A Mixed Method Study on Transitioning Engineering Graduate Attributes into the Workplace

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ABSTRACT

Canadian engineering schools are required to follow an accreditation program as outlined by Engineers Canada. This program determines the qualifications of a graduating engineer through a series of graduate attributes. These attributes are an outline of the skills/abilities required in their educational programs.

This study was developed in conjunction with Manitoba Hydro to determine an understanding of the knowledge gaps between a senior professional engineer and a newly graduated engineer. Training and engineering design knowledge transfer is a primary concern for this corporation. The research question focused on determining the activities of a senior and junior group of engineers and how these activities differed. The second question was on determining the skill/ability level of a new engineering graduate upon entering the workplace. This skill/ability level can be determined with respect to the graduate attributes.

Data was collected using a mixed method approach. Interviews were conducted with a group of professional engineers and another group of engineers in training. Following the interview process two sets of questionnaires were completed by each group of participants. One questionnaire was based on engineering activities undertaken in the workplace. The second questionnaire was based on assessments of graduate attribute requirements and abilities for new graduates.

The findings showed that engineering activities for these participants matched closely to information as reported in the literature. It was also determined that differences between the two groups in the study were due to the supervisory duties of the senior group and the technical nature of the junior groups responsibilities. Findings for the second question showed that engineers in the workplace are more critical of their skill/abilities that are newly graduated engineers. The study showed that this group of participants felt the level of knowledge for a newly graduated engineer was at an introductory level. They also indicated

that generally this level was adequate for the responsibilities of the workplace. It was determined that the most important skill area was in the social aspects of the graduate attributes and this was the area of the greatest deficit in educational knowledge.

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1 INTRODUCTION

"Deficiencies in engineering education have been exhaustively enumerated in recent years. Engineering schools and professors have been told by countless panels and blue-ribbon commissions and, in the United States, by the Accreditation Board for Engineering and Technology that we must strengthen our coverage of fundamentals; teach more about "real-world" engineering design and operations, including quality management; cover more material in frontier areas of engineering; offer more and better instruction in both oral and written communication skills and teamwork skills; provide training in critical and creative thinking skills and problem-solving methods; produce graduates who are conversant with engineering ethics and the connections between technology and society; and reduce the number of hours in the engineering curriculum so that the average student can complete it in four years" (Felder et. al. 2000, p. 26).

In evaluating this statement can it be said that our engineering programs have this multitude of deficiencies? Each year thousands of new engineering graduates transition into the workforce successfully. These individuals develop their skills and spend countless years performing engineering tasks from the routine to new creative design. So are there deficiencies or are the expectations too high for our educational programs? A study by Nicolai (1998) indicated that recent graduating students have a good scientific background with strong technical skills. Even so, the study showed industries indicated that students were unprepared to become designers within their organizations. Graduating students may have strengths in the sciences, but they lack these same qualifications in design knowledge. This may indicate that industry places many demands on their engineering graduates that go beyond traditional technical competence. Can these required competencies be defined and is there an ability to address them in our educational programs? A more important question may

be whether these competencies are learned through the present educational system or in more traditional methods?

1.1 Research Partner

The research partner in this project is Manitoba Hydro, a Provincial Crown Corporation that provides hydro electric energy and natural gas to customers throughout Manitoba (further detail on page 50 – Chapter 4.1 – Research Site). They have expressed concern that as some engineering designers complete their careers, the organization loses valuable knowledge. They are struggling to bring their junior engineers to a point of meaningful contribution to their design process. Their goal is to hire design ready engineers or to develop methods to educate junior engineers more quickly. Manitoba Hydro, as with other corporations, struggles with training engineering designers. Engineering graduates are often not design ready. Currently, students are taught common procedures with the expectation of learning the details on the job. Many organizations have training manuals along with mentoring systems as the training method for new engineering designers. Experience has taught that individuals do not always follow the corporate policy. Everyone has their own way of completing tasks which works best for them. So which steps are taken or left out are unknown, along with how engineering designers are arriving at a design solution. The understanding of the transfer of design knowledge to new engineering designers is a source of concern. The expectation is that there is some commonality in methods, as success directs individuals down certain paths. But without actually understanding how individuals work, the most successful methods are unknown. The realization is that each individual will have their own unique process but there will still be common procedures and practices. There is a real concern that natural designers are not being recognized and developed by the "apprenticeship" approach which trained many of the present designers. It was noted that recent engineering graduates are capable of “doing” the most demanding design work. There is little knowledge of the specific design work or how designers are able to accomplish their designs.

The second partner in the project was the design group in the faculty of engineering at the University of Manitoba. This university is the largest educational facility in the province of Manitoba with the only engineering school in the province. Within the faculty is a design group that is concerned with enhancing the understanding of the design process and engineering education.

Discussions between this design group and Manitoba Hydro resulted in the development of a research project to better understand the design process. The engineering design education program at the University of Manitoba was looking for ways to improve methods in preparing students for the workplace. The management at Manitoba Hydro was concerned about loss of knowledge and expertise from retiring design staff. A cooperative plan was developed to study engineering design groups at Manitoba Hydro. The purpose of this proposed research project was to better understand how engineers design and how this design process is communicated to potential designers. The belief is that a better understanding will result in the ability to identify and train new design engineers. If the key pieces in the engineering design process are unknown, how can organizations be expected to train new staff? How can the characteristics that make a person a good designer be identified? A plan was undertaken to enter the workplace in order to research the activities undertaken during the design process and to discover how experienced designers transfer design knowledge. By understanding how design knowledge is transferred there is an opportunity to discover the key knowledge. The importance of the real world research is that it observes designers in the workplace performing under their normal constraints. “The fundamental assumption is that understanding the design process and the form and nature of design decision can only be gained by studying the designing in the professional practice. You cannot isolate the designer from the norms and values to which he conforms and expect to learn the true meaning of design" (MacDonnell 1997, p. 473).

Issues that are important in understanding engineering design include an understanding of design knowledge, a definition of the design process, models of the design process and the current state of research of the subject. It is also necessary to understand how engineering education fits into the role of developing a new engineer. These issues are important in understanding how industry works and how our engineering schools respond to the challenges. An understanding is needed of what knowledge requirements are in the process of engineering design. These topics will be discussed in relation to the research question put forward by our partner Manitoba Hydro. These factors are studied in relation to engineering design in order to discover our current understanding and identify the gaps that need to be filled.

1.2 Researcher

The researcher, Donald Petkau, is a professional engineer employed as an instructor in the Biosystems Engineering Department in the Faculty of Engineering as the University of Manitoba. He received a Bachelor of Science in Agricultural engineering in 1985 and a Master of Business Administration in 1999. He worked in industry as an engineer from 1985 to 2003. His experience includes organizations of various sizes and roles from Manager of Research and Development to Engineering Manager. This background offers a unique opportunity to compile and analyze data from this study. His background allows for an internal understanding of organizational structure, culture, and the unique language of the engineering profession.

1.3 Background

Engineering as a profession has been practiced for hundreds of years. It includes a variety of disciplines and a multitude of tasks. It is understood that the profession is all about producing the things needed for everyday living. Historically engineering design was a one person job. The world was more simplistic and one person could understand all the aspects of a new design. "The ancient designer was an absolute authority who could handle any professional design challenge" (Goldschmidt 1995, p. 189). As recently as a few hundred years ago, designers spent years working on understanding all aspects of their idea and then work their whole life to produce their design. This system was successful because their competition worked at the same speed.

Today there are too many contributing factors involved in design for one person to spend enough time to learn and understand. It is not just the speed of information required, it is also the breadth, as it now includes technology, computers, new materials, safety, economics, and politics. Therefore there are now many individuals working on engineering design, each with their own contribution and area of expertise. Today our engineering educational needs are not solely technical but also include social and cognitive skills (Cross 1995).

Training in the past was carried out in the apprenticeship program. The designer would take on an assistant who would be expected to help. Over the many years that they worked together the assistant would gain knowledge from the designer. The apprentice would then become the designer. This model does not fit the speed of development today. Training programs are needed to match the speed that society is moving. Does this mean that educating our students is just a matter of speed? Yilmaz (2011) stated that to become a better designer may be related to finding alternative ways to complete a design rather than becoming faster. It is seen that the educational needs of our new generation of engineers becoming broader than in the past and the necessity for a more comprehensive definition.

In Canada the engineering educational programs are accredited by the Canadian Engineering Accreditation Board (CEAB). Currently there are a set of standard graduate attributes that engineering schools are utilizing to assess their performance of their programs. These attributes are listed as outlined in the CEAB Accreditation Criteria and Procedures handout (2012).

“3.1 Graduate attributes

The institution must demonstrate that the graduates of a program possess the attributes under the following headings. The attributes will be interpreted in the context of candidates at the time of graduation. It is recognized that graduates will continue to build on the foundations that their engineering education has provided.

3.1.1 - A knowledge base for engineering: Demonstrated competence in university level mathematics, natural sciences, engineering fundamentals, and specialized engineering knowledge appropriate to the program.

3.1.2 - Problem analysis: An ability to use appropriate knowledge and skills to identify, formulate, analyze, and solve complex engineering problems in order to reach substantiated conclusions.

3.1.3 - Investigation: An ability to conduct investigations of complex problems by methods that include appropriate experiments, analysis and interpretation of data, and synthesis of information in order to reach valid conclusions.

3.1.4 - Design: An ability to design solutions for complex, open-ended engineering problems and to design systems, components or processes that meet specified needs with appropriate attention to health and safety risks, applicable standards, and economic, environmental, cultural and societal considerations

3.1.5 - Use of engineering tools: An ability to create, select, apply, adapt, and extend appropriate techniques, resources, and modern engineering tools to a range of engineering activities, from simple to complex, with an understanding of the associated limitations.

3.1.6 - Individual and team work: An ability to work effectively as a member and leader in teams, preferably in a multi-disciplinary setting.

3.1.7 - Communication skills: An ability to communicate complex engineering concepts within the profession and with society at large. Such ability includes reading, writing, speaking and listening, and the ability to comprehend and write effective reports and design documentation, and to give and effectively respond to clear instructions.

3.1.8 - Professionalism: An understanding of the roles and responsibilities of the professional engineer in society, especially the primary role of protection of the public and the public interest.

3.1.9 - Impact of engineering on society and the environment: An ability to analyze social and environmental aspects of engineering activities. Such ability includes an understanding of the interactions that engineering has with the economic, social, health, safety, legal, and cultural aspects of society, the uncertainties in the prediction of such interactions; and the concepts of sustainable design and development and environmental stewardship.

3.1.10 - Ethics and equity: An ability to apply professional ethics, accountability, and equity.

3.1.11 - Economics and project management: An ability to appropriately incorporate economics and business practices including project, risk, and change management into the practice of engineering and to understand their limitations.

3.1.12 - Life-long learning: An ability to identify and to address their own educational needs in a changing world in ways sufficient to maintain their competence and to allow them to contribute to the advancement of knowledge" (CEAB, 2012, pp. 13-14).

Engineering students graduate from these educational institutes each year and become practicing engineers in the workplace. In the province of Manitoba new graduates are not yet considered professional engineers. They must first complete a number of stages of development as required by the Association of Professional Engineers and Geoscientists of the Province of Manitoba (APEGM). Engineering graduates must complete a four year term as an Engineer in Training (EIT) prior to receiving their professional designation (P.Eng). This program includes performance of engineering work under the supervision of a professional engineer, individual development opportunities, and exams in engineering practice and ethics. This is an indication that engineering graduates must gain additional skills and knowledge in the workplace after graduation. These are not currently defined and it may be difficult to determine this additional knowledge as each engineering position within each organization will require a different knowledge basis.

In order to understand the learning that occurs in the first years of an engineer's career an understanding is necessary to first understand the job requirements of an engineer. What knowledge do new graduates enter the workforce with and how does that compare to the knowledge of a professional engineer? A determination of these factors could lead to the better understanding of whether this knowledge could be incorporated into an engineering educational program. This may also determine that this knowledge is more suited to a training program undertaken in the workplace during the first years of an engineers' career.

Trevelyan (2008) developed a framework of engineering practice in a study of engineers in the workplace. In his study he found that in some cases there was a mismatch between the work that young engineers were asked to perform and the training they had received. "A longitudinal study of our own engineering graduates is showing that nearly all the skills and knowledge they need for their work is learned on the job" (Trevelyan 2008). What is the knowledge that is necessary for a professional engineer? It is known that an engineering education is an important part of becoming a professional engineer. There are many technical aspects of the profession that are expected of a new graduate and our educational institutes are exceptional at teaching these. Nicolai (1998) in a study found that industry considered engineering graduates as being trained to a high standard in the sciences. The consensus was that engineering schools produced graduates that had exceptional skills in the technical aspects of the job. Earlier Cross had described engineering educational needs to consist of technical, social and cognitive skills. If the technical needs are being met, what are the social and cognitive needs of a new engineering graduate? Are these the areas in which engineering graduates must gain competence in their four year EIT program? In order to understand these questions a definition is needed of a professional engineer's knowledge that will also be required of a new graduate. The first step in this process is to define the practice of engineering. Trevelyan (2008) through a process of interviews and observations of engineering work developed a framework of engineering practice. He was able to come up with a list of ninety aspects of engineering practice and grouped these descriptors into categories as follows:

1: Managing self & career development

2: Coordination, working with other people

3: Engineering management processes

4: Financial processes

5: Procurement

6: Human resources

7: Business development

8: Technical, creating new concepts, problem solving

9: Technical test, inspection, measurement, review, checking

10: Hands on work

The data were collected from more than seventy engineers with up to thirty five years experience. This study provides a basis from which to evaluate engineering tasks and to learn what engineering knowledge is learned on the job.

2 RESEARCH OBJECTIVES AND QUESTIONS

Currently our system for determining the qualifications of a graduating engineer is found in the graduate attributes as determined by the accreditation program in Canada (Engineers Canada 2011). This program determines the parameters for the education of engineers in the engineering schools in Canada. These attributes are a definition of qualifications for engineering graduates upon their completion of an accredited program. The question is how these attributes define the capabilities of a new graduate. There is an understanding that a new graduate is not considered a professional until they have completed a further four years of mentorship under the tutelage of an experienced professional engineer. Therefore what are the additional qualifications an engineering graduate must attain subsequent to their formal engineering education? How do these qualifications provide a link between the formal education of an engineer and the practice of a professional engineer?

In the literature review, it was found that there was relatively little research on the practice of engineering. Information that was available on engineering design was discussed and the various definitions on how engineers perform engineering design. The review identified challenges in defining the different roles of an expert and a novice engineer. There is little information on how a newly graduated engineer's education relates to the workplace and what additional learning takes place subsequent to their formal education. Therefore the primary objective of this research was to define how the graduate attributes used in our engineering education programs link to the practice of professional engineering.

The specific objectives to achieve this goal are:

1. identify the role of an expert or professional engineer
2. identify the role of a novice or newly graduated engineer

3. identify the knowledge of a newly graduated engineer with respect to the graduate attributes
4. identify the knowledge requirements of the workplace for a newly graduated engineer with respect to the graduate attributes
5. determine the link and/or gaps between these abilities and knowledge requirements of newly graduated engineers to that of a professional engineer.

3 LITERATURE REVIEW

3.1 Engineering Design Knowledge

If our goal is to understand how novice engineers learn the process of engineering we must first define engineering design knowledge. Dorst believes that "design is not just a process or a profession, it is experienced as a situation that a designer finds him/herself in" (Dorst and Dijkhuis 1995, p. 264). Each design problem is unique and is solved by the professional knowledge of experienced designers. It is this knowledge that engineers find difficult to define and describe. Technical knowledge is more easily defined and so individual capabilities are recognizable and educational techniques can be structured. Design knowledge is more abstract and unique to each problem. We therefore need to define what is meant by design knowledge.

Cross (2006) points out different views on how design differs from science. Design is solution focused while science is problem focused. Science concerns itself in the fact about situations, while design is concerned about making things better. The design process has some pattern in the design activity that is very difficult to understand. Designers know how to design through tacit knowledge. This makes it difficult to describe and it is why design education has relied on the apprenticeship model of education. In the classroom we explain the problem, show students how to solve the problem, and then get them to practice.

Cross identifies five aspects of "designerly" ways of knowing including;

- "designers tackle ill-defined problems.
- their mode of problem-solving is solution focused.
- their mode of thinking is constructive.
- they use codes that translate abstract requirements into concrete objects.

- they use these codes to both read and write in object languages" (Cross 2006, p. 12).

Cross points out that while most people think of design as being original and exciting, most designing is carried out as routine changes to existing designs. So if most engineering design is routine and consists of changes to an existing design, it seems reasonable that an educational model could be devised to teach the individual concepts. We believe that engineering students do learn design knowledge in their educational programs because these same students become design engineers in the workplace. What we do not understand is whether this knowledge is strictly from the educational program or if it is learned in the workplace. The inclusion of design as a subject area is a fairly recent development through our engineering accreditation programs. The use of project based design classes is the primary method of design education today. If these are the appropriate methods to educate engineering students on design how did they learn in the recent past before these methods were implemented?

Description of design processes are made difficult by the fact that there seems to be intuitive methods that designers' use which are the most effective. "We still need a much better understanding of what constitutes expertise in design, and how we might assist novice students to gain that expertise" (Cross 2006, p. 27). The belief is that design knowledge resides in people as a natural human ability. Secondly it resides in processes, strategies, and tactics of design. Thirdly design knowledge resides in the products that are the result of the design process. Therefore design expertise is not another course that anyone can learn. If this expertise is part of the process and products of our design, it is learned by involvement in the process. Therefore some techniques could be taught in a classroom but the real learning would be in the actual designing activity. Also if it is a natural ability does this mean that only certain individuals would be proficient in design? Smith (1988) seems to agree with this theory in a description on the development of engineering expertise. He states that the standard educational model does not develop expertise which is only developed through these four approaches.

1."the modification of in-school activities to model out-of-school activities

2. the cognitive apprenticeship

3. the reflective practicum, and

4. active student involvement through cooperative learning" (Smith 1988, p. 321).

In today's classroom these four approaches would be defined as our design problems in project based assignments. This is the process of finding solutions to open ended problems. It involves development of real world problems that require the ability to develop solutions rather than utilize a theory. These problems are chosen to illustrate certain techniques which the students learn through application. This is an apprenticeship model of teaching closely related to the apprentice/craftsman relationship of the past.

This is not a new educational model but actually an innovative way to utilize a practical method of teaching expertise. The challenge is that expertise is not so simple to acquire. "Expertise is not simply a matter of possessing 'talent', but is the result of a dedicated application to a chosen field" (Cross 2004, p. 428). While we may be able to teach students aspects of expertise in engineering design, becoming an expert takes years of dedication and practice. The notion of designer experience is not always seen as positive as Dorner (1999) discusses in how it encourages conservatism and the restriction of new ideas. "Experience can be a great help, but it can also be a barrier to new developments" (Dorner 1999, p. 408). Do seasoned designers rely on experience and if so how do they come up with new ideas? If they are transferring this design knowledge to junior designers are we restricting the new designers in their ability to be creative?

Research has shown some insight into how experience could affect the design ability. Studies were conducted by Purcell (1996) on the problem of design fixation. There is a feeling that if designers get an idea or a picture of a solution in their head they become fixated on that solution and find it difficult to move to a new idea. Experiments were conducted using students to test the theory. Results showed that by giving a design problem along with a picture of a potential solution it resulted in a lack of flexibility and a reproduction of the example. This would even carry over into the reproduction of faults in the design. This effect was even more pronounced if the designer produced their own drawing of the solution. This effect was only seen when the designer was working in an area where they had no domain knowledge. If working in their area of expertise the fixation effect did not occur. Would this have an effect on transferring design knowledge from an expert to the novice? Is experiential knowledge transfer the best option for our new designers?

So what type of knowledge is needed for engineering designers? Research studies have compiled lists of knowledge needed in the 21st Century. These include; problem definition, design requirements, creativity, concept evaluation, test planning and evaluation, goal setting and task delegation, design evaluation relative to customer, company, and society, life cycle design evaluation, budget and schedule control, economic evaluation of design (Hight et al 1993). We now have a list of skills needed for the successful designers of today. The question is how can these skills be transferred to the new engineering designer? Some are straightforward, such as the technical skills. Others have recently been enhanced within the curriculum such as the teamwork and communication skills. Many of these activities undertaken by design engineers are difficult to understand, define and in turn they are difficult to describe and teach to students. Another challenge is defining which of the skills are most suited to be taught by educational programs and which skills are more suited to the apprenticeship model of learning by doing on the job. We do understand that certain skills are learned under the guidance of a professional engineer in the workplace. This is known as the Engineer in Training (EIT) program through the local engineering associations in Canada. New engineering graduates must work as an EIT for a period of four years and complete a number of qualifying parameters prior to becoming a Professional Engineer. This is recognition of the additional training an engineer must undertake following the completion of a recognized engineering educational program.

Engineering schools have started to develop programs which include a greater level of design education. Students are taught professional skills such as; teamwork, communication, following a standard design model, and how to work on design tasks. Graduating students now have more than just technical skills. They leave university with many professional skills but, even with this additional training, organizations are spending years preparing these graduates for design responsibilities. Design education for students consists of a design problem with expectations to produce a conceptual design. Support comes from academic staff and is generally in the form of technical expertise or directing the student towards where an answer can be found. Upon completion of the project the students are evaluated on their final presentation and whether they followed a standard design process model. Rarely are the projects evaluated on how the process contributed to the success. In past years few studies of engineering design education were on the design process. Instead design studies were focused on teamwork (Fruchter 2001), studying communication (Hirsch et al 2001) and integrating design into the curriculum (Linder and Flowers 2001).

Our educational focus has been on the technical and social aspects of design so do we need to understand the design process in more detail? Currently our designers are meeting the needs of society. Innovations are moving forward and our engineering designs are successful, correct? Bucciarelli (2002) suggested that if we look at the process of engineering design we see that we may not be as successful as is believed. Final designs are made to work, but iterations are necessary to get to the final stage. In most cases it takes multiple versions and many prototypes prior to reaching the final product. There are also the design changes, modifications, and updates that occur during the process. Budgets are overrun and deadlines are passed. Therefore it is not entirely accurate to say that the design process is efficient and effective. The success is measured in the final product not in the actual design process. A more thorough understanding of the process would result in an opportunity for improvements. Even with all these challenges there are many successful design engineers/engineering teams that complete successful designs daily. The success of engineering design projects is dependent on a multitude of factors. These include:

- how well the project is defined
- the necessity of the project
- the economic parameters
- the environmental parameters
- whether it is a new design or a extension of an existing design
- the makeup of the design team
- the commitment of the design team
- the commitment of management
- the political will to complete the project

Along with all these factors for design there are also many types of design including; engineering, architecture, artistic, interior, etc. Is it any wonder that the definitions are dissimilar and complex? Each time the design process is studied, it is depicted from a different point of view. The engineering manager strives to streamline the process and increase production. The engineer wishes to understand the activities to be completed. The researcher looks at many different design aspects. The programmer wants to develop tools to assist the process. The student wants to understand what is expected of them. So when someone asks "How do you define the engineering design process?" we receive a variety of answers.

Since the 1960's researchers have attempted to gain insight into the design process. Bucciarelli (2002) discusses the team aspect of design and how different team members have different interpretations and understanding. What is the process for completing a design if the team members are seeing a problem from different viewpoints? This becomes an even greater issue as our design teams expand to include financial, political and environmental influences. Cross (1986b) found that individuals have different styles of thinking, and learning. This makes it extremely difficult to teach a single approach to design as a standard methodology.

There are also other external changes to the design process. Our definition of design no longer has the same meaning as in the past. Design tasks no longer include only engineering and technical competencies. Societal needs are now measured in minutes rather than years. This has sped up the design process and also the parameters that are necessary for design. Along with these changes is the fact that we now have a world market and so designing is for a broader audience. This has changed the customer which now has different and more complicated needs. They also demand designs that meet their functional, behavioural, and experiential needs (Faste 2001). How does this affect the engineering design process? We had a poor understanding many years ago and have slowly gained knowledge on how design works. Does the demand of the customer and the speed of knowledge change how the design process works or only the speed at which it must be accomplished? Do the educational demands also change more rapidly? Are we likely to understand a basic common design process or are we chasing a moving target?

There is a consensus that the design process is difficult to define or at the least there will be numerous definitions. Individuals tend to develop their own style based on their education, experience, personality, and the type of problem to solve. Darlington (2004) stated that there is no single approach to managing the design process that works for all companies or individuals. Kruger (2006) evaluated concepts from nine experienced designers and found that there were four different design strategies used. In evaluating the concepts it was found that there were individual differences between designers and little consensus on what constituted a successful design. This brings up another question on how to define a successful design. Bucciarelli (2002) discussed the concept of repeated iterations to find final success. If engineers need multiple iterations to complete a design and then not reach a consensus as to the level of success, how do we agree on a model to educate new engineering designers? We now see how difficult it will be to develop a model on design education as workplaces are unique, design is poorly understood and there is difficulty agreeing on some of the basic concepts.

One idea of why design is such a difficult subject to understand is that design problems are considered as ill-defined or "wicked problems". The idea is discussed and explored by Zeiler (2007), Ahmed (2003), Brock (1993), Dorst (1995), Cross (1987), Thomas (1979), Akin (1989), and Lloyd (1994). The authors feel that design problems are ones that cannot be fully understood and are solved by a different thought process. These are problems in which the solution must be formulated to fully understand the problem and at times the problem may not have a definitive answer.

Salustri and Eng (2007) defined the characteristics of wicked problems. One of these was to solve the problem through a definition of the solution. "The problem is not understood until after a solution is formulated. The act of designing a solution brings to light many otherwise hidden aspects of a design problem" (Salustri and Eng 2007, p. 22). Lloyd and Scott (1994) agreed that a definition of the solution was needed to analyze the problem. They found that a solution focused approach appears to be related to previous experience of the designers. This approach would be difficult for new designers with little experience and make the transfer of design knowledge complicated. Cross (2006) also felt that designers explore both the problem and solution together. To move forward in their understanding of the design problems, designers use alternative solution conjectures and impose additional constraints that narrow the solution space. He felt that designers should treat all problems as though they are ill-defined and use a solution-focused cognitive strategy for problem resolution. One of the reasons for this approach is that ill defined problems generally have missing information. "A designer has to have the self-confidence to define, redefine and change the problem as given, in the light of an appropriate solution as it emerges or becomes apparent" (Cross 1987, p. 36).

One reason that the design process is so difficult to understand could be a result of the poorly/ill defined design problems. If this is true it would also result in a poor understanding of the design process. If our understanding of the design process is dependent on our definition of the problem, our focus may not be in the area of design tasks but rather in the area of how the understanding is communicated between designers.

3.2 Defining the Engineering Design Process

The engineering design process has been studied extensively resulting in numerous definitions ranging from how it operates to what is included in the process. One of the more extensive versions defines the design process as: "identifying the real as opposed to perceived needs, developing creative or innovative conceptual solutions, developing detailed solutions, incorporating manufacturability, quality assurance, product safety, reliability, and maintainability considerations into the design, selecting the appropriate materials and manufacturing processes, ensuring that performance and cost goals will be met, and ensuring that the needs of the external environment in which the product is marketed, used and disposed, are met" (Sivaloganathan et al 1995, p. 450). This definition covers many areas of engineering design along with the many tasks that can be undertaken to complete a design. What it does not cover is how someone completes a design. It covers a list of tasks or events that are used during the design process but does not describe how to use these tasks for engineering design.

Some of the other theories to describe the engineering design process include; Beitz (1994) discussing engineering design methodology from a scientific basis, relating the most important elements of design through design activity models (Morley and Pugh 1987), observing design activity as a social process through teamwork (N Cross and A Cross 1995), the role that communication plays in collaboration during the design process (Sonnenwald 1996), and the role that critical thinking plays in the engineering design curriculum (Hight et al 1993). The many theories of design have been researched and studied from the perspective of academia, student, novice and experienced designers. There are also many definitions of design that have been proposed including;

- "A goal-directed problem-solving activity" (Archer 1964, p. 72).
- "The performing of a very complicated act of faith" (Jones 1966, p. 295).
- "... the creation of a synthesized solution in the form of products, processes or systems that satisfy perceived needs through mapping between the functional requirements (FRs) in the functional domain and the design parameters (DPs) of the

physical domain, through proper selection of the DPs that satisfy the FRs" (Suh 1990, p. 27).

- "…the use of heuristics to cause the best change in a poorly understood situation within the available resources" (Koen 2003, p. 59).

In looking at the many theories and definitions of the engineering design process we understand the inability to come to a common theory. Starting at the very basic level the engineering perspective would suggest that design is problem solving. The most common class of problem solving is the scientific method. Scientists want to find out what exists. They look at the world around them and try to discover. The designer discovers differently as they do not look for what is already there but strive to invent things that do not exist. The engineering designer has some additional restrictions in that not only do they need to invent things but these designs must also meet a need, they must function, and they must be economical. The research community understands the scientific method and therefore tends to look at problems from this scientific perspective. But science is descriptive while design is prescriptive (Lawson 1997). In the 1960's to 1980's the idea was to agree on a design method in the same way as a scientific method, suggesting that designers should emulate scientists who used a scientific model. But science and engineering do not evaluate situations in the same way. Science studies what exists and designers produce what does not exist. "Designing relies heavily on modes of thought and ways of knowing which are incompletely defined and poorly understood but are characterized as being neither scientific nor literary" (Cross et al 1981, p. 198). Design activity attends to levels of detail, some even at the subconscious level, which rely on the skilled performance of the designer. These skills include talents such as judgement, reflection, and experience which Dym (2006) suggests are needed for design thinking. The consensus is that design requires analysis but that this does not account for the mental processes needed to synthesize. Additional skills for an engineering designer are described by Dorner (1999) as different forms of thinking that help in the design process. These include sketches, models, the picture word cycle, and elaboration. This form of design thinking is familiar to the engineer and may be a method of design learning in which designers transfer information to junior designers.

How do these many design skills and activities fit together to define a design process? There have been many theories on the strategies of how the design process works. One was as a structured linear process in which decisions were made at each step prior to moving to the next. A person would move through the process in a very serialistic way. Another portrayed it more as a way to construct your own path as an exploratory route through the design process. This route can change direction, even backtrack and is holistic in nature. In the early years other views also included convergent/divergent and a focused critical path approach to a flexible cascade approach. This shows that views on how design is performed can be as diverse as the individuals performing the act. It seems that rather than there being a specific way of “designing”, design is more of an experience that needs to be worked through by the individual. If this is true then everyone should be able to perform engineering design. But it still does not answer the question of why some are more proficient than others or as to how we teach the skill. Felder (2000) says that a student’s potential to learn is governed by matching their learning style with the instructors teaching style. So how do we teach under one particular style when design is performed and learned in many different methods?

Ullman (2001) theorizes that the key to the design process is in the decision making process and in the information that is used for the decision. Earlier work showed that one third of the strategies in design were in deductive reasoning and two thirds of the strategies were in searching the design space (evaluation, criteria). From these studies and their attempts to computerize the decision making process they theorized that "design is the evolution of information punctuated by decision making" (Ullman 2001, p. 3). In the decision making process there is lots of information gathering, developing and sharing activities. The importance of these activities is in commitment to resources for a final decision. In the design process the decision is the important milestone. Ullman has produced a twelve step robust decision making model. The steps are a model for the design process and include major areas such as: prepare the decision makers, clarify the issues, develop criteria, generate alternatives, evaluate alternatives, and decide. Each of these major classifications has additional steps to help clarify the activities. The idea is that the key to the design process is making decisions and therefore an outline in making robust decisions is key to assisting in the decision process.

There have been theories such as Darke (1979) that have moved away from the analysis/synthesis approach and suggested a conjecture/analysis approach in which the designer imposes a limiting set of objectives. In this way a designer could test a single solution against a set of requirements and constraints until an appropriate solution could be found. A question here would be on how an optimal solution would be found if the only requirement was to find a solution that works. Many options would be overlooked or discarded if the goal was only to find a solution. This would not actually teach engineering designers to solve design problems but only to solve that particular design problem. This was shown by Darke on a study of intuitive design using protocol analysis, in a controlled design task, which found that designers attempted to find a solution to satisfy the constraints rather than optimize the solution.

Macmillan (2001) in looking at a generic framework for design states that "the conceptual phase of any design project is potentially the vibrant, dynamic and creative stage of the overall design process. However it is at present the least understood." This leads to teams with little focus or structure. "Currently, design procedures tend to be simple lists of deliverables rather than guidance documents providing design teams with an outline of what to do and by what method it should be achieved" (Macmillan et al 2001, p. 170). The assumption is that there is no consistent approach to conceptual design, but rather we rely on the experience of the designer.

The information covered shows that the design process is extremely complex, poorly understood and interpreted in many different ways. If our engineering designers and educators struggle to find a common definition, it is because a definition does not yet exist. Ishino (2002) breaks down the design process into different types of knowledge. The first step is breaking knowledge down to domain and strategic knowledge. The domain side includes design principle, product (including function/constraint/accompanying), and process (including task decomposition and dependency) knowledge. The strategic side includes know how (including design procedure and knowledge of features) and know why (including reasons behind procedures and reasons behind product) knowledge. Looking at the design process in this way gives a different perspective. The domain knowledge is fairly straight forward and easy to share and understand. This is the information such as technical knowledge and analysis. To truly understand how engineers design we need to understand the strategic knowledge. This is the information included in the intuition, human values, experience, creativity, etc part of the "know why" knowledge. It is hard to identify, difficult to observe in action and challenging to teach. We must first identify the knowledge, then determine how to educate the student and finally identify when it is most productive or even possible to teach these techniques.

3.3 Teams and Communication

"One feature common to all the design process models that we have surveyed is that management and transformation of information is central to the design process" (Dym 1994, p. 33). "The interpretations and assumptions that people bring to bear in the information they communicate are important determinants of errors in the design process" (Busby 2001, p. 234). Bucciarelli (1984) argues that design is as much a matter of people sharing perspective and working towards consensus as it is about analysis, evaluation, and information. The design process has been studied extensively from many aspects and one of the common themes to emerge is the importance of communication. This can present itself in many forms as in negotiation (Eris 2003) (Wood 2003) (Sonnenwald 1996), design failure (Eckert 2000) (Busby 1998) (Maier 2005), and as a design activity (Larsson 2002) (Court 1998) (Badke-Schaub 1999) (Baird 2000) (Geisler 1991) (Busby 1998) (Wallace Hales 1993) (Milne Winograd 2003).

Dieter (1983) describes the engineering design process as the recognition of a customer need, definition of a problem, gathering information, conceptualization, concept selection, refinement, and design review/communication. Cross (1995) states that today the design team needs to have a shared understanding of the design problem which makes communication an important part of the process. The methodology of engineering design has described the design process to be a series of activities carried out to complete a technical problem. Some other domains such as architecture and software have more recently considered that designing may be a cognitive process which relies on the cognitive skills of the individual designer. There is also consideration being given to the idea that the design process is a social process with influences from clients and fellow colleagues. Therefore it may be important to develop a design methodology that considers the integration of the technical, cognitive, and social aspects of the engineering design process. We now see design as more of a team and social process, so how does this concept change our approach to educating design engineers?

In the past design was undertaken by individuals over long periods of time and knowledge of the process was transferred by a mentorship relationship with an apprentice. Today engineering training is undertaken at an educational institute followed up by a four year mentorship through the EIT program (Association of Professional Engineers and Geoscientists in Manitoba). The apprenticeship model changed to an educational model with schools teaching the technical aspects of engineering. Over time the technical expanded and the cognitive and social aspects were introduced. As our capacity to undertake the technical increased with tools that became available (i.e. computers) we increased our capacity to complete tasks. This increased the necessity for proficiency in the cognitive and social aspects of design. The technical aspects of engineering are well understood and therefore educational transfer of knowledge keeps pace with the speed of technical innovation. This increase in technical capacity requires an increase in the cognitive and social parameter in engineering design. These areas are not as well understood which makes the transfer of knowledge more difficult. They have not been a part of the engineering educational experience for as long as the technical aspects so they are not as well developed in engineering education. Another aspect to consider is the natural recruitment of engineering students. Many students enter engineering programs because they like the technical aspects and are usually proficient in these areas. So we end up with engineering graduates that have strong technical skills but weaker cognitive and social skills because they started at a lower level and the training is not as developed.

Design is conducted in teams and therefore has a need for proposal/negotiation questioning. Designers come from different backgrounds and therefore have divergent thoughts on best solutions. To come to a consensual solution the team must understand and consider all the alternate opinions. From a team perspective communication and negotiation are key components to the design process. A study of communication across multiple design phases "suggests that the practices of negotiating understanding, conserving ambiguity, tailoring engineering communication for recipients, and manipulating mundane representations are important strategies used by design participants" (Sonnenwald 1996, p. 283). This shows the importance of negotiation within the design group in order to aid the development of design ideas and to come to an agreement on a plan of action. Negotiation is also used outside of the design team. Engineering design requires the cooperation of many parties. Consideration must be given to aspects such as finance, environment, politics, etc. Negotiation is a consideration well beyond the technical requirements of design. "Enhancing communication among stakeholders in the negotiation process is vital to improving design" (Wood 2003, p. 39).

The success or failure of many designs can be attributed to the failure to communicate. In engineering design, practitioners generally look at communication as the transmission of information. Many times failures occur not because of a lack of communication but rather in a lack of the appropriate form of communication. While the transmission of information is important, it is equally as important that the message be in a form that the recipient can fully understand. "Design is a technical and social process and it is henceforth necessary to consider the technicality of information transmission as well as the richness of the social-technical interplay in communication processes" (Maier et al 2005, pp. 252-253).

"Engineering is fundamentally social, requiring a lot of interaction and communication between people involved" (Larsson et al 2002, p. 2). Design communication takes on many forms as in direct communication, indirect through media, in a group setting, even informally. In our current settings the importance of this communication has increased as we have larger design teams which can be separated by time and space. Communication is important to convey ideas, gather information and in understanding the design problem. It can be conducted using traditional face to face methods or through written and spoken word. Larsson (2002) proposes that informal communication is conducted as team members meet throughout the day. These are times to gain insight on progress without involving the whole team. The importance of timely interaction has increased along with the speed of technology. The types of interaction have also changed as most new entrants in the workforce are well versed in electronic communication. This form of interaction is socially blind and a large part of the message can be lost. This is very important to the engineer as they are technically astute, generally work under time constraints and so are comfortable utilizing the speed and convenience of electronic devices. Research into communication into the design process showed that "language, both oral and written, plays a significant role in the engineering design process, matching and in most cases, surpassing the use of the nonverbal activities more traditionally associated with engineering design such as sketching, building, and analysis" (Geisler 1991, pp. 131-133).

Bucciarelli (2002) discusses the idea of design being a collective process with different participants who see the object of design differently. Many individuals contribute to the successful designs. These individuals both collaborate and compete with different aspects of the design. The language of design is hard to understand because we think it is the language we speak (ie English). So we form our own interpretation to the words which may be different than the intended meaning.

The key to success is the shared design strategy and the shared understanding between team members. We know that today, design is a team effort but our research has only been on individual designers. Design is an integration of technical, cognitive and social processes. “Design is a social process as much as it is getting things right within object worlds” (Bucciarelli 1994, p. 83).

3.4 Design Models

The engineering design process is often portrayed with a model. There are many different models but most are comparable. These models are used as teaching tools for students, as a base for design research, and to follow the design procedure. The models have changed over time which is not surprising due to the fact that we have an evolving understanding of the design process.

Zeiler (2007) discussed the history of the design model. In the 1960’s the original design methods were based on the application of scientific methods. At this time it was even called the science of design. This model was rejected by even some of the founding fathers as design problems were recognized as wicked problems which were unsolvable by the standard scientific methods. At this point they started moving away from attempts to optimize the solution to finding an appropriate solution. By the 1980’s researchers started to look at a systematic model of describing the design method. The models were developed from system theory to three stage methodical design including problem definition, working principle, and detail design. In 1993 Zeiler proposed an extended model breaking the working principle into a synthesizing phase and a selection phase. He then split it into strategies, stages, and activities. The strategies are related to design phases while the stages relate to abstraction levels. In this way he developed a design matrix in which you could cycle through the stages to complete a design. You move through the process from higher levels of abstraction (definition) to lower levels (detail). The author concludes that designers should subjectively interpret design assignments to create their own design criteria. In this way they are able to structure further actions they need to undertake to complete an effective solution.

Roozenburg and Cross (1991) discuss a consensus model for engineering design. "The consensus model portrays the engineering design process as a recommended sequence of activities, leading to certain typical intermediate results: performance specification, function structure, principal solution, modular structure (concept), preliminary layout, definitive layout, documentation. The activities are grouped into four phases: clarification of the task, conceptual design, embodiment design and detail design" (Roozenburg and Cross 1991, p. 215). This model is based on a systems approach to the development of technical and socio-economic systems. It has two separate dimensions one of which is vertical and covers the origination phases. The horizontal dimension is for the problem solving process but is not strongly represented and so tends to be forgotten by users. Other characteristics of the model are that design proceeds from abstract to concrete to keep the solution space as large as possible. It also suggests that complex problems should be broken down into sub problems prior to solving. The authors consider this model to be weak as it is built on a heuristic method, requires interpretation by the designer, and has no guarantee of success. Criticism of this model is that it focuses on the conceptual design phase. Its development is based on innovative design with little attention paid to the idea that many designs work from known or proven concepts. Most design models are developed from a practitioners viewpoint and are descriptive. This offers little to the researcher that wishes to develop models to show new ways of working.

A standard design process model is available in many forms. One standard form is; needs assessment, problem formulation, abstraction and synthesis, analysis, and implementation (Voland 2004). Another model is; explore problem and write performance specification, generate range of concepts, evaluate and select most promising, develop concept to detailed design, and communicate (Cross 1997). A third model is; problem definition, design solution creation, design solution evaluation, and decision (Kurakawa 2004). What we see is that most models have many of the same categories, at times with different names. Dieter (1983) shows a number of steps in a problem solving methodology. They include:

- Definition of the problem
- Gathering of information
- Generation of alternative solutions
- Evaluation of alternatives
- Communication of results

These steps can be used at any point in the design process and are comparable to other definitions.

Some models have more detailed specifications on each activity. An example for the idea generation activity includes; brainstorming, listing alternatives, looking for ideas via internet, what if, and preliminary design models (Sobek 2002). This brings a clearer understanding of the tasks necessary to complete a specific design activity. Each of the design activities in a standard model has tasks which can be defined. These are the steps that need to be completed in the design process.

There are many block models to define the design process. We teach the models to engineering students and expect them to follow them in their design problems. “The presumption seems to be that once a correct goal is articulated, the right motivation put forward, a schedule and budget defined, the team assembled, then quality design will follow" (Bucciarelli 1988, p. 160). These design models define the tasks but do not define what needs to be done, who is to complete the work, and how the work is to be completed. The question is, do these models give insight into how the design is undertaken by the designer? "We define the engineering design process with a block diagram. But this sheds little light on how design acts are carried out, who is responsible, what they need to know, how they must work with others" (Bucciarelli 1988, p. 160). Block diagrams give wide ranging activities to complete as engineering designers. How we complete these activities is left to the individuals or may be specified in a corporate policy book or manual.

An extensive review of current design models showed a common structure with each model: "describing a sequence of phases which imply iteration within phases but not between phases, showing progression from broad outline to elaboration of detail, starting with an analysis of requirements before the generation of possible solutions, and having comparable, though not identical terminology" (Macmillan et al 2001, p. 171).

3.5 Design Summary

There are many different theories on design knowledge and the structure of the design process. We see that ideas have changed over time from a problem solving to a solution space perspective. The most common theme is that the design process is poorly understood. This comes through clearly when evaluating the research studies on design. Many of the studies use students as subjects who are not experienced in the design process. Many studies set up simple design projects in a defined setting under restrictive time constraints. Data collection is through interviewing, video, and audio recording. Currently we do not understand how the researcher's presence in the research affects the design process. The data collected generally consists of the steps or tasks undertaken by the designer. We seldom study how or why these tasks are undertaken. We do understand that each time engineering design is undertaken the designers follow a different path. Designers use personal intuition, experience, and knowledge to work through the process. So if it is ever changing, how do we learn more about the process?

Over time we have changed from a single engineer designing a product to design teams. In some cases the teams are able to get together and work through their design. In larger organizations and with larger projects time is a major factor. Designs can take months or even years to complete. How do designers work together to maximize results and production over long periods or large distances? How do designers communicate over time and distance to achieve the best results? Design expertise is important but hard to describe. Why are some designers great at designing? Is it IQ, education, knowledge, experience (personal or professional)? If we wish to train new designers we need to understand design knowledge and how it is used in the design process. Once we understand design knowledge we can better transfer this knowledge to new designers. This should also help to understand who will be a good designer. How is design knowledge communicated from senior to junior designer? The old way was through the apprenticeship program. The new way is more difficult as employees are less likely to work in one position or one firm throughout their career. So we need to transfer knowledge quickly and with minimum interaction. This needs to be accomplished while everyone continues to fulfill their job descriptions.

We would expect that there is some commonality in methods, as success directs individuals down certain paths. But without actually understanding how individuals work, we are unsure as to the most successful methods. We realize that each individual will have their own unique process but that there will be common procedures that are undertaken generally. These common methods are key to the training of new staff. Manitoba Hydro's goal for this project is to research the activities undertaken during the engineering design process to discover how experienced designers transfer design knowledge. By understanding how design knowledge is transferred there is the opportunity to discover the key knowledge involved.

Our goal for this research was to define the work practices of professional engineers and of junior engineers. This will define the educational needs of new graduates entering the workplace and the education knowledge transfer in the workplace. The importance of the real world research is that it observes designers in the workplace performing under their normal constraints. "The fundamental assumption is that understanding the design process and the form and nature of design decision can only be gained by studying the designing in the professional practice. You cannot isolate the designer from the norms and values to which he conforms and expect to learn the true meaning of design." (MacDonnell 1997, p. 473).

3.6 Novice to Expert

An understanding of the term novice for this study will be that of an engineer in training in their first four years of engineering employment after graduation from an engineering program. The term expert will be defined as a professional engineer with ten years experience after attaining their professional status. In order to study the transition from a new graduate (novice) to expert engineer we must first understand the roles and responsibilities of engineers in their daily tasks. Research studies of engineering groups (students/professional, junior student/senior student, etc.) have shown differences between novice and experienced engineer as they conduct identical tasks performed on staged projects (Atman et al. 1999, Ball et al. 2004, Cross 2002, Eisentraut 1999, Lloyd and Scott 1994).

We would expect experienced professionals to perform tasks more quickly and have better results than novices. But if novice engineers are not required to perform these same tasks in the workplace does it matter if they are not as proficient in the completion of those tasks? To evaluate whether the training a novice engineer receives, through their education, properly prepares them for the role as an engineer, we should observe how they perform the tasks they are given. To understand this transition we must first understand what a professional engineer does in relation to that of a newly graduated engineer. Once we understand the different roles and tasks undertaken by the novice and expert engineer we can begin to understand the steps needed to transition from one role to the next. Initially we need to define the roles of a professional engineer and of a novice engineer as they enter their initial engineering position.

Bucciarelli (1994) argues that only once you know what engineers do and what scientists do can you truly distinguish what engineers know from what scientists know. So in fact would it also be true that you need to understand what expert engineers do in comparison to what novice engineers do to recognise the difference between the groups. We currently can cite studies that identify experienced engineers activities but have very little data as to the activities novice engineers are required to perform (Sheppard 2006, Trevelyan 2007, Trevelyan 2008). We have industry requirements as to what is expected of newly hired graduates with respect to becoming a professional engineer and we have studies on whether new graduates feel they are properly trained for the workplace (Martin 2005). There are also studies on engineering student's expectations of the type of training they feel is required to be an engineer (Domal 2008). None of this information tells how newly hired engineering graduates' duties are related to their educational training.

