FTE Experience in Government Service <5	5-9.99	10-14.99	15-19.99	20-24.99	>25
Communication							
Both	53.53%	49.29%	55.64%	53.23%	52.54%	60.00%	49.67%
On the job	18.06%	17.14%	17.29%	22.58%	14.41%	15.00%	23.84%
Life exp.	15.84%	14.29%	15.79%	17.74%	20.34%	15.00%	13.91%
College	11.65%	17.14%	10.53%	6.45%	12.71%	9.38%	11.26%
Neither	0.92%	2.14%	0.75%	0.00%	0.00%	0.63%	1.32%
Teamwork							
Both	37.77%	47.47%	42.11%	47.22%	35.56%	26.67%	34.48%
On the job	29.28%	26.58%	21.71%	19.44%	22.22%	35.00%	41.95%
Life exp.	29.28%	20.25%	36.18%	31.94%	31.85%	38.33%	18.97%
In college	2.07%	3.80%	0%	0%	2.96%	0.00%	4.60%
Neither	1.61%	1.90%	0%	1.39%	7.41%	0.00%	0.00%
Life exp.	54.87%	46.67%	61.99%	46.91%	60.26%	62.32%	47.45%
Both	28.90%	27.78%	29.82%	39.51%	25.17%	20.29%	36.73%
On the job	7.40%	5.56%	2.92%	13.58%	4.64%	4.35%	15.82%
Neither	7.00%	17.78%	1.75%	0.00%	5.30%	12.56%	0.00%
College	1.83%	2.22%	3.51%	0.00%	4.64%	0.48%	0.00%
Social and emotional							
Life exp.	58.77%	55.00%	70.67%	61.11%	57.35%	61.96%	48.86%
Both	23.23%	18.75%	18.67%	27.78%	22.06%	15.22%	38.64%
On the job	10.02%	15.00%	4.00%	0.00%	10.29%	11.96%	12.50%
Neither	4.78%	6.25%	2.67%	0.00%	5.88%	10.87%	0.00%
College	3.19%	5.00%	4.00%	11.11%	4.41%	0.00%	0.00%
Intellectual traits							
Both	37.33%	35.29%	39.64%	33.96%	29.70%	29.20%	53.08%
Life exp.	35.64%	26.05%	33.33%	43.40%	43.56%	45.26%	26.92%
On the job	14.59%	15.97%	13.51%	16.98%	12.87%	11.68%	17.69%
In college	8.14%	15.13%	11.71%	5.66%	6.93%	6.57%	2.31%
Neither	4.30%	7.56%	1.80%	0.00%	6.93%	7.30%	0.00%