Trevelyan (2009b) reported that a number of qualitative studies have been undertaken in which engineers are interviewed to develop a list of descriptors or aspects of engineering practice. It is not expected that engineers will experience or practice all of these but it does provide a framework of what an engineer needs to know. These studies include experiences of expert engineers but seldom include the experience of novice or new graduates. Studies have been undertaken to look at newly hired engineering graduates and how they learn job requirements, what activities they undertake, and what factors affect them as they begin practicing engineering. Interviews were conducted of novice engineers in a large global manufacturer with results showing the biggest challenge was social aspects of dealing with people and the organization (Korte et al. 2008). Trevelyan (2010) wrote that engineering practice involves specialized knowledge and different aspects of practice that are developed through many years, unwritten, and difficult to transfer to others. So how do novice engineers gain knowledge with the difficulty of transfer from experts and their own struggles with the organizational and people issues? This emphasizes the importance that communication has in an engineer's career as reported by Trevelyan (2009a). He reported that novice engineers spend more than 60% of their communication efforts in direct interactions. This gives a very good indication as to the importance of this skill to novice engineers. A study by Pilottea (2012) discusses the communication norms of retiring engineers and novice engineers. They found that even with the current changes to social interaction of the new generation (social media, texting, emails, etc.) novice engineers still sought out experienced individuals to act as mentors. This reiterates the fact that communication is a powerful tool for the novice engineer and that the link between novices and expert is important to the learning process.

A study was undertaken by Domal (2008) to better understand the student's perceptions of professional engineering practice. He referred to the thirty nine aspects of engineering practice identified by Trevelyan (2008), narrowed these aspects into six themes and asked students and professional engineers to rate the importance. They found that both students and industry engineers ranked the importance of these aspects very similarly. This is valuable to consider as it could signify that the novice engineer focuses on the same aspects as the expert. The transitioning from novice to expert would be easier if all parties had the same understanding of the requirements. The biggest difference between the two groups was that the early year students felt that these skills would be taught at university while the engineers expected the skills to be learned on the job or through alternative methods after graduation. This could pose some challenges as the novice may feel that they have the appropriate education to perform at an expert level. The expert might have the opposite idea and have expectations that the education is incomplete and needs to be complemented by additional knowledge.

Another question could be whether students feel prepared for entry to the workplace. Martin (2005) conducted a study of chemical engineering graduates by asking whether they thought they were prepared for the workplace. They used a semi-structured interview process that allowed for interaction and in-depth exploration. Results showed that students felt they were well prepared in areas of technical background, problem solving skills, communication, and lifelong learning. They also identified areas of weakness such as teams, leadership, practical preparation, and management. This gives a base to start exploration. Graduate engineers feel they have appropriate training and seem to understand some important aspects of an expert engineer's responsibilities. We now need to develop a better understanding of what the terms expert and novice engineer really mean.

When first looking at the terms we find that the development of engineering expertise is a goal of engineering education programs (Canadian Engineering Accreditation Board 2011, American Society of Civil Engineers, 2008, Accreditation Board for Engineering and Technology 2000). In order to achieve this goal certain requirements must be met. Accreditation boards are used to ensure that engineering schools meet appropriate standards.

These standards are set based on the needs of the profession and on what is expected of an expert engineer. In Canada there are a set of standards called graduate attributes, which engineering schools are striving to implement. These graduate attributes define the knowledge required by a graduating engineer. If this is the standard for a novice engineer, how does it transition to an expert engineer? The challenge is that new engineering graduates are considered to be novices and will not have the knowledge or skills to perform as an expert. So how do we transition that gap from a raw novice to proficient expert? Are the attributes even the right set of guidelines for this transition? Patel (2008) in a study indicates that literature shows that students are not necessarily receiving the skills required by industry. Therefore is it through additional proficiency training during their schooling years or is it through engineering practice and specialized training as a novice engineer that skills are learned? The first question is to define the knowledge deficiency (if any) of a newly graduated engineer.

To better define the novice engineer we need to define what is a novice and how does that differ from an expert. Dorst (2004) published a paper on the levels of expertise in design education. These are defined as; novice – consider objective features given to them and follow strict rules, advanced beginner – follow rules but some sensitivity to exceptions to hard rules, competent – selects elements that are relevant and chooses a plan, proficient – immediately sees the important issues and an appropriate plan, expert – responds to a situation intuitively and performs action. Benner (1982) also describes the same levels of moving from novice to expert within the nursing profession. The development of a professional from novice to expert is consistent across professions with differences in the skill set. Benner also explains how the skilled performance changes with movement through the levels to an expert. These changes include; “movement from relying on abstract principles to using past concrete experiences to guide actions, change in learner’s perception of situations as whole parts rather than in separate pieces, and passage from a detached observer to an involved performer, no longer outside the situation but now actively engaged in participation" (Benner 1982, p. 403). We now have a question of whether the graduate attributes are defining an expert engineer and how we expect our students to meet those criteria? Or more likely, do the graduate attributes define the knowledge level of new graduates and how does this transition into an expert engineer. It would seem that a new graduate engineer goes through an extended program to learn how to use their attained knowledge and to gain practical knowledge, experience, and specialized knowledge prior to becoming a professional engineer. Therefore the question is how does the knowledge, as defined by the graduate attributes, transition to the knowledge of an expert engineer. A secondary question is how the additional knowledge and skills, not taught in a university education program, fit into this picture.

A second part of this story is defining the role of an expert. This is not as simple as it seems as the definition of what constitutes an expert and at what stage one is considered an expert is not clearly defined. Schunn, in an expert/novice study, describes how experts have knowledge that is tacit and situationally evoked. They do not always know how they know what to do in each situation they just know what to do. This makes it very difficult to extract the information in order to pass it on to the novice. Another issue is that not only do they know what to do but they also know when to use the information. This does not describe activities of the expert but does explain some difficulties in linking novice to expert and in the transfer of the knowledge.

Deken (2009) conducted a study looking at what makes an expert different from a novice. The base premise is that experts have more detailed knowledge, are better at structuring the knowledge, and better at applying the knowledge. This study claims that research shows it takes ten years to become an expert. They analyzed questions that novices asked of experts to classify the needs of the novice. These questions covered a wide range of items including obtaining information, defining terminology, defining what issues and when to consider issues to describing the design and company processes. The researchers felt that most studies did not consider elements directly related to interaction between experts and novices as needed to describe the evolution from novice to expert.

A study conducted by Anderson (2010) looked at six engineering firms, with interviews and observations of identified effective or experienced engineers. The goal was to see if these engineers agreed with identified list of skills for engineering students as defined by ABET, the National Academy of Engineering, and the American Society of Civil Engineers C*ivil Engineering body of Knowledge for the 21st Century*. These groups emphasized a list of common skills including communication, business acumen, interdisciplinary teamwork, creativity, life-long learning, and technical problem solving. The findings showed that engineers see engineering work as technical work with communication and coordination the most important aspects. The engineering identity is a factor of problem solving, teamwork learning and personal contribution with the most important constraint being organizational. They recognized the limitations of the study and noted that more work was needed to evaluate differences between senior and new engineers, and male and female engineers. One of the limitations of the study was that it only included engineers from six firms all which were situated in the Midwest. We understand that each firm is unique with their own organizational strategy. Therefore firms will have unique methods to complete their tasks and even the tasks will be unique. Another limitation was that the study was conducted by outsiders. These individuals were not part of the engineering team and so would not be privy to ‘insider’ information which could be vital to understanding the methods of operation. The team of researchers were also not professional engineers and admittedly did not understand all the nuances of the engineering skills. This could be a particularly important point during the analysis of the data. Conclusions drawn are important to develop a general framework for how the engineering industry develops skills but not particularly useful to individual situations.

Jonassen (2006) conducted a study using case based reasoning asking engineers about how they solved a problem. Results gave researchers a list of themes for skills that students needed to solve problems better. "The conclusion was that students need to learn to analyze, manage, communicate, collaborate, identify, and reconcile problems better" (Jonassen et al. 2006, p. 146). While this is interesting information it does not define what novices should learn or what method they would use to learn.

Another study looking at the knowledge profile of a structural engineer by observing junior engineers (less than seven years experience), mid level engineers (up to fifteen years experience), and senior engineers (Gainsburg et al. 2010). They were trying to understand which type of knowledge engineers used based on Vincenti's (1990) six knowledge types. They also came up with an additional four knowledge types to cover gaps they felt were missing. The study calculated how often an engineer would use each knowledge type and in which project phase it would be used. What they found was that practice-generated knowledge dominates the work of structural engineers. The question might be that if newly graduated engineers were studied would the trend be different? New graduates have little practice to provide as a base for knowledge and so do they make decisions based on their educational knowledge. Does this change as they gain additional forms of knowledge and should this information affect the structure of their education?

In 2009 Anderson conducted a study that tried to explain what engineers really do. They used interviews, focus groups, online surveys, case studies, and observation. They used engineers, technologists, marketing, human resources and asked each to explain a notable event, what engineering skills were needed, and what skills their education had lacked. Their conclusions identified that problem solving was the skill that was the most lacking and needed additional support in the educational system. One of the limitations of the study was their use of first year technical communication students to conduct the interviews.

Another study investigated nursing expertise by conducting interviews and work observation of four groups of nurses (Benner 1996). These included groups with less than one year experience, two to five years experience, more than five years experience and considered experts, and more than five years experience but not considered experts. Some of the challenges they experienced were that within the profession some rules of thumb have been developed based on experience which are too complex to define and analyze in scientific terms. "Theory and practice intertwine in a mutually supportive bootstrapping process as the nursing graduate develops their skill. Only if both are cultivated and appreciated can full expertise be realized" (Benner et al. 1996, p. 29). The same could be said for the engineering practice. There needs to be an understanding of both the theory and the practical to analyze what extent each plays in the development of engineering expertise. We need to understand which skills are learned through each method in order to know what is best taught as theory and what is best learned through the practical. Benner (1996) points out the complex relationship between theory and practice. Theory guides new graduates where to look and what type of response to expect. But theory falls short in describing each situation and in guiding the response to a situation. Experience helps to recognize situations and guides to set up a plan to provide a solution. We are attempting to graduate students that are as close to becoming experts as possible or at least students that have the best opportunity to reach expertise.

We know that the graduates are not experts and require at least four years of training and mentorship to be recognized as professionals. What are the expectations that they will learn within those four years? How do they change from graduates to professionals? We need to understand what the expectations are of a new graduate in their first job to understand what education gives the best preparation. But this is a very difficult question. Each job placement has different opportunities and requirements. In some situations graduates are developed in a mentorship program while in others they are expected to perform immediately. Manitoba Hydro has a mentorship program which tries to develop graduates over a number of years. This would seem as an appropriate workplace to examine graduate placement and their development to expertise.

4 METHODOLOGY

This study is a quantitative descriptive study characterizing engineering experiences within the work environment using descriptive statistics with a series of mixed method data collection tools. The initial research plan was to study the design process within an engineering workplace. The preliminary work was completed as a pilot study at Manitoba Hydro. That study consisted of a period of observation within an engineering department, interviews of engineers and technologists, and evaluation of project data. Preliminary evaluation of the data preceded and informed the main study which was designed to develop an understanding of how engineering education translates into the workplace. There have been a number of methods to carry out research studies on engineering education as described by Borrego (2009). These include quantitative, qualitative and mixed methods. Borrego explains that engineering education researchers seem to prefer the quantitative methods. Since many researchers of engineering education are engineers themselves, it is likely they prefer quantitative methods as this is their training and familiarity. The quantitative method attempts to test a hypothesis to a set of variables. This study is at a more primary stage and gathered information to develop a hypothesis on how engineering education translates into the workplace. Currently information is not available to show how the formal education of a newly graduated engineer is relevant to the beginning of their career or how they transition to a "professional" status. This study is described as a mixed method study as it used two methods of data collection over a number of stages.

"A mixed method study involves the collection or analysis of both quantitative and/or qualitative data in a single study in which data are collected concurrently or sequentially, are given priority, and involve the integration of the data at one or more stages in the process of research"(Creswell et al, 2003, p. 112). This type of research uses both the qualitative and the quantitative data collection methods. The timing of the data collection, the relative weight of each type of data and the stage at which the data are mixed can vary with these studies. This study was of an exploratory nature using a sequential data collection method. The first stage was in the collection of engineering task related information using an open ended interview style. A total of three interviews were conducted with two sets of participants. The first set was a group of professional engineers in senior management positions. The second set of participants was a group of newly graduated engineers in their first three years of employment. The interviews were designed to gather information on the job tasks of each group of engineers. The senior engineers were also interviewed on the required job tasks of the newly graduated engineer.

The second data collection technique was the use of questionnaires. A total of three questionnaires were completed by each participant. The first one was on the aspects of engineering practice which were correlated to the participants' job tasks compiled from the interviews. The second questionnaire was on the graduate attributes and correlated engineering education to the job tasks of a newly graduated engineer. The third questionnaire was also on the graduate attributes but this one evaluated the strengths and weaknesses of the new graduate. Upon completion of data collection the interview information was evaluated using NVivo software. This resulted in the correlation of data for each group and a comparison between each group. The questionnaire data was compiled for each group of participants and evaluated between the groups. Evaluations were also completed between education strengths of the newly graduated engineers and their job requirements.

There were a total of three interviews and three questionnaires for each participant. A guide to how these data collection methods inform the objectives in the study is shown in Table 1.

Table 1: Guide to which data collection method informs each objective.

Objective 1. identify the role of an expert or professional engineer	Interview 1 P.Eng
	Interview 2 P.Eng
	Questionnaire Aspects of Engineering Practice P.Eng
Objective 2. identify the role of a novice or newly graduated engineer	Interview 1 EIT
	Interview 2 EIT
	Interview 3 EIT
	Interview 3 P.Eng
	Questionnaire Aspects of Engineering Practice EIT
Objective 3. identify the knowledge of a newly graduated engineer with respect to the graduate attributes	Interview 1 EIT
	Interview 2 EIT
	Interview 3 EIT
	Interview 3 P.Eng
	Questionnaire Graduate Attributes self assessment EIT
	Questionnaire Graduate Attributes P.Eng assessment of EIT
Objective 4. identify the knowledge requirements of the workplace for a newly graduated engineer with respect to the graduate attributes	Questionnaire Graduate Attributes workplace assessment EIT
	Questionnaire Graduate Attributes workplace assessment P.Eng
Objective 5. determine the link and/or gaps between these abilities and knowledge requirements of newly graduated engineers to that of a professional engineer	Analysis of data

4.1 Research Site

This study took place in the offices of Manitoba Hydro. This organization is a Crown Corporation in the province of Manitoba. It is the province's major energy utility supplying electricity and natural gas to customers throughout Manitoba. It also supplies electricity to other markets in Canada and the mid-western United States. The corporation has more than 6000 employees and operates out of numerous locations in Winnipeg and throughout the province of Manitoba.

Manitoba Hydro is a large corporation with multiple engineering departments in areas such as electrical distribution, gas distribution, construction, operations, planning, design, capital projects, and engineering services. This was one of the major reasons for choosing Manitoba Hydro as a partner in this project. The second reason for working with the corporation was they had expressed an interest in the topic and were willing to cooperate.

4.2 Pilot Study

Prior to the main research study, a pilot study was completed at Manitoba Hydro . This pilot study was completed in 2008 and was undertaken to understand the design process at Manitoba Hydro. The original question was to study and evaluate a number of design engineers and determine if there was a common process they undertook to complete their designs. A common describable process would lead to an ability to understand and therefore teach the process to new individuals. This would meet the goals of Manitoba Hydro in transferring design knowledge and that of the university in the development of design education. There were four data collection methods utilized or considered. These included interviews with individual engineers and technologists, an observation role in an engineering department, evaluation of individual email communication over a period of time and evaluation of completed project files. A more detailed description of each method follows along with the description of the participants and the evaluation of the findings.

Initially four departments were identified as being willing to cooperate in the study. Within each of these departments individuals were asked about their willingness to volunteer their time. Ethics approval for this portion of the research was granted and extended throughout the entirety of the initial study. The four departments chosen were in unrelated fields in order to gain a broader perspective. The departments involved were, structures, station design, gas distribution, and transmission design, and electrical distribution planning and design. These departments were chosen because of their diverse nature of operation and their willingness to volunteer. Within each of these departments individuals were approached and asked for their cooperation. The pilot study was not restricted to engineers as the original question proposed by Manitoba Hydro was focused more on understanding the design process. Initial discussions led to the understanding that within an organization the design process is undertaken by a diverse group of individuals.

It was decided that the pilot study would not be restricted to only engineers and therefore included technologists as well. There were no restrictions as to the number of participants at this stage. The first method of data collection was in the role of an observer within an engineering department. This method consists of a researcher identifying themselves and then setting up an observational location or gaining access to another setting (Palys 2008, p. 194).   The observer then tries to remain inconspicuous while observing the activity with the full knowledge of the participants.   At this stage of the project, the observer method of data collection was very important. One of the groups that agreed to participate was situated in an open area office setting and consisted of an engineering manager supervisor with three technologists. There was an empty work station within this area that was suitable for the observer. There were plans in place for this group to relocate to another location within two months. In this new location the group would be positioned in cubicles in close proximity to each other. Once the move took place the opportunity for observation would be more difficult as it would consist of observing each individual separately, not of their group interactions. The other three departments in the study were already situated in locations where individuals were in cubicles or offices physically separated from each other. The participants in this stage of the study consisted of four technologists and the senior engineering manager. The technologists were situated in a common area that could be easily observed by the researcher. The engineering manager had a private office and therefore was not observed directly. The manager only contributed to this portion of the study by clarifying and enhancing the researchers understanding. One of the technologists was a more senior employee and was involved in more of the decision making aspect of the projects underway. This individual also had more interaction with outside consultants and contractors. The remaining three technologists were involved in specific project job tasks and worked quietly at their stations.

This portion of the study took place over a six week period in the fall of 2007. The researcher attended the workplace for two half days a week to observe how an engineering department conducted work. During this period of observation it became apparent that this method of data collection would only result in a superficial understanding and not capture any depth of understanding of the work tasks. In this situation the workplace arrangement was such that each individual had a work station and computer. This is typical of most work environments today that undertake technical tasks. Computer programs are available to complete drawings and calculations. Specialized programs are available for many types of engineering design. Communication is conducted through email with the ability to contact many individuals at one time. Observation of the group consisted of watching a number of individuals staring at computer screens. At times there was conversation which occurred mostly to discuss coffee breaks or lunch. Since each of these individuals was working on separate projects, they had little need to communicate with each other. At times other individuals would show up to discuss certain aspects of the design. These individuals would generally be responsible for constructing or initiating the designs and would have specific questions for the designer. The engineering manager also worked in the same manner, generally in front of a computer. At times the researcher would observe individual technologists at work. This work consisted of producing new drawings or making corrections or adjustments to existing designs.

Data collection in this stage consisted of observation and note taking. The researcher would attend the workplace and sit quietly at a workstation while recording the activities as they occurred. During periods when the group stopped work for a break or at the end of a session the researcher would ask questions for clarification on situations observed. Over time the relationship was such that the technologists would discuss aspects of their job tasks with the researcher at the time of observation in order to help clarify the situation.

There was one benefit to the observation in the workplace. Over time the staff accepted the researcher as part of the group. This would prove beneficial in the next stage of the pilot study. Participant observation is central to identifying and building relationships important to the future of the research endeavor" (Schensul, 1999, p. 91). The value of this relationship was obvious during the second stage of the pilot study.

The next stage consisted of interviews with participants. These were conducted as in-depth open ended interviews to explore how engineers conduct the design process. This type of "exploratory interviewing is intended to expand the researcher's knowledge of areas about which little is known" (Schensul, 1999, p.122). Little is known about the actual tasks an engineer undertakes to complete a design. It is understood that there is a technical component and that the process generally follows the typical design model discussed earlier. The difficulty is in describing the actual steps to design. An open ended interview style is meant to accomplish a number of goals including:

“-Explore undefined domains in the formation of a conceptual model.

-Break down domains in component factors and sub-factors.

-Obtain orientating information about the context and history of the study and the study site.

-Build understanding and positive relationships between the interviewer and the person being interviewed” (Schensul, 1999, pp.121-122).

These goals fit well with this portion of the study. There was an attempt to define the area in which engineers perform their design. To accomplish this there needed to be an understanding and dismantling of the tasks that are performed in engineer design into individual components. The attempt was to define the context of the study and use the interviews to build relationships among individuals and within the organization.

The participants of the interviews were a mix of engineers and technologists. There were two senior technologists, two new engineering graduates and three senior engineers. Each individual had very different responsibilities within the organization. In one case the Professional Engineer (P.Eng) was the supervisor of the technologists. In all other cases the participants had no employment relationships with each other. Two of the participants, in this portion of the study, were also involved in the earlier observation portion of the study. One individual was the senior technologist who had been observed and now was involved in the interview process. The other was the engineering manager who had not been directly observed but had participated in the observation study as the manager and for detail clarification.

The interviews were conducted with seven individuals over a three month period. There were a total of fifty nine interviews with an average of nine interviews per person. They were conducted on a weekly basis and lasted on average between fifteen and twenty minutes long. The goal was to meet with the individuals each week and discuss what had transpired in the past week. They would explain to the researcher the work they had been involved in and discussed the tasks they had undertaken. It was not possible to meet with each individual each week as they had duties in the workplace and at times were busy in meetings or out of the office. However in most instances, the researcher was able to meet the once per week schedule for interviews. In four of the cases, with four separate individuals there was a gap of one month between interview sessions. In eleven cases the gap between interviews was two weeks with all the rest of the interviews being held within a one week interval.

The data collection methods consisted of taping the interviews complemented by note taking. Each interview was fully recorded and then transcribed by a third party. During each session the researcher would take minimal notes during the session to avoid affecting the candor of the participant. After the session was over and the parties had dispersed the researcher would record notes on general impressions and any important details of the meeting. At the completion of the interviews and their transcription, the data was evaluated to see if a process could be observed into how these individuals carried out their designs. While the information showed the tasks that were undertaken it did not inform on the process to make those decisions. What was learned was the actual tasks engineers undertake, not how or why they make those choices.

The idea of conducting interviews over a short period of time was for a number of reasons. Firstly it was to gain an understanding of the actual tasks the participants undertook during the each day. By recalling the past few days the participant would give a more detailed description of their work and therefore provide a better understanding of their work tasks over a period of six weeks. The advantage was the ability to gain an understanding of their job requirements and how they meet those requirements. The disadvantage was that this understanding was limited to the particular work or project they were undertaking at the time of the study. This could be a small sample of their overall duties. This could also be a special project and so the tasks undertaken could be somewhat unique for the individual. In discussions with each individual about the projects to which they were currently assigned, six of the seven participants indicated that they were currently occupied either on typical project work or standard daily tasks. The seventh individual was working on a special project but this project was one that would require him to spend up to three years to complete.

The interviews in the pilot study took place in the months of April to June of 2008. They were conducted as open ended conversations over a twenty minute time frame. Each interview was started with two basic questions as follows: “Tell me about how your week is going. What tasks have you been up to?” From that point the discussion was a description of the participant’s week with probing questions on clarification and further details. The interviews were deliberately kept short to reduce any time constraints on the participants and because descriptions on activities were brief without the detailed technical aspects. The goal was not in looking for detail on how work was accomplished but rather on the type of tasks undertaken. The original question at this point was to help Manitoba Hydro discover how the design process was undertaken and then how to transfer this knowledge to inexperienced engineers. What the interviews uncovered was the determination of what tasks each of these individuals performed on a daily basis. These tasks could not be related to an understanding of design knowledge of a senior engineering designer in relation to that of an inexperienced engineer.

There were also some two additional methods used to try to gather information. Studies have shown that communication plays a vital role in the design process. (Sonnewald 1996, Court 1998, Badke-Schaub 1999, Geisler 1991). Currently engineers are required to produce new designs more quickly than in the past but they also have the advantage of new technology to support them. Much of this technology is in electronic form which enables designers to produce their designs and communicate them more quickly. Studies from the past showed that "language, both oral and written plays a significant role in the engineering design process, matching and in most cases, surpassing the use of the non verbal activities more traditionally associated with engineering design such as sketching, building and analysis"(Geisler 1991, pp. 131-133).

Today the technology has advanced so that communication through methods like email is not only fast but can include the whole design group. A decision was made to look at this communication method to see if any insight into the design process could be uncovered. The participants, who had been interviewed, were asked if they could forward a copy of their email communication. The plan was that they would send a copy of each email they sent out and forward the emails they received. In order to not burden them with extra work or have them filter information they were asked not to worry about the relevance of the material and just send all messages.

In this portion of the study only two individuals participated. One was an engineer who also had participated in the interviews while the other was a technologist who only participated in this portion of the study. This second individual did participate in one earlier interview but due to extenuating circumstances was not able to continue so that single interview was not included in the study. These two participants were diligent in sending every email communication they sent or received between October 2007 and April 2008. An evaluation of the data showed that most of the material was either detailed technical data or communication unrelated to engineering design. This data gave an indication that much of the engineering work is in the detail of the projects. Very little information was discovered on the tasks within the design process. The most valuable findings were in the understanding of the engineering tasks undertaken at different levels in the organization. The other greater issue was that these email communications were sent and received by multiple individuals within the organization and from numerous other sources. The ethical considerations were an obstacle as receiving ethics agreements from that large a group would be next to impossible. Since I could obtain the same data using other methods, a decision was made to forgo this method of data collection.

The final method of data collection considered for the pilot study was through project files. It was suggested by one of the participants that old computer project files may be helpful. This was seriously considered as the files would contain information such as the original project plan, budgets, communication, technical information and who had performed the work. After some discussion it was realized that the ethical consideration would also be an issue. These project files would include information from individuals who may have retired or moved on to another job. There would also be information from the consultants, suppliers, and contractors. The ability to obtain ethical approval from all those individuals would be too great an undertaking even if they could be found. The separation of the information to exclude these individuals from the data in the files would be either impossible or detrimental to the data being collected. Therefore this method of data collection was not undertaken.

At the end of the pilot study consideration was given to the value of the data collected, the participants involved and the methods used for data collection. The study was undertaken to consider information on how the design process is performed by engineers. It was found that the data collected was of value to this study of transitioning graduates as the pilot study included information on the tasks that an engineer undertakes in their normal workday. The main benefit in the pilot study was the observation of the different tasks at the different levels of responsibility in the organization and the progression of these tasks with increased responsibility. This information would add value to the main study and will be commented on in the discussion. The value of the participants involved was also under consideration. All seven individuals contributed to the pilot study but only two of them qualified to meet the parameters of the main study. These were two individuals who were senior engineers. One of these participants was a senior member of a department working in teams and supervising EIT's. The other individual was working independently on a high level project and had no interactions with EIT's. A decision was made that the data from the one senior supervisor would be considered in the main study.

Two of the pilot study participants were EIT's who could also qualify for the study. One of these was a new graduate who did not have the experience required for the main study. The other EIT had very different circumstances. This individual had started as a technologist and been promoted to a supervisory position and then completed an engineering degree. At the time of the study the individual had some experience as an EIT but was in a supervisory position. A decision was made that this individual did not fit the parameters of a junior engineer. There were also two individuals who held the position of technologist. This did not meet the parameters of the main study so their interviews were not included. The last decision made was on methods for collecting data. The pilot study used interviews, observation, communication, and project files as data collection techniques. Only one of these methods, the interviews, resulted in data that could contribute to the main study. This also impacted the decision that the interview would be a suitable data collection method for the study on transitioning graduates into the workplace.

4.3 Selection and Recruitment of Participants

When selecting the appropriate participants it was important to maintain variability in the sample as well as to eliminate bias in the selection methods. The size of this corporation and number of engineering departments allowed for potential variability. The type of study would restrict the number of participants involved. In order to be able to generalize results participants were choosen from a number of engineering disciplines. Manitoba Hydro has a variety of engineering disciplines on staff. Another important factor for recruitment was the availability and cooperation of the participants.

The main recruitment criteria were the years of professional experience. Recruitment was for individuals that had graduated with an engineering degree with at least one year experience and had been employed by the corporation for that year. These individuals would have been working for less than three years and would make up the EIT cohort. The second set of participants to be recruited were four individuals that had been working as professional engineers for at least ten years, preferably with Manitoba Hydro. This would mean that they were at least fourteen years post graduate from their graduation as an engineer. The initial recruitment was made with an email request from the researcher. This email was sent to the participants who had cooperated with interviews during the pilot study phase. Only the professional engineers were contacted as the study would not involve technologists. One other engineer was also contacted that had not been interviewed during the pilot study. Contact had been maintained with pilot study individuals subsequent to the study and so this contact for recruitment was anticipated. One of the initial engineers did not fit the recruitment parameters while two others were non responsive. This initial email contact was able to secure two professional engineers for the study.

The next step for recruitment was to discuss the issue with the human resources department at Manitoba Hydro. A recruitment letter was drafted and an email was sent to all engineers who fit the criteria within Manitoba Hydro. From that communication, replies were received from three individuals that were willing to participate. The final individual was recruited by one of the senior participants after the first interview session. During that first interview session general information was exchanged along with the need for an additional junior recruit. Within days a name had been received and the final participant was in place.

Once all the recruits were in place they were sent an email with two documents attached. The first was a letter complying with research ethics board content (Appendix F). This explained the project in detail and solicited informal consent. The second document was a questionnaire on background information (Appendix B). This asked basic questions as to length of employment, job title, job duties and experience preceding the current role. It was stated that these documents were for their information and official signing of consent would take place at the beginning of the first meeting after an opportunity to have all questions answered. All participation was voluntary and no compensation was offered as per ethical considerations.

4.3.1 EIT

There were two sets of participants in this study. The first was a group of four recent graduates from the engineering programs at the University of Manitoba. This was a diversified group with two electrical engineers, one mechanical engineer, and one civil engineer. They had graduated from their programs from between fourteen months earlier to the longest at three years earlier. One of the individuals had no previous engineering experience even in a summer job. The other three individuals had been working in engineering related summer jobs prior to graduation. Two had worked for Manitoba Hydro in the past and so had additional experience in regards to some of the orientation and cultural aspects of the corporation. Three of the four individuals were currently in or had gone through the EIT program at Manitoba Hydro. This program allows new graduates to spend six months working in a particular area of the corporation. At the completion of their six month term they choose another department for the following six months. The EIT's are allowed to complete up to four of these terms prior to their permanent placement. The one individual who had not entered through this EIT program had spent a summer term in a particular department and upon graduation continued in the same role as a permanent employee. This information is relevant to the study as the individuals in the EIT program spend the first two years of employment in a situation equivalent to four new positions. This affects their job role as they need additional training and orientation with each of these placements. This could affect this study as individuals are involved with more entry level activities rather than a steady progression to increased responsibilities. This should not have a major affect though as only one of the individuals is currently in the EIT program. All of the other three participants are in permanent placements with two of them already in the second year of their positions.

4.3.2 P.Eng

The second set of participants in this study was a group of professional engineers. This group consisted of four individuals involved in the current round of interviews with one of these individuals that had been interviewed in the pilot study. All of these individuals have spent their careers with Manitoba Hydro and have had their professional engineering status from between nine to twenty-two years. These engineers are all in supervisory positions. They are currently supervising EIT's or have done so on numerous occasions in the past. All four of the professional engineering participants were electrical engineers.

4.4 Interview Process

The interview process took place over a three month period between July and October of 2013. The individual interviews were all conducted as one-on-one interviews moderated by the researcher. Each interview was recorded with the researcher additionally keeping a set of hand written notes. The written notes were kept to a minimum in order to avoid upsetting the flow of the discussion. It was observed that when the researcher undertook to write notes the interviewee would take an interest in what they had said that was important enough to require additional notes. The notes during the interview were kept as triggers for more in-depth discussion at a later time. The researcher rather made a point to make a set of notes following the interview. The recorded interviews were transcribed by a third party following each interview session. These transcriptions were then evaluated by the researcher to confirm the content. The attempt was made to minimize the time frame between each individual's interviews. The first two interviews for each participant were held within a one week timeframe. The third interview occurred at a later date and so was on average one month after the other interviews. The focus group interviews were held following the completion of the individual interviews. These were held separately with the P.Eng. group and the EIT group. Both of the focus group interviews were held over the lunch hour with the researcher supplying lunch. These interviews were moderated by the researcher and recorded along with some hand written notes. Following the interviews the recordings were transcribed by a third party and evaluated.

The initial data collection period started in July of 2013. Participants were receptive and the first sets of interviews were completed quickly. This first encounter was used to define the process, explain and sign any documentation and develop a relationship between the researcher and the interviewee. These interviews ranged in length between 30 and 60 minutes. One particular interview with a P.Eng was cut short at 30 minutes due to a time constraint. All the interviews were completed in a comfortable location under relaxed conditions.

4.4.1 First Interview

The first interviews started with some basic questions such as “why are you an engineer?” These questions gave the interviewee an opportunity to consider the engineering profession and provided for a relaxed atmosphere as they considered their personal motivation. Questions were then directed to asking for a description of the work they undertook on a daily basis. A list of guiding questions is available in Appendix C. In the first interview the main question would be “describe a typical day, what activities do you undertake?” Following this, questions would be used to ask for clarification or more detailed descriptions of their activities. These questions would come in the form of “what were you actually doing?” in the completion of reports. Additional questions were asked on how they defined the term engineering and on what percentage of their time was spent on engineering tasks. These questions were used to gain a comfort level in the participants in discussing their daily activities. All too often their descriptions would be general or too broad to identify individual engineering activities. Overall the first interview went well with participants in gaining their confidence, helping them to understand the process and some valuable information on engineering activities was gathered. A sample interview guide is included in Appendix C.

4.4.2 Second Interview

The second interview process was undertaken to uncover additional information on the daily activities of engineers. These interviews involved the same group of participants and were conducted as a continuation of the earlier interview. A new set of probing questions was used to allow individuals to articulate their work in a new method. A list of guiding questions is available in Appendix C. The first question in these interviews was "how did you learn to do your job." This allowed them to consider not only the tasks they undertake, but also how they learned the process. The interview continued with discussion on resources used and interactions undertaken to complete their work. The final question during this session was "describe to me a job you've done that was not routine." This question was asked to allow participants to think about some particular work they had completed rather than just describing routine activities. There was some concern that they would describe a unique project that was out of the realm of their normal duties. This was not the case as each individual described as instance where the conditions were non-routine while the activities undertaken were still within their job description. This second interview was generally longer than the first and provided more detail in the engineering activities description. A sample interview guide is included in Appendix C.

4.4.3 Third Interview

The goal of the third interview was to tie the activities of the EIT to that of their education. This interview was conducted in a different manner between the EIT and P.Eng participants. A sample interview guide is included in Appendix C.

EIT Interview

This interview sought to have the EIT's describe their entry into the workplace and how that related to their education. A list of guiding questions is available in Appendix C. The interview started off with the question "when you first started, what did they ask you to do?" This would be followed by a discussion on the orientation process and the initial type of activities required to be completed. This would move to the first few months and how expectations and responsibilities increased. The next step was in questioning about any type of training they had received since starting their employment. A discussion on training continued with questions on what type of training they felt they needed for their work and in relation to their education. One question which asked “can you think of any areas where some additional education would have been helpful?” generated some interesting responses. These responses generally referenced the need for more detailed technical courses. Other discussions were held with regard to general areas participants felt they lacked appropriate training for the workplace. These areas correlated with the results in this study. Questions were also asked about individual strengths and weaknesses the engineers brought to the workplace.

P. Eng Interview

This interview process was undertaken to determine what the expectations of the company were on newly graduated engineering employees. A list of guiding questions is available in Appendix C. Participants were asked whether they had supervised new engineers and to relate their answers to their personal experience. The initial question would ask “for a new graduate starting work, what would you expect them to do, what kind of work would you give them?” The discussion would then revolve around orientation, training, and initial work duties. Questions were asked about expectations and types of responsibilities given. Follow up questions were on training availability and requirements for individuals. The professional engineers would also be asked what strengths or weaknesses new graduates brought to the workplace. One comment that caused some second thought was regarding the technical capabilities of new engineering graduates. They said that their hiring process identifies the individuals with the strongest technical skills. Consideration was given to this comment during the analysis of the data.

4.4.4 Focus Group Interview

An additional interview was conducted with each group of participants. After all the individual interviews were complete a meeting was arranged with the EIT's and a separate meeting for the professional engineers. Both of these focus groups were conducted in the same manner. A list of guiding questions for each group is available in Appendix C. Each interview was opened with questions on aspects of their position and then on any training they may have received. These questions were to find any new information on aspects of engineering practice. The final portion of this interview was on the expectations and responsibilities of new graduate engineers. The EIT's were asked about what expectations were asked of them when they first entered the workplace. They were also asked about their strengths and what training they had received. The P.Eng's were asked about expectations they had of new graduates and about their strengths and training requirements. These interviews were conducted over a lunch period to accommodate the participants. All the EIT's attended and participated. One of the P.Eng's was not able to find time in their schedule and therefore this interview had only three participants.

4.5 Questionnaires

4.5.1 Aspects of Engineering Practice

The first questionnaire was developed from Trevelyan's work on engineering practice. Trevelyan reported in 2008 on an ethnographic study of engineering practice. Through interviews and study of engineers in the workplace a framework was developed consisting of eighty-five different aspects of engineering practice. These aspects were grouped into ten categories which defined the different areas of engineering activities as follows: (Appendix A)

1. “managing self and personal career development
2. coordination, working with other people
3. engineering processes, projects and operations management
4. financial processes
5. procurement, buying products or services
6. human resource development, training
7. business development or marketing, selling products or services
8. technical work, creating new concepts, problem solving, programming
9. technical reviews, checking, testing and problem diagnosis
10. hands-on technical work, construction or repairs.” (Trevelyan)

Trevelyan’s study was able to quantify the activities of a large group of engineers which resulted in an initial classification of defining engineering practice in the workplace.

An objective of this study was to evaluate an engineer’s education as they transition into the workplace. To understand this it was necessary to define the engineering practice of a new graduate in relation to their work in later years as a professional engineer. To accomplish this the practice of a current P.Eng was compared to that of an EIT. Trevelyan’s work defined a list of the aspects of engineering practice. This list with modifications was developed into a questionnaire which the participants in the study could complete. This self assessment would show all the activities they completed in their work and a relative importance of each item. After completion of the interview process and initial evaluation of those transcripts two changes were made to Trevelyan’s list. The first was the addition of a new task within category #2 - coordination, working with people. It was discovered that the EIT participants fit into one of the original descriptors but with a significant difference. This descriptor was “coordinate insiders, mentoring” and describes an engineer working with peers evaluating their work and providing mentoring. The new engineer generally does not provide mentoring but more likely receives mentoring. Therefore an additional descriptor was added and labelled "coordinate with insiders, receive mentoring". This had a description as follows: "working with more senior engineers to receive technical checks on work, receive advice and feedback, review of technical competence, assessment of training needs, informal training when appropriate." The second change that was made was the deletion of one of the descriptors. This was again in category #2 - coordination, working with people. The descriptor "cross cultural supervision" had a description as follows: "coordinating supervision of people from different cultural backgrounds." It was felt that this item was appropriately covered in the descriptor "supervise staff" with a description as follows: "supervise staff for which engineer has line management responsibility." The remainder of Trevelyan's list of aspects of engineering practice were unchanged.

The next step in developing a questionnaire for engineering practice was to determine a method to rank the categories and the descriptors. Since this document describes all the tasks an engineer undertakes in their work, it is expected that most engineers would be involved in many if not all of the activities. It would then be difficult to determine which of these activities would comprise a major part of an engineer's duties. The questionnaire was set up with options for each of the descriptors. These options included columns labelled for time periods. Instructions were to mark one column for each descriptor that most represented your activity in the past year. The time periods included: Daily- refers to work you would expect to be involved in on a regular basis, Weekly- refers to work you have been involved in but not expected as your main duties, Monthly- refers to work you have completed in the past, on more than one occasion but that you see intermittently, Occasionally- work that you have completed in the past year but not something you would normally be expected to complete, Not applicable- refers to work you have never done or would not be expected to complete.

A second step of the questionnaire was to obtain a rank for each activity the engineer undertook. This portion of the research project was to evaluate the activities engineers undertook and look at a comparison between professional engineers and EIT's. This questionnaire, once completed, could show that most engineers are involved in most of the activities but not which are the most important to each individuals work day. An additional column was added and the participants were asked to rank each descriptor. Each category had its own column so that the ranking would be within a particular category. It was expected that the frequency of an activity would be an indicator of the importance. Individuals may indicate the same frequency on some of the descriptors and so a ranking system would show the relative importance. The participants were then asked to rank the importance of each category. It was felt that this would be another measure to indicate the relative importance of individual activities.

These questionnaires were distributed to the participants immediately following the third interview. A discussion was held to explain the purpose of the questionnaire and give detail on the instructions. Questions were answered and instructions given on the collection of the document. A sample copy of the questionnaire is included in Appendix D.

4.5.2 Graduate Attributes

The second questionnaire was developed from a graduate attributes exit interview as reported by Cicek (2013). The template used for the graduate attributes was developed by the Biosystems Engineering department at the University of Manitoba. It was developed as a survey for graduating students. This instrument adapted the CEAB graduate attributes by classifying each attribute into the six levels of knowledge from Bloom's Taxonomy. It then asks the participant to indicate the level of skill/ability they attained at time of graduation for each category. The skills/abilities are classified as three levels consisting of 1. not developed, 2. introduced, 3. mastered.

The original questionnaire took each graduate attribute and broke them into six levels based on each level of Bloom's Taxonomy of Learning Domains. Each level in each graduate attribute had a description developed to guide understanding. The first level in Bloom's Taxonomy is known as the knowledge level. The descriptor for this level asked the participant to indicate their ability to recall, describe, identify, recognize, or list standard characteristics of that graduate attribute. The second level in Bloom's taxonomy is the comprehension level. The descriptor for this level in the questionnaire asked the participant to describe, explain or understand the problems, processes, or principles of the particular graduate attribute. One of the graduate attributes had an additional level added in this the comprehension level. The attribute Professionalism broke this level into an understanding of the role of engineers in society and to the expected professional behaviour of a professional engineer. The third level in Bloom's taxonomy is that of application. The descriptor for this level asked for the ability to identify and solve problems, to analyze and utilize decision making skills, and to implement procedures. Two of the graduate attributes had additional levels included under application. The eighth attribute Professionalism had the attribute split between an engineer's professional role and an engineer's professional behaviour. Additionally in the eleventh attribute, Economics and Project Management, the application level of Bloom's taxonomy was adapted. This was split into a project management category and an economics category. The fourth level of Bloom's Taxonomy is analysis. The descriptor for analysis asked the participant to indicate their ability to analyze and solve complex problems, to test proposed solutions, examine, and critique others work. The fifth level of Bloom's taxonomy is the level of synthesis. The descriptor asked participants for their ability to devise complex equations, assemble outside information, combine techniques, and create initiatives in problem solving. The final level of Bloom's taxonomy is that of evaluation. At this level the participants were asked to identify their ability to evaluate models, select system solutions, evaluate techniques for whole processes, and critically evaluate management techniques and activities. The questionnaire was then developed individually for the EIT group and the P.Eng group. A sample copy of each questionnaire is included in Appendix E.

EIT

The questionnaire was adapted to be used as an instrument to understand engineering in the workplace. The objective was to define how the graduate attributes link to the practice of engineering. This instrument was used as a tool to define the level of engineering knowledge a new graduate has when entering the workplace. This was accomplished by modelling the questionnaire used by Cicek in their exit surveys. The participants were asked to indicate one of the three levels of understanding for each level of each graduate attribute. The levels were as follows: skill/ability not developed within engineering curriculum; skill/ability was introduced within the engineering curriculum, but the coverage was insufficient for it to be mastered; and skill/ability was covered in sufficient depth within the engineering curriculum that it could be mastered. This modelled the original questionnaire.

Included as an additional section to the document was an assessment of the requirements for a new graduate within their work environment. The participants were asked to assess the work they had been requested to complete upon entry to the workplace. This was assessed in one of the three levels of competency required for each level of each graduate attribute. The levels were as follows; skill/ability not used in any of the work I have been asked to complete, skill/ability was used but I needed support or additional training when completing these tasks; skill/ability was used in my work and felt comfortable completing these tasks.

P.Eng

The questionnaire was then adapted to be completed by the professional engineers. One objective of the study was to have a definition of the competency levels of the new graduates regarding the graduate attributes. This questionnaire was developed to allow the professional engineers to evaluate the competency level of the new engineering graduates. The professional engineers were asked to evaluate only those individuals that had been under their direct supervision. The same questionnaire used with the EIT's was used with some modifications to the competency levels. The professional engineers were asked to assess one of three levels of competency seen in new graduates for each level of descriptor for each graduate attribute. The three levels of descriptors were as follows: skill/ability was not evident in the new engineering graduate; skill/ability was evident in the new engineering graduate, but that they had not yet mastered the skill or needed additional support or training; skill/ability was evident in the new engineering graduate and they could readily use the skill in the workplace.

The professional engineering version of the questionnaire also includes an assessment of the workplace. They were asked to assess the work environment in the same manner as the EIT's. The descriptors for these levels were adapted as follows: skill/ability would not be expected to be used by a new engineering graduate; skill/ability would be expected to be used by a new engineering graduate with additional training or support; skill/ability would be expected to be used readily by a new engineering graduate.

This questionnaire was sent by email to the participants of the study following the completion of the third interview.

4.6 Coding

Following the completion of the interviews they were transcribed and checked. The information was then evaluated by coding the interviews in NVivo. The initial goal of the interviews was to evaluate the practice of engineering by assessing the activities of a practicing engineer. The interviews had been an exercise in discussing the tasks of an engineer. To evaluate this information it was coded based on Trevelyan's Aspects of Engineering Practice. Each interview was assessed and any reference to an engineering task was assigned to the appropriate aspect of engineering practice. Initial coding included the first two interviews from both the professional engineers and the EIT's.

The second stage of coding was for the graduate attributes. Nodes were set up in NVivo for each graduate attribute as described in the questionnaire. The third interviews from all participants were coded to these nodes with references that indicated the skill of that attribute. Upon completion of this coding it was felt that additional work was necessary. It was recognized that the information contained in the third interview closely matched the information in the first two interviews. While each interview had its own set of questions, they were based on the same premise. Information in the interviews were based on engineering activities. This included the tasks undertaken and the skill level necessary. Therefore the first two interviews contained information to complete a task along with the task itself. The third interview also contained information on tasks undertaken as well as the skill level. A decision was made to recode the first two EIT interviews based on the graduate attributes. The third interview was also recoded based on the aspects of engineering practice. This gave a greater breadth to the data as it included a larger database of coded information from all the interviews. With each interview coded to both aspects of engineering and skill level, this increased the opportunity to find a correlation. The first two interviews by the professional engineers were not recoded with respect to the graduate attributes. Those interviews were based on their own professional activities not that of the new graduates.

There was another set of interviews that were coded as well. Initially as stated there had been a pilot study. One of the engineers in the current study had been involved in the earlier pilot study. Those interviews were also based specifically on the tasks that a professional engineer undertakes on a daily basis. Therefore these interviews were included and coded to the aspects of engineering practice.

4.7 Data Collection

4.7.1 First Interviews

The initial portion of the project involved the individual interviews. During the initial meeting an extensive discussion was held. Details of the project and expectations of the participants were outlined and time was given to ensure the participant was comfortable. Given that the interviewee was an instructor at the University of Manitoba all of the EIT's had met and knew the individual. Additionally two of the senior participants had been involved in the earlier study so were also familiar with this interviewer. This made the initial meetings run smoothly. These interviews were conducted in an open-ended format for a maximum of 60 minutes duration and were used to collect data on their professional role, career path, engineering experiences, activities they undertake daily, and understanding of engineering. A sample interview guide is included in Appendix C.

4.7.2 Second Interview

Following the first interview session, a second interview was scheduled with each participant. It was felt that additional information could be obtained in a second meeting by probing in alternative areas. This interview was conducted in an open-ended format with questions on defining success, comparing their jobs with others in the organization, defining engineering tasks and considering resources they use to complete their work. This interview session was more productive than the original. The participants were more comfortable and willing to expand on their responses. A sample interview guide is included in Appendix C.

4.7.3 Third Interview

A third interview was conducted with all participants on how the graduate attributes relate to the activities an engineer undertakes. This interview was conducted in an open-ended format with a different set of questions for the EIT's and professional engineers.

EIT

The purpose of the interview for this group was to determine how the tasks they undertook related to the education they had received. The guiding questions asked about their roles and responsibilities, training they had required, their strengths and weaknesses and on their comfort level with the position. A sample interview guide is included in Appendix C.

P. Eng

The purpose of the interviews for the P. Eng's was to determine what their expectations were for a new engineering graduate. This information would then be compared to tasks actually undertaken and to the EIT's perceptions. Guiding questions included information about roles and responsibilities, expectations of new graduates in their work, training offered, and strengths and weaknesses of new graduates. A sample interview guide is included in Appendix C.

4.7.4 First Questionnaire

At the completion of the third interview a questionnaire was given to the participants. An informational discussion was held on specific instructions to complete the form. This questionnaire was adapted from work by Trevelyan (2008) and the aspects of engineering practice. The questionnaire was adapted after the initial two interviews were coded. Trevelyan's work classified engineering work into categories and broke the categories into specific tasks with descriptors. These classifications are for typical engineering work while this study included individuals that were still EIT's. It was found that instead of being the leaders, these individuals would spend time seeking support. Therefore additional task descriptors were included which would be more inclusive of the junior engineering experience. Participants were asked to complete the questionnaire indicating which tasks they completed on a daily, weekly, monthly, and occasional basis. They were then asked to rank the importance of each task to the position that they held in the organization. The same questionnaire was given to all of the participants (both senior and EIT's). A sample questionnaire is included in Appendix D.

4.7.5 Second Questionnaire

Following the third interview a second questionnaire was sent to each participant by email with instructions for completion. This questionnaire was adapted from an exit survey used for mechanical engineering graduates at the University of Manitoba (Seniuk et al, 2013). The original survey was on student perceptions of graduate attribute competencies. The original was adapted for both the junior engineering and senior engineering participants.

EIT Questionnaire

The original exit survey revised the indicators for each graduate attribute "to reflect the six levels of Bloom's taxonomy of educational objectives in the cognitive domain: knowledge, comprehension, application, analysis, synthesis and evaluation"(Cicek et al, 2013, p.2). Students were asked to evaluate at which level; not developed, introduced, mastery, they considered themselves to be for each domain under each graduate attribute at time of graduation from their engineering degree. The adaptation for this study was the addition of another evaluation. The EIT's were still asked to complete the questionnaire with a self-evaluation of which level they felt they had graduated with after completing the engineering program. They were then asked to evaluate which level would have been appropriate with respect to the tasks they were asked to complete. A sample questionnaire is included as Appendix E.

P. Eng Questionnaire

This questionnaire was also adapted from the Cicek model. The P.Eng's were asked to evaluate at which level; not developed, introduced, mastery, they would classify the EIT's that had worked under their supervision. The second part of their document asked them to evaluate which level would be required of a new engineering graduate entering the workplace for the tasks that would be expected of them. A sample questionnaire is included in Appendix E.

4.7.6 Focus Group

Following the completion of all the individual interviews focus groups were held with each group. They were scheduled over a lunch period with the researcher to accommodate individual schedules.

P. Eng

The four senior engineering participants met for a focus group discussion which lasted between 60 to 90 minutes. There was great difficultly scheduling all four to a common time, therefore only three members attended. The focus group was conducted in an open ended format and used to gather additional information on their role in the organization and on expectations of a newly graduated engineer. The focus group was used to compliment information from previous interviews and to allow individuals to use each others' comments to trigger new information. The final question in the focus group was on the questionnaires they had received. Participants were asked to give their opinion of the questionnaires and to add any further insight. A sample interview guide is included in Appendix C.

EIT

All four EIT's were contacted to attend a focus group discussion. After some juggling of schedules an appropriate time and place was arranged. The meeting was conducted in an open ended format and lasted for 60 minutes. Guiding questions included information on the demanding aspects of the work, training opportunities, expectations of the job, and advice for the new graduate program at Manitoba Hydro. As a final question the group was asked to comment on the questionnaire they had received. A sample interview guide is included in Appendix C.

4.8 Data Analysis

A number of data analysis methods were used to evaluate the different objectives. The first two objectives of the study were to identify the role of either a P.Eng or an EIT with respect to the tasks they undertook at the workplace. Due to the low N-value the data was compiled with averages and means as a comparison tool.

The interview data portion was analyzed and categorized into the different aspects of engineering practice using the software NVivo. The questionnaire data was analyzed with weighted averages used through the choosen categories and rank attributed by the participants. This method gave a weighted average of the job task undertaken and its relative importance to the other tasks.

The third and fourth objectives of the study were to identify the abilities and knowledge requirements of a newly graduated engineer with respect to the graduate attributes. The data were collected through the use of interviews and questionnaires. The interview data was analyzed and categorized into the different graduate attribute categories using the software NVivo. Following this the data was averaged for the P.Eng and EIT groups over the different categories.

There were a number of challenges with the data analysis. The first being the low N-value, not only of there being only eight participants but that these participants were separated into two groups with four participants in each group. The second challenge was the subjectivity of the data in multiple ways. The first subjectivity is the interview information from the participants. Discussions centred around work activities undertaken and the participants would describe current information they remembered. The discussions they undertook were on activities they felt were important and based on tasks they felt were engineering tasks. The second area of subjectivity was with the researcher interpretation of the data. The researcher was a practising engineer which gave a certain perspective to how the different tasks should be categorized.

A third challenge was in the perspective of the two groups. The P.Eng group had years of experience in which to base their discussions and an understanding of the workplace roles they had moved through in their careers. The EIT group had very little perspective as they had only worked in limited positions. Therefore the analysis of the data needed to be coordinated between the two groups. Another challenge with data analysis was that all the participants were employed by the same organization. It was a large organization and the participants worked in very different areas which was a benefit for the diversity. The disadvantage was that each organization has its own culture which plays a role in influencing the employees. There would be benefits in the consistency of corporate goals and activities. The challenge would be that employees would be hired with expectations to have similar knowledge or abilities. Each employee would then also receive internal training in similar corporate driven knowledge and abilities.

The fifth objective of the study was to determine the link between an EITs knowledge and abilities with that of a P.Eng. The analysis of the data for this objective was done with analysis tools within the NVivo software. The diversity of the data made this difficult with matrix coding being the only method that showed recognizable correlation. The difficulty in this analysis was due to the large separation of job classification between the P.Eng and EIT groups. The senior group were all in managerial positions with minimal responsibilities to specific engineering work. There were no direct employment links between the two groups.

4.9 Ethical and Confidentiality Considerations

This is a study involving individuals employed by a large corporation. Anytime people are part of a study considerations are required to protect the individuals. This is especially important for this study as interview information is requested from the participants on their engineering tasks and how these tasks are performed. Another consideration is the fact that all participants are employed by the same corporation. Some of the participants in the pilot study had supervisory/employee relationships. It was important to protect information exchanged and to eliminate the prospect of any coercion to participate. These issues were dealt with through appropriate ethical approval procedures. Anonymity measures were undertaken with all data sources including individual interview, focus groups, and questionnaires. Participants were never identified and data was coded to strip any identification prior to any publication. Consideration was taken that there was no position of power between members of the senior engineering group and the junior engineering group. There is also the situation of the researcher's position of power with respect to the participants. The researcher had no prior contact or knowledge with any of the senior engineering participants or any of the members of the pilot study. The researcher was known to the EIT's as an instructor at the University of Manitoba. In all cases this was for one first year design course and preceded the study by at least four years. All ethical issues were covered by signed agreements between participants and the researcher. The protocol for the project was approved by the University's research ethics board. Approval certificates and letters of consent are included in Appendix F&G.

An issue of confidentiality for this project was of a corporate nature. Manitoba Hydro was concerned that information detrimental to the corporation expressed during an interview could be released by the researcher. An agreement was reached with a signed contract between the corporation and the researcher to protect both parties.

5 RESULTS AND DISCUSSION

This chapter begins by discussing each set of collected data for each category within the aspects of engineering practice and the graduate attributes. Summaries are given for each category of each data collection method with an overall summary following each section.

5.1 Interviews on Aspects of Engineering Practice

Once the interviews were complete and transcribed, coding was undertaken in NVivo. Initially nodes were set up for each aspect of engineering practice as described earlier. Each interview was then evaluated and references were identified that fit the description of one of the aspects of engineering practice. The reference would then be assigned to the node. Once the interviews had been coded in this manner each of the aspects of engineering practice were printed along with all the references that had been assigned to that node. Each of these documents were then evaluated to ensure that the reference did indeed fit with the description of that particular node. Once that was complete the data was evaluated to gain an understanding of the activities undertaken by an engineer on a daily basis.

The original plan for the EIT interviews was to take the first two interviews and code them with respect to aspects of engineering practice. There was a change in this plan once the third interview took place. In coding the third interview it was noticed that the discussion included many references to activities undertaken that would fit with engineering practice. A decision was made to code the third interview into the aspects of engineering practice. This gave three full interviews of reference data for each member of the EIT group. Also included was the focus group interview with the EIT group.

There were a total of 648 references to aspects of engineering practice in the EIT interviews. It can be seen from Figure 1 that there is a distribution across most of the areas but grouping is dominant in certain regions.

The three main categories of activity that the EIT's indicated dominated their work environment consisted of 73.7% of all the references. These categories were; #2 - coordination, working with people at 31.9%, #8 - technical, creating new concepts, problem solving at 23% and #9 - technical test, inspection, measurement, review, checking at 18.8%. There are a number of reasons why these areas received such a high proportion of the references. These participants were young individuals early in their careers and so expectations would be that they had a high incidence of interaction with other staff. They would be closely monitored and expected to report on a regular basis.

These individuals, as EIT's, are required to have their work supervised and so a high reporting of interactions with others would be normal. Secondly, as new graduates, expectations are that they would be assigned technical tasks so it is not surprising that most of the activities fall into technical categories.

A final reason is in the makeup of the categories that were not highly represented. These categories include tasks that would be considered at a more senior level. These include finance, human resources, business development, and project management. Overall these are areas that an EIT's skills will develop over time and so it would be unusual to see a high number of references for a new graduate.

In Trevelyan's study he found that the top individual line items that received the highest percentage of references were, coordinating people inside the organization

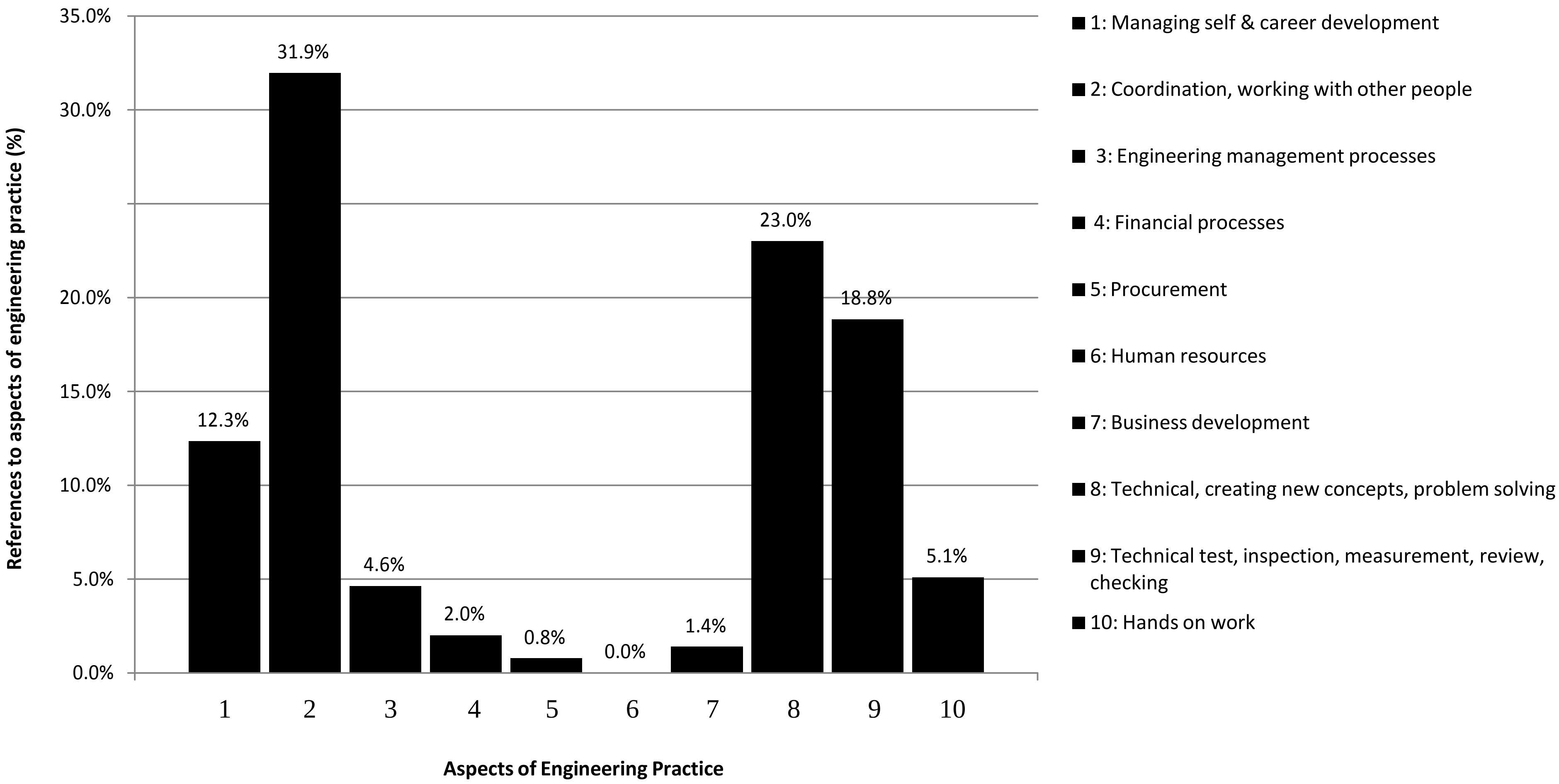


Figure 1: Interview responses as a percentage of total responses by Engineers in Training to overall categories of aspects of engineering practice.

3.5%, and coordinating clients at 3.2%. In the EIT study the most frequent reference found was for the activity coordinate with insiders, receive mentoring at 11.6% (Figure 2). This was the additional descriptor that had been added to include the many references from the participants referring to seeking advice and support. The EIT's also referenced the original coordinating insiders, mentoring descriptor 4% of the time. So the total reference for the EIT group to coordinating with insiders was 15.6%. The next most frequent references were for coordinating outsiders at 6.6%, personal research at 5.6%, hands on work at 5.1%, programming at 5.1% and formal training at 4.9%. The EIT's top activity matches closely to an overall engineering community of communication within the local work environment. The next highest one is in coordinating with others category.

In his paper the definition is of working with others not of the same organization. This was considered, in light of the size and structure of Manitoba Hydro, and a decision was made that this would include working with other departments. The organization is so large and diverse that working with other departments would mirror working with other organizations for a small engineering firm. The other top activities for the EIT group are consistent with an entry level position and therefore would differ from Trevelyan's study. Those next most prominent activities were in the technical and personal growth areas. This differs from Trevelyan's study of professional engineers who would be expected to be involved in more managerial duties.

The interviews for the professional engineers were also coded to the aspects of engineering practice. These P.Eng's had two separate types of interviews. The first two interviews were on the activities they undertake on a daily basis.

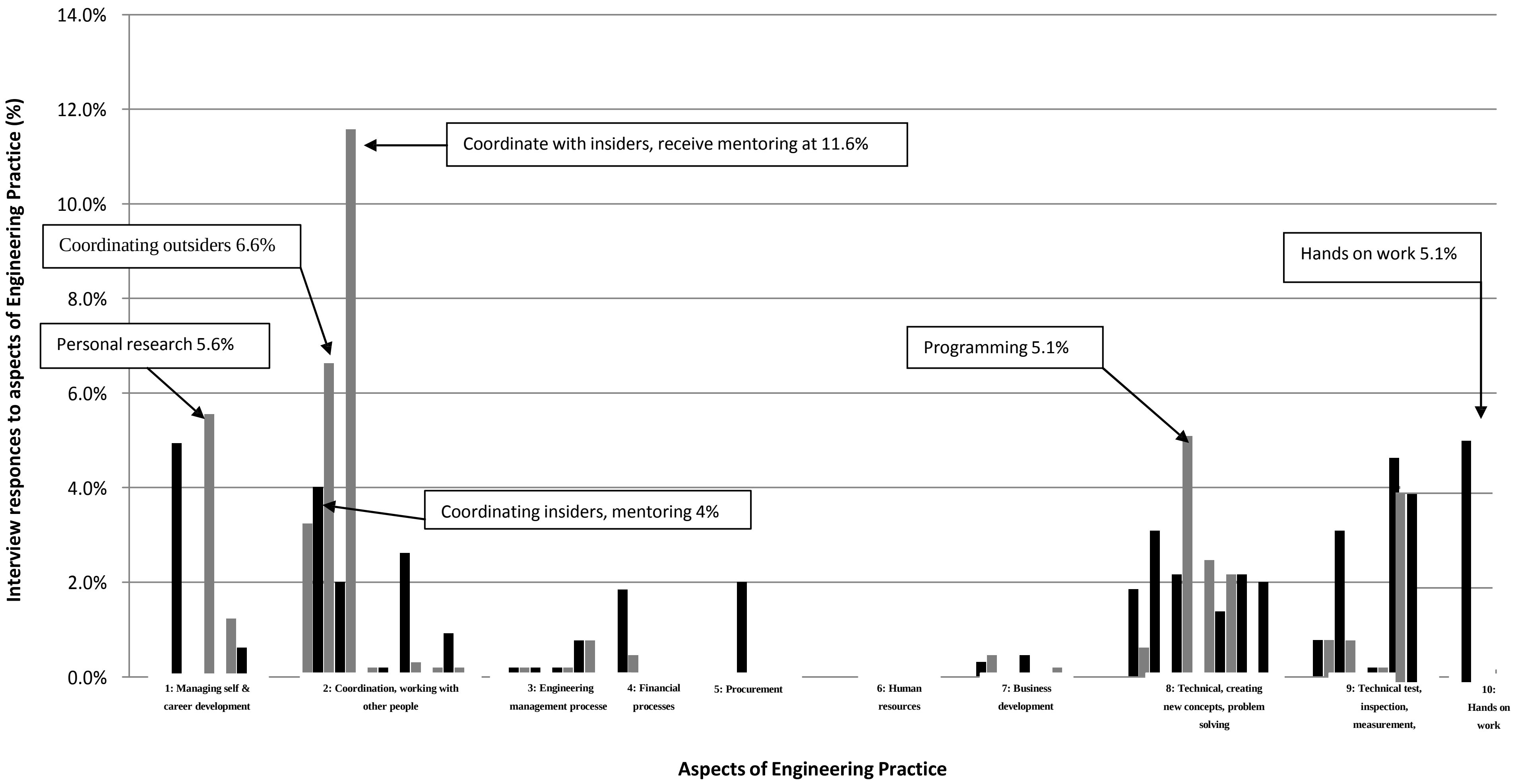


Figure 2: Percentage of questionnaire responses by EIT's on aspects of engineering practice.

The third interview was on the activities of EIT's under their supervision. These interviews were all coded in the same manner as explained for the EIT's.

In studying the results of the analysis a comparison was made to the Trevelyan study. This study showed that the P.Eng's indicated the most prominent category for their activities was in #2 - coordination, working with people at 42.9% level (Figure 3). The next two levels were in #3 - engineering management processes at 17.7% and #8 - technical, creating new concepts, problem solving at 13.8%. This comprised of nearly 75% of the total, leaving very little remaining for the rest of the categories. Trevelyan's study had levels of 27%, 18.5% and 13.5% for the same categories. In that study they ranked first, second and fourth. These results are consistent with his earlier study.

In looking at individual activities, the most prominent ones that were referenced by the professional engineers were: team work at 12.3%, supervise staff at 9.7%, coordinate insiders at 9.3%, plan projects at 7.5% and business development at 6.5% (Figure 4). These differ from the Trevelyan study but the activity of coordinating insiders played a prominent role in both studies.

The final interviews that were coded for aspects of engineering practice were the third interview with the professional engineers evaluating the activities of a new graduate. The category with the highest references was again #2 - coordination, working with people at 37.0% (Figure 5). This compares with the EIT's rating of 31.9%. The next categories were #8 - technical, creating new concepts, problem solving at 25.9% and #1 - managing self and career at 13.0%. Both the EIT's and P.Eng's interviews resulted in the same categories chosen for the two most important groups of activities for a new graduate. In both cases the top category also matches previous work by Trevelyan. This seems to fit the earlier discussions in the literature

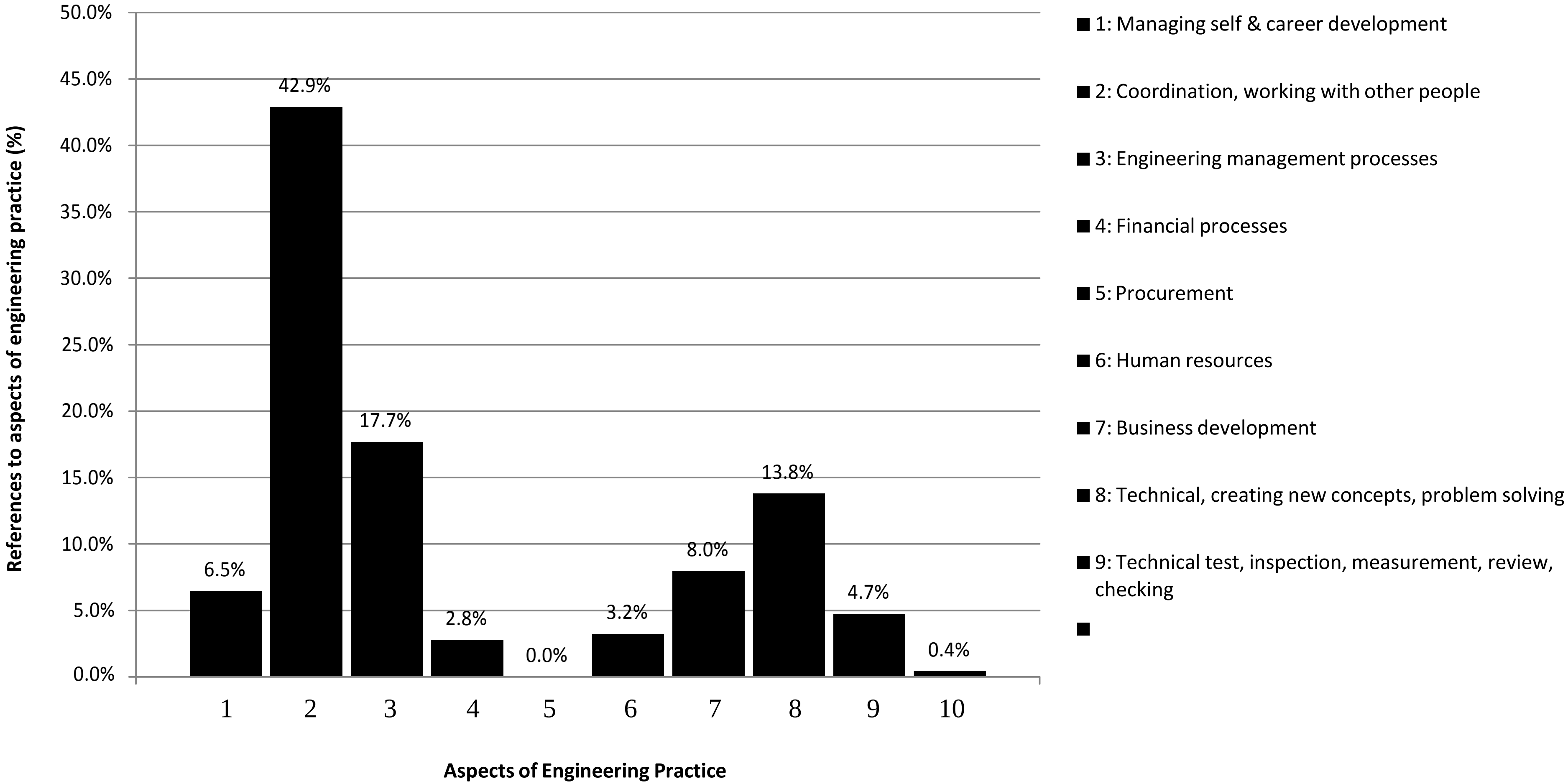


Figure 3: Overall Interview responses as a percentage of total responses by Professional Engineers to overall categories of aspects of engineering practice.

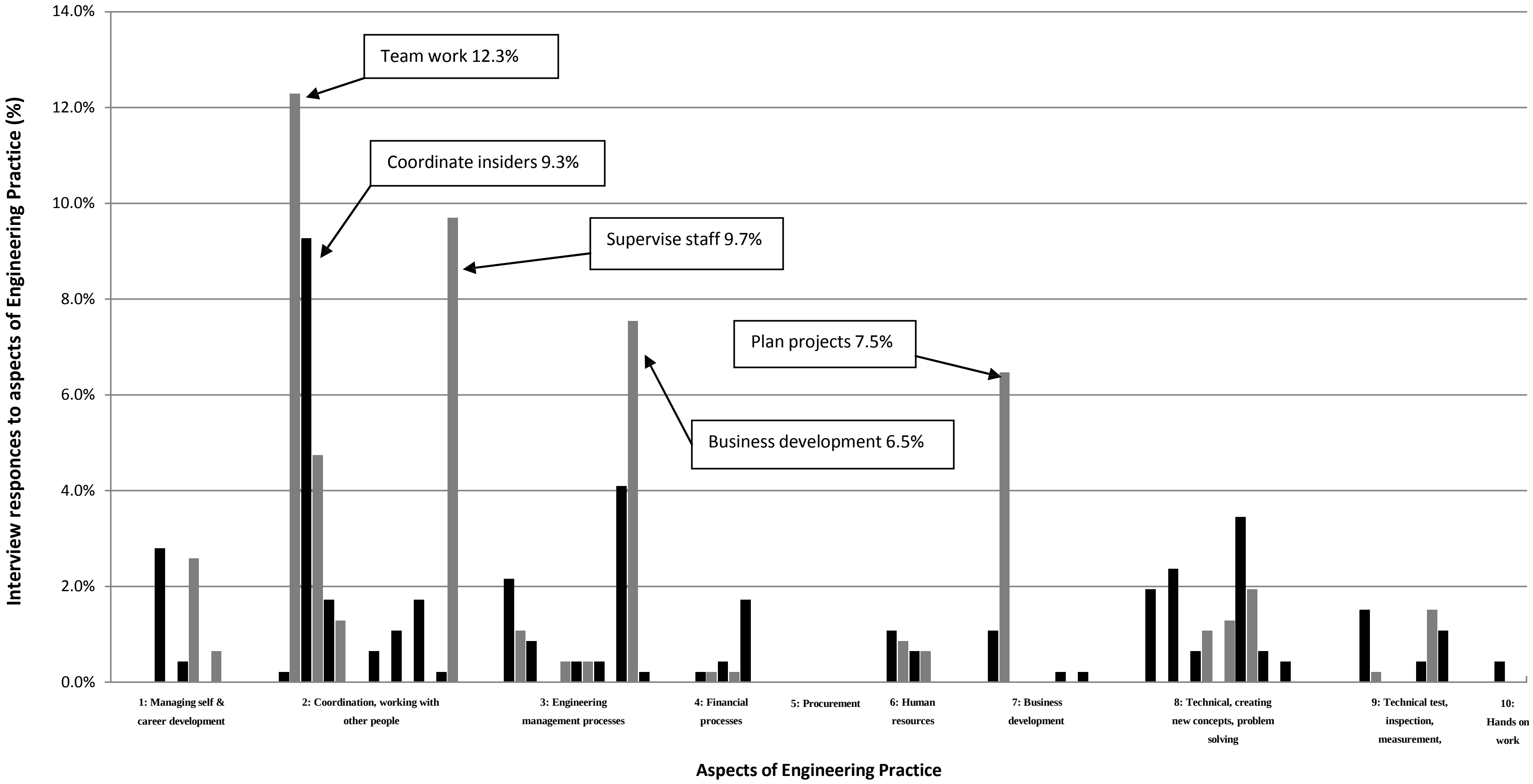


Figure 4: Percentage of questionnaire responses by professional engineers on aspects of engineering practice.

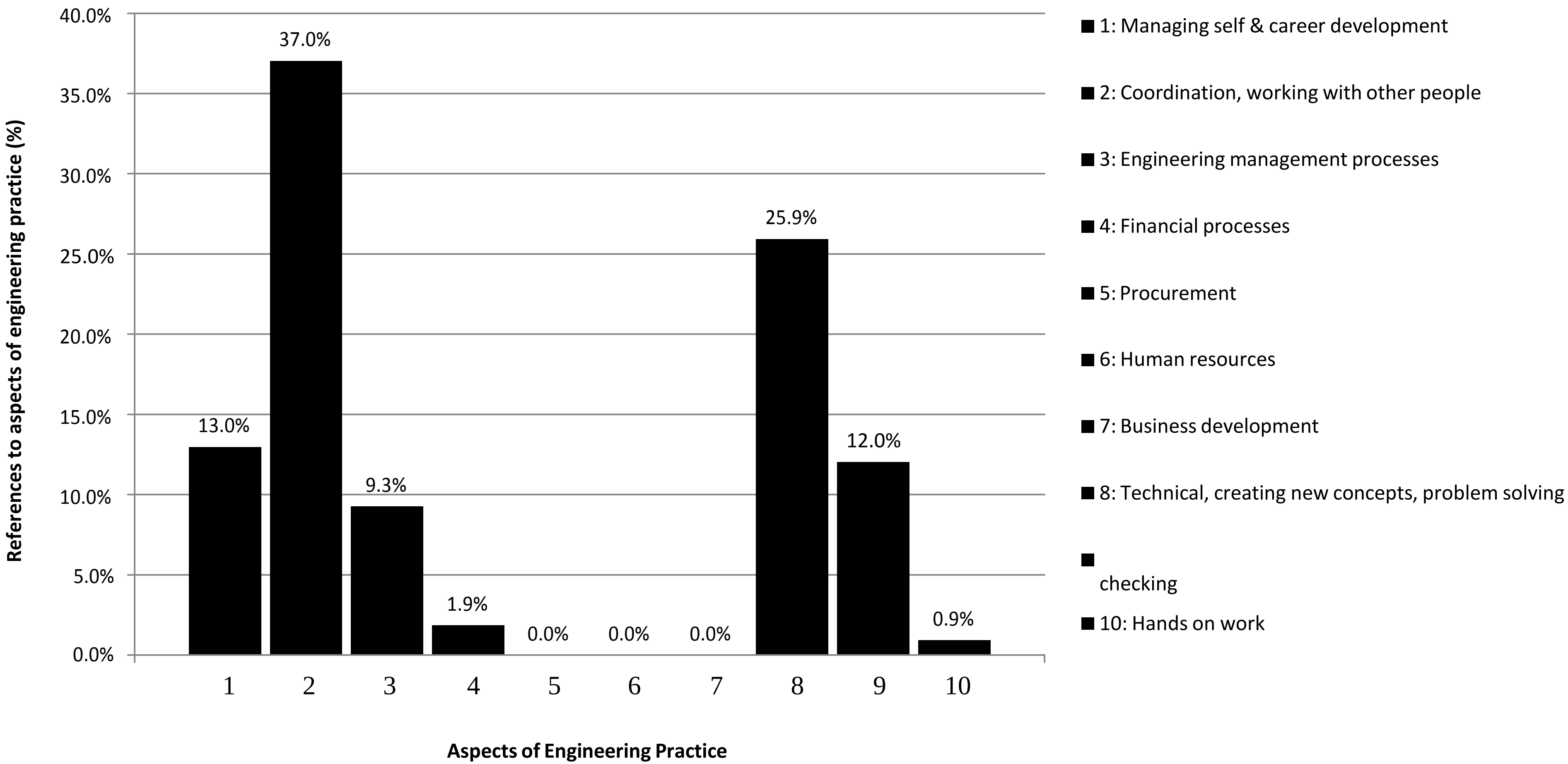


Figure 5: Interview responses as a percentage of total responses by Professional Engineers assessing EIT's as to overall categories of aspects of engineering practice.

on the importance of communication and teamwork. Each category was then evaluated in detail to understand which are the most important activities for each level of engineering at Manitoba Hydro.

Managing Self and Career Development

This category consists of descriptors for activities that aid in personal growth. Some of these had no references attached from the interviews. This would be a result of interview style and the fact that certain areas were not the focus of the research.

These areas would also have been areas where the participants felt uncomfortable and/or had no interest. They included areas such as promotion, internal transfer, and apply for a job. Expectations were that these areas would be avoided in discussions.

In a comparison of the results from the three groups of interviews it was observed that the professional engineers spent 6.5% of their time in this category, the EIT's spent 12.3% and the P.Eng's noted that EIT's spent 13% of their time here (Figures 1,3,5). The P.Eng's time was split between formal training (2) at 2.8% and personal research (5) at 2.6% (Figure 6b). The EIT's spent time in personal research (5) at 5.6% and formal training (2) at 4.8% (Figure 6a). These two activities were important to both groups but played a much larger role for the EIT's relative to other activities. This result would fit a pattern of new employee's spending more time in learning their position and in upgrading their skills. The P.Eng evaluation of the EIT was almost exclusively in the area of formal training (2) at 10.2% (Figure 6c). This result shows the importance senior individuals place on the proper training of new entrants to an organization.

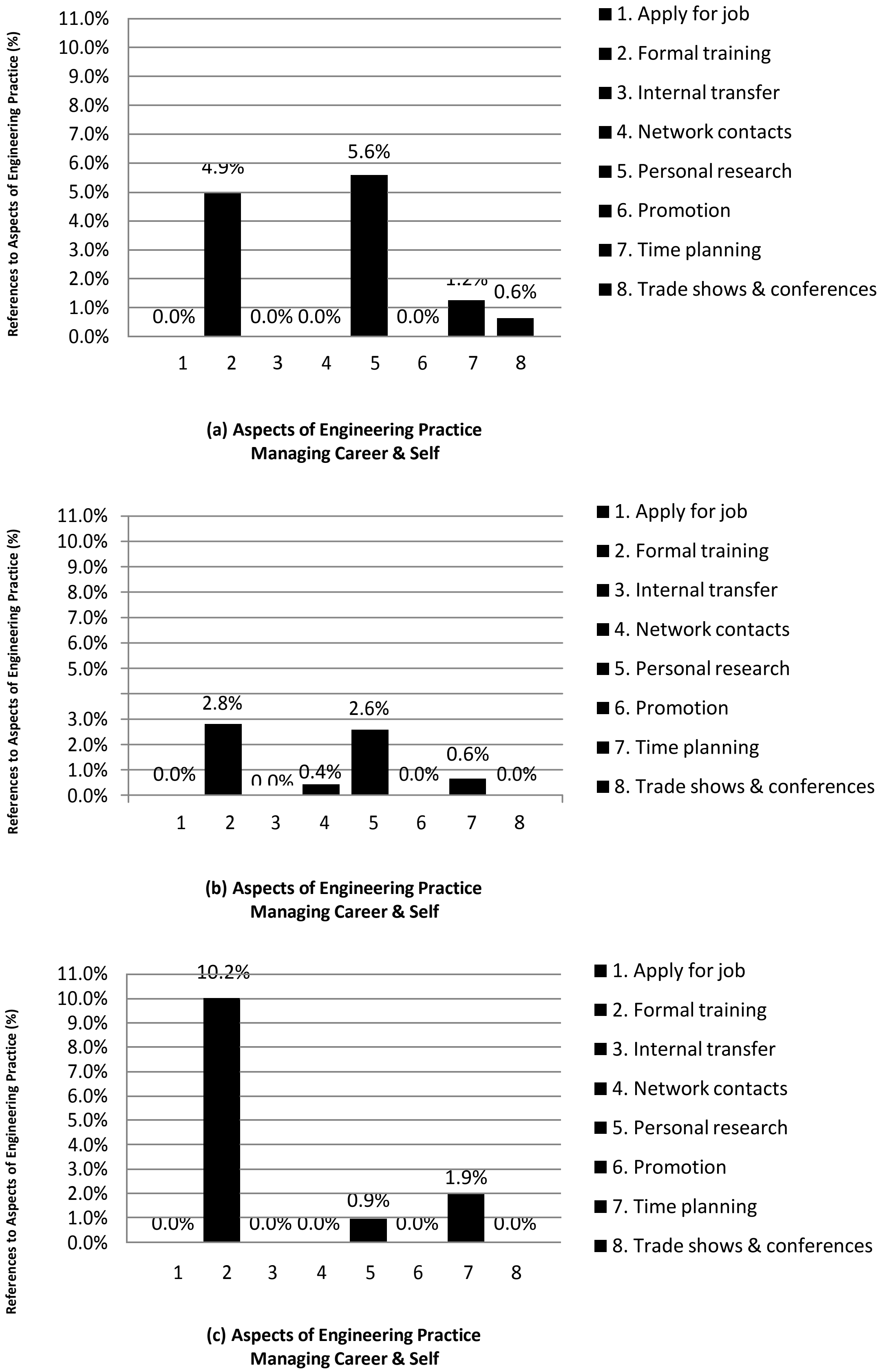


Figure 6 (a,b,c): Interview responses by (a) Engineers in Training, (b) Professional Engineers, and (c) Professional Engineers assessing EIT's within the Managing Career & Self category of Aspects of Engineering Practice.

Coordination, working with people

This category is where all the interviews showed the greatest number of references. This would indicate that this is an area of importance to the workplace and also an area where most activity occurs. One reason for the high number of references is that most work today occurs not in isolation but in relation to others. Many of the references here would be in discussion with team members and others about aspects of the work. Therefore they relate both to the communication aspect and also to the technical or management aspect.

In this category the P.Eng's top activities were team work (2) at 12.3%, supervise staff (16) at 9.7% and coordinate with insiders (3) at 9.3% (Figure 7). These results show that a large proportion of our discussion was on their team communication and supervisory duties. This is a reflection of the size of the organization and position of responsibility of the individual. All four of these P.Eng's needed to ensure that their group produced results and fit in with the larger organization. The EIT focus was on receiving mentoring (6) at 11.6%, coordinating with outsiders (4) at 6.6% and coordinating with insiders (3) at 4.0% (Figure 8). As junior members their responsibility was in learning their job and communicating both inside and outside their departments.

The P.Eng perception for the EIT's was the importance of receiving mentoring (6) at 14.8%, report progress (11) at 11.1%, team work (11) at 4.6% and coordinate insiders (3) at 4.6% (Figure 9). The overall response of this group matches the self assessment of the EIT's with the importance of learning the job and communicating. A comment that was raised on numerous occasions was "they have to be able to ask the right questions to find out so they can do that." In discussions of qualities for

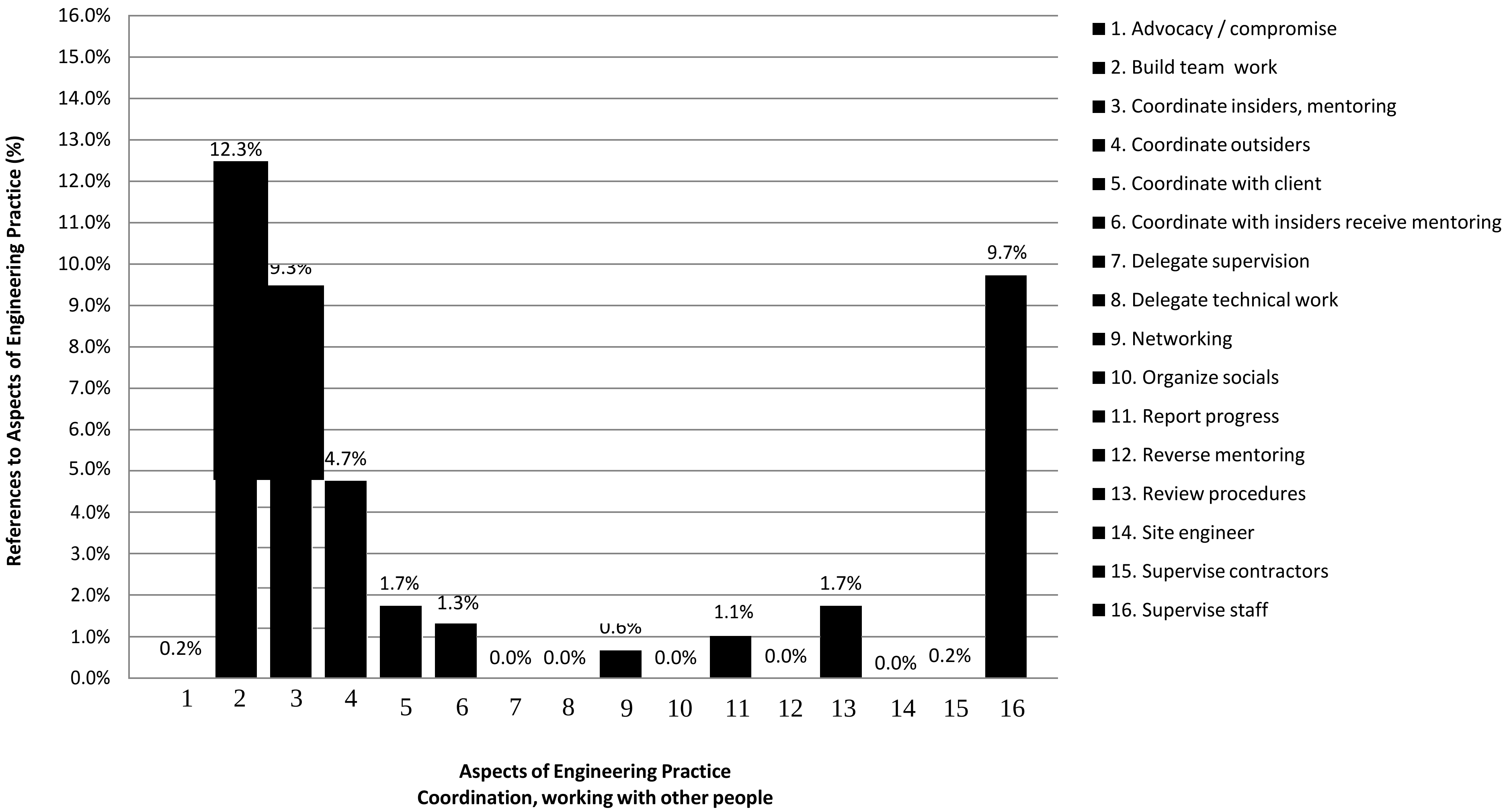


Figure 7: Interview responses by Professional Engineers within the Coordination, working with other people category of Aspects of Engineering Practice.

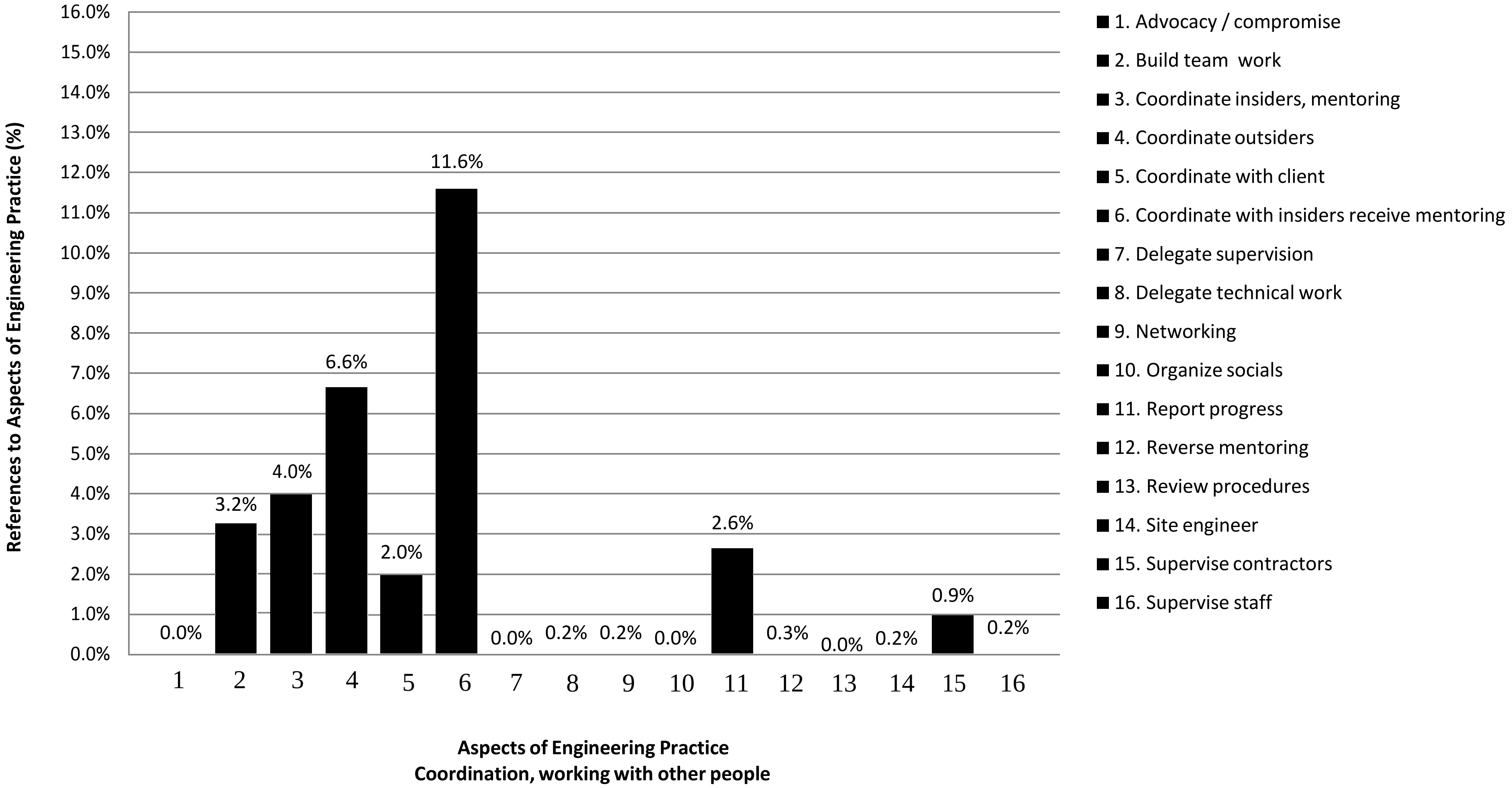


Figure 8: Interview responses by Engineers in Training within the Coordination, working with other people category of Aspects of Engineering Practice.

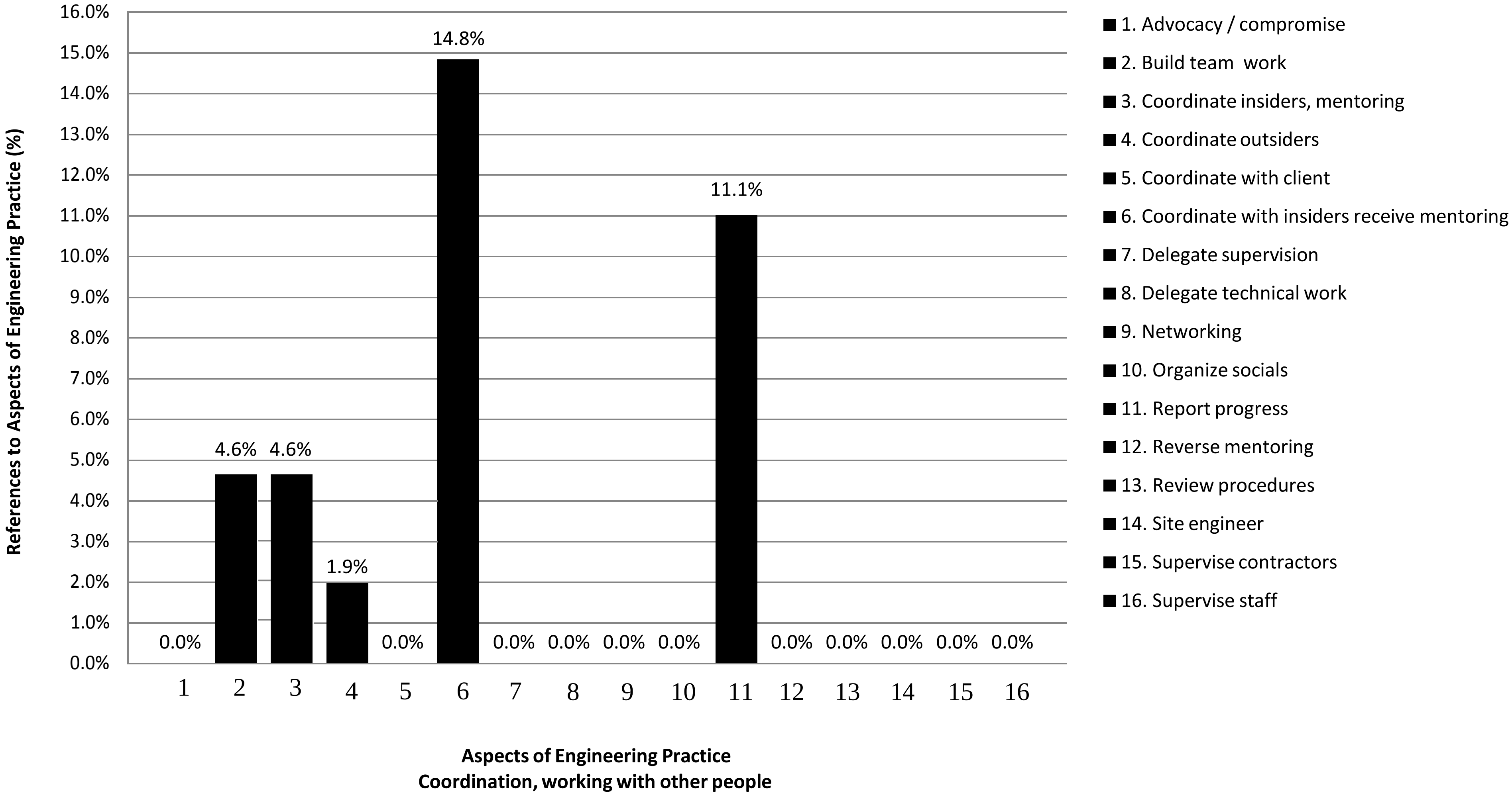


Figure 9: Interview Responses by Professional Engineers assessing EIT's within the Coordination, working with other people category of Aspects of Engineering Practice.

hiring new employees it was stated that the ability to ask questions was more important than average technical abilities.

Engineering Management Process

In the category of engineering management the expectation would be that the P.Eng's have a prominent involvement. The interviews showed that P.Engs indicated in 7.5% of their responses that they planned projects (12) and in 4.1% they managed projects (11) (Figure 10). This category consists of management type activities as the title implies. Some of the activities would only occur on a more sporadic basis such as a completion report. This activity would be dependent on the length of a project but generally would not be acted on nearly as often as an activity such as manage a project. Other activities are more organizational dependent such as manage maintenance or production. The activities relevant to Manitoba Hydro would be related to project management which are the ones referenced in the interviews. The senior individuals would be responsible for the planning of these projects as indicated by the results. The EIT's results showed that 1.9% of their responses were for managing projects (11) (Figure 11). There was very little reference to this category in any of the other activities. The senior members rated the EIT's as managing projects (11) in 7.4% of the responses (Figure 12). This matches the EIT's response only at a higher level. The P.Eng's discussion on project management for the EIT's was on the progression from small projects or parts of larger projects as in the following: "you're managing your little project", "they would be given a smaller project to deal with." The P.Eng saw project management as an activity EIT's were assigned. The EIT's discussed project management in more detail explaining all their individual tasks which are considered to be more technically based assignments.

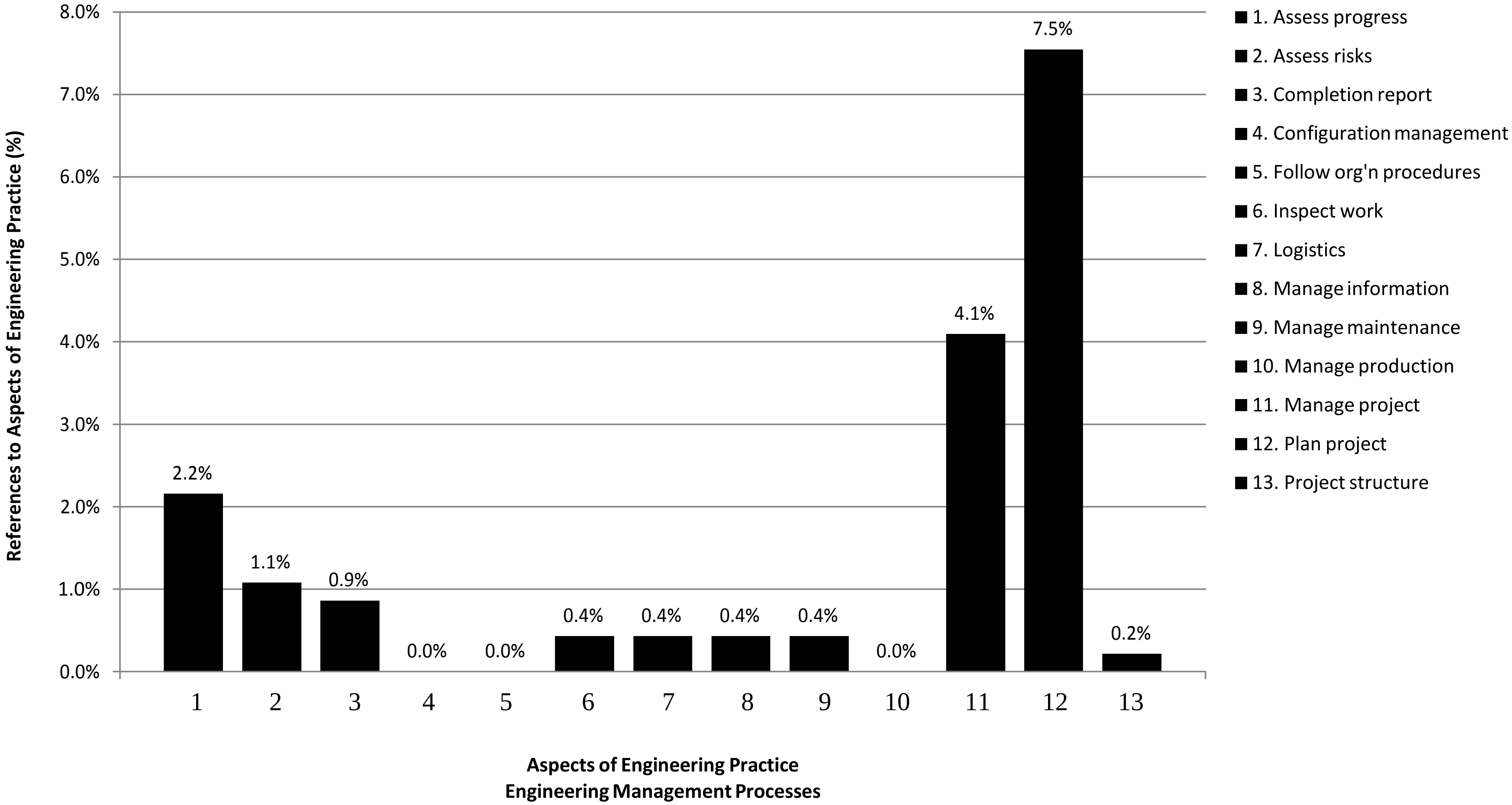


Figure 10: Interview responses by Professional Engineers within the Engineering Management Processes category of Aspects of Engineering Practice.

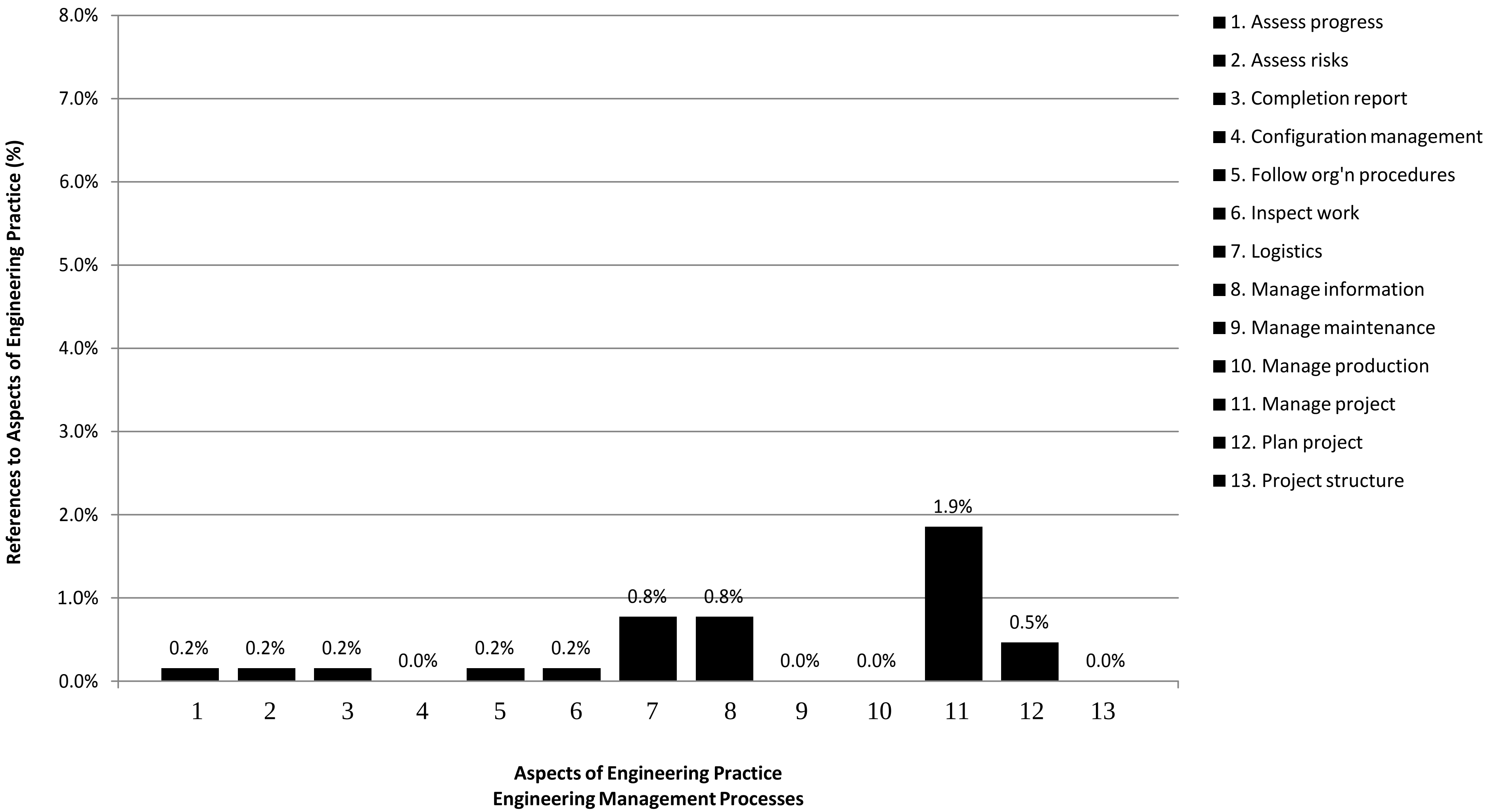


Figure 11: Interview responses by Engineers in Training within the Engineering Management Processes category of Aspects of Engineering Practice.

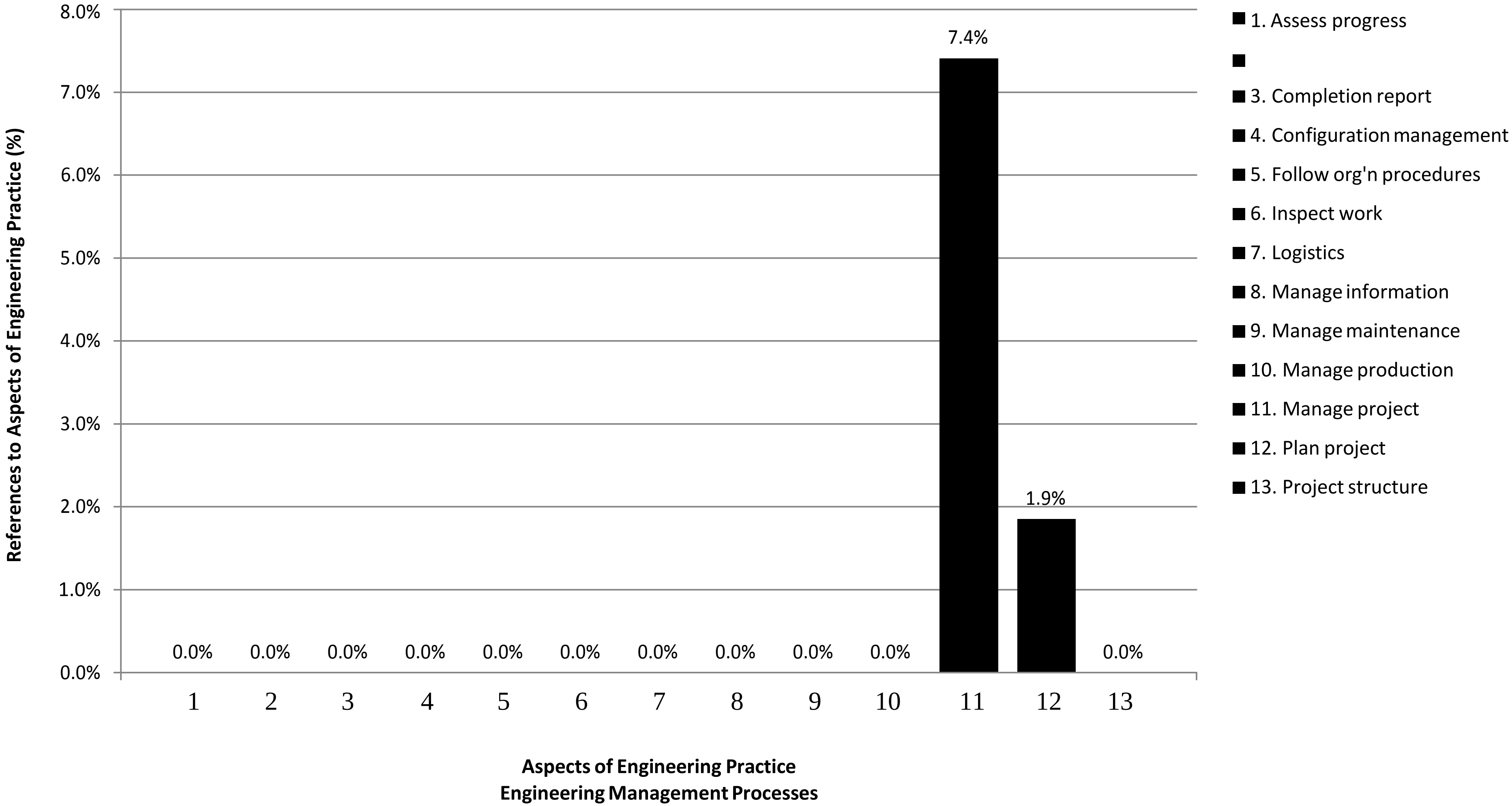


Figure 12: Interview responses by Professional Engineers assessing EIT's within the Engineering Management Processes category of Aspects of Engineering Practice.

Financial Processes

This category had a very minimal discussion by all the participants. The references from all these types of interviews came from the area of predicting costs. The total references on these cost predictions were only in the 2% range for all groups. Specific references were made on predicting costs for projects or as an example “some totally manage the capital and operating budgets.” This discussion was minimal and so is not considered a major aspect of the participant’s employment.

Procurement

This is another category which had minimal discussion in the interview process. There was some discussion by the EIT’s about evaluating some tender proposals. The P.Eng’s had no referenced discussion in this area to themselves or in their evaluation of EIT’s. In total only 0.8% of the references applied to this topic and so it is not considered a major aspect of this section of the research study.

Human Resources

This is a category which would normally be an aspect of a more senior position. It involves recruitment, training, and performance evaluation tasks. This was evident from the interview. There were no references with regard to any of the EIT’s. The P.Eng’s had brief discussions in these areas but it only amounted to a total of 3.2% of all references. This was basically equally split between each of the activities. This would be an area of activity that is not on a regular task list but attended to as necessary.

Business Development

Business development is another P.Eng activity. The tasks in this category fall under more long term development and require some experience within an organization. They are also generally assigned to more senior individuals. It was found that 6.5% of the references from the interviews of P.Eng's were for business development. These discussions were for longer term plans such as, "expanded to doing some planning studies for the distribution system," and "one was a business plan, working on the business planning for the division and then for the business unit." There were no references from the EIT's in this category and none indicated by the P.Eng's when referring to activities of the EIT.

Technical, creating new concepts, problem solving

This was the category that had the second highest overall number of references for all groups. It received a high rating from each of the sets of interviews. The references were also represented over all the activities in the category. The total references for the category for each group was: 13.8% for the P.Eng, 23.0% for the EIT, and 25.9% for the P.Eng rating on the EIT.

The activities the P.Eng referenced most often were research standards and solutions (9) at 3.4%, document (3) at 2.4%, design (1) at 1.9% and scoping (10) at 1.9% (Figure 13). These activities are more common to a large range of engineers with varying experiences. The high number of references with regards to standards in this group was due to one of the participants being involved in a project to develop new standards. Therefore job requirements increased the level of this activity for that professional engineer. Even so this is an activity that all of the P.Eng's had some involvement. The EIT's in their interviews referenced programming (6) at 5.1%, document (3) at 3.1% and research (8) at 2.5% (Figure 14). They also referenced

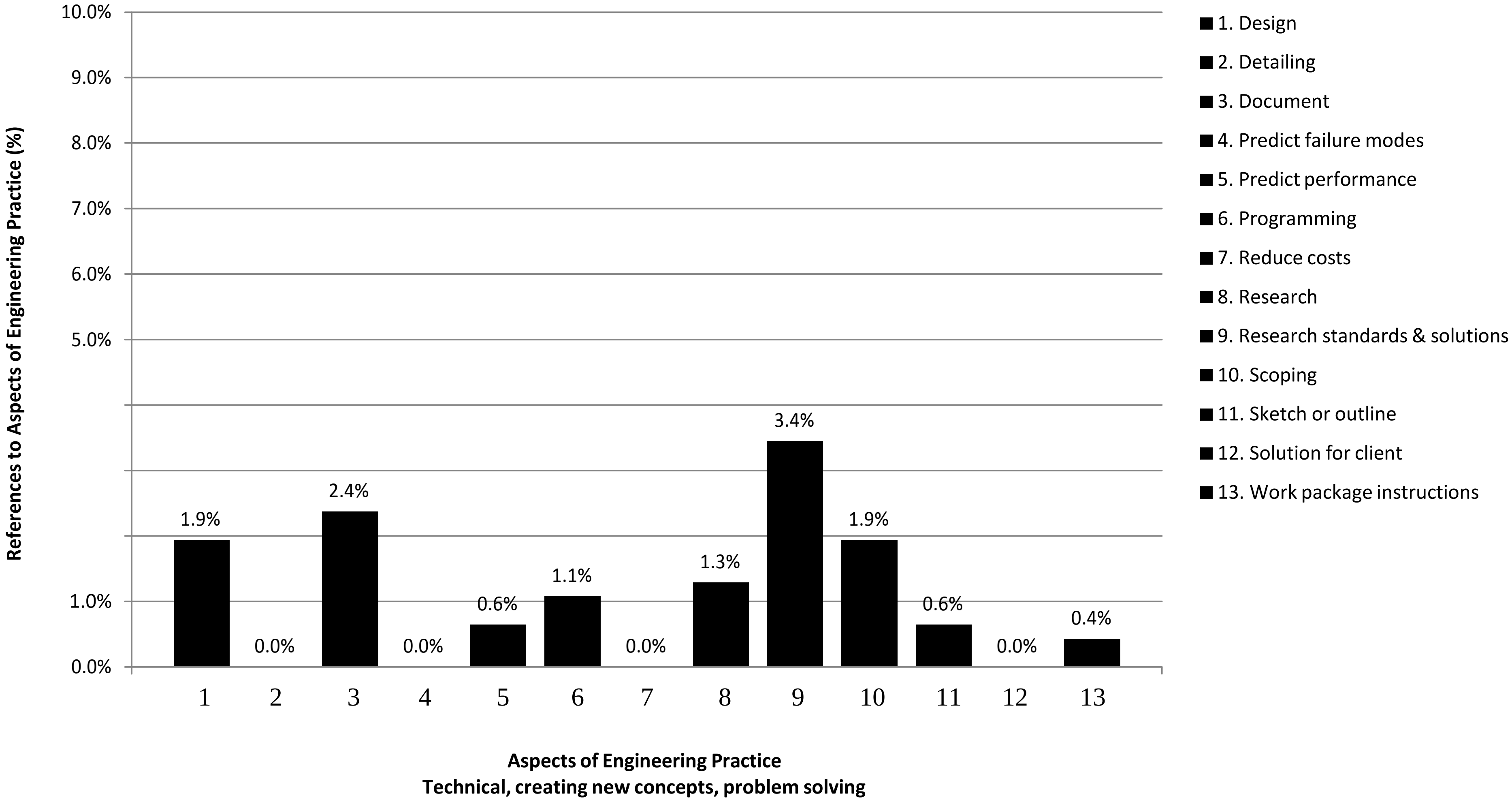


Figure 13: Interview responses by Professional Engineers within the Technical, creating new concepts, problem solving category of Aspects of Engineering Practice.

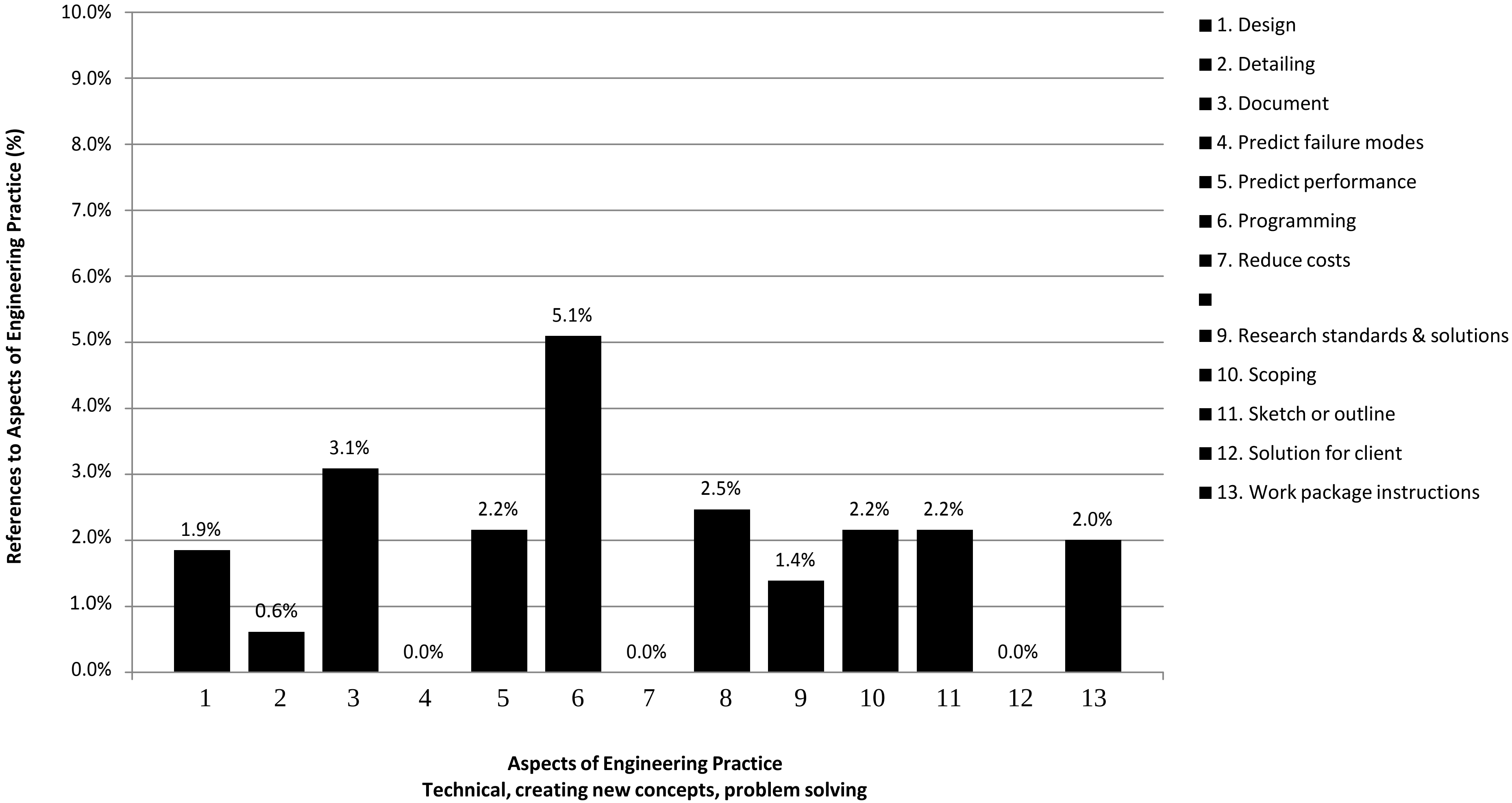


Figure 14: Interview responses by Engineers in Training within the Technical, creating new concepts, problem solving category of Aspects of Engineering Practice.

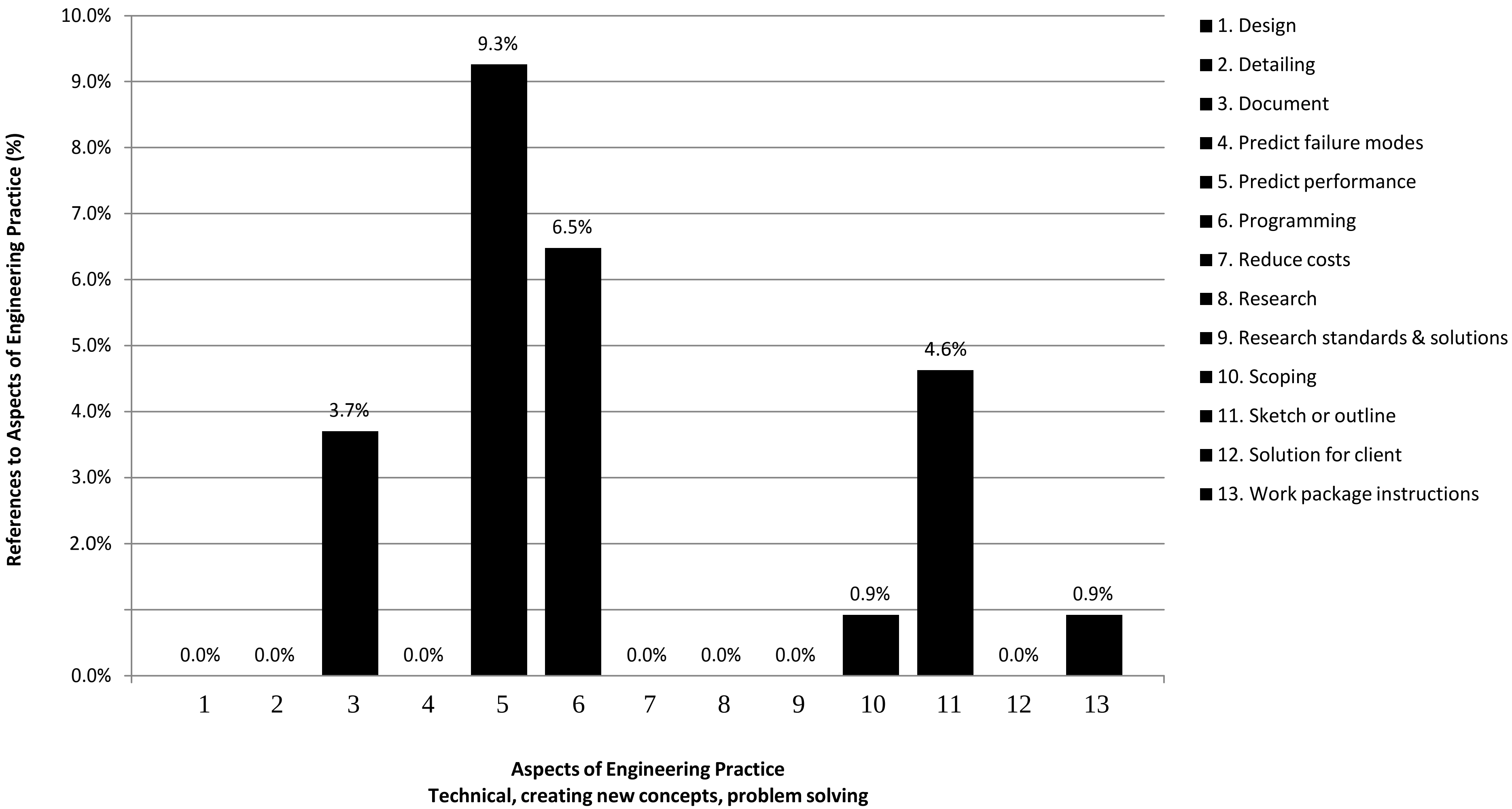


Figure 15: Interview responses by Professional Engineers assessing EIT's within the Technical, creating new concepts, problem solving category of
Aspects of Engineering Practice.

most other activities at a level around 2%. These individuals were involved in most of the aspects within this category. It is not surprising that the more junior members are required to perform a large portion of the technical work within an organization.

The P.Eng evaluation of the EIT's had them involved in predict performance (5) at 9.3%, programming (6) at 6.5% and sketch or outline (11) at 4.6% (Figure 15). Again it was observed that the EIT's were involved in the programming activity referring to work with different software and computers. Trevelyan's definition of this activity was in creating software. In this study this definition was expanded to include references to working with software. The P.Eng assessment indicated that predicting performance (5) was an integral part of an EIT's responsibility, which did not show up in the EIT's interviews. This could be a result of the low sample size. Two of the P.Eng's made numerous references to this activity. These individuals worked in areas where this type of analysis was common. All other individuals in the study did not have the same responsibilities. What was fairly consistent across all groups was the documentation aspect. Results show that all engineers are involved in documentation of some sort and that it is an important aspect of their employment.

Technical test, inspection, measurement, review, checking

This category is referred to as the analysis portion of engineering projects. It is all about reviewing, measuring and checking details. This shows up in the evaluation of the interviews as it comprises only 4.7% of the P.Eng references, but 18.8% of the EIT and 12.0% of the P.Eng evaluation of the EIT. The more senior engineer is involved in some aspects such as diagnose problem (3), survey measurement (9) and technical standards (10) but only at a referenced level of around 1% of the total (Figure 16). On the other hand the EITs referenced most aspects in this category with survey measurement (9) at 4.8%, review tech solution (8) at 4.6%,

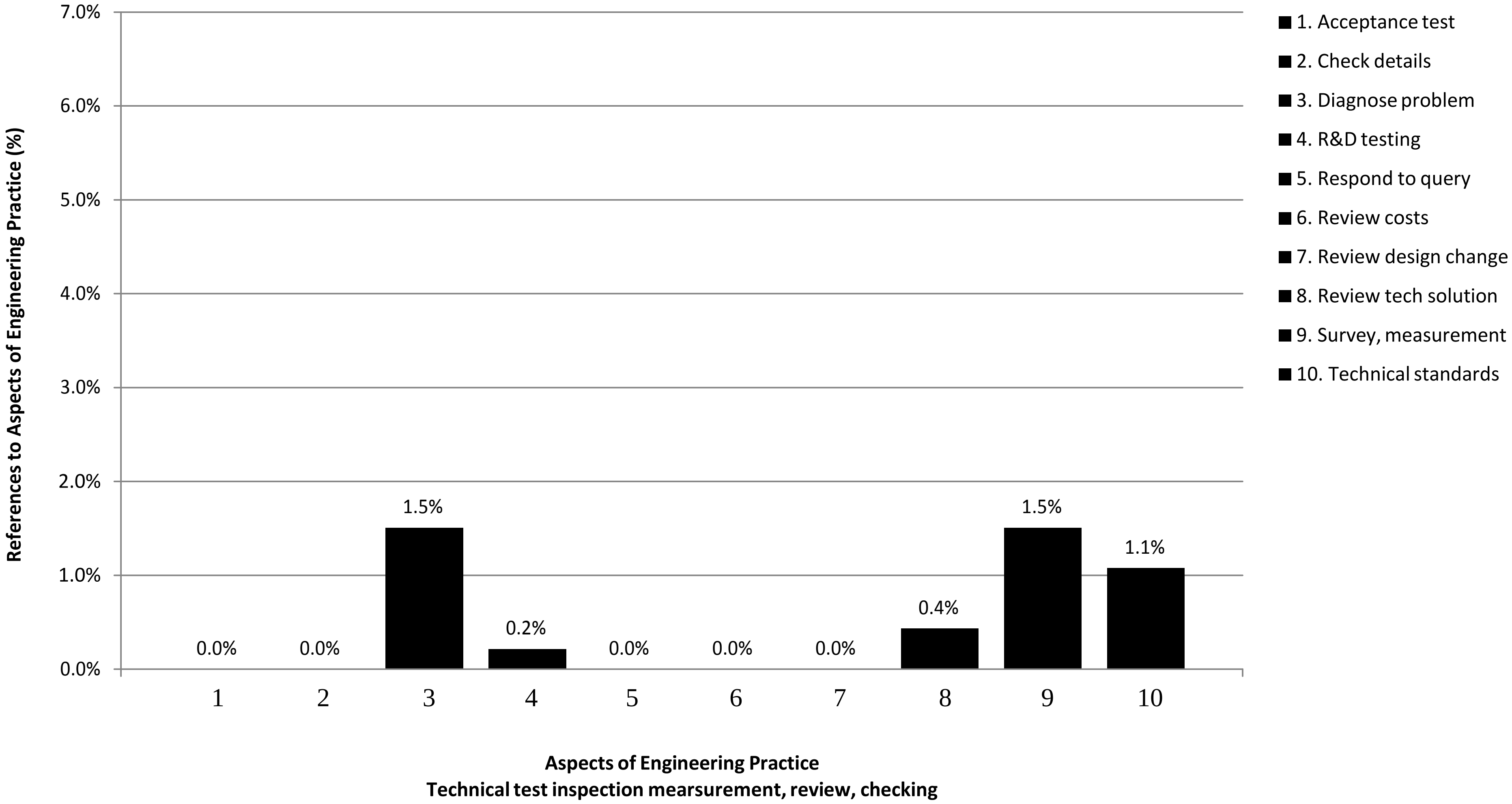


Figure 16: Interview responses by Professional Engineers within the Technical test, inspection, measurement, review, checking category of Aspects of Engineering Practice.

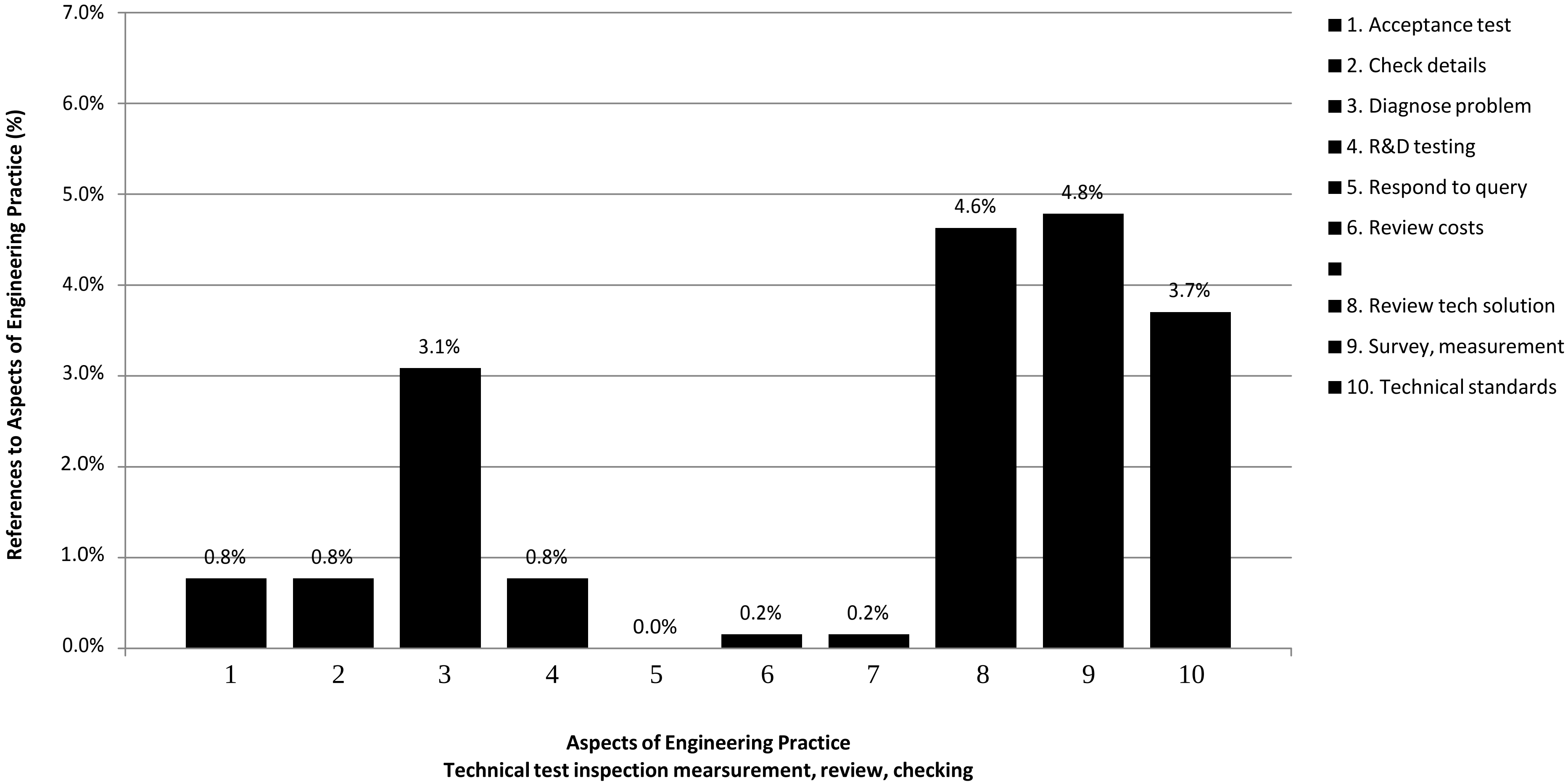


Figure 17: Interview responses by Engineers in Training within the Technical test, inspection, measurement, review, checking category of Aspects of Engineering Practice.

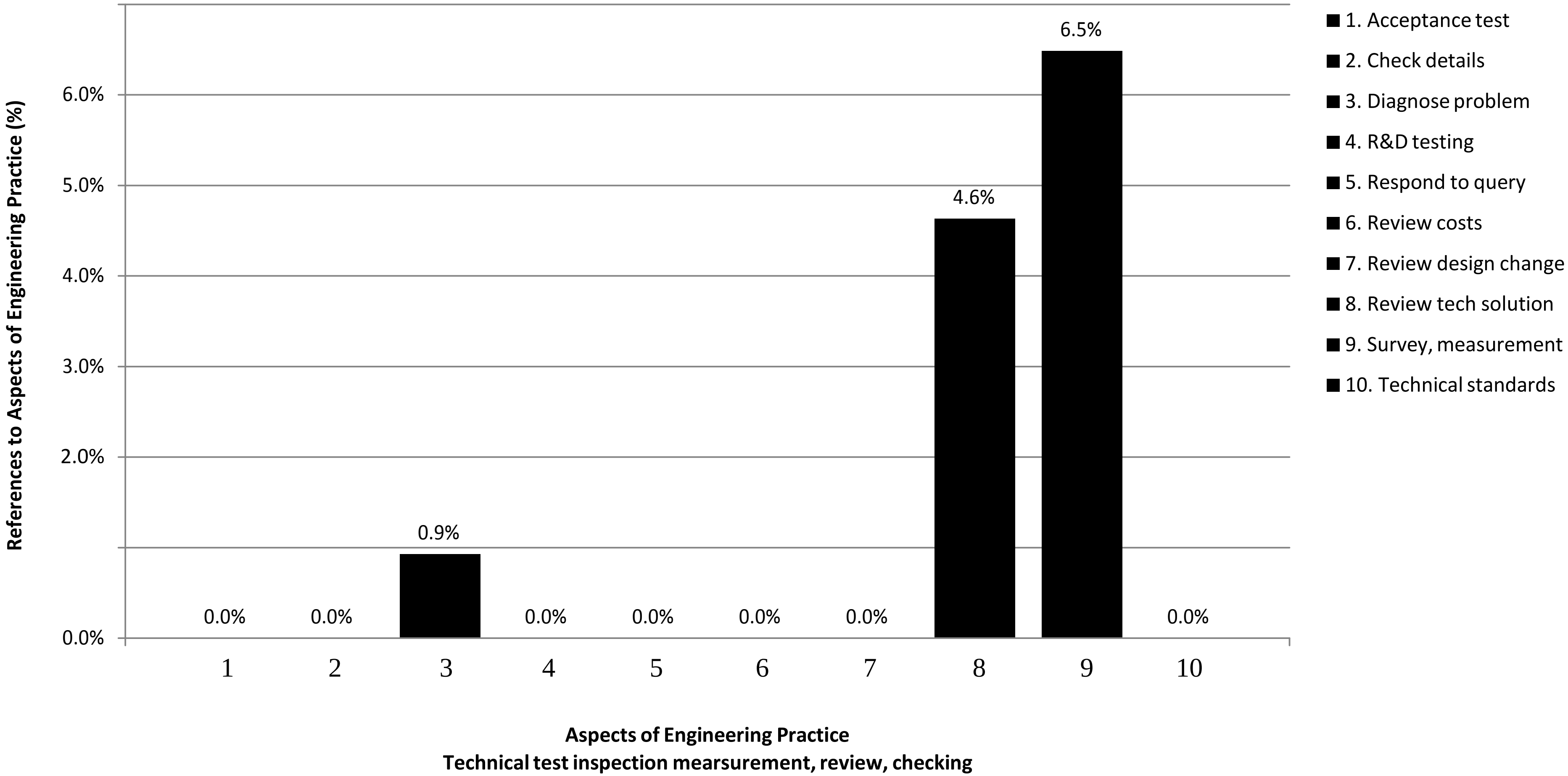


Figure 18: Interview responses by Professional Engineers assessing EIT's within the Technical test, inspection, measurement, review, checking category of Aspects of Engineering Practice.

technical standards (10) at 3.7% and diagnose problem (3) at 3.1% (Figure 17) . These are tasks assigned to junior members to evaluate. The P.Eng's evaluation of the EIT also showed similar results with survey measurement (9) at 6.5% and
review tech solution (8) at 4.6% (Figure 18). Both the EIT's and P.Eng's referenced the same activities as the most common to an EIT.

Hands on work

This category has only one activity which is hands on work. The P.Eng did not indicate this to be a part of their responsibilities or the responsibilities of an EIT. The EIT's did reference this as 5.1% of all their references. This was discussed as a part of their experience in learning the technical requirements at Manitoba Hydro. These references were either from a time when EIT's worked on a dam site or when they were working with technical staff in the field to learn about equipment.

Summary on Interviews on Aspects of Engineering Practice

The interviews in this study were designed to answer the objectives on the roles of a professional and a newly graduated engineer. These questions were answered by comparing interview data to the aspects of engineering practice as proposed by Trevelyan. The P.Eng group spent over 42% of their time in coordinating efforts and working with other people. They also spent nearly 18% of their time in engineering management and another 14% in the technical area of creating solutions and problem solving. Breaking these tasks down even further the P.Eng spent 31% of their time supervising staff, in team work and coordinating others. The other major areas indicated were business development and planning projects. It can be concluded from these values that the P.Eng responsibilities of these four participants was in the area of managing the people and operations within their control. They were somewhat involved in some planning tasks but spent the largest portion of their time dealing with people. Many other tasks were also undertaken throughout the workday but these were spread over many different areas and only at low levels of interaction.

The EIT group spent over 31% of their time in coordination efforts with others and another 23% in the technical area creating solutions and problem solving. The other area this group had a high percentage of activity was in the technical area of testing, inspection and checking solutions at 18.8%. These were the main areas of activity for this group but they also indicated over 12% of their activity occurred in the managing self and career category. This category included training aspects and personal research which could explain the increased activity for the junior engineer looking to enhance skills. In breaking down the individual tasks even further it is observed that the major activities for the EIT group was in coordinating with others especially in the mentoring classification at more than 22%. Other areas of high activity were in personal research at 5.6%, programming at 5.1% and hands on work at 5.1%. One difference between the P.Eng group and the EIT group was that the EIT's spent more of their time spread over a greater variety of activities while the P.Eng's were focused on management tasks.

Another evaluation undertaken was in classifying the P.Eng understanding of the EIT responsibilities. Interviews by the P.Eng's were evaluated and it was found that they classified the work activities of the EIT's very closely to the EIT's self evaluation. The major activity was in the coordination with others at 37% followed by 26% of their tasks in the technical area of creating solutions and problem solving. The other areas which were considered important were the managing self and career at 13% and the technical area of testing inspection and checking solutions at 12%. While the percentage within each of these areas differs slightly the areas of activity matched exactly when both P.Eng or EIT's classified the work of EIT's. Evaluating each individual category it is seen that the EIT's classify their work activities over a wide range of tasks. The P.Eng evaluation of the EIT's contains the same major tasks but tends to classify the activities over a smaller range. There could be explained by the knowledge base of the two groups. The EIT group, having performed the task, discussed and classified each task as a separate activity. The P.Eng group would classify the activities as more general tasks covered under broad headings. The importance of this data was that both groups classified the activities of EIT's under the same categories and tasks. This indicates that this is a good representation of the activities performed by EIT's with the Manitoba Hydro workplace.

Another objective was to determine links or gaps between the abilities and knowledge of these two groups of engineers. While information on job classification does not directly show this link, comparisons of activities undertaken by each group can lead to this information. When comparing the activities of the two groups it is seen that the largest percentage of each group's activities is in the coordination working with others category. The P.Eng's spend their time building teams, supervising staff, and mentoring others. The EIT's time is spent receiving mentoring and coordinating activities. The link between these two groups is the communication aspect while the gap is that the EIT's are on the receiving side and the P.Eng's are on the giving side of the communication. This is now an area where there would be a requirement for the EIT's to gain additional knowledge and abilities. The only other area where both groups had a substantial time of activity was in the technical area creating solutions and problem solving. While both groups performed tasks in this category the tasks were generally not the same activity. Both groups spent time in documenting which is a standardized task with the P.Eng's also spending time on researching and on standards. The EIT group generally performed tasks in all the activities in this category. The other areas of activity for the groups include technical and personal for the EIT's and managerial and business development for the P.Eng's. This would be expected as the more junior employees perform the technical tasks and move into more managerial responsibilities with time and experience. Therefore the gaps in knowledge and abilities for these areas would be in supervisory, and management tasks along with gaining experience in the technical areas.

5.2 Questionnaire on Aspects of Engineering Practice

The second data collection method was on the first questionnaire developed from Trevelyan's aspects of engineering practice. This was developed from the model used to code the information from the interview sessions. It was used exactly as previously described with the changes made to the original list of descriptors. This document was converted into the questionnaire with adaptations to allow the participants to self assess their activities. This information was to be used as a comparison to the results of the interviews. Therefore the participants were required to not only indicate which activities they undertook in their employment but also some form of rank as to the frequency and importance.

These questionnaires were handed out after the second interview with additional verbal instructions. Participants were asked to only consider activities over the past year. They were also asked to rank each activity in each category. An additional column was included for this ranking. The instructions asked them to "please rank the items under each category from the most to least likely you are involved in during your workday." The final instruction was to "please rank the 10 major categories from the most to least importance in your current position." The objective of this questionnaire was to have a self assessment of the participant's activities that could be related to the interview assessment. In the interviews the activities were ranked by the number of references they were assigned. Therefore it was important to not only have an indication that an activity was part of their employment duties but how important it was in relation to other activities.

The next step was in the evaluation of the questionnaire results. Each of the activities undertaken was given a value. An activity performed daily was given the value 4, a weekly activity- 3, monthly-2, occasionally-1, and not applicable-0. An activity that was performed more often was given a higher value as a way to assess the value of the work performed. Work that is performed most often would be an indication of the importance of that activity to that individual. There were two issues under consideration based on this theory. First if more than one activity is undertaken with the same frequency how is the relative importance assessed? Secondly just because an activity is performed frequently does not signify the relative importance to other activities. This is why the ranking system was used. Participants ranked each activity with a top value of one as most important. Each value for each activity was then divided by its assigned rank. This produced a rank of the activities within each category signifying the relative importance within each category. The maximum rank within each category was a value of four. There was one final assessment on the questionnaire on ranking the overall categories. Each participant was asked to rank each overall category with a value between one and ten. These average values for the P.Eng group and the EIT group produced a relative importance for each category with a low value signifying a high importance.

This method of ranking is not ideal but the attempt was to have a clear distinction between important activities performed on a regular basis to the occasional work activity. This could be a cause for concern if an individual had two activities they performed often but had a difficult time choosing which was the most important. Then two activities that may be equal in the participants' opinion could show considerable difference in the study. The small sample size of this study allowed for an individual evaluation of each questionnaire to protect from these issues.

In the evaluation of the results the first comparison was of the overall ranking of the ten aspects of engineering practice categories. The actual value of the rank was an average of the rank given by each of the four participants in each group of the study. I then took those averaged values and converted them to a value of 1, as the bottom ranked, and of 10, as the top ranked categories (figure 19). If participants were consistent with each other in their evaluation of the categories the average ranking would range from a high to a low ranking. In figure 19 it can be seen that there are categories that are ranked with both high and low values which would indicate consistency between the participant rankings. The other trend seen is that there is a consistency between the rankings of the P.Eng's and the EIT's. The category with the highest rank was, coordination, working with people. The professional engineer's average ranking was a value of 1.75 which consisted of three individual's rank of a number one and one individual's rank of number four in importance. The low number of participants allowed an opportunity to check the data individually to look for discrepancies. In this case the individual that ranked this category as fourth in importance is also the one who is currently working on an individual project. This would affect their ranking of the category especially if they had limited requirement for interaction. Even with this consideration the category was the most important.

This was also the category that ranked as most important by the EIT's. When comparing these values with the previous results from the interviews a strong correlation is observed. In the interview results the most important rank was considered to be the category with the highest number of references to activities. When an individual refers to a particular activity most often you understand that it is a prominent part of their work day and that it also plays an important role. In Figures 1, 3, 5 we saw that category #2 coordination had the highest number of references and therefore was ranked most important to the P.Eng's, EIT's and in the P.Eng evaluation of the EIT's. This category is ranked the most important by all participants in each of the data collection methods. This also coincides with the category that ranked first in the study by Trevelyan.

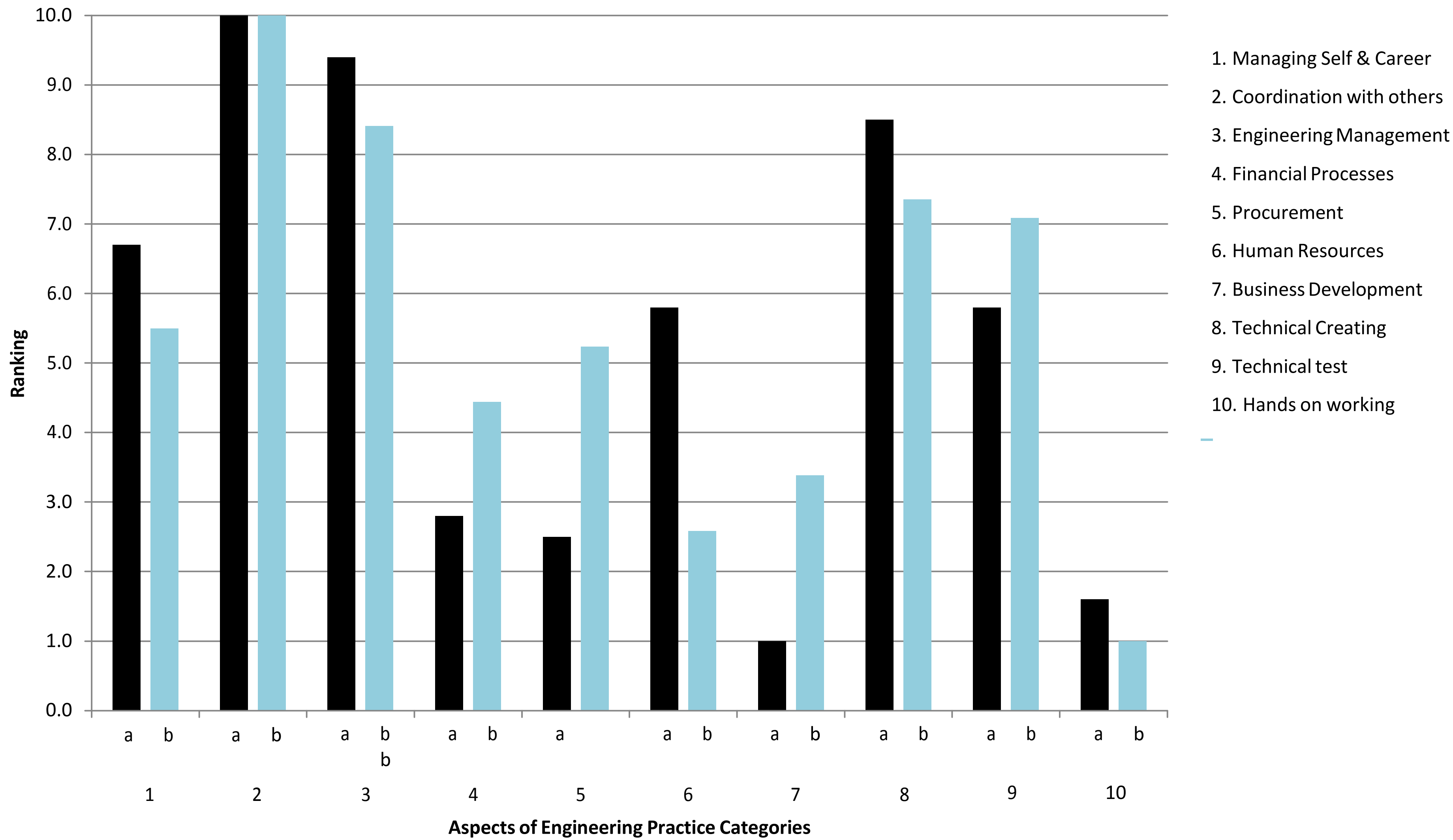


Figure 19: Rankings of Categories of Aspects of Engineering Practice by (a) Professional Engineers and (b) Engineers in Training.

The category which ranked second for both the P.Eng's and EIT's in the self assessment was engineering management. This was overwhelming the case for the professional group as three of the four individuals ranked it second with the last giving a rank of third. This matched well with the interview portion of the study which also shows a rank of second (Figure 3). The consistency continues as Trevelyan's study confirms this position. This would give confidence that these categories are ones in which P.Eng's spend a large percentage of their time. The observation of the EIT ranking shows that while participants self assessed this category with a rank of second, it shows up with a low rank in the interview data (Figure 1). In studying individual activity data in the category, certain detail in the references in the interviews could be linked to technical work while the participant could see this detail as project management. There could be some differences here in understanding of the definitions of the activities.

The category that received the rank of third most important for both the P.Eng and the EIT's was #8 technical, creating new concepts, problem solving. This was clearly ranked as third for the P.Eng which corresponds with a ranking from the interview data. In the Trevelyan study this category ranked fourth but was very close to the third ranked category. Therefore the rankings of the P.Eng's were consistent in two data collection methods for this study which also corresponds to previous studies. The EIT group ranked this category as third in the self evaluation and received a rank of second in the interview data.

From the interviews the P.Eng group also ranked this as second for the EIT's. This shows consistency between how an EIT describes their job, how the supervisor describes their job and how they self evaluate their job.

Managing self and career

When considering the evaluation of this category the main activity indicated by both groups was time planning (figures 20 & 21). This was by far the main activity with personal research as the next important activity. Studying the individual responses, time planning was considered a daily activity by most individuals with personal research as a weekly or monthly occurrence. All other items were either attended to occasionally or not at all. A comparison of these results to the interview data showed that in the interviews the tasks of formal training and personal research were chosen with very few references to time planning. These results show some of the discrepancies between the two data collection methods. In an interview about engineering activities most individuals will not discuss some of the more mundane standard tasks they repeat on a daily basis. Rather they will tell about the project they completed. While in filling out the questionnaire they see that time planning is a daily task that holds importance to keeping workload on track.

The opposite could be said for the formal training activity. In an interview, discussions are held on how knowledge was acquired. Manitoba Hydro has a very structured process for a new employee that includes formal training. These references and their importance were evident in the interviews. Then when participants completed the questionnaire they would see the formal training as something that was available occasionally but not as part of a normal work load. They would understand the importance of training is the knowledge gained not as a job responsibility.

Personal research was another activity referenced in the interviews when individuals discussed how they gather information and learned about their job. In the questionnaire it did show up as somewhat important but was an activity that is attended to more on a weekly or monthly basis. This would lower the significance rating even though engineers may feel it is an important aspect of their employment. There was no real difference between the results of the two groups other than the EIT's feeling time planning is more of a weekly event rather than daily.

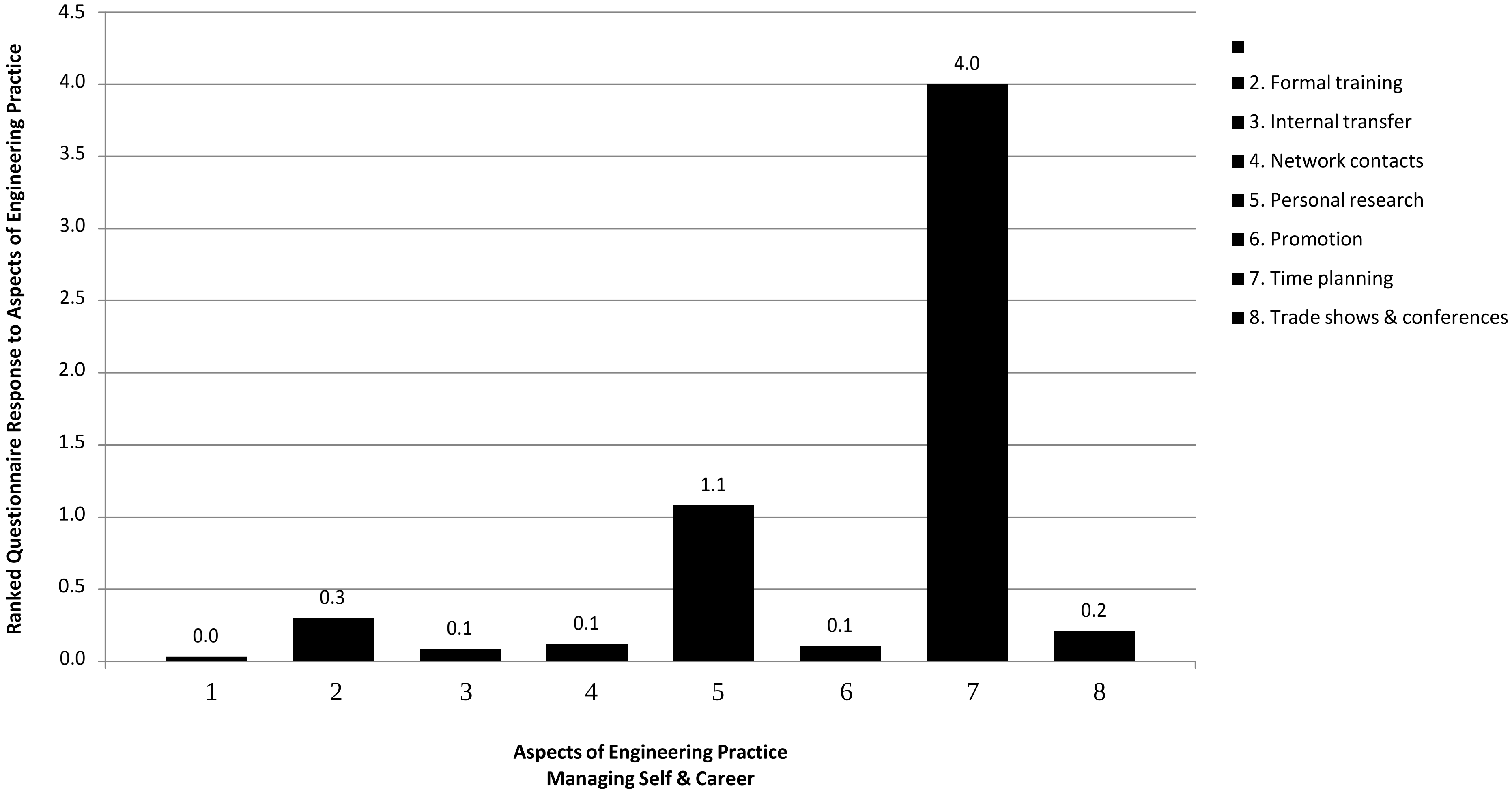


Figure 20: Aspects of Engineering Practice Questionnaire Responses within the Managing Self & Career category, Averaged and Ranked for Professional Engineers.

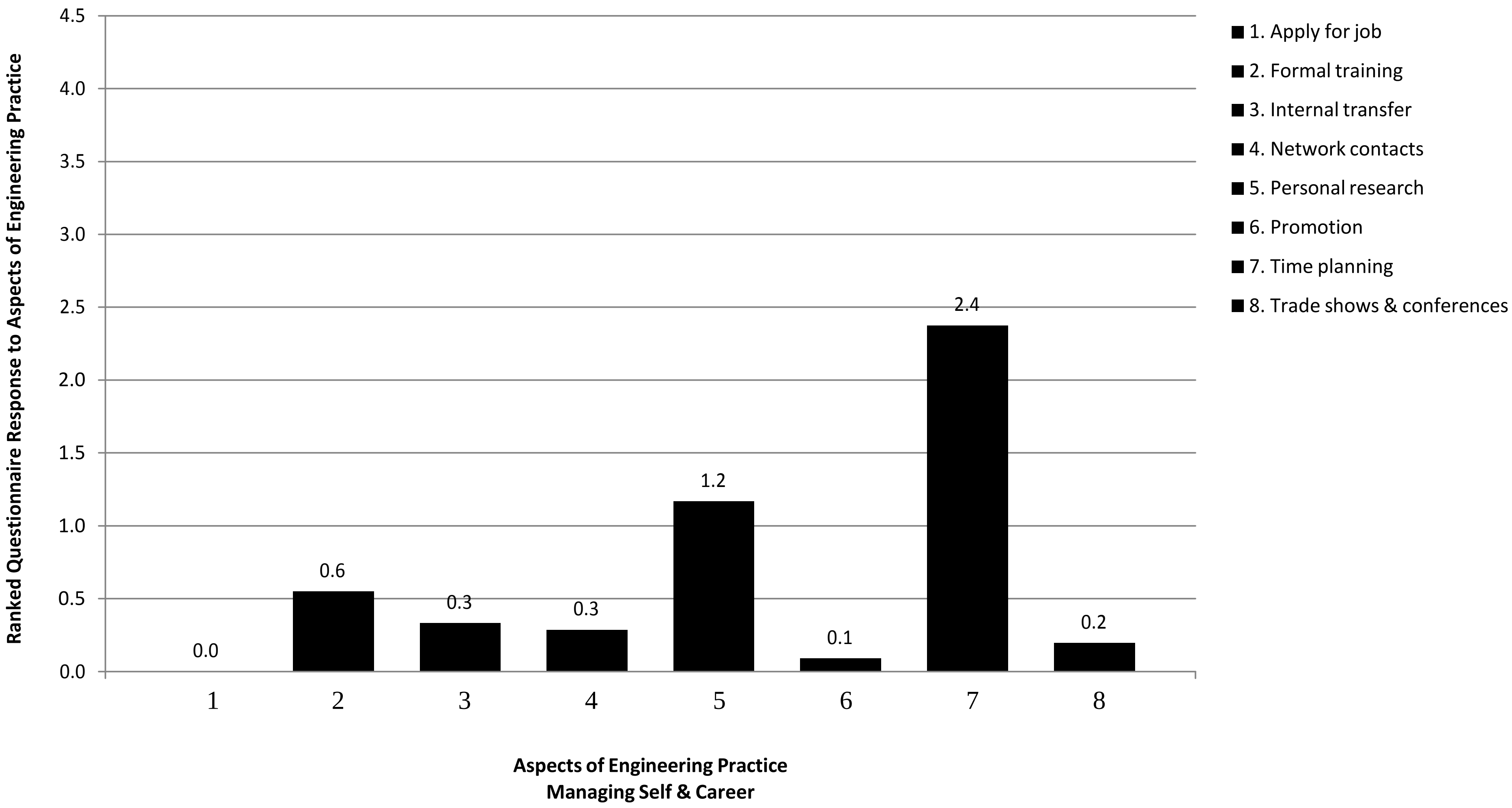


Figure 21: Aspects of Engineering Practice Questionnaire Responses within the Managing Self & Career category, Averaged and Ranked for Engineers in Training.

Overall this category was ranked either fourth or fifth in number of references from the interviews. As a self evaluation from the questionnaire the ranking would also show up as fourth or fifth. This shows that the two methods of data collection are complimentary as they produce similar results.

Coordination working with others

This category, as expected, shows some major differences between the P.Eng and EIT groups. The P.Eng's indicated that supervision was their main duty followed by coordination with staff (figure 22). This fits nicely with information from the interview session. Earlier interviews showed that team work was the key activity, but in self evaluation it is not prominent. This difference could be a result of the coding methods. Interviews were coded by referencing any discussion of group meetings or getting the staff to cooperate as building team work. In the self evaluation this could be seen as a supervisory duty. The two other activities with fairly high ratings were delegate supervision and delegate technical work. These again may be regular tasks of a senior engineer, but could be seen as more supervisory or team building type activities when coding interviews. In general these two collection methods identified the same types of activities as being part of this group's responsibility. The EIT group identified the activities of, report progress, receive mentoring, networking, and coordinating insiders as the most important (figure 23). The top activity of report progress was not a major activity in the EIT interviews but did show up as a major item when P.Eng's were asked about responsibilities for EIT's. Differences here could be due to EIT's description of job tasks more related to a discussion of steps to complete a project rather than discussion of reporting process. The fact that the activity of networking was so prominent seemed out of place.

An evaluation of individual results showed that one EIT participant felt networking was a daily event and the top ranked activity in this category. This activity was almost non-existent in the interviews. The expectation is that there is an interpretation of this term that differs from a standard definition. This individual considered networking to include discussion in their daily activities. The next three activities this group considered important were in coordinating with insiders and outsiders. These were also key in the interview information. It was already pointed out that this category was the top ranked in both sets of data. Looking at the activities in the category the top ranked ones are also closely aligned between data collection methods.

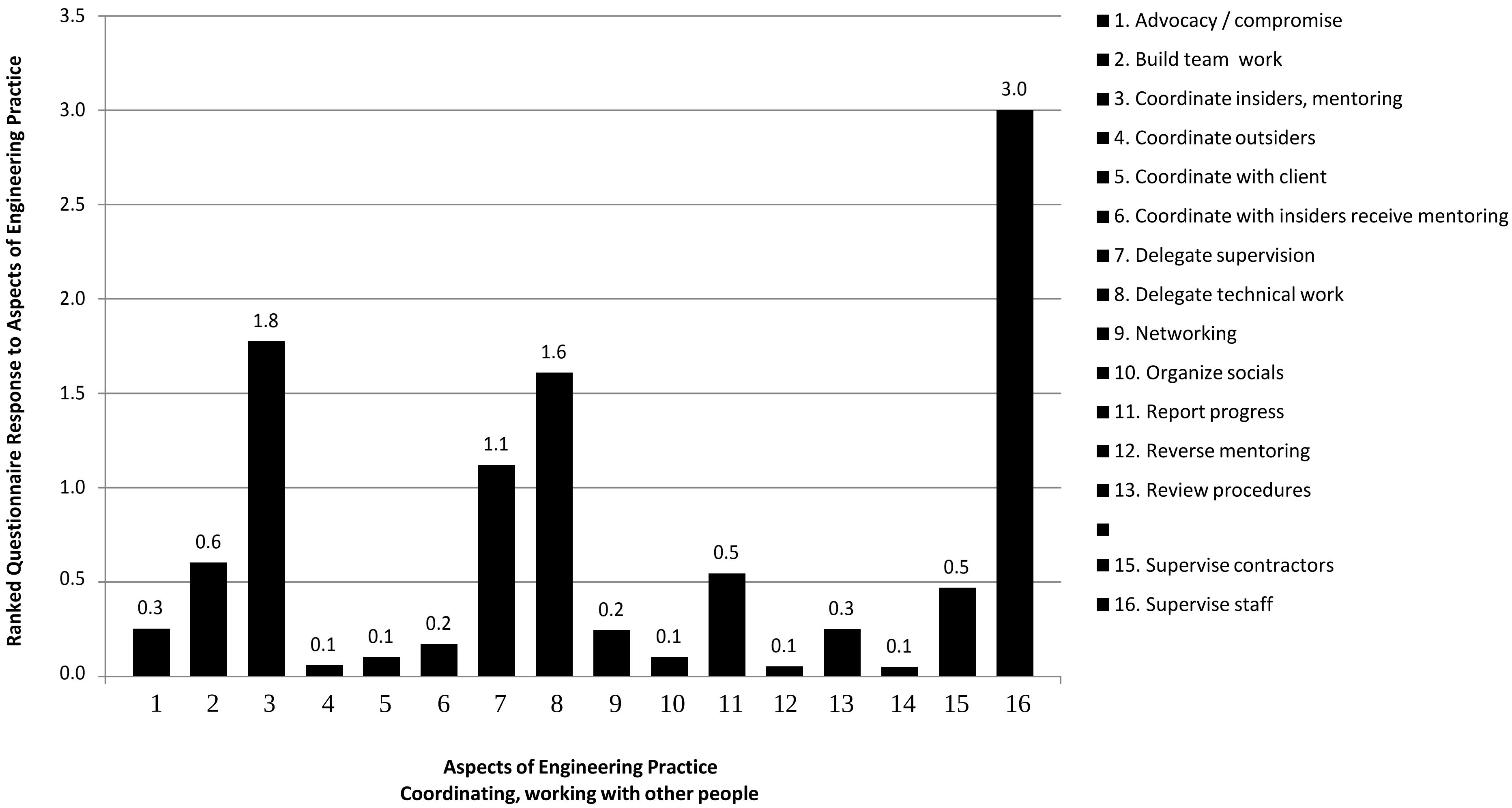


Figure 22: Aspects of Engineering Practice Questionnaire Responses within the Coordination, working with other people category, Averaged and Ranked for Professional Engineers.

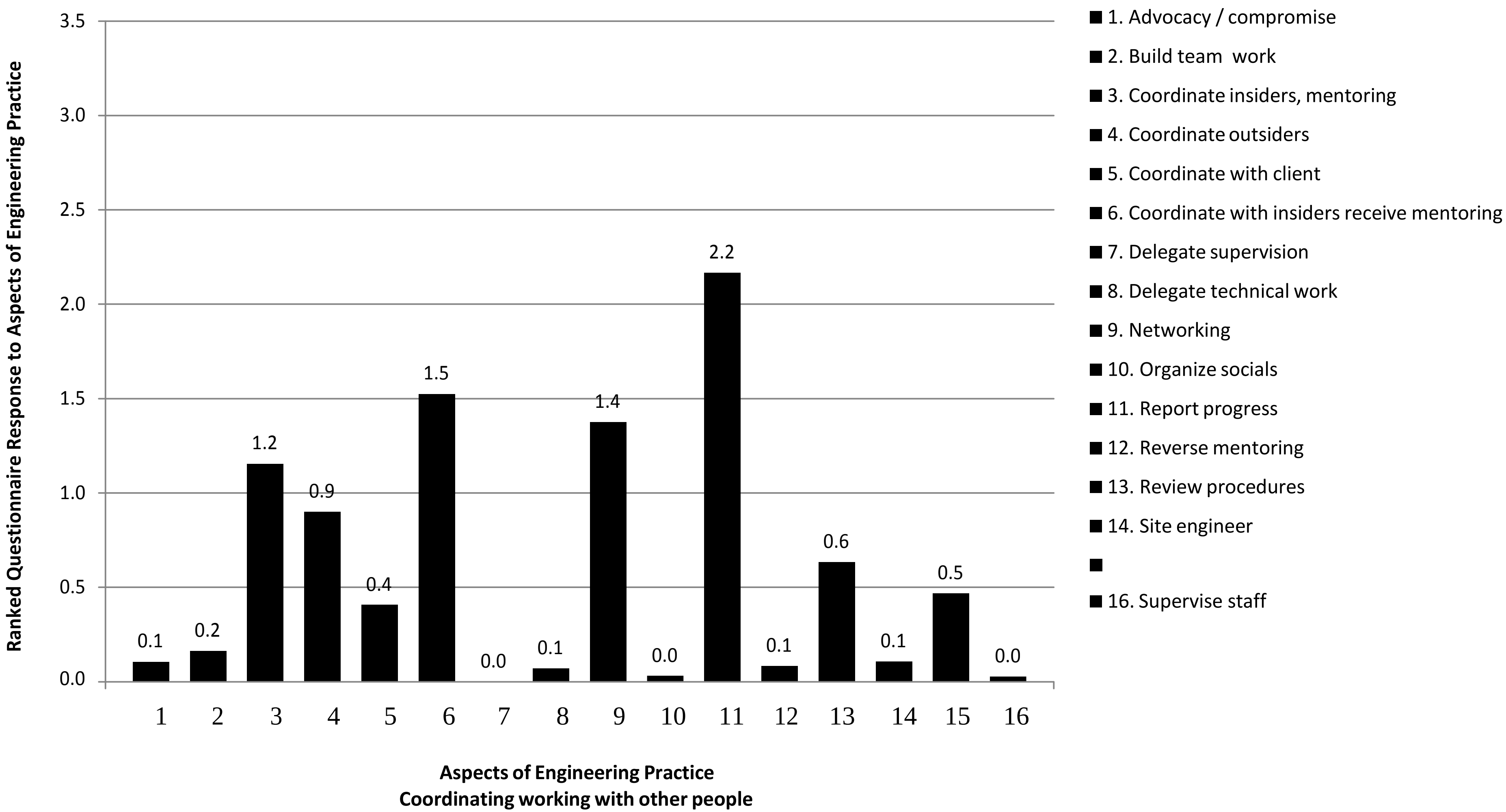


Figure 23: Aspects of Engineering Practice Questionnaire Responses within the Coordination, working with other people category, Averaged and Ranked for Engineers in Training.

Engineering management processes

When studying this category some differences were seen between results from the data collections methods. The P.Eng's felt they spent their time managing production, and managing information (figure 24). These two activities were almost non-existent in any references from the interview. The interviews showed that these individuals spent time planning and managing projects, while their self evaluation showed little activity in these areas. The individual results show that even though this group felt this was the second most important category, they spent very little time on a daily basis on the activities. One individual did indicate that they managed production on a daily basis and ranked it the most important activity. This shows that with a small sample size how results can be affected. This also shows how the meaning of a description can have subjective interpretations. The EIT group ranked their top activities as manage information, follow procedures, and manage project (figure 25). Earlier in the interview data, it was observed that managing project was the only prominent activity for the EIT's. In this self evaluation this group ranked the category second highest. Looking at each individual's data, it was observed that participants consider many of these activities as daily responsibilities. The top activity in both sets of data was managing projects. The other activities indicated as important in the questionnaire are ones that may not be indicated in an interview. Following procedures and managing information are not activities that would necessarily be on a discussion list when explaining your job.

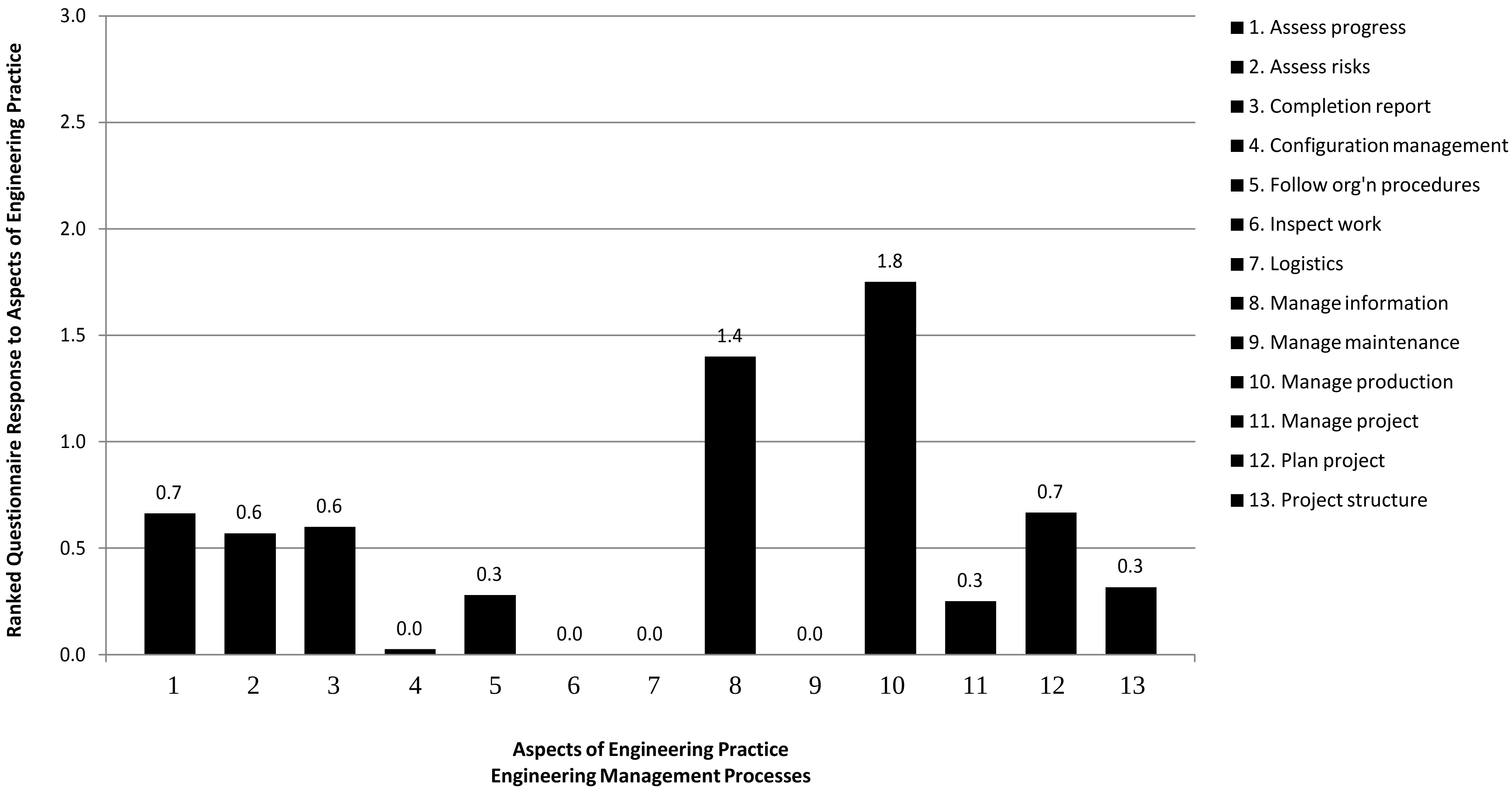


Figure 24: Aspects of Engineering Practice Questionnaire Responses within the Engineering Management Processes category, Averaged and Ranked for Professional Engineers.

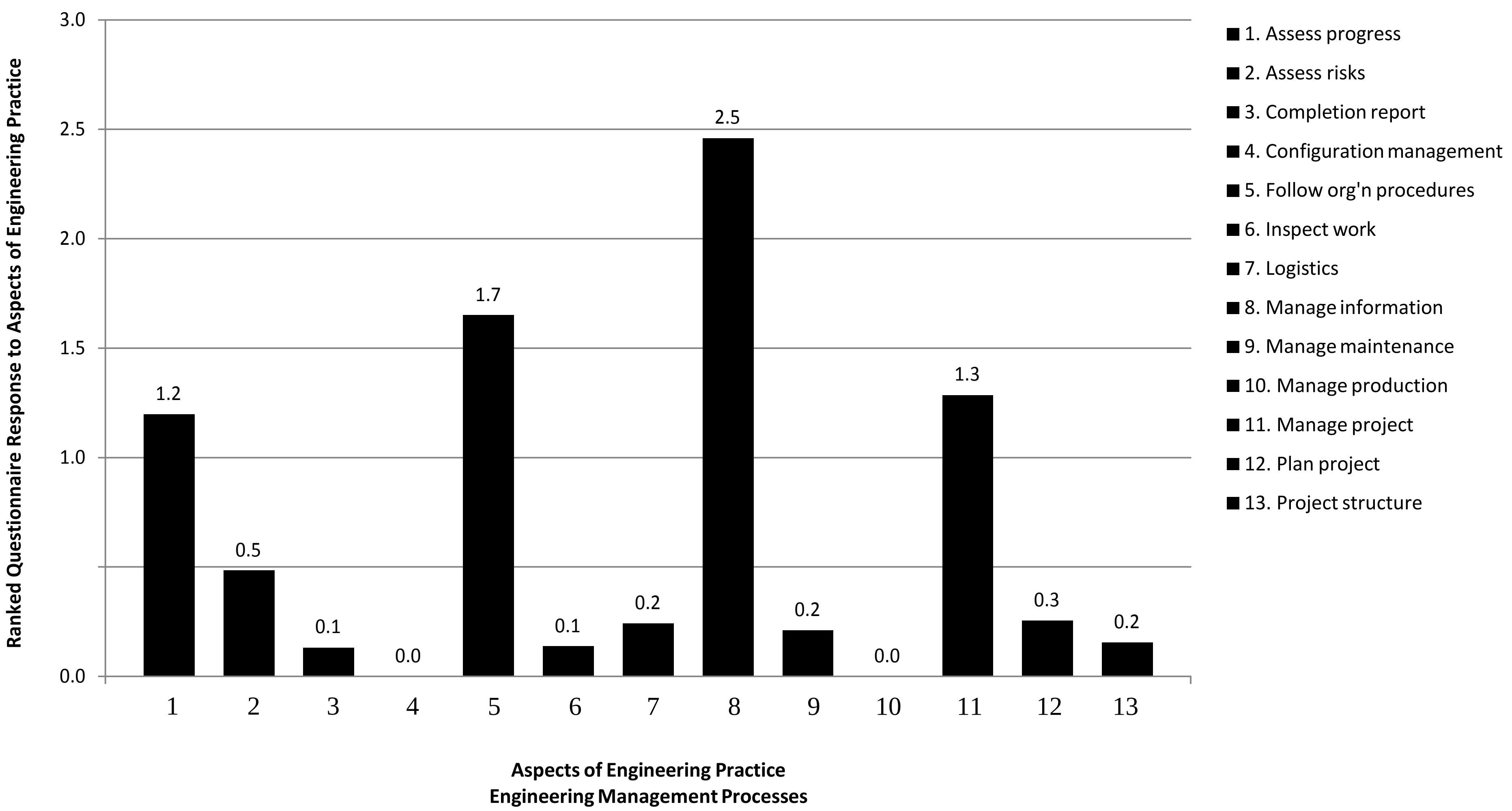


Figure 25: Aspects of Engineering Practice Questionnaire Responses within the Engineering Management Processes category, Averaged and Ranked for Engineers in Training.

Financial processes

This is one of the categories ranked fairly low in importance to this group of participants and additionally has very little activity indicated. The P.Eng group ranks the classification of negotiating internal resources as the main activity (figure 26). In looking at individual results it was observed that two of the participants indicated this was a weekly activity. Virtually no other activities in this category were conducted more than at minimum monthly. Earlier data from the interviews showed some evidence of predicting costs but at a fairly low level. The EIT's prominent activity was in researching regulations (figure 27). This was also at a low level with one individual's results influencing the rank. The earlier interviews showed this group to be involved in some prediction of costs but at a very low level. The conclusion is that there was little evidence that this research study group was involved in financial matters.

Procurement

This category received virtually no references from the interview data and is also rated as fairly low in importance. The P.Eng's had no activity to speak of with only some occasional opportunity indicated (figure 28). The EIT's also ranked this category low other than for one individual (figure 29). Their questionnaire showed that they were involved in these activities on a daily basis. These values are high based on their low overall ranking with reasons being due to a different interpretation of the descriptors for the activities. These young engineers indicated they are asked to review completed tender documents and proposals when first joining a new department. This is to familiarize them with the procedures and provide another review of the document. All the EIT's indicated they were asked to complete those

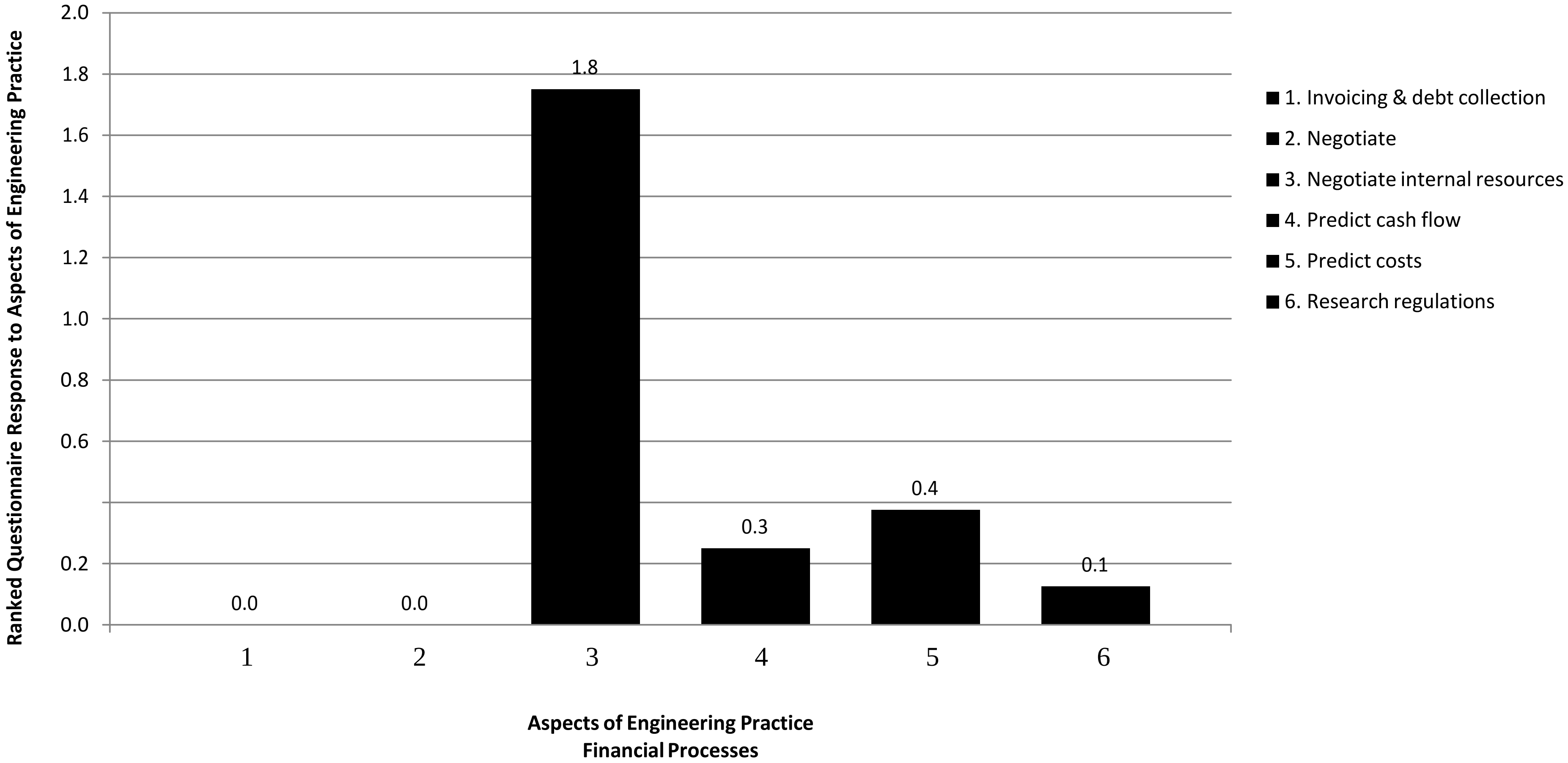


Figure 26: Aspects of Engineering Practice Questionnaire Responses within the Financial Processes category, Averaged and Ranked for Professional Engineers.

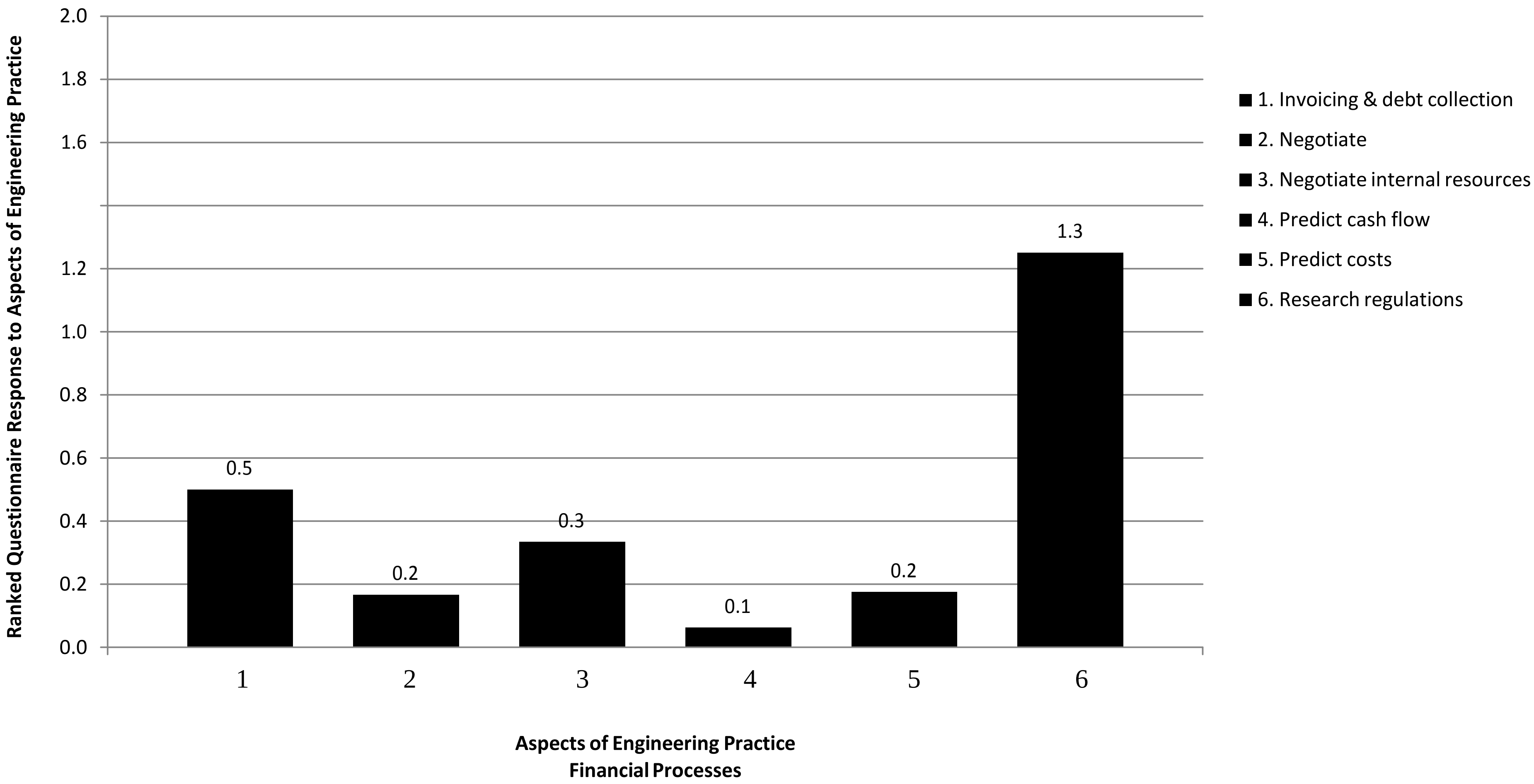


Figure 27: Aspects of Engineering Practice Questionnaire Responses within the Financial Processes category, Averaged and Ranked for Engineers in Training.

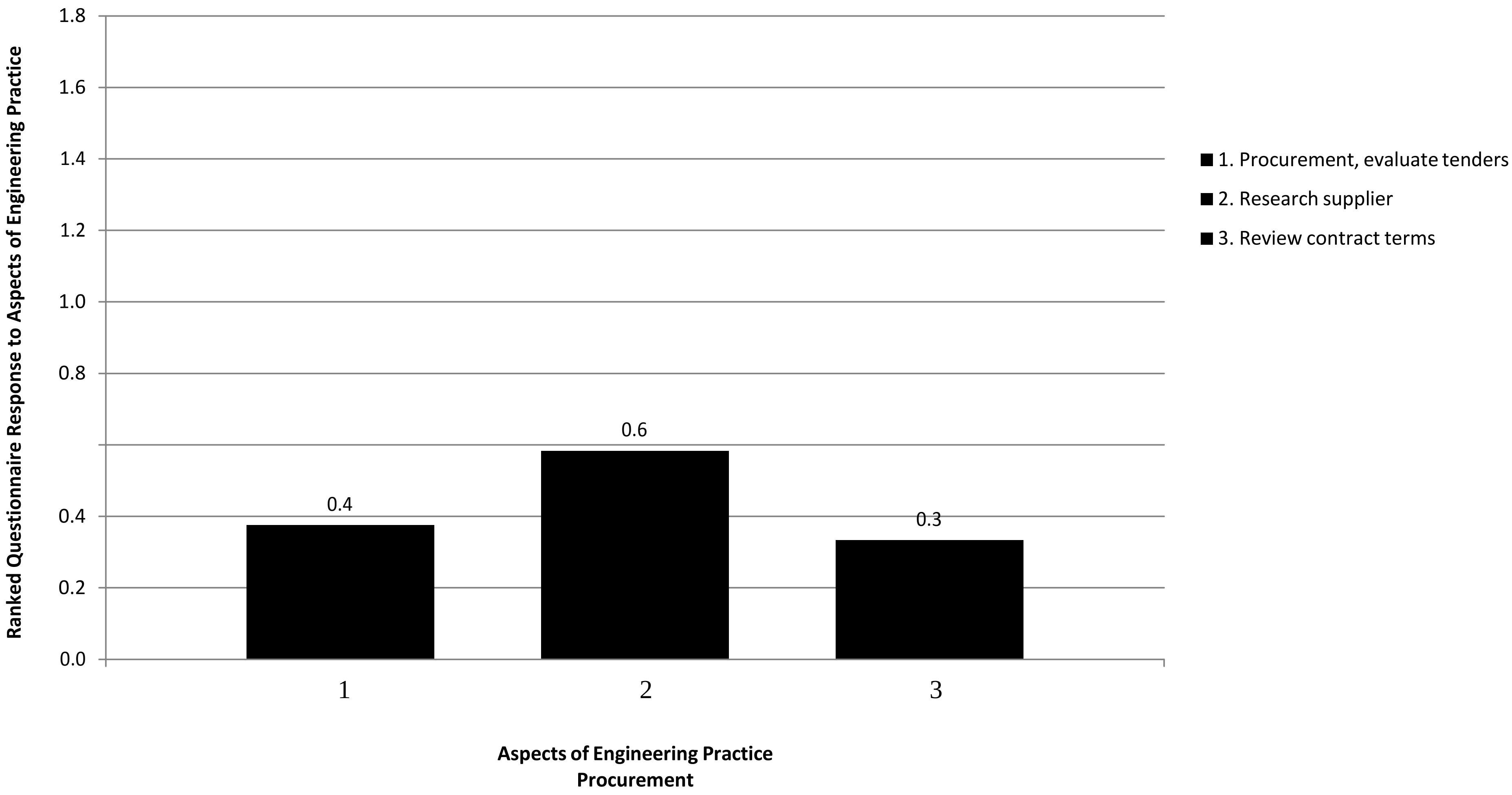


Figure 28: Aspects of Engineering Practice Questionnaire Responses within the Procurement category, Averaged and Ranked for Professional Engineers.

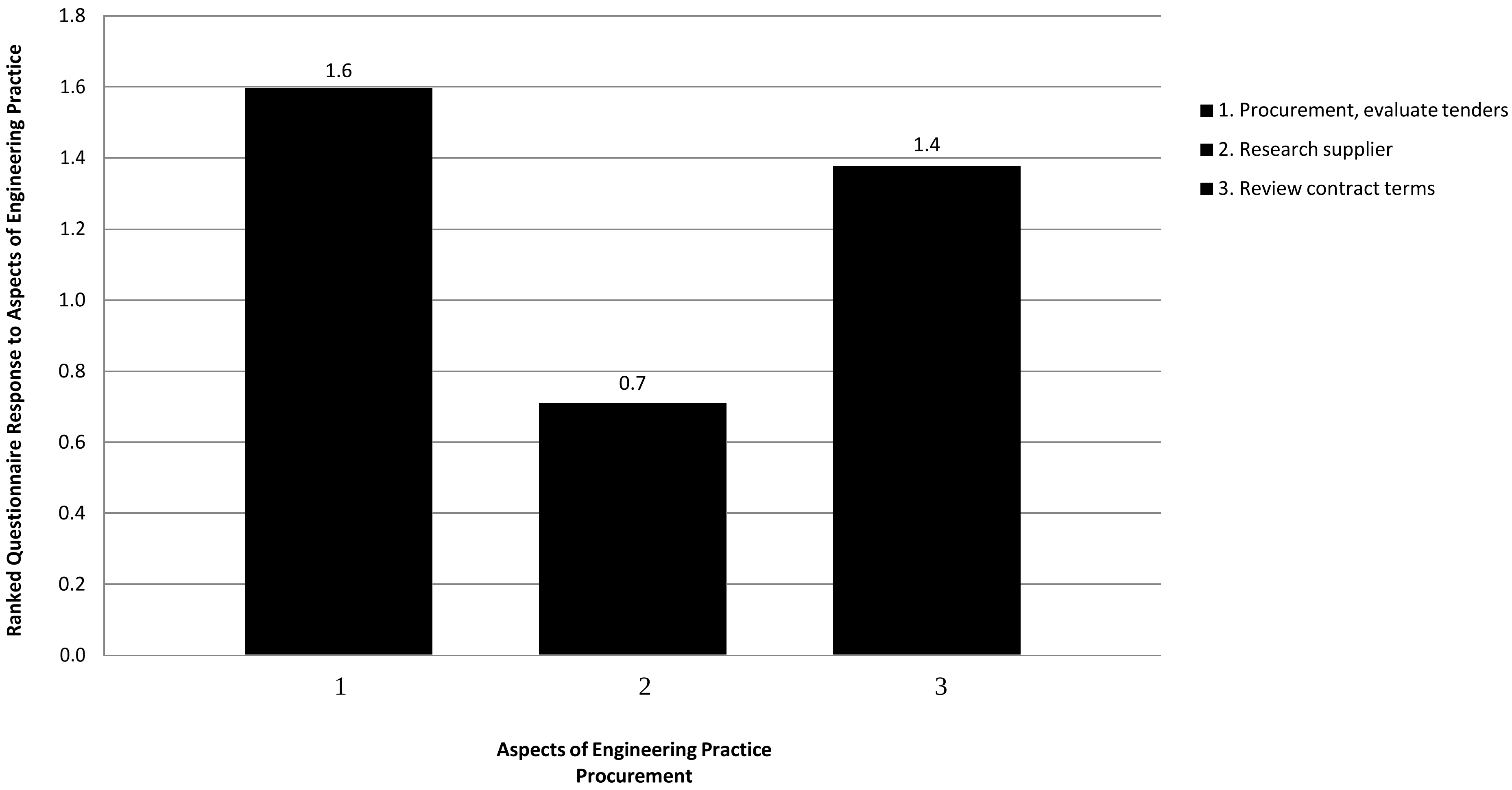


Figure 29: Aspects of Engineering Practice Questionnaire Responses within the Procurement category, Averaged and Ranked for Engineers in Training.

tasks when first entering a new department. One of the participants was still in the EIT program. This individual said that they were given a task of replacing old equipment and had been required to source and purchase the replacement. These would be activities that fit in this category. This again shows that with the small sample size how one individual can have a substantial effect on the results. In general this is a category which the research group had little regular activity.

Human resources

This is another category in which the engineering group did not seem to have much activity. The P.Eng group had some involvement in performance evaluations and providing training (figure 30). These activities are generally only undertaken occasionally as was indicated. This matched the results from the interviews. The EIT group had no activity reported in the interviews and very little in the questionnaire (figure 31). One result that seemed a little out of place was the level of activity in recruitment. One of the EIT's reported that they were involved in recruitment and performance evaluations on a monthly basis. Considering that even the supervisors did not report this much activity in these areas it would seem that this could be questioned. In general this category was consistent through the results from both stages of the research.

Business Development

This category surprisingly rated lower for the P.Eng's than for the EIT's. Three of the P.Eng's indicated they did not work in this area and one reported analyzing client requirements a few times a year (figure 32). It would seem likely that this area is more of a senior level with an emphasis to longer term planning. Previously in the interviews 6.5% of the references included some aspect of the

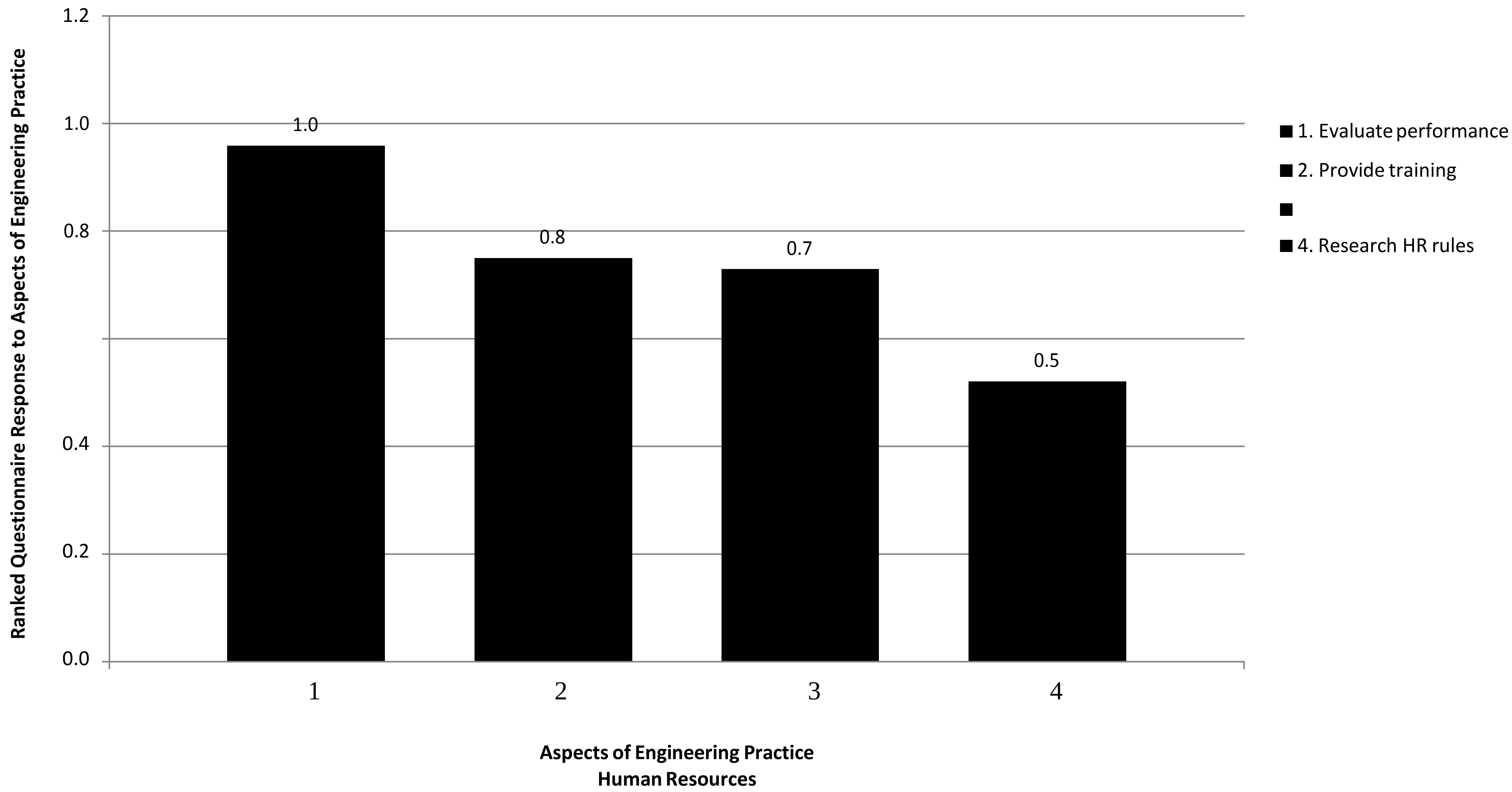


Figure 30: Aspects of Engineering Practice Questionnaire Responses within the Human Resources category, Averaged and Ranked for Professional Engineers.

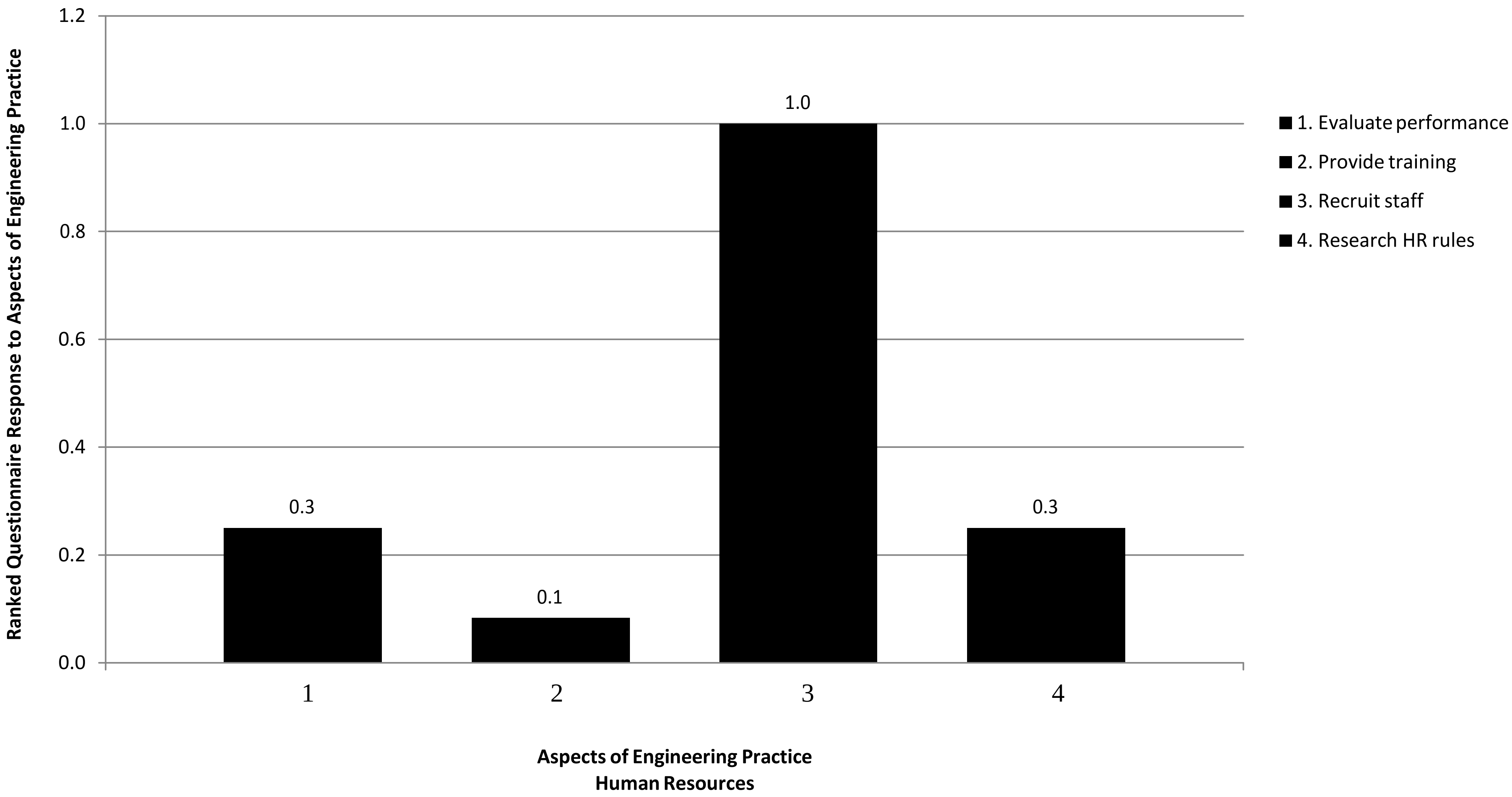


Figure 31: Aspects of Engineering Practice Questionnaire Responses within the Human Resources category, Averaged and Ranked for Engineers in Training.

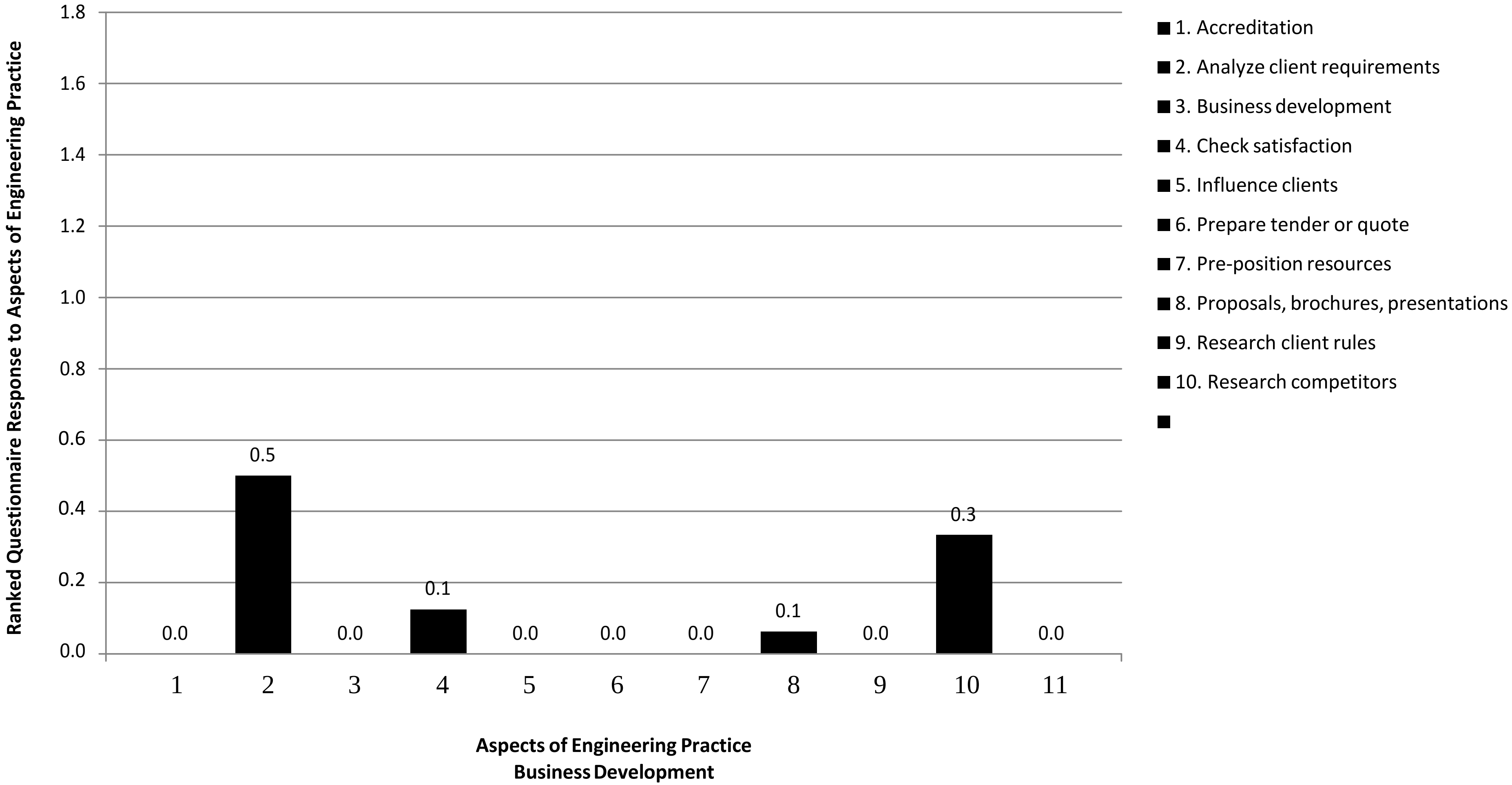


Figure 32: Aspects of Engineering Practice Questionnaire Responses within the Business Development category, Averaged and Ranked for Professional Engineers.

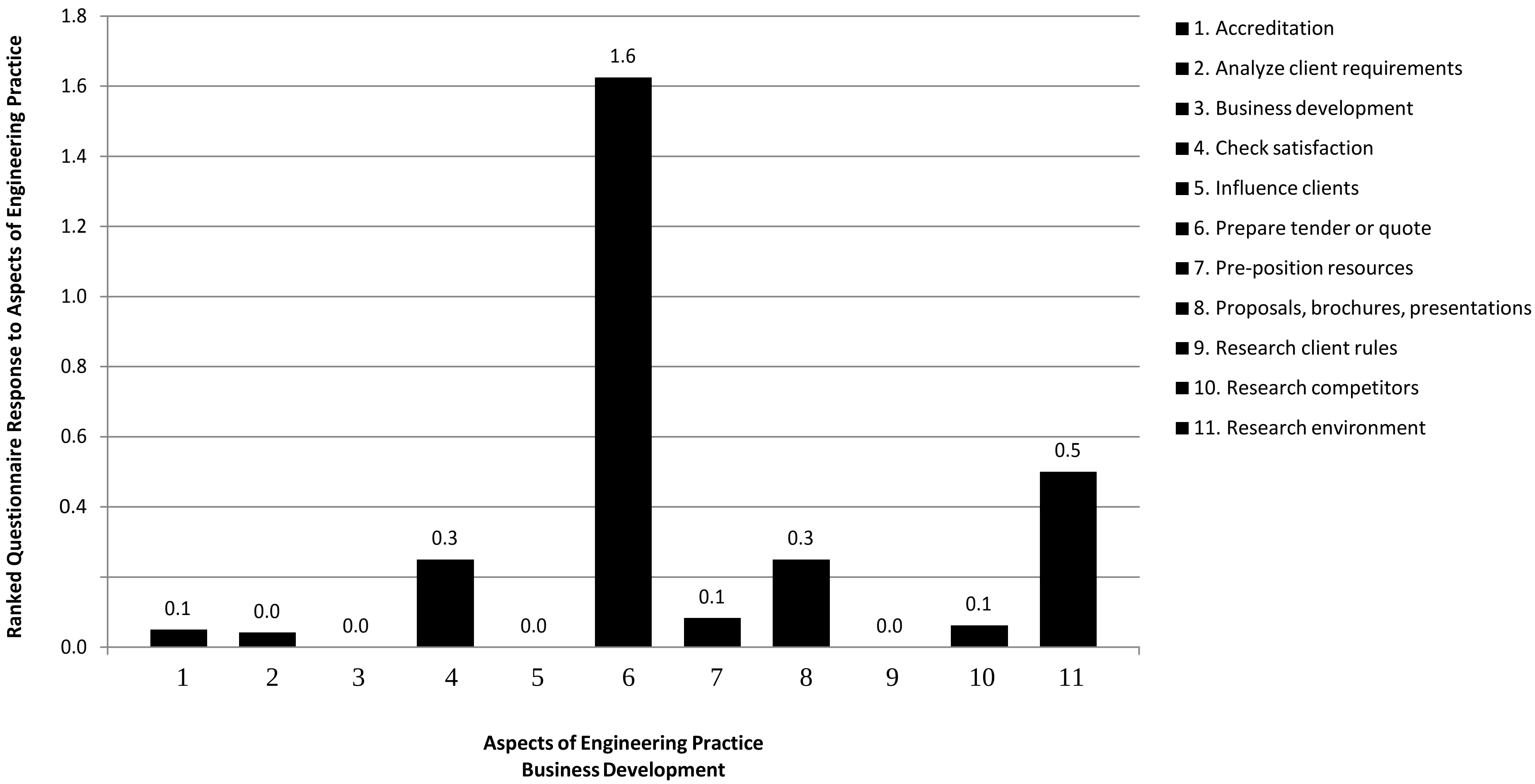


Figure 33: Aspects of Engineering Practice Questionnaire Responses within the Business Development category, Averaged and Ranked for Engineers in Training.

business development activity. There was also a reported 1% reference activity level for analyzing client requirements which matches with the self reporting. It is difficult to speculate as to why no business development was self reported as discussions in the interviews pointed directly to this activity.

The EIT's evaluated this category as their eighth least important which matched with the interview data (figure 33). This group reported a fair level of activity in preparing tenders and quotes. This though was the reporting of one individual as the other three reported very little activity in this area.   The individual reporting this activity indicated that this was a daily task. This fact alone seems a little unrealistic especially considering this was the junior member of the group. They were still in an EIT rotation and even self reported that they were learning the position. There was very little activity indicated in preparing tenders in the interview references but there was numerous references of working on tenders and proposals. Coding of this information was considered to be reviewing technical solutions. A number of the EIT's discussed looking at tender documents and checking proposal information. These were in the form of "basically I read those tender documents" and "the consultants to write a detailed design as well as specifications for that tender, so we'll review those, basically word by word." It would seem that one of the EIT's is evaluating tender documents and self reporting this activity as preparing tenders.

Technical, creating new concepts, problem solving

This was considered to be the third most important category to both the professional engineers and EIT's, which closely matches the ratings with regard to references in the interviews. In this category at least one individual from each of the groups had worked in each of the activities listed.

The P.Eng's reported their main activities as documenting, detailing and research (figure 34). In comparison their interviews showed the main activities as research standards and solutions, documenting, design, scoping and research. While these activities are not an exact match they do show similarities. The activity of documenting was rated one of the highest ratings in both sets of data. In the interview data, the activities of research standards and solutions and research rank as main activities. When considering the definition of these two activities it was observed, that in participant self reporting, these both could be classified under the heading of research. Some of these descriptors would have overlapping interpretations as they require similar job tasks. Therefore these job activities do match closely between the two forms of data collection.

The EIT group reported that their main activities were design, research standards and solutions, predicting failure modes and work package instructions (figure 35). The interviews showed the main activities as programming, documenting, and research. One area with a large difference was in the programming activity between the two collection methods. This can be explained by the coding methods. During the process many references were made in regards to working on difference types of software. These references were not specific to a particular activity but it was necessary to record that information. Therefore it was placed in the programming activity as it was closely related. The descriptor for programming does include this as an activity but also is written more as a software development activity. None of the participants engage in much development of software so would not self report this as a prominent activity. This then shows up with greater occurrence in the interview data collection. In comparing the other main activities it was observed that while the top rated activities do not match there are other similarities. The large number of references in the interviews translated into numerous activities having a fairly high rating even if not in the very top. The activities such as design, predict performance, scoping, sketching and work package instructions all received substantial mention in the interviews. Therefore there is correlation between the two sets of data.

This category was ranked third by both of the research groups in their self assessments. In the interviews it was ranked third most prominent by the P.Eng's and second by the EIT's. While some of the individual activities did not match exactly for each group, this was a category of activity that was important for both groups. It was an area where these individuals spent a lot of their efforts throughout the work day.

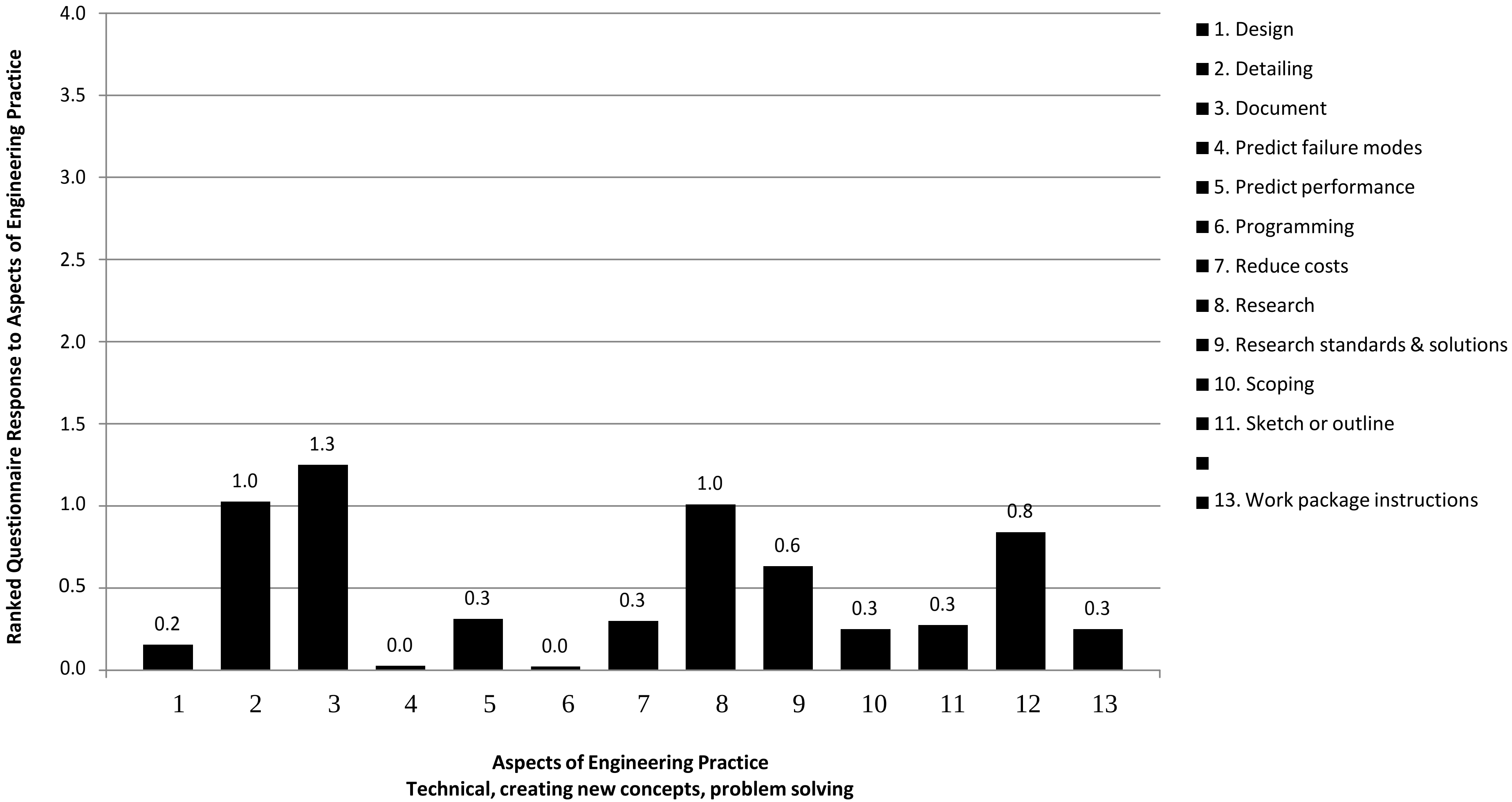


Figure 34: Aspects of Engineering Practice Questionnaire Responses within the Technical, creating new concepts, problem solving category, Averaged and Ranked for Professional Engineers.

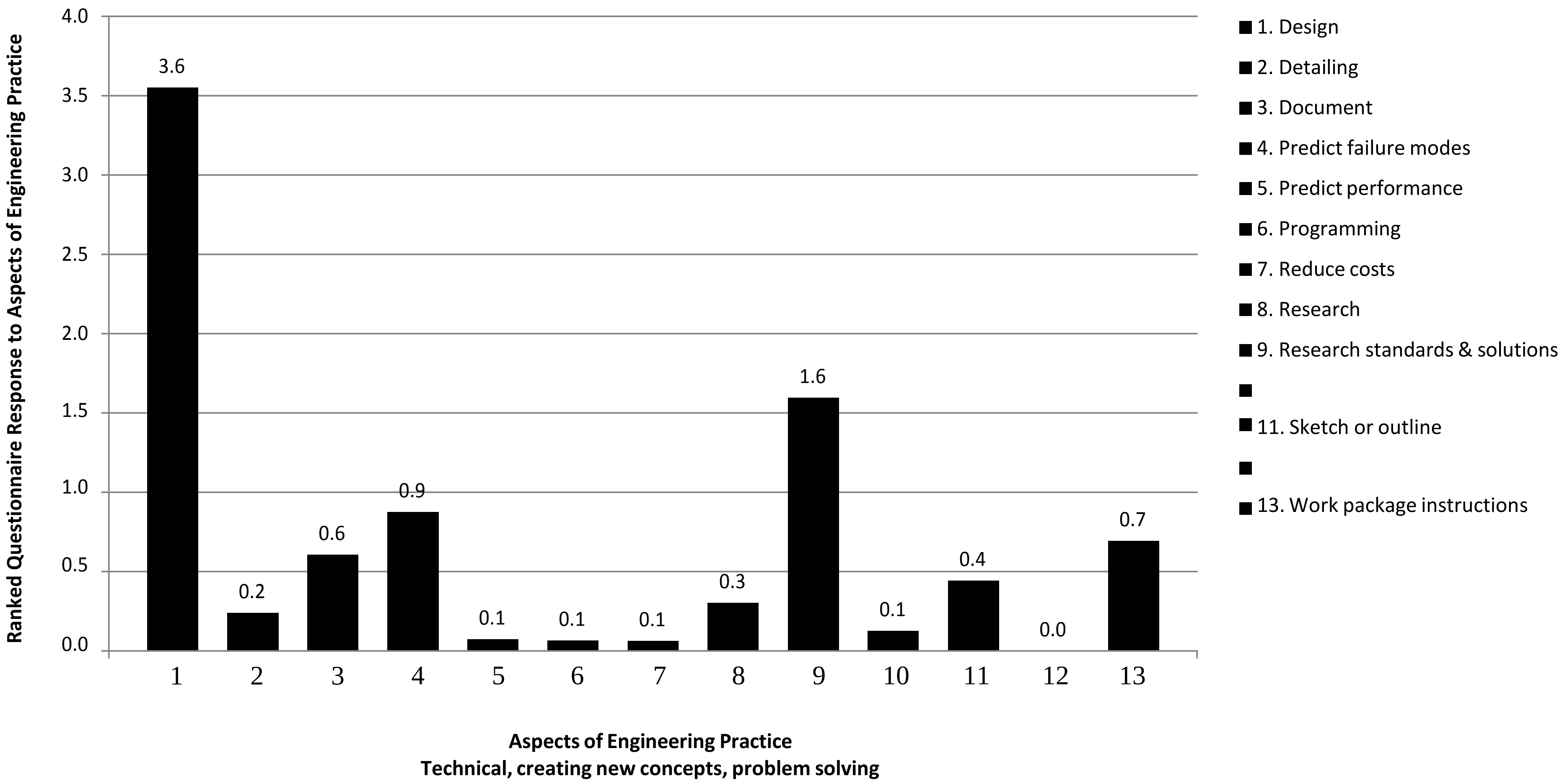


Figure 35: Aspects of Engineering Practice Questionnaire Responses within the Technical, creating new concepts, problem solving category, Averaged and Ranked for Engineers in Training.

Technical test, inspection, measurement, review, checking

This category is comprised of technical analysis activities which would be generally assigned to more junior members of a team. In their self assessment the P.Eng's ranked this category in fifth spot while in their interview process it was sixth. The main activities indicated by the P.Eng's were respond to query, check details, and technical standards (figure 36). The top item of respond to query did not show up in the interviews and could be a matter of interpretation. In discussions on work activities, references to communication with others would be coded in category 2 - coordination. These discussions are not necessarily referred to as responding to someone but rather as gathering information. In the self assessment the P.Eng's recognized that they spend a certain period of time answering information that was requested of them. The interview references showed a higher activity level for P.Eng's in the areas of diagnose problems, survey and technical standards. One of these was a direct match with the self assessments. It is also noted that in the self assessment each one of the activities were represented at some level. Therefore activities identified in the interviews were also areas which had activity indicated in the self assessment.

The EIT's identified this category as their fourth highest ranking which compares to the rank of third in the interviews. There was really only one activity that stood out in the self assessment which was diagnose problem (figure 37). The results did show that all of the activities were a part of the groups work responsibilities. The results of the interviews showed EIT's spent time in reviewing technical solutions, survey, technical standards, and diagnose problem. Two of these activities also match with the assessment the P.Eng's had on the EIT's. This category is made up of analysis type activities and is in many cases performed by technologists and EIT's.

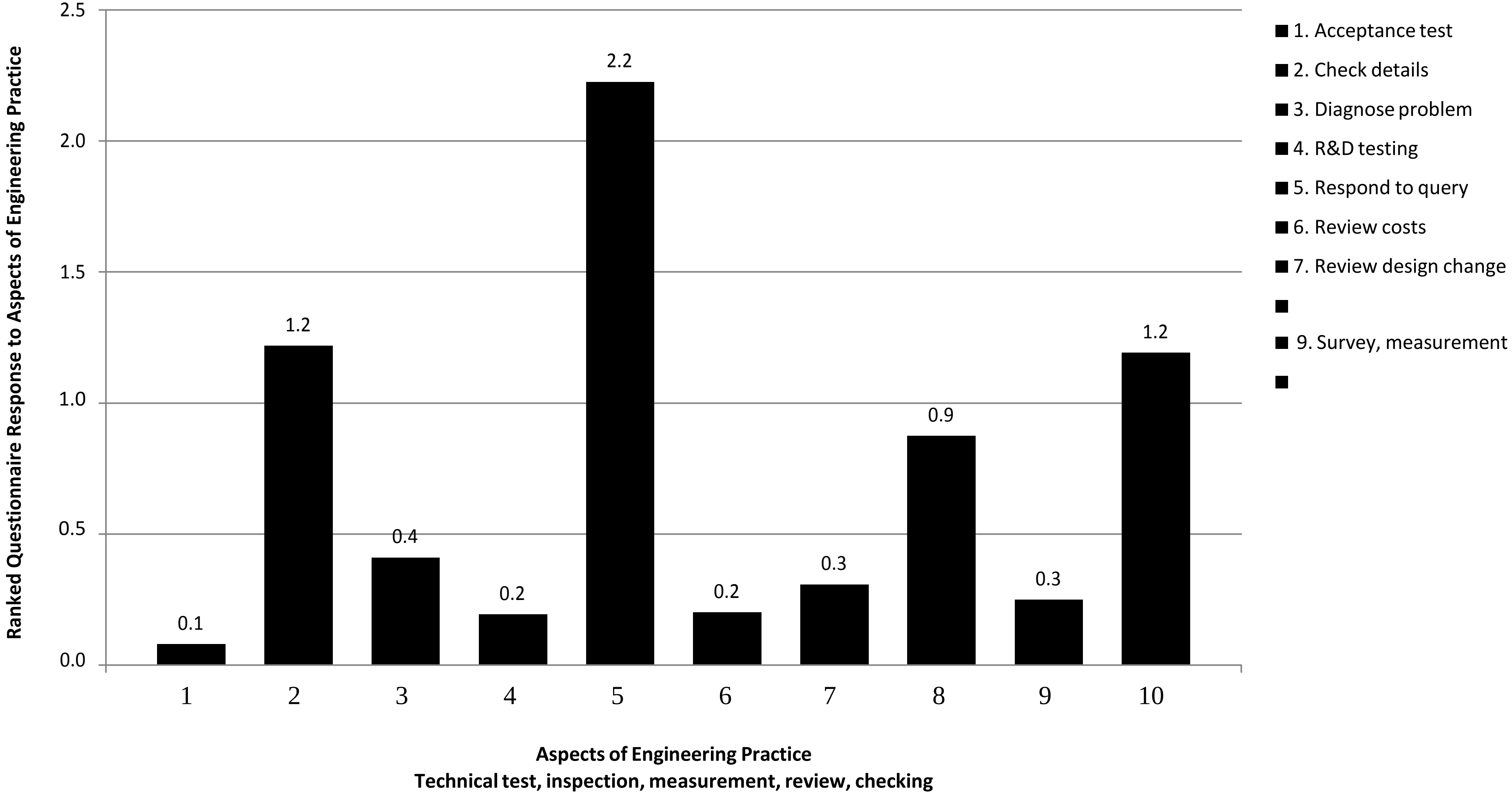


Figure 36: Aspects of Engineering Practice Questionnaire Responses within the Technical test, inspection, measurement, review, checking category,

Averaged and Ranked for Professional Engineers.

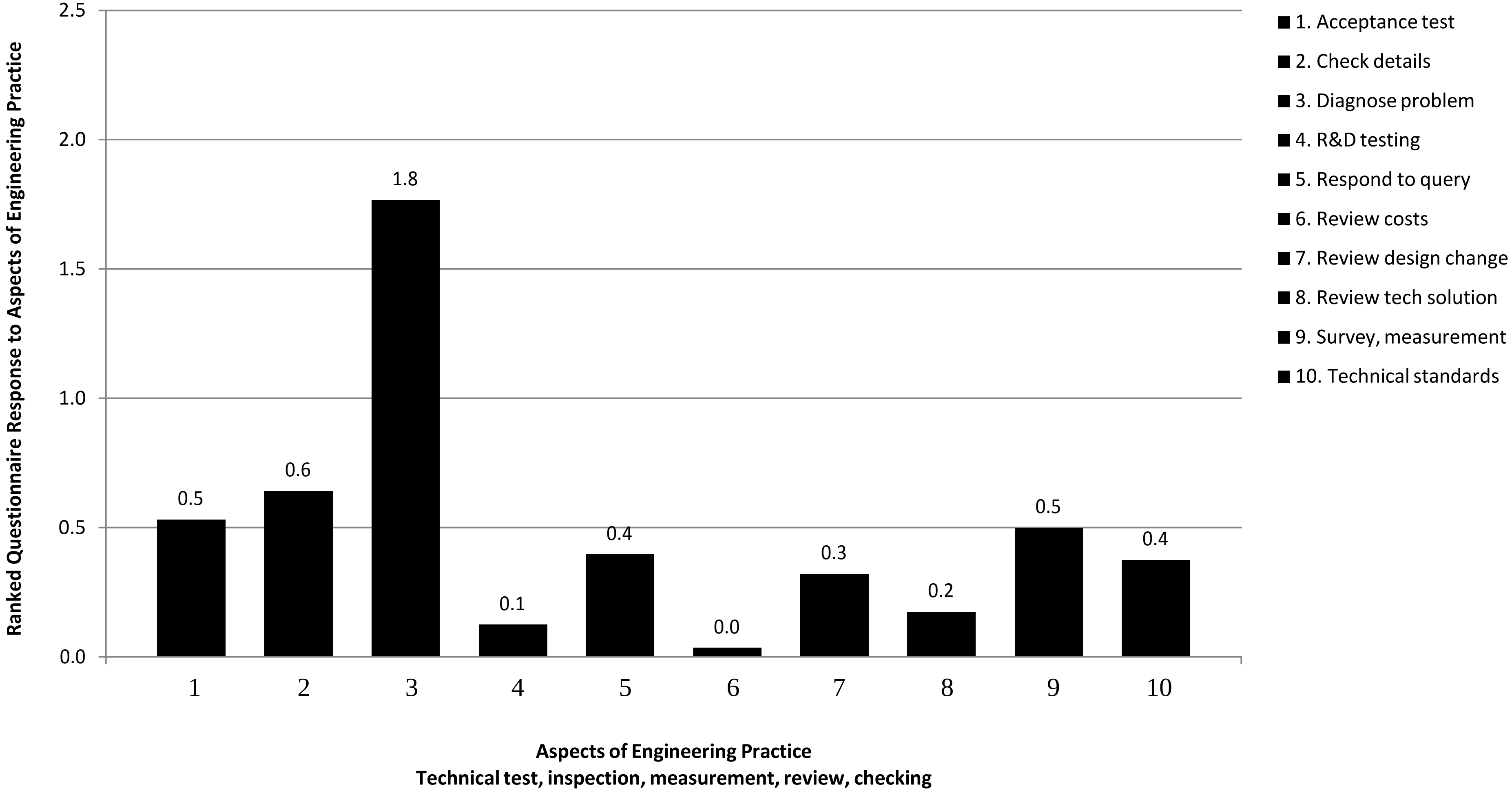


Figure 37: Aspects of Engineering Practice Questionnaire Responses within the Technical test, inspection, measurement, review, checking category,
Averaged and Ranked for Engineers in Training.

It is no surprise that this is considered an important category for this group. While individual activities did not match between the two data collection techniques, each activity in the category was shown to be a vital part of an EIT's workload.

Hands on work

This category was ranked as one of lower importance by both sets of engineers. In both groups only one individual even indicated being involved in this type of activity. Comparing this to the interviews the observation was that this category was ranked on the lower end of the scale especially by the P.Eng's. The interview references showed some activity by the EIT's but this could be a difference in interpretation. Coding was based on individuals attending to the field whether to perform tasks or even to observe. When self assessing, it is likely that the EIT's considered this an area of strictly working in the field, based on the descriptor.

Summary on Questionnaires of Aspects of Engineering Practice

The questionnaires in this study were designed to complement the interview information on the objectives on the roles of a professional and a newly graduated engineer. An overall ranking of the aspects of engineering practice categories, gave an indication as to which of the categories these participants felt were the most important. The P.Eng group indicated that the categories coordinating working with others, engineering management, and technical area of creating solutions and problem solving were the most important to their work activities. This matched with the information given during the interview sessions. The EIT group felt the most important categories were coordinating working with others, engineering management, the technical area of creating solutions and problem solving, and the technical area of testing, inspection, and checking solutions. This again matched with their interview information with one exception. The category engineering management did not appear as a category of importance during the evaluation of interview data but showed up as the second most important in a self evaluation by the EIT's. This is attributed to the the interpretation of the job activities by the two groups. The P.Eng group, as senior engineers, have an understanding of their role within the organization and the definition of the tasks. The junior group seemed to take a different definition of the term engineering management to mean project management. Definitions of the tasks within this category refer to managing documentation, and technical tasks so could be seen by this group as the daily routine they undertake. This was one area of difference between the results of the interviews and questionnaire data. All other categories ranked as important in the questionnaire data matched the interview results. When evaluating each category separately it was observed that there was much greater detail to the data. Each group of participants filled out the questionnaire with references to completing tasks in most categories. The difference between interview data and the questionnaire is the time for contemplation. During the interview participants had limited time to formulate their thoughts and discuss their activities. Therefore they would focus on activities that they felt important or were current. During the completion of the questionnaire participants had no time constraint. They were able to evaluate each activity and think of personal examples to match the activity. Therefore this data showed a much broader range of activities than the interview results.

The questionnaire also requested that each individual rank the tasks within the categories and also rank the categories. This information resulted in more depth to the data. The P.Eng group indicated the same tasks to be the most important as seen in the interview data. In the category of coordinating with others the tasks of supervision and working with others were the most important. The EIT group also chose the category of coordinating working with others as the most important. The individual tasks within the category were similar to their interview data with the only differences being the high ranking of the tasks listed as reporting progress and networking. An explanation for this would be that the EIT's interpretation of these tasks are more closely related to the other communication tasks within the same category. Differences in interpretation between the analysis of the interview data and the participants' interpretation while completing the questionnaire would provide an explanation. Overall the questionnaire results mirrored the data from the interviews to provide an identity for the role of a P.Eng and an EIT.

Summary of Aspects of Engineering Practice

The evaluation of aspects of engineering practice is important to this study and to engineering education. New entrants to the engineering profession will undertake tasks that allow them to learn how to perform engineering tasks and act like a professional. By understanding the differences between the activities of a P.Eng and an EIT we can understand the knowledge that must be gained by a new entrant to the profession. This study helps to show these differences between the levels of engineers. The importance is not in the details of each activity but in the general activities undertaken by the two groups..

Both groups showed a trend to performing activities in categories that matched earlier work by Trevelyan. The questionnaire data matched the general trends of both Trevelyan's work and the detailed interviews. This gives the questionnaire credibility as a general tool to gather data over the broader engineering community.

The results show that both senior and junior participants performed activities in the same general categories. This would be expected with individuals working in the same organization. The differences between the two groups were in the type of activities performed. The P.Eng participants performed activities in supervision, management, and technical oversight of projects. The EIT participant's activities were in technical areas, project management, and training. Both groups spent much of their efforts in team work and coordination with others. Study of differences between knowledge requirements of these activities could lead to an understanding of what knowledge needs to be acquired in a transition for new entrant to a professional engineer.

5.3 Interviews on Graduate Attributes

In this, the second stage of the research project, the transcribed interviews were coded into using the software NVivo this time based on the graduate attributes All three interviews by the EIT group and one interview by the P.Eng group were analyzed and categorized to the graduate attribute template. Nodes were setup for each graduate attribute as described. Each interview was evaluated and references were identified that fit the description of one of the graduate attributes. Once the reference was identified to a particular graduate attribute a decision was made as to the level of Bloom's Taxonomy it most closely matched. This was a difficult and subjective procedure but did work as the subjective nature was between adjacent levels of Bloom's Taxonomy. There was little difficulty distinguishing between references assigned to a knowledge level in comparison to an evaluation level. As an example in the attribute Project Management a knowledge level reference would be "learn all the steps of project management." Compare this with a synthesis reference "you work on your scope of work for your project. From there, you look at the resources you have, whether we procure a consultant to design the system. From there, we can take that detailed design, put it out to tender, get the contract rolling. You manage your risk, try to follow your schedule and work to completion."

Therefore even with the subjective nature of the coding these results provided the level of knowledge these EIT's were exhibiting at the workplace. The value of this portion of the study is in identifying which graduate attribute is exhibited in their work activities and whether this tends to be more in the lower end knowledge level or trending towards the higher evaluation levels. Once the interviews had been coded the results were printed and each of the documents were evaluated to ensure the reference fit with the description of the node. This was completed for all three of the EIT interviews and for the one P.Eng interview in which they were asked about the EIT's. This data was then evaluated and compared to the other methods of data collection in this study.

There were a total of 544 references to the graduate attributes in the EIT interviews. Figure 38 shows that the distribution is concentrated in about half of the twelve attributes. References were assessed to each of the attributes but some such as; ethics and equity (10), impact of engineering and society and the environment (9), professionalism (8), design (4), investigation (3) and a knowledge base for engineering (1) received less than 17% of the total references. Three of these attributes received less than 6% of the total. This can be explained as information assigned to these attributes would not be part of a general discussion about someone's work activities. When someone is asked to describe their work they generally do not discuss the details about the impact it has on society. The issue of ethics or professionalism is also not expected to enter the discussion. To gain understanding in these areas specific questions would be asked during an interview session. These interviews did not ask these questions and so the information is not available. This has no reflection on the knowledge level of these individuals in these areas. The other three attributes with minimal references received only 11% of the total. Two of these attributes are a measure of an engineer's theoretical knowledge level. In the first, a knowledge base for engineering; the descriptors are on recognizing, analyzing or evaluating numerical results which was not an area of discussion in the interviews. The second attribute, investigation, is also based on mathematical and experimental relationships. The third of these areas was design. This is an area of decision-making in which most new engineers spend little of their time. The expectation would be that EIT's would be more involved in tasks that allowed them to learn procedures rather than making design decisions. Therefore the fact that these six graduate attributes where discussed minimally fit with the type of interviews conducted.

The attributes that received the most attention by the EIT's were, lifelong learning (12), individual and team work (6), communication skills (7) and economics and project management (11). These four graduate attributes had a total of 66% of all the references made by these individuals. This was not surprising when relating this back to the results from the Aspects of Engineering Practice. The observation from those results showed a large portion of all engineer's activities involved coordination with others. This would relate well with the communication and team work attributes. In the area of project management it was found the EIT's repeatedly discussed their work in terms of having to set up a project or described the work as project management.

The attribute which received the largest number of references at 19% was lifelong learning. In discussions with the EIT's they described where their knowledge came from and the importance of learning on the job. The other two graduate attributes not yet listed are, problem analysis (2) and use of engineering tools (5).

These had a total of 17% of the references. In the interviews, participants would explain how they solved problems and what resources they used which would reference into these areas. An example of an application of problem analysis would be; "I went into actually reviewing blast designs from the consultant, I was responsible for doing post-blast reports for the blast designs, like setting up the monitors." This was a situation where a decision was made between coding as application or analysis. In the area of engineering tools discussion on activities frequently involved the use of software which is considered a tool. There were also other tools used by the EIT's including instrumentation for testing equipment.

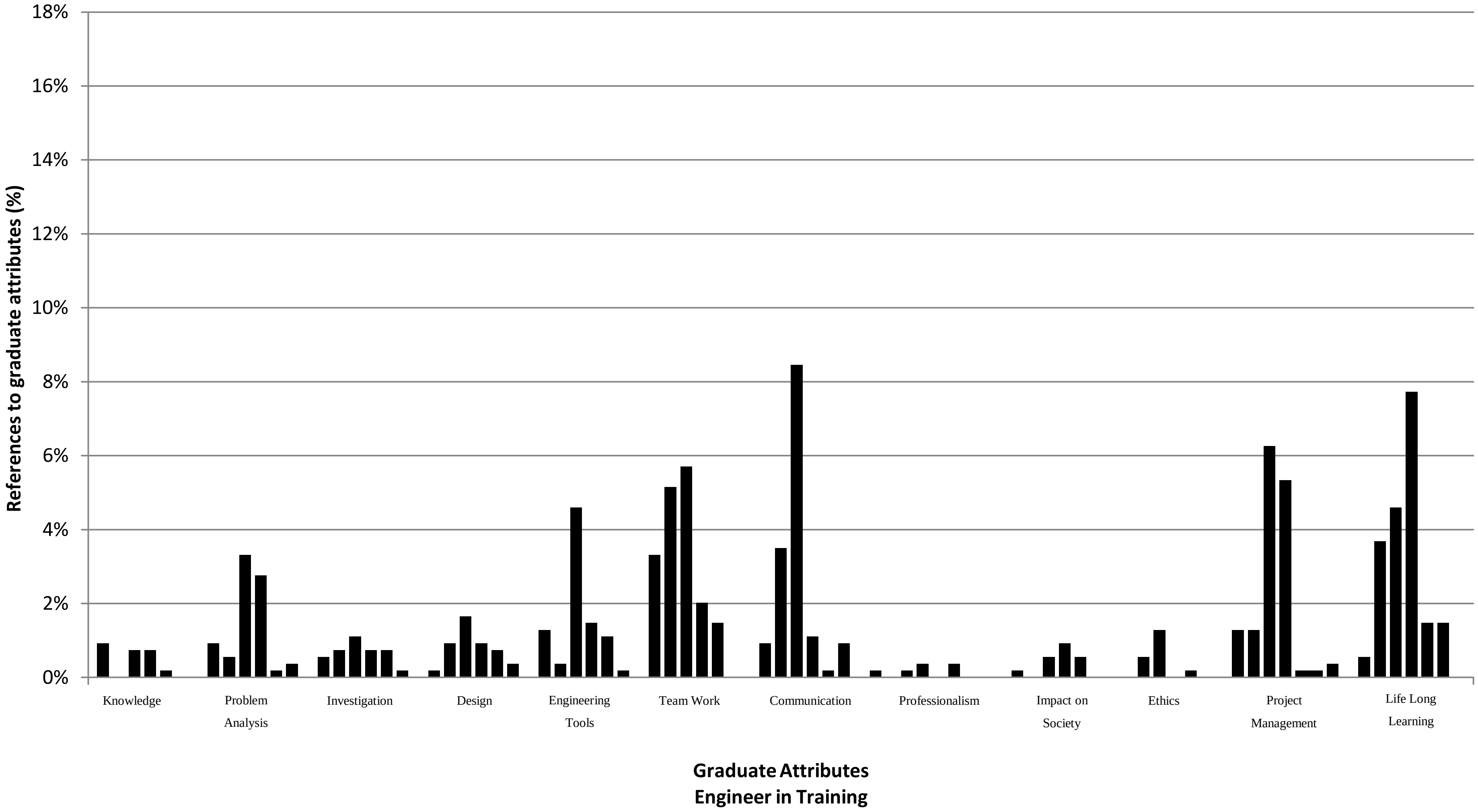


Figure 38: Interview responses as a percentage of total responses by Engineers in Training to overall categories of graduate attributes.

The coding for graduate attributes also included the third interview of the P.Eng group. This was an interview where they were asked about the activities and training for a new engineering graduate. Questions were asked on work activities and training requirements. Additional references for coding were also obtained during the focus group discussion with this group of interviewees. This comprised of only a total of four interviews of up to an hour in length and so the total data was limited. There were a total of 141 references obtained and coded. These references were coded in the same manner as the EIT interviews with a difference being that rather than a discussion on their own activities, as with the EIT's, it was a discussion on someone else's work. The same trend was seen as with the EIT data in that certain graduate attributes were referenced while others had little data (Figure 39). In this instance, ethics and equity (10) and impact of engineering on society and the environment (9) received no references in any of the interviews. The other attributes, with limited discussion were knowledge base for engineering (1), investigation (3), design (4), professionalism (8) and lifelong learning (12) which received a total of 23 references or 16% of the total. These results mirror that results from the EIT data with the exception of the lifelong learning attribute. This explanation for low data numbers in certain attributes would be the same as in the previous discussion. These are areas which did not come up in the types of interviews conducted. A different set of questions would be needed to gather that information. As for the lifelong learning attribute, this groups discussion focused more on the particular skill levels of the EIT group and not on their ability to understand their learning needs. This leaves the other five graduate attributes with 84% of all the references from the P.Eng participants. These are the same attributes that were prominent with the EIT group. Therefore there is an excellent correlation between the two groups of interviewees. The interview technique and questions asked would have a large affect on this trend.

The next step was to analyze the overall results within each attribute level. To do so there needs to be a way to express the results in a consistent manner for comparison. The list of graduate attributes is from a study on exit surveys of mechanical engineering students by Cicek (2013). In that study participants indicated one of the three levels of skills/ability for each level of knowledge (Bloom's Taxonomy) for each graduate attribute. In this way each level would receive a value of between one and three. Since this study also used the same evaluation in the questionnaire, a method was required for a comparison of these different stages of the study. It was decided to calculate the results for each graduate attribute with a weighted average between one and three. In this way each attribute would have a learning objective level with a rating of three and another with a rating of one. This would show the area of strength and weakness within each graduate attribute. This is not the same evaluation level of competence as in the questionnaire. The questionnaires ask specifically for participants to evaluate competence while the interviews only record when the participants discuss competence.

The interview data shows competence in an area while undertaking an activity, not competence at that level of knowledge. The interviews also have certain levels with minimal or no references. This does not indicate a low level of competence but only that there is no data. The interview discussion and related references to a certain level of knowledge would indicate a level of competence in that area. Therefore the number of references in a learning objective would indicate the organizations requirement of competence in that area. This is not feasible in this study as the number of participants is too low to gain confidence in the data. The data can only be used to compare results between what P.Eng's say about EIT's to what the EIT's say about themselves.

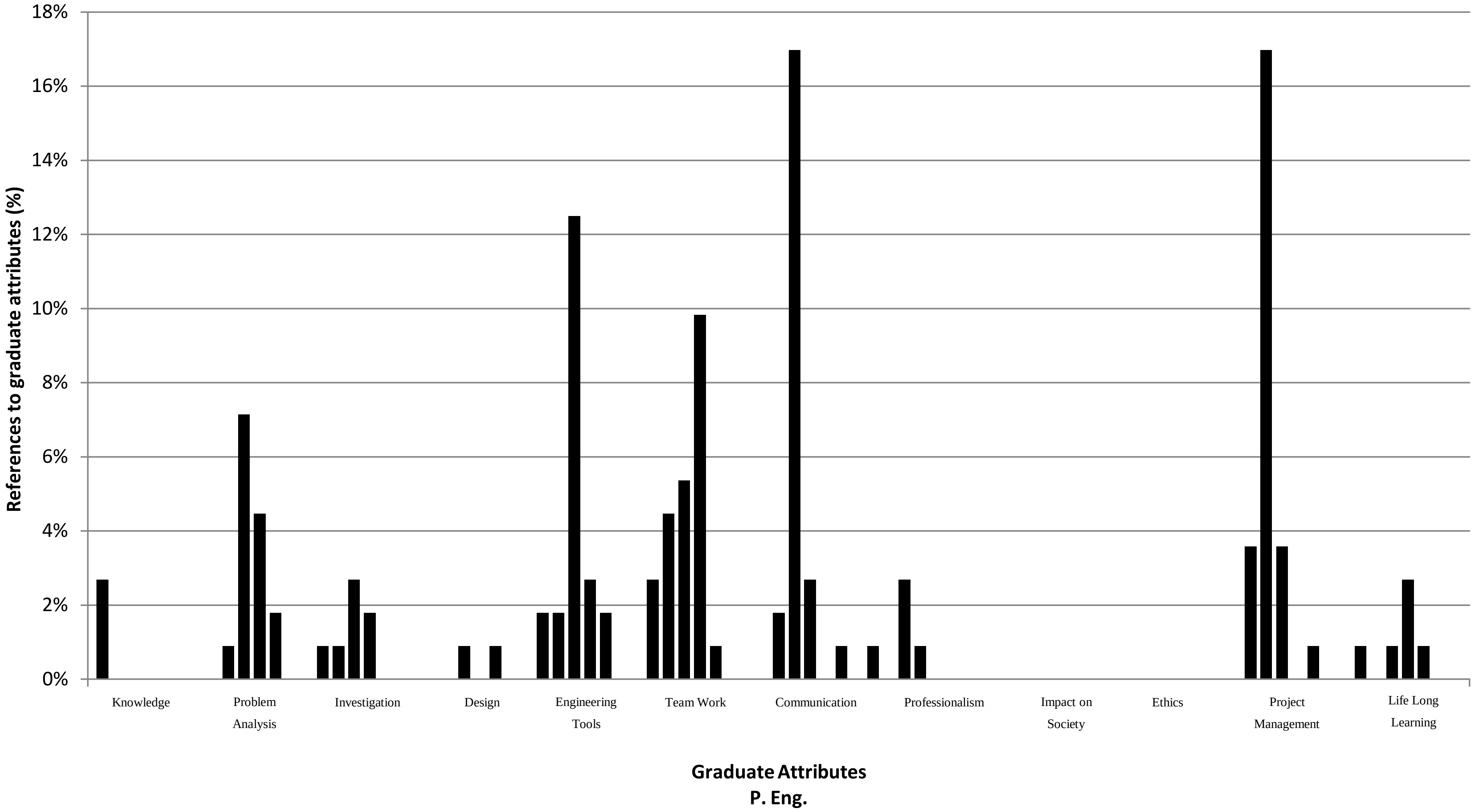


Figure 39: Interview responses as a percentage of total responses by Professional Engineers to overall categories of graduate attributes.

A knowledge base for engineering

This is one of the graduate attributes in which there were minimal references. The P.Eng's only had three references and they all were in the knowledge level of ability (figure 40). This does compare well with the EIT data. Although there were only fourteen references in these interviews the largest number was also in the knowledge level. This group also had references in the application level and analysis level.

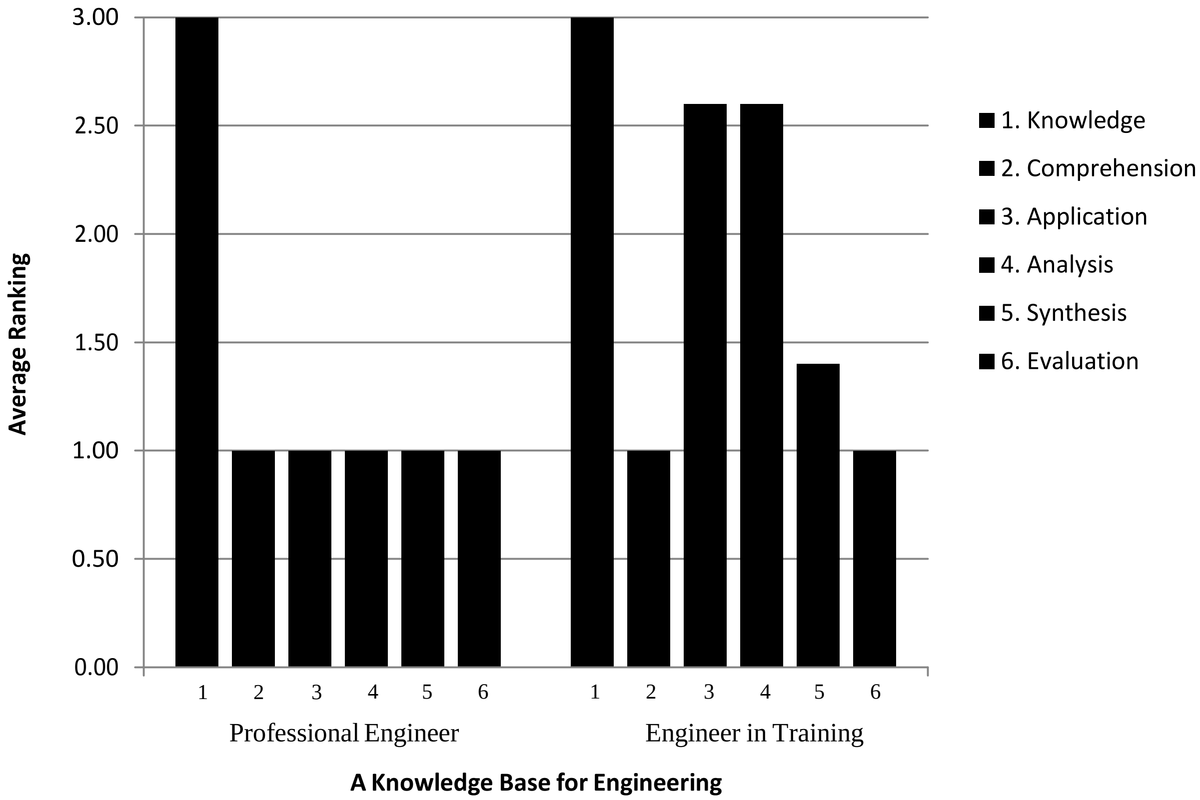


Figure 40: Average weighted rankings from graduate attribute (a knowledge base for engineering) interviews on new graduate skill/ability on entry to the workplace.

Problem Analysis

The second graduate attribute had a greater percentage of the reference data with 11% of the P.Eng's and 8% of the EIT's (figure 41). While this is not one of the more prominent areas referenced it is substantial and is interesting that the percent of responses between each of the groups is comparable. Both of these group's references were greatest in the application level and the analysis level. This consisted of 81% of the P.Eng responses and 75% of the EIT's in their attribute. There were additional references but only a few and distribution throughout the other learning objectives.

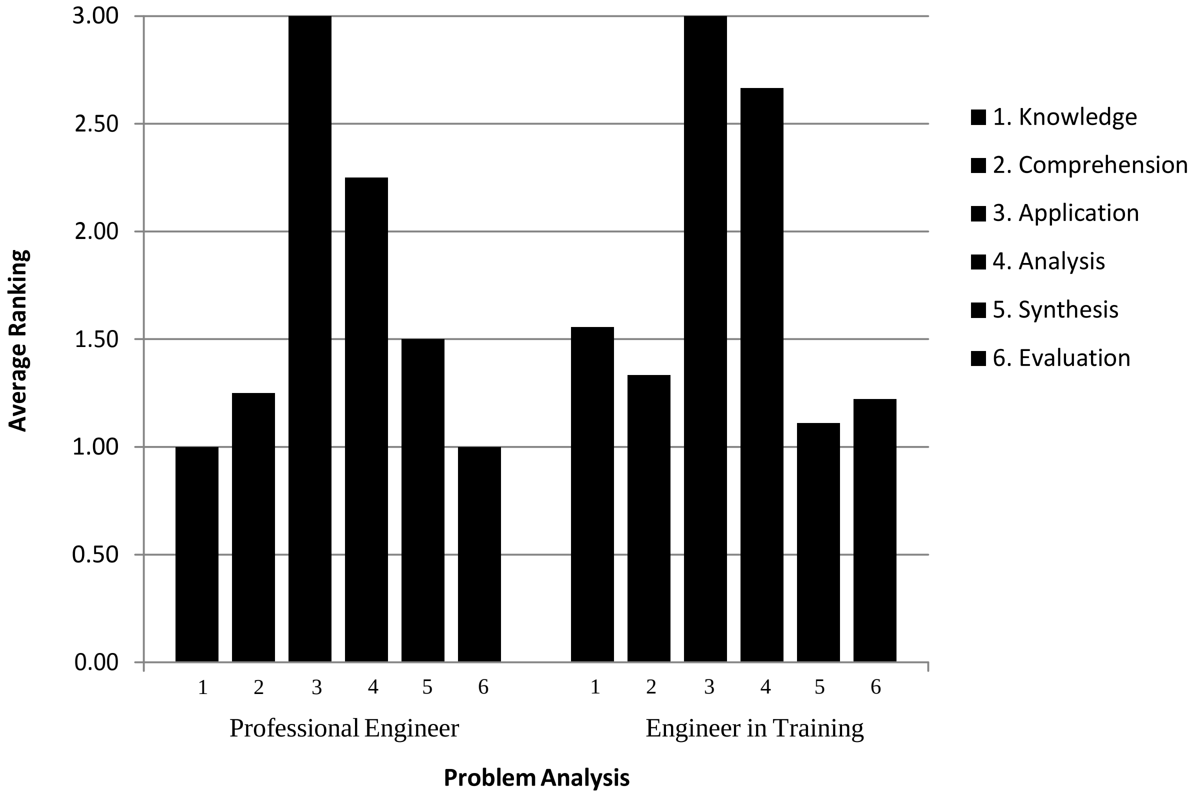


Figure 41: Average weighted rankings from graduate attribute (problem analysis) interviews on new graduate skill/ability on entry to the workplace.

Investigation

This is another attribute that received minimal attention during the interviews. But again in both groups the majority of these references occurred in the same level. This is the application level but with the EIT group references were spread over the whole range of learning objectives (figure 42).

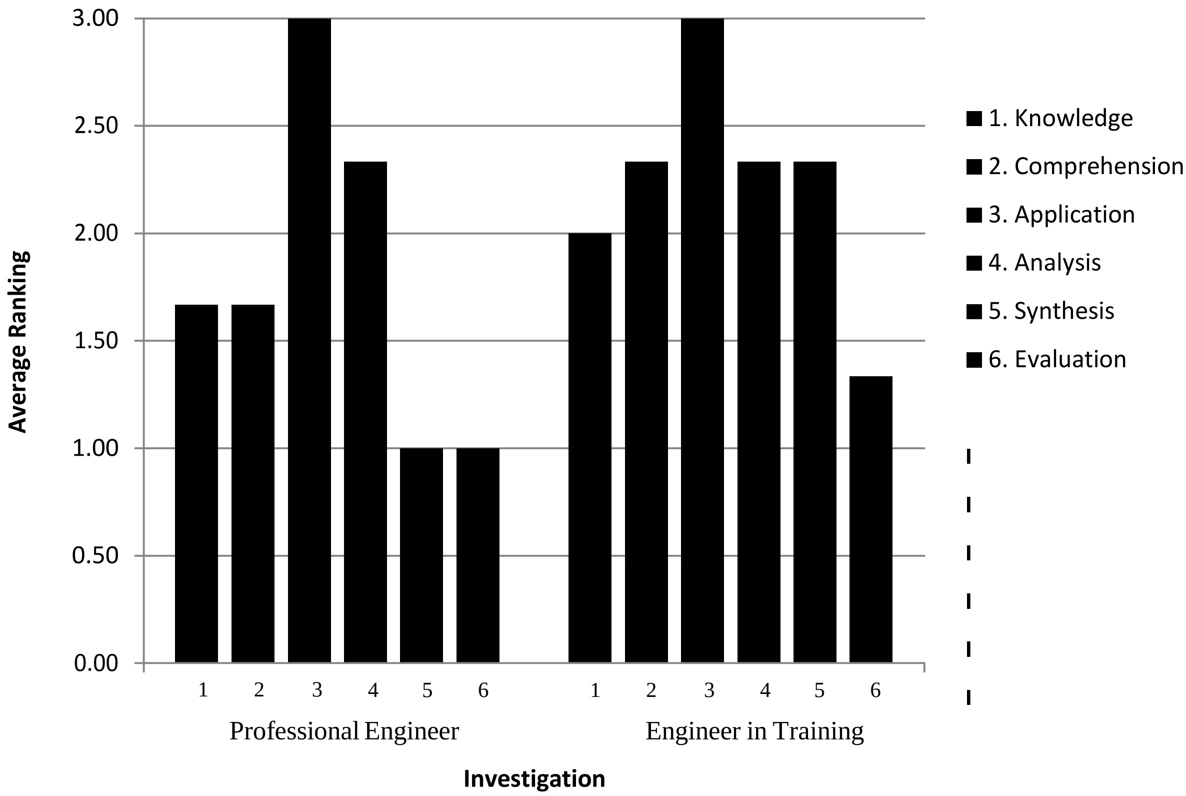


Figure 42: Average weighted rankings from graduate attribute (investigation) interviews on new graduate skill/ability on entry to the workplace.

Design

The design level had no real response from the professional engineering group with only two references (figure 43). The EIT's did have some data but only a small overall proportion. These references were over the range of knowledge levels with the largest number based on application. The comments ranged from the EIT's discussion about designing such as "you can have a design criteria and you have to run through all those points" by the EIT's to the P.Eng's classifying individuals as designers as in "their role becomes as designers".

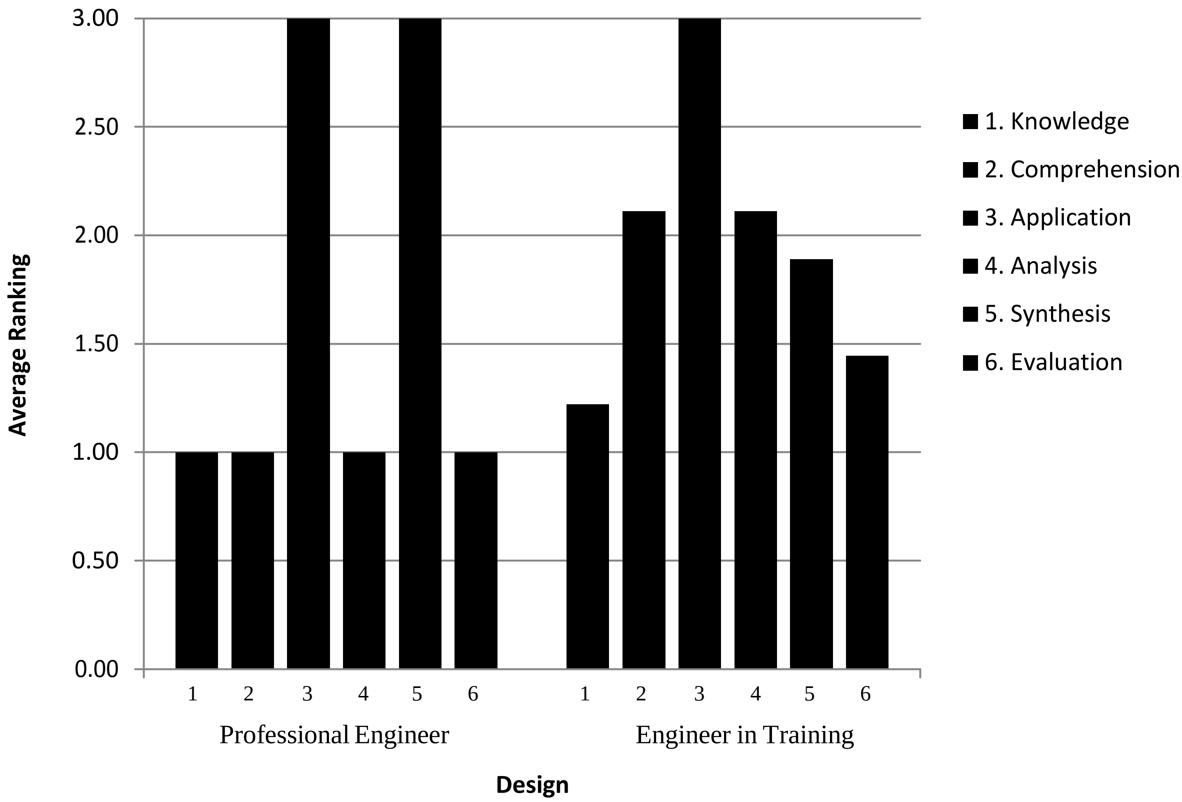


Figure 43: Average weighted rankings from graduate attribute (design) interviews on new graduate skill/ability on entry to the workplace.

Use of Engineering Tools

References to activities within this attribute were more common in the interview sessions especially for the professional engineers. 76% of the total references for this group were in this section (figure 44). A majority of these, 61% were under the application level which included references such as, "he's working on some scripting in Excel for load modelling program" and "so it may be running models that have already been built and not really doing any analysis." There was additional discussion by this group in other levels of ability with regard to engineering tools but mainly it consisted of the use of software and drafting capabilities.

The EIT group also had numerous references to the use of engineering tools but this comprised only 9% of their total. Within this attribute, 51% of these were assigned to the application ability level. These discussions did include software and drafting but also were on more specific types of instrumentation and modelling. Looking at the overall distribution of references it can be seen that there is consistency between what the EIT's reported as their activities and in what the P.Eng's reported.

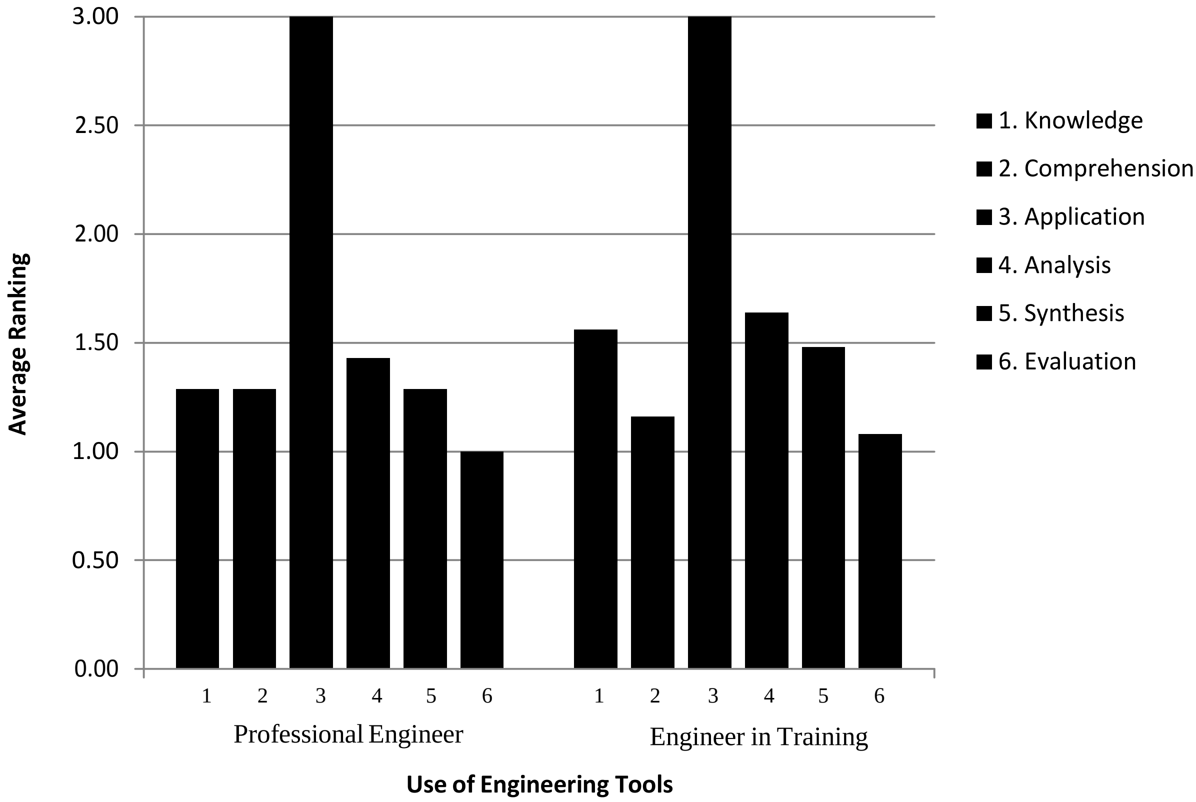


Figure 44: Average weighted rankings from graduate attribute (use of engineering tools) interviews on new graduate skill/ability on entry to the workplace.

Individual and Team Work

This graduate attribute is all about working within a team. It does refer to the importance of individual work but in the upper levels of Bloom's taxonomy the descriptors are describing team evaluation. This is also a fair assessment of the data for the interview section of the research. Individuals in discussions of their work will refer to meetings, group work and coordination with others. They will seldom self evaluate their own abilities unless asked specific questions. The interviews were open ended discussions and did not include questions of this nature. Therefore the responses received were almost exclusively on team performance.

This does seem to be an area of importance in this workplace as 18% of the total responses were reported in both the P.Eng and EIT groups. The professional group references were mostly in the comprehension, application, and analysis levels (figure 45).

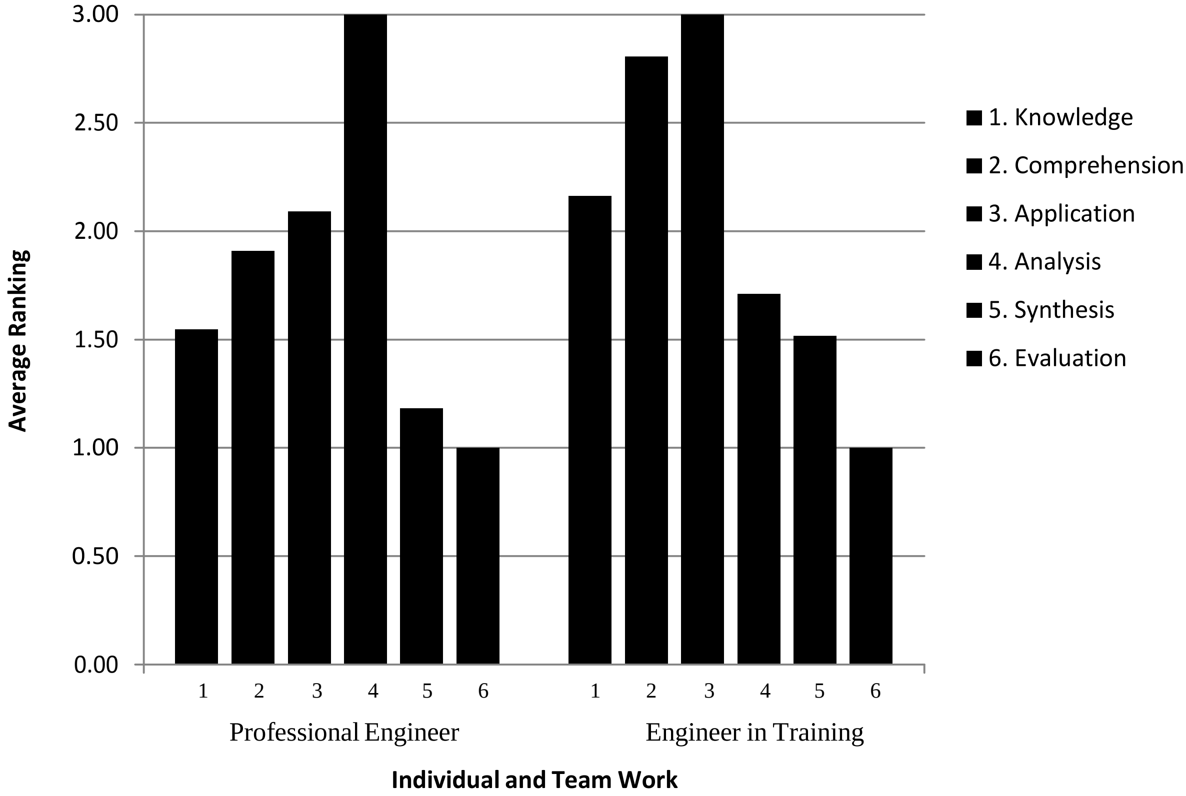


Figure 45: Average weighted rankings from graduate attribute (individual and team work) interviews on new graduate skill/ability on entry to the workplace.

The largest proportions were in the analysis area at 42%. This gives an indication that the supervisors believed that the EIT's understood team work and were able to evaluate their own and others contributions.

The EIT's also felt this was an important factor in the workplace with a total of 18% of their references in this attribute. This group's discussion was more in the comprehension and application levels of ability. This would indicate that the EIT's were less confident in this area. Discussions in the interview sessions were on the importance of team work and communication. This group also indicated that they did not feel prepared for the workplace and would have benefited from additional education or practice in this area.

Communication skills

Communication is an important ability for a professional engineer and this was discussed in the interview sessions. Along with team work the EIT group felt that this was an area where they were most unprepared upon entry to the workplace. They said they did not have the realization of the importance of communication for both the written and verbal form. The application level of this attribute held the majority of references for both the P.Eng's and the EIT groups (figure 46).

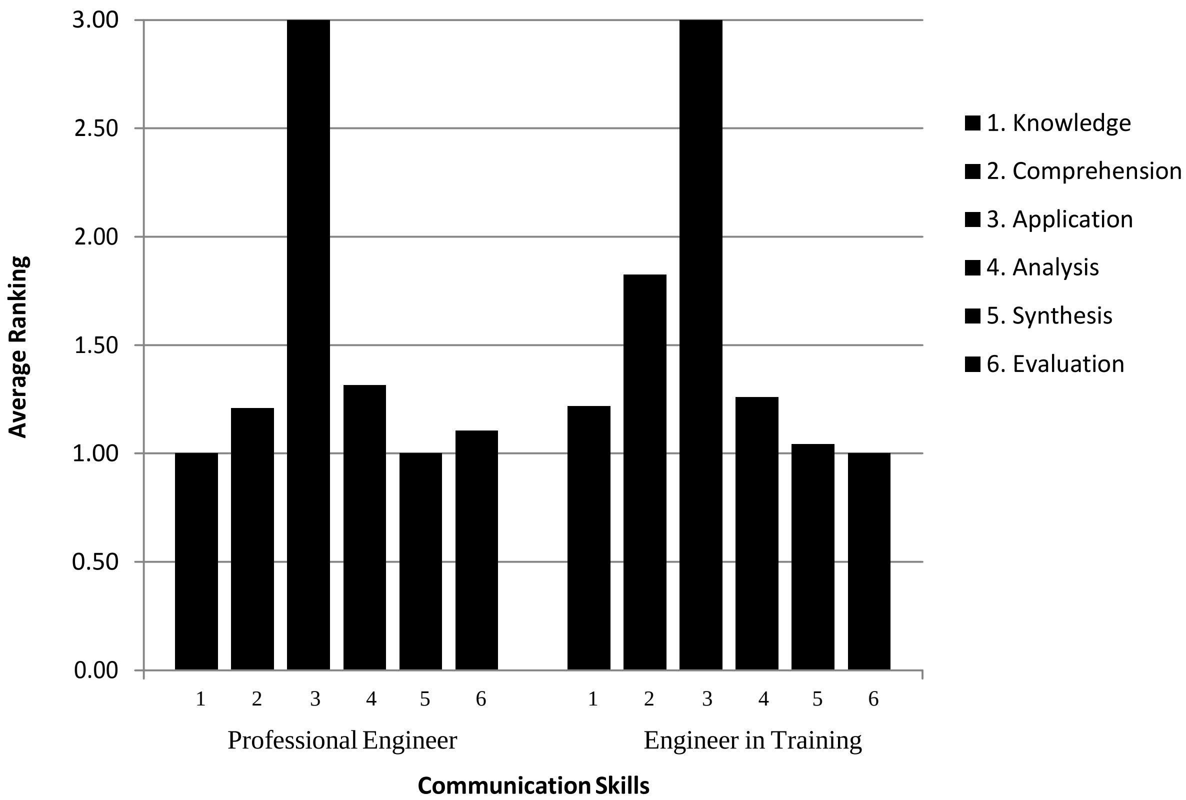


Figure 46: Average weighted rankings from graduate attribute (communication skills) interviews on new graduate skill/ability on entry to the workplace.

The majority of the references were for report writing and presentation. In both groups of interviewees this level had the highest number of references of any level overall.

One of the explanations for this high level is that it is an important and vital part of the job and was required on a regular basis. A second explanation is that it is seen as important and therefore discussed in the interviews more often than other more routine tasks. It could also be that a reference to a report was part of the description of each task undertaken. In any case both groups of interviewees considered the ability to produce written, spoken or visual documents to be a major aspect of new graduate activities.

Professionalism

This attribute had very few references from either group (figure 47). The interview sessions were set up to inquire on the work activities of a new graduate. In those discussions the particular topic of professionalism did not arise. In the coding procedure inferences could be made that activities undertaken could be seen as to being completed in a professional manner. It was decided that this was too subjective and that the only references would be those that directly referred to a professional aspect. This type of information could be obtained through an interview process with questions directly relate to this issue.

Impact of Engineering on Society and the Environment

This was another attribute that received little attention in the interview process. There were no references in this area from the P.Eng's and only 2% of the total from the EIT's (figure 48). The references were in the analysis level with discussions on activities related to local impacts. They included discussions such as, "update for environmental, socio-economic is huge, impact on local communities is a big thing to update." While this is an important area, it is also an activity that was not prominent in the activities assigned to the group of participants. Therefore very little discussion was held and the data was inconclusive for this attribute.

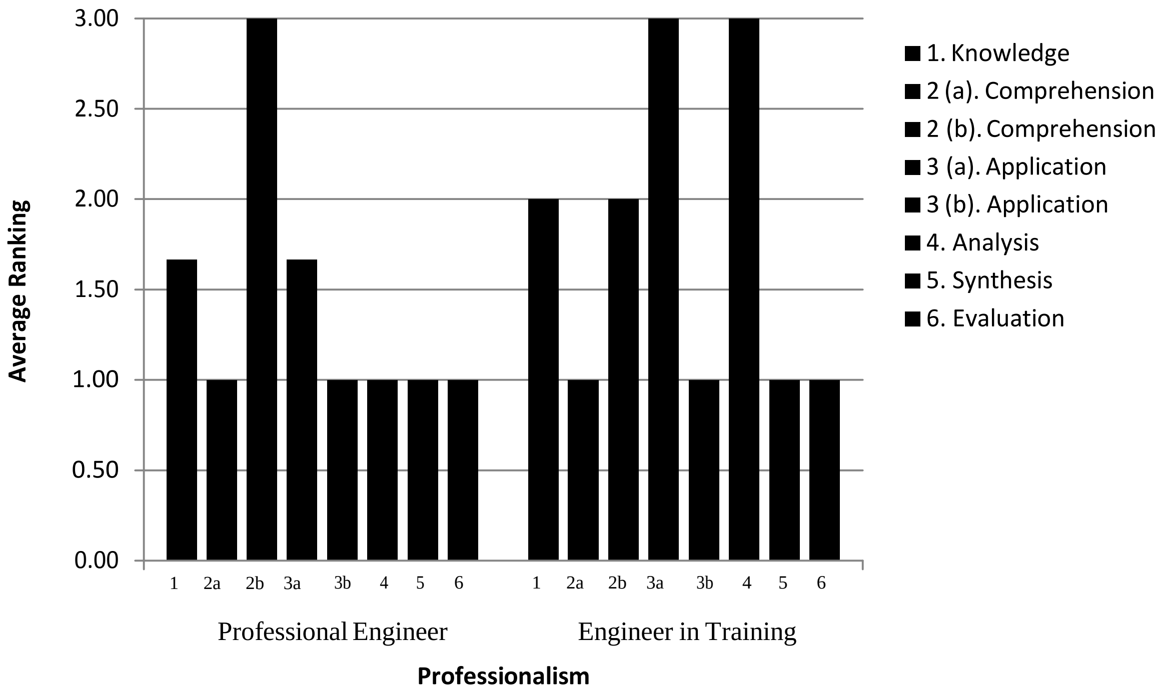


Figure 47: Average weighted rankings from graduate attribute (professionalism) interviews on new graduate skill/ability on entry to the workplace.

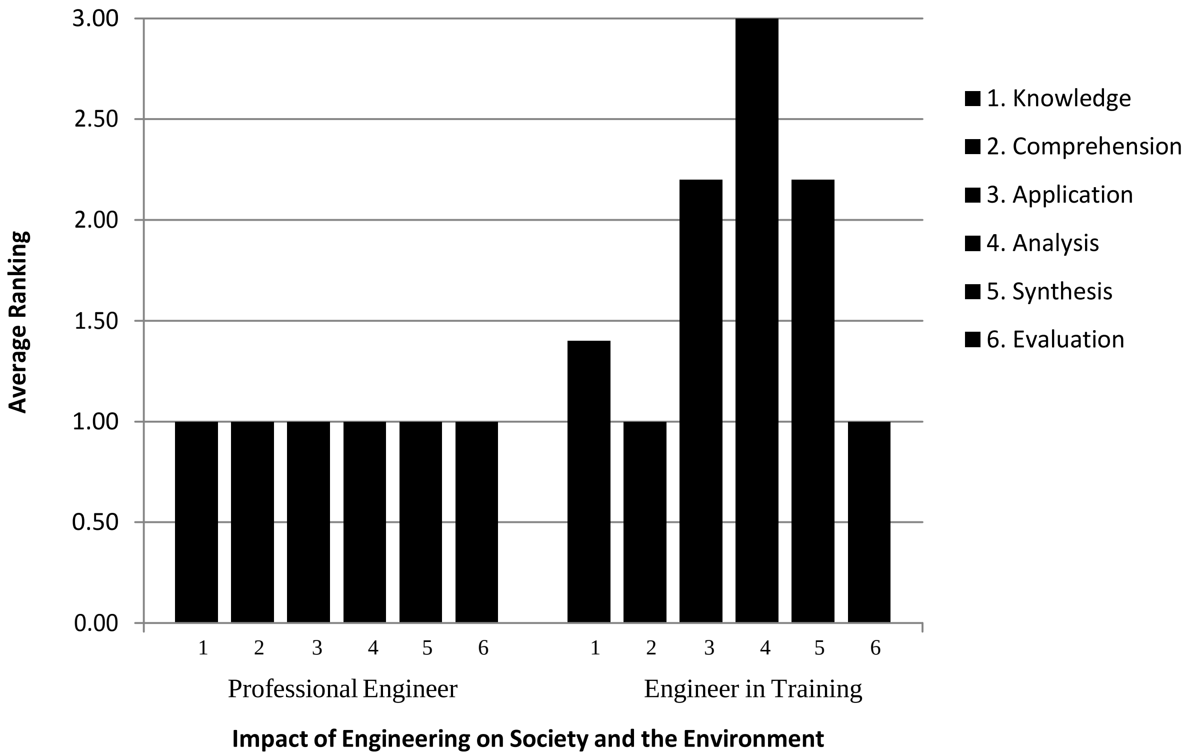


Figure 48: Average weighted rankings from graduate attribute (impact of engineering on society and the environment) interviews on new graduate skill/ability on entry to the workplace.

Ethics and equity

This attribute received no references from the P.Eng group but did receive a few from the EIT's (figure 49). These were generally on areas of using codes and standards. Coding was carried out with the consideration that recognizing the necessity of referencing the appropriate code was an indication of ethical behaviour. The lack of these references does not reflect unethical behaviour. This is another attribute that received little discussion due to interview technique. A description of work activities only included a general account of the procedure. This did not include the details such as evaluating the ethical implications. As with some previous attributes, to gain an understanding from a new graduate's perspective, additional interviews with specific questions would be necessary.

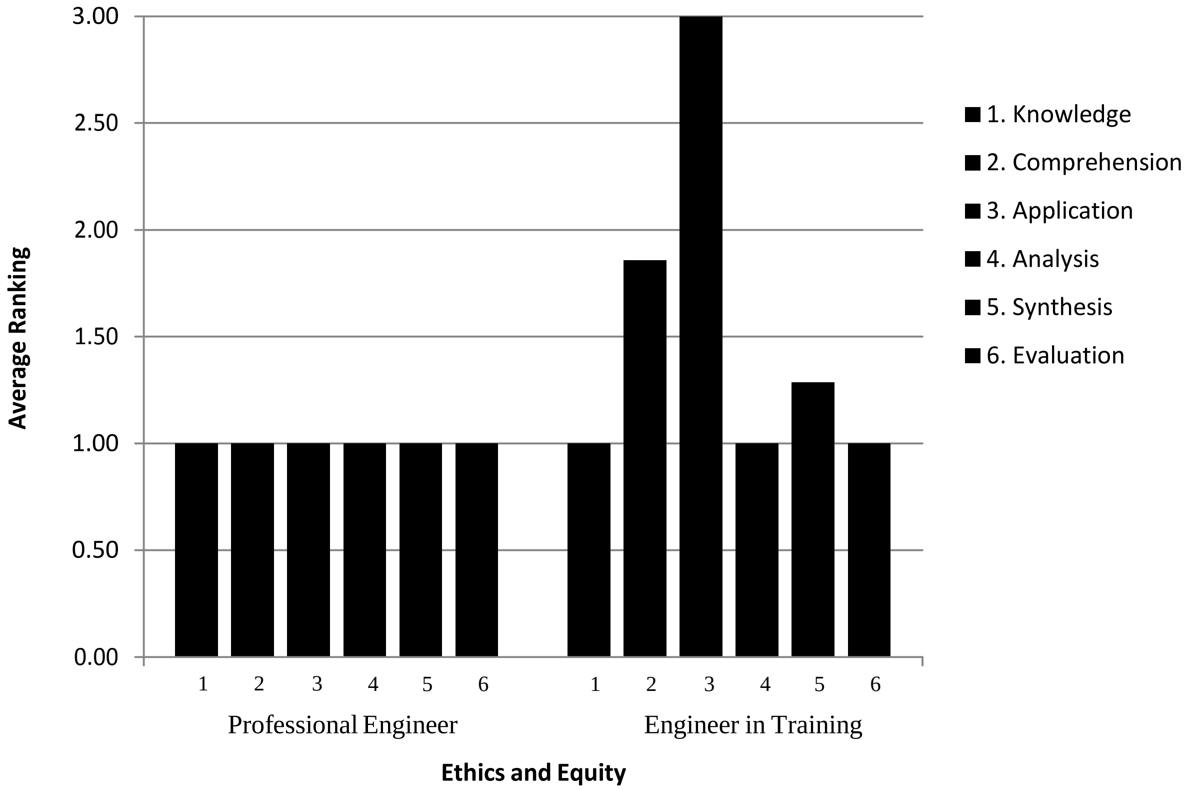


Figure 49: Average weighted rankings from graduate attribute (ethics and equity) interviews on new graduate skill/ability on entry to the workplace.

Economics and Project Management

Project management showed up as one of the top activities assigned to new graduate engineers. This was the most referenced attribute in the discussions with the professional engineers. There were a total of 20% of all the references for this group with 68% of these coded to the application of project management (figure 50). The interviews with the P.Eng's on the work activities was generally a discussion of the projects assigned. Care needs to be taken in the definition of a project as in this organization work is described in terms of projects. The descriptor defines this as the ability to establish scope, map out mile stones and budget along with utilizing appropriate tools. The interview references from the P.Eng's met these requirements. They included, "you're doing a little bit more of a project management role, you likely have to go and get technical approval from the concept review team, you are probably going to have a capital budget, single line diagram that you have to put through the process and get input from other areas of the corporation" and "I want them to have some projects where they're kind of the lead so they can put that into their reports." This application level of project management was the most important as it had 13% of the total references which was equal to the application level in communication as the top level.

The EITs also considered this attribute as being of great importance. This was one area that when asked about training the response was "I'd probably take more project management." This group had the interview responses split between the application levels of project management and economics. While the professional group discussed assigning project work to the EIT's, gave more detail to the activities involved. Therefore they made many references to the budget and economic aspects of the activity. If both the application levels in this attribute were combined, this would be the most referenced activity in the interviews as seen in the P.Eng assessment.

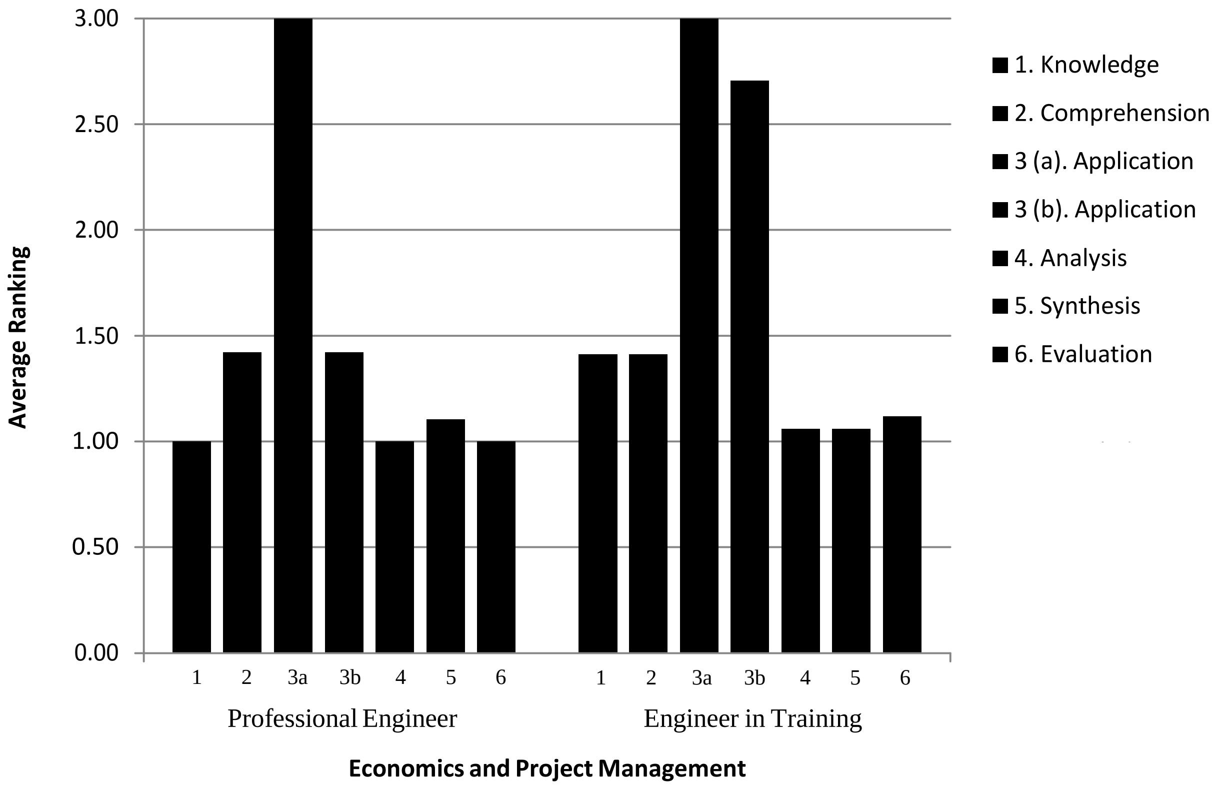


Figure 50: Average weighted rankings from graduate attribute (economics and project management) interviews on new graduate skill/ability on entry to the workplace.

Lifelong Learning

This attribute would not be expected to be referenced frequently in the P.Eng interviews. The specific questions for this type of evaluation were not asked. Therefore very little information was received and there were only a few references (figure 51).

The EIT group on the other hand did not need specific questions to assess lifelong learning. The descriptors for the levels in this attribute ask about the ability to understand, describe, analyze or create learning styles, needs or opportunities. The EIT's in their description of the activities they undertake often covered this type of information. Therefore this was an attribute that received substantial data from this group. The most referenced level was analysis with 40% of the data. This included comments such as, "I mean I have confidence and outgoing attitude to complete work", "I would certainly like to have some leadership skills" and "my degree has transformed my life because it has transformed the way I think and in my mind it has made me a technical authority."

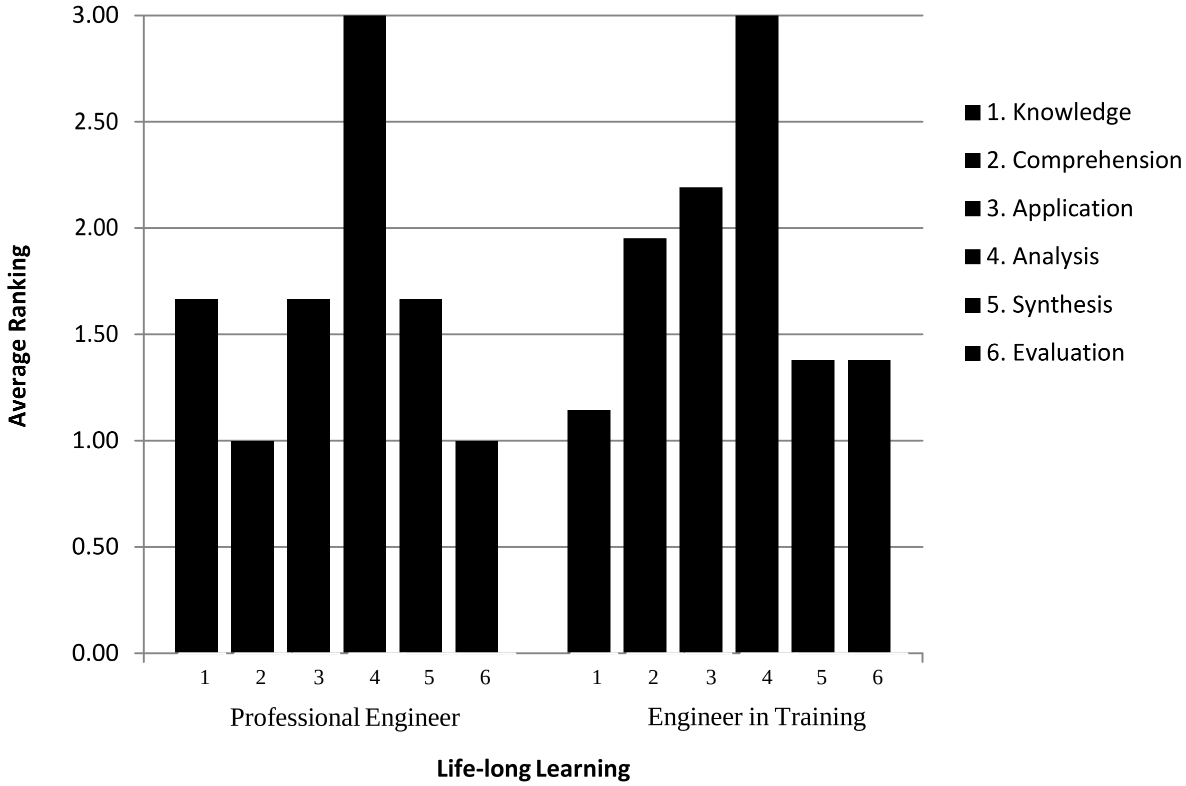


Figure 51: Average weighted rankings from graduate attribute (life-long learning) interviews on new graduate skill/ability on entry to the workplace.

In evaluating the results of this stage of the study a correlation can be seen between information from the senior and junior cohorts. With the exception of lifelong learning the discussions in the interviews was consistent with the graduate attributes and even within each attribute. Certain attributes had little mention or reference from either group which is not a reflection of the lack of that skill/ability. This is a reflection of the interview process and a lack of discussion in these areas. The attributes that were part of the discussion were equally represented by both the senior and junior groups. This would indicate that both groups see the responsibilities of the new graduate to be of similar activities. The other aspect is that in all these cases where discussions were held the major responses were at the level of application and analysis. So not only did both groups agree on which attributes had the most activity but they also agreed on the level of activity that was most common. This is an indication of the level of education that these students have acquired. If these students are being asked to perform this level of work, the indication is that they are capable of this performance. It should be noted that the group of P.Eng's are not related in this study to the EIT's. Therefore the information is general, not specific to this group.

Summary on Interviews on Graduate Attributes

The interviews on the graduate attributes were designed to identify newly graduated engineers abilities and knowledge. There were two sets of interviews, one with each set of participants. The EIT's were interviewed to try to identify what type of work activities they were asked to complete and at what knowledge level these activities were conducted. The data was analyzed with respect to the definitions for each graduate attribute in the graduate attribute questionnaires. The P.Eng interviews were designed to identify the work activities assigned to newly graduated engineers. The original plan was to evaluate the first two EIT interviews to the aspects of engineering practice and the third interview to the graduate attributes. Upon completion of the interview process it was observed that the information from all three interview sessions fit the parameter of describing the activities of these individuals. Therefore a decision was made to code all three interviews with respect to the graduate attributes. The P.Eng third interview was the only interview of this group to inquire on the activities of the EIT group.

The overall summary of the data showed that the EIT's mainly discussed activities in four of the twelve attributes. These four were in team work, communication, project management, and life-long learning. The discussion was referenced most often in the comprehension, application, and analysis levels of Bloom's Taxonomy. The other graduate attributes also had some references from the EIT's but at a lower occurrence level. This shows which area of activity is generally the most prominent for this group of new engineers at this workplace. When comparing the data with results from the P.Eng group there are similarities in the responses. The senior engineers when asked what duties were assigned to a new engineer responded with the same tasks as indicated by the EIT's. The most referenced were the attributes of team work, communication, and project management. They also felt that the areas of problem analysis and engineering tools were important activities for the new engineers. These two areas were not as prominent in the EIT interviews but were considered secondary with fewer references than the main attributes. The P.Eng references also mirrored the EIT data with the majority of references falling in the comprehension, application, and analysis levels. The one area not represented in the P.Eng data was in the area of life-long learning. This can be explain in that the subject individuals (EIT) will discuss opportunities for advancement and learning in their own careers, but others (P.Eng) will be focused on job activities as assigned. The strength of this data was that both parties indicated that not only were activities assigned to new engineers in the same areas but also at the same level of knowledge.

5.4 Questionnaire on Graduate Attributes

The final stage of data collection was the questionnaire on graduate attributes. This document was distributed to all participants. One of the P.Eng's was unable to return the completed questionnaire and therefore these results include only three of the four senior participants. All of the EIT's completed and returned the form.

The results of the questionnaires were evaluated in the same manner as the study by Cicek (2013). Numerical values were assigned to each response. A value of one was assigned to the response that the skill/ability was not yet developed. A value of two was assigned to a response that the skill/ability was introduced but coverage was insufficient for it to be mastered. A value of three was assigned to a response that the skill/ability was covered in enough depth to be mastered. These values were assigned to the evaluation the EIT participants made on the section label University Graduation. This gave an evaluation of the skill level these individuals felt they had possessed at the time of their graduation.

The second section of the questionnaire for the EIT's was labelled Work Environment. This section was also assigned numerical values between one and three. The value one was assigned to a response that the skill/ability was not used in any of the work that they had been asked to complete. A response of two was assigned to the skill/ability that was used but that needed support or additional training when completing the tasks. A response of three was assigned to the skill/ability that was used in their work and they felt comfortable completing those tasks.

In this way the results from the work environment section can be compared to the results from their self assessment at graduation. A value of one means that they were not taught the skill and that the skill was not used at work. A value two means the skill was taught but not sufficiently to master and that support was needed for the skill at work. A value three meant the skill was mastered in school and used comfortably at work. The questionnaire was set up in a way that the respondent would evaluate each skill/ability from a personal perspective and a work perspective at the same time. This would give an evaluation of both their education level and the requirements of the job with respect to graduate attributes.

The questionnaire for the P.Eng participants was set up in the same manner. A numerical value was assigned to each response. For the University Graduation portion a value of one was assigned for the skill/ability that was not evident in the new engineering graduate. A value of two was assigned to the skill/ability that was evident in the new engineering graduate, but that they had not yet mastered or needed additional support. A value of three was assigned to the skill/ability that was evident in the new engineering graduate and they were readily able to use the skill. This gave an evaluation from professional engineering supervisors as to the skill level of newly graduated engineers.

The second section of this questionnaire was also labelled as Work Environment. In this section the value one was assigned to the skill/ability that would not be expected to be used by a new engineering graduate. A value of two was assigned to the skill/ability that would be expected to be used by a new engineering graduate but with additional training or support. The value three was assigned to the skill/ability that would be expected to be readily used by a new engineering graduate.

This questionnaire was set up in the same manner as the previous one. The respondent would evaluate the new graduate's skill level and then the level that was required for the workplace. The value assigned to each response of between one and three allow a comparison of a P.Eng evaluation of a new graduate with respect to the job requirements. The rating system also allowed an assessment of the EIT's evaluations against the P.Eng's evaluations. This also gave the ability to compare these against the Cicek study on new graduates.

Overall there was an average ranking of 1.98 for the EIT self assessment (Figure 52). This compares to the P.Eng overall average of 1.96 (Figure 53) which are both substantially lower than the average of 2.55 reported by the exit survey in the Cicek study. It would appear that students at graduation rate their skill level substantially higher than ratings after a period of time at the workplace. The range of averages in this study for each graduate attribute was from a low of 1.33 to a high of 2.38 for the EIT group and 1.39 to 2.67 for the supervisory P.Eng group. We must remember that the sample size is extremely small for this study. The results show that the participant's assessment of graduating students was that they have an average skill/ability level that would be considered only at the introduced level. Overall they also felt that half the graduate attributes were even barely introduced. The EIT participants rated the attributes of problem analysis (2), investigation (3), knowledge base for engineering (1) and team work (6) as the highest for their skill/ability levels. The P.Eng participants listed knowledge base for engineering (1), communication (7), and problem analysis (2) as the ones with the highest skill level. The attribute levels that were ranked the lowest for the EIT group were impact on society and the environment (9) and project management (11). For the P.Eng's they were the same two just in the reverse order.

Overall only two of the attributes have substantial variation in rankings between the groups. The first was use of engineering tools (5) with a rank of fourth for the P.Eng's and tenth for the EIT's. The other was design (4) with a rank of ninth for the P.Eng's and fifth for the EIT's. Therefore the senior members felt the new graduates were capable using tools but needed more training in the design area while the EIT's felt they were good designers but needed support with engineering tools.

In looking back at the interview sessions it was seen that EIT's discussed designing as part of their project work and so it would be interesting to get a definition on terms like design from both groups to see if that accounts for the difference in ratings. The other area of difference was for the engineering tools category which was discussed during the interview sessions. The definition for this attribute includes software as tools. EIT's commented of having to learn a lot of new software. While the EIT's may consider this as one of their deficiencies which needs additional support, the supervisors may see this as a strength that the new graduates are accomplished enough to learn the new software.

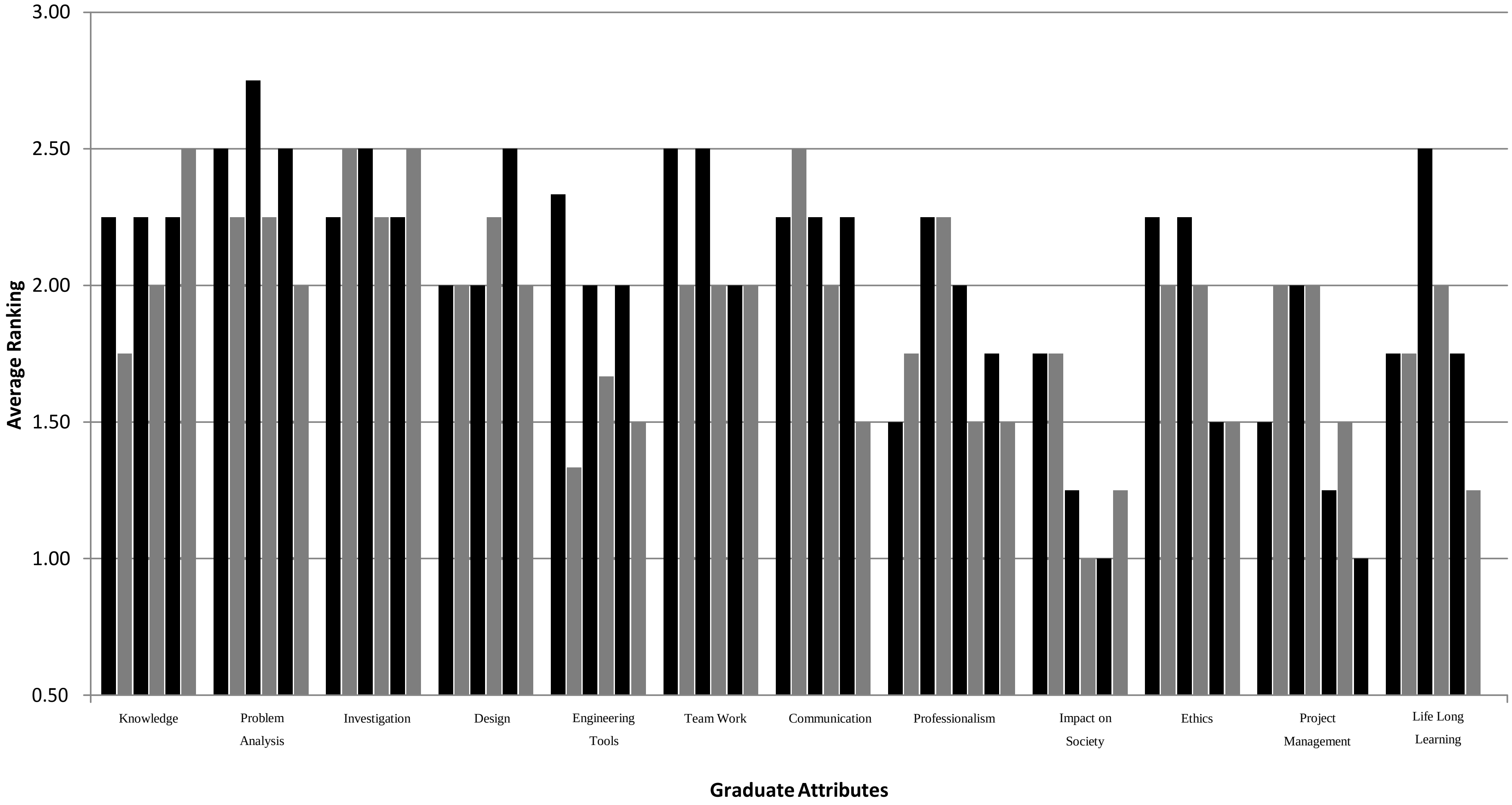


Figure 52: Engineers in Training average perceived graduate competencies from questionnaires to overall categories of graduate attributes.

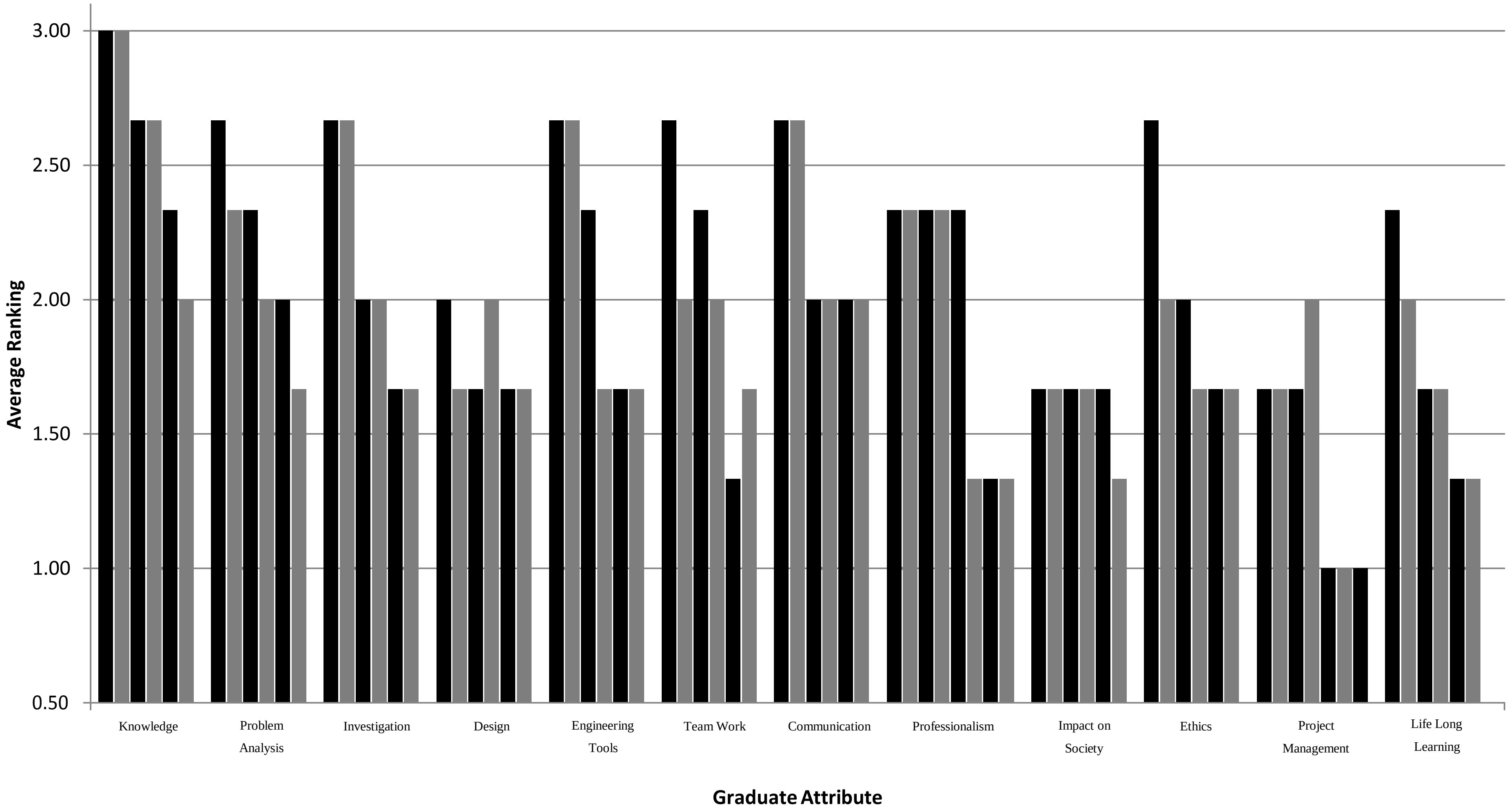


Figure 53: Professional Engineers average perceived graduate competencies for Engineers in Training from questionnaires to overall categories of graduate attributes.

The other set of data collected was the assessment of what skill/ability level a new graduate should have upon entry to the workplace. The average level between these two groups was again consistent but increased over the assessment of skills of a new graduate. The average rating for the P.Eng's was 2.2 while for the EIT's it was 2.31 (Figures 54 & 55). These numbers are substantially higher than their ratings of new graduates' skill levels at 1.96 and 1.98. This would signify that the new graduates are entering the workplace with a deficiency of skills/ability in regards to the requirements. Looking at this average in relation to the average of 2.55 from the Cicek study shows that those graduates are meeting the standard needed by industry.

The range of ratings as a requirement to the work environment for each category by the P.Eng's was 1.61 to 2.67 which was only marginally higher than their assessment of the new graduates. There was a much larger shift in the range of the EIT data. The low end of the range here is now 1.71 with the upper end at 2.96. This signifies that the EIT's rated one of the graduate attributes as needing a near mastery level at graduation. This graduate attribute was individual and team work (6) for which they only rated themselves as having a 2.17 level upon graduation. This deficiency of 0.79 is not even the highest as that belongs to professionalism (8) at 0.88. Looking at deficiencies between what the EIT's rated themselves upon entry to the workforce to what they felt they needed as education there were only three areas where they felt they met the workplace requirements. These were the attributes a knowledge base for engineering (1), problem analysis (2), and investigation (3). These are all technical areas which were pointed out in the literature as being areas of strength. The P.Eng data shows the only attribute they felt new graduates were not deficient was a knowledge base for engineering (1).

When looking at which of these attributes are the top rated for the work environment, the same three showed up in both groups.

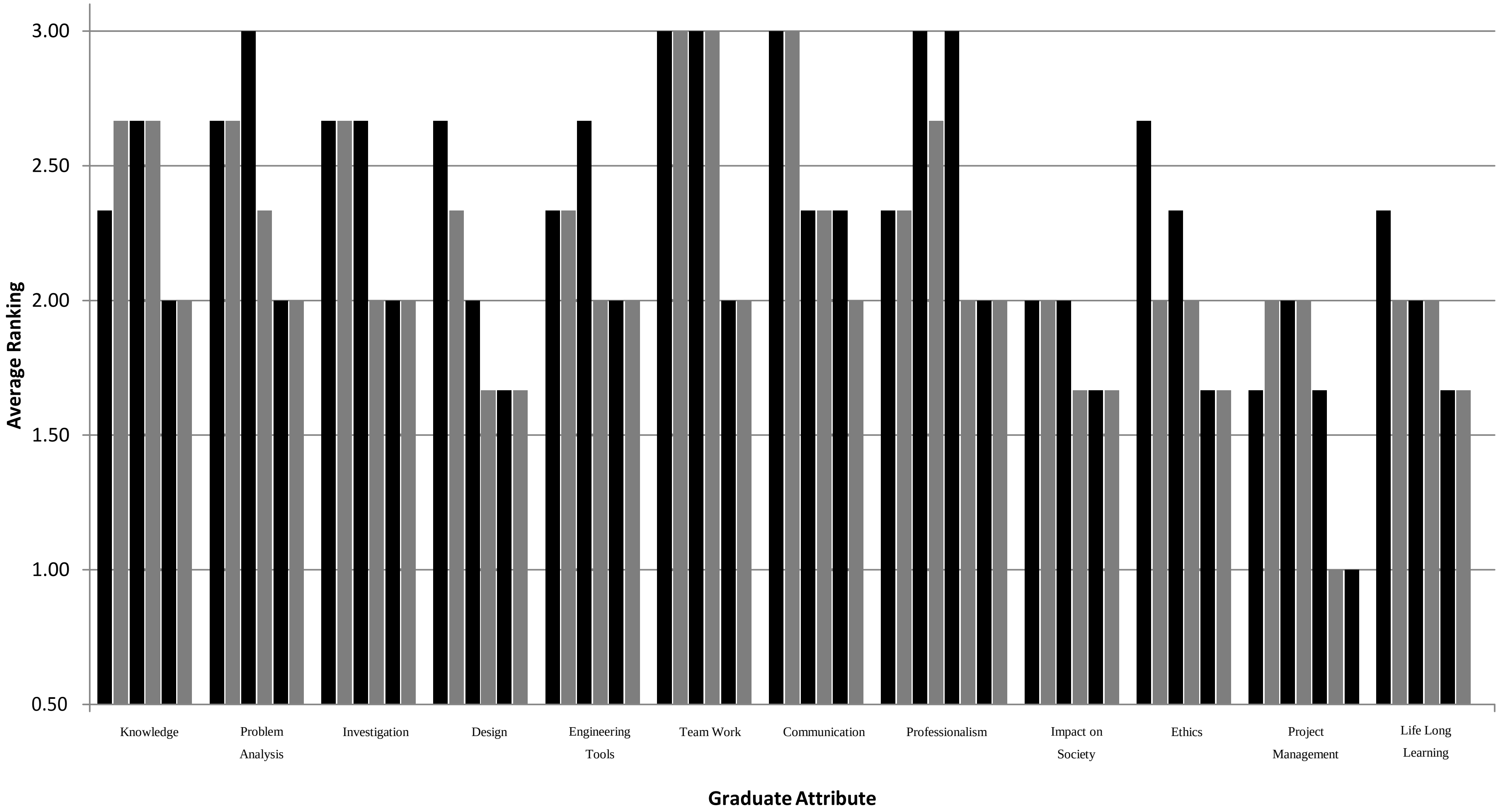


Figure 54: Professional Engineers average perceived graduate competencies required for new graduates at entry to the workplace.

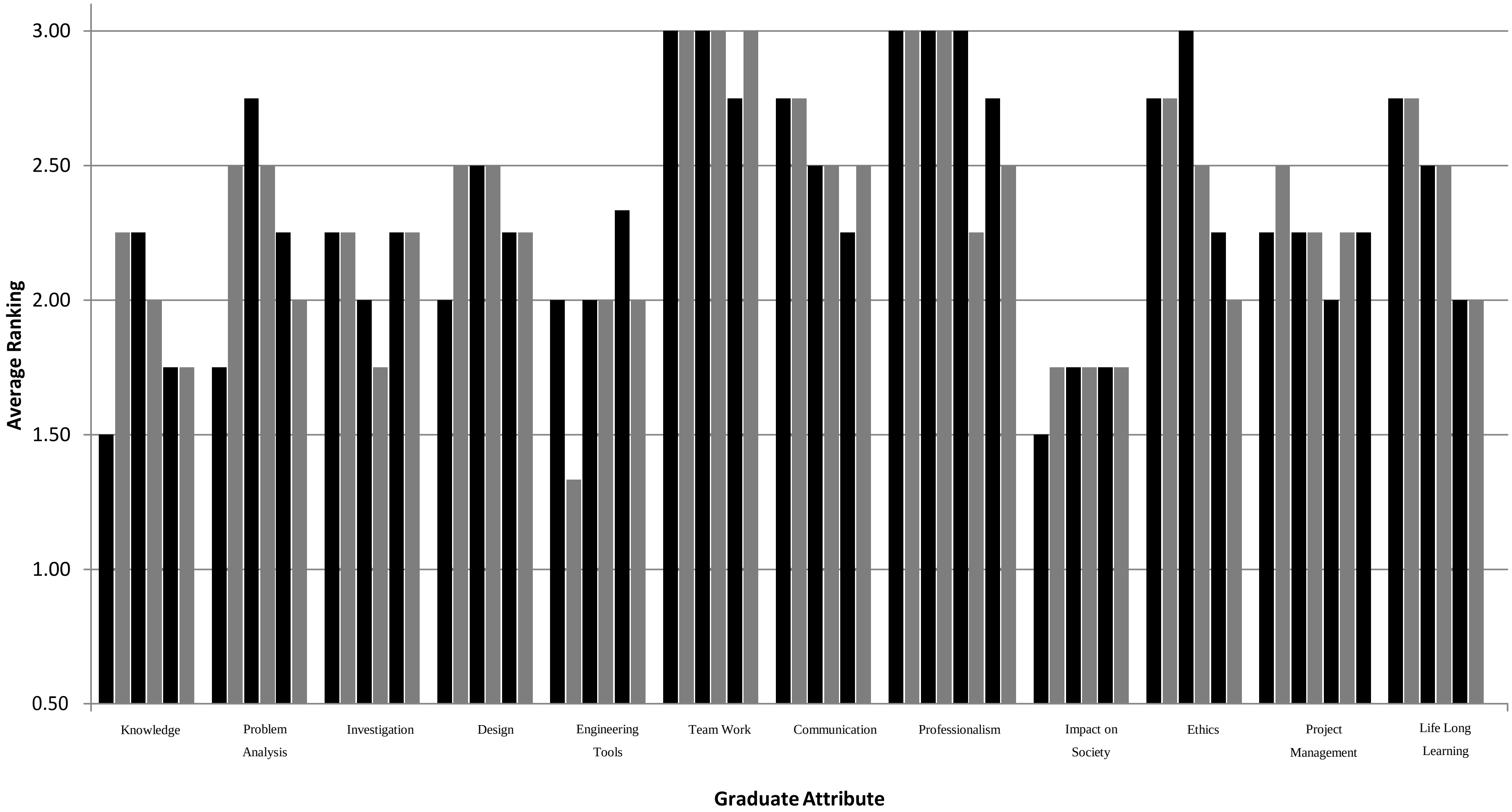


Figure 55: Engineers in Training average perceived graduate competencies required for new graduates at entry to the workplace.

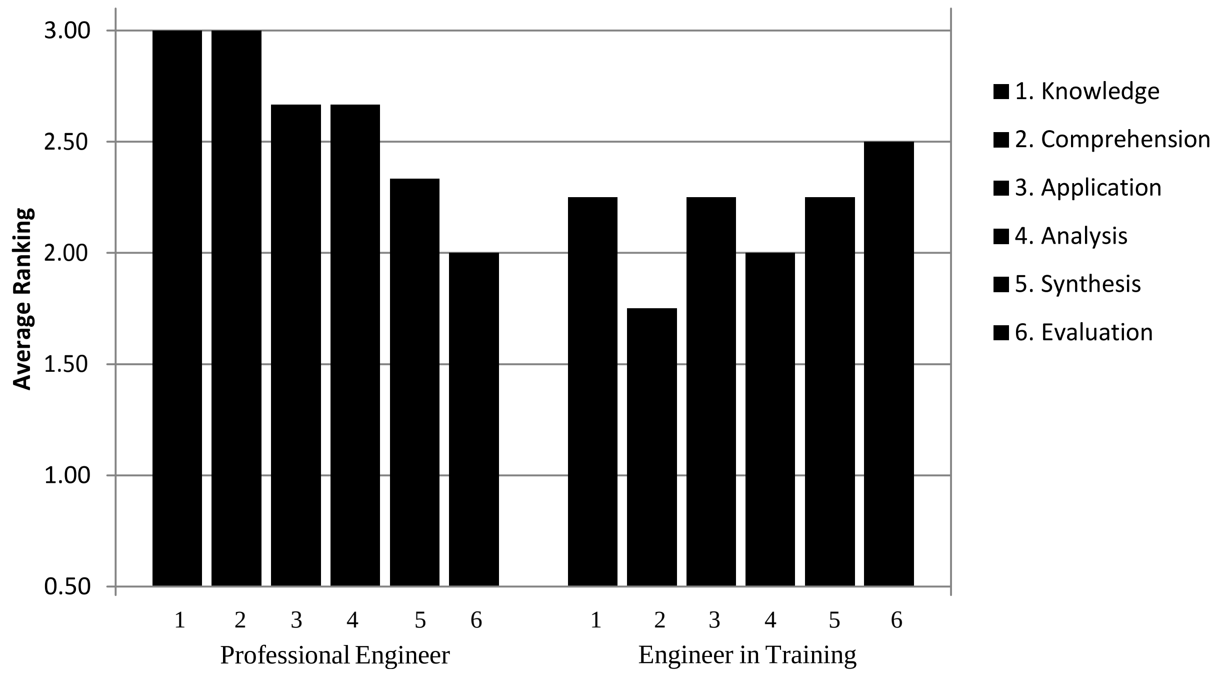
These are individual and team work (6), communication (7) and professionalism (8). They are ranked first, second and third by the professional group and first, third and second by the EIT group. This is very interesting in the fact that they are consistent between groups and that these are considered the soft skills. Rankings for the lowest rated attributes are not as consistent as the top ones. The P.Eng's ranked their lowest as project management (11), impact on society and the environment (9), and lifelong learning (12). The EIT group only had one of these on their lowest list, impact on society and the environment (9), with the other two being a knowledge base for engineering (1) and use of engineering tools (5). This average data indicates that the most important attributes in the workplace are not the technical skills but are communication and team work. This could be due to the small sample size and the particular tasks of responsibility for these individuals. This seems unlikely though as in the interview process and the questionnaire all of these individuals indicated their involvement in the technical side of the organization.

A Knowledge Base for Engineering

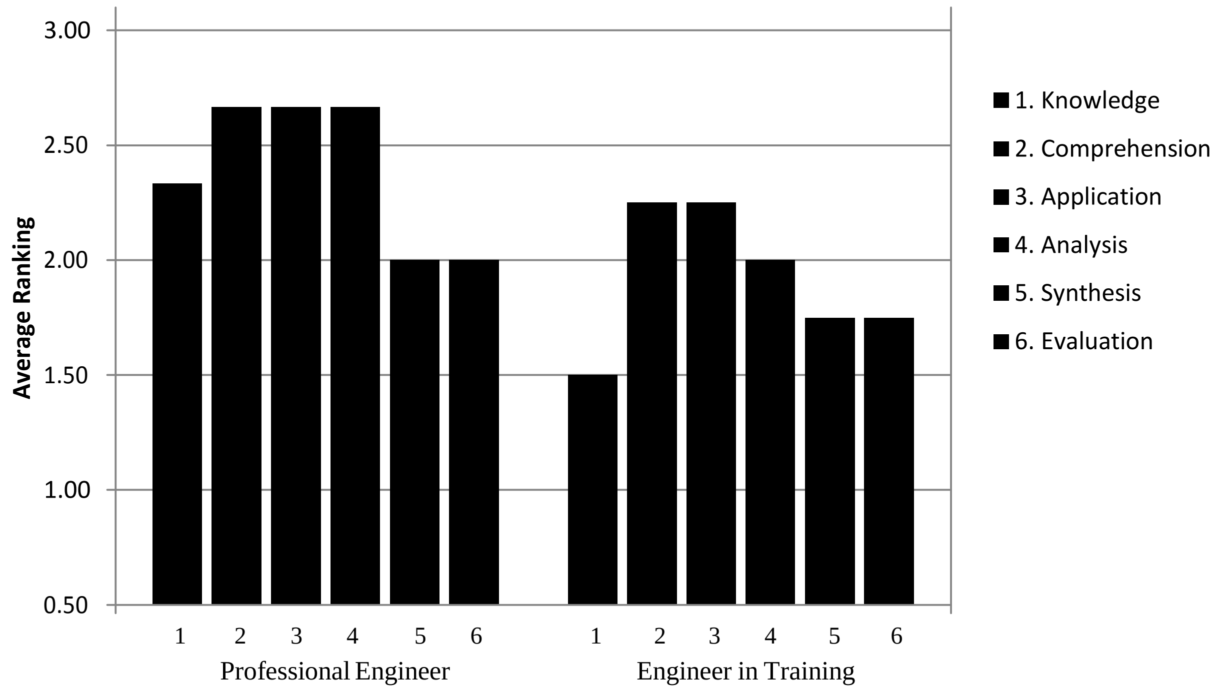
The definition for a knowledge base for engineering is the demonstrated competence in university fundamentals and specialized knowledge appropriate to the program. This is the technical area of study for engineering education and is the area reported by industry to be a strength of engineering graduates (Nicolai, 1998). It is observed that the P.Eng assessment of the new graduates fits that report. Within this attribute their range of values for knowledge levels was from a low 2.00 to a high of 3.00 (Figure 56a). They evaluated the lower Bloom levels of knowledge and comprehension at a value of 3.00 which is the level of mastery from the definition. The next two levels of application and analysis were rated at the value of 2.67. The upper two Bloom levels of synthesis and evaluation were rated with values of 2.33 and 2.00. Therefore the P.Eng's rated the new graduates at a decreasing rate from the lower order objectives to the upper order objectives. This is exactly what would be expected. The EIT's rated themselves more consistently over all the six learning objectives at a lower value than the P.Eng's. The overall average was only 2.17 with a range from 1.75 to 2.50 (Figure 56a). The lowest rating was for comprehension with the highest for evaluation. This seems a little concerning as it indicates that they have little comprehension of the material and yet are half way to mastering the evaluation of the material. This can be somewhat explained by discussions during the focus sessions which followed the completion of the questionnaires. In these discussions participants stated that it was difficult to relate the questions to the work they do and that they struggled with the word "mastery". This is also a factor of the small sample size.

One individual's answer can produce a large variation on the overall results. The individual line items are less important than the average of the groups. Even more valuable are the comparison between groups and the comparison of abilities at graduation to abilities required at the workplace.

The ratings for the work environment show that the P.Eng's assigned a lower value of 2.1 to the highest two learning objectives and values of 2.33 to 2.67 for the other objectives (Figure 56b). This is consistent with their ratings for new graduates but with a slight drop in overall averages from 2.61 to 2.39. This would signify that the new graduates they had supervised either met or exceeded any job requirements for this attribute. The EITs values saw the same trends with about the same level of decrease in the overall ratings between requirements at the workplace (1.92) and their abilities at graduation (2.17). The self assessment group tended to evaluate themselves more critically than the supervisory group. Both groups though felt that the new graduate engineer has more than adequate skill/ability to complete the technical requirements of the workplace.



(a) A Knowledge Base for Engineering University Graduation



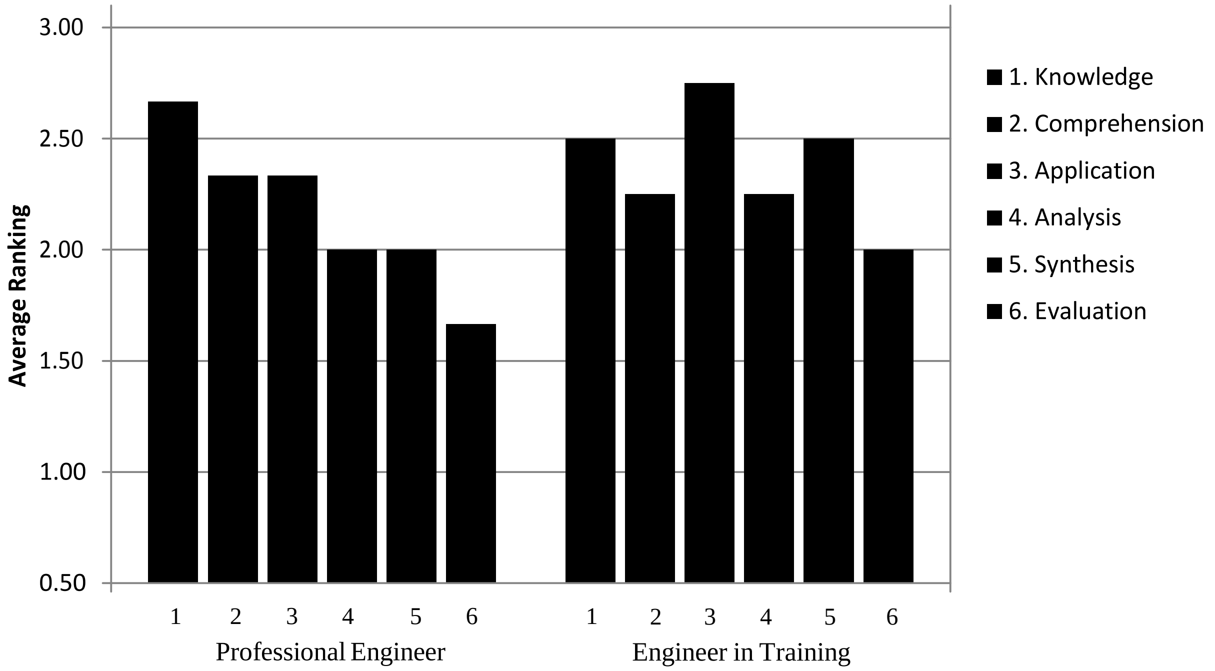
(b) A Knowledge Base for Engineering Work Environment

Figure 56 (a&b): Average rankings from graduate attribute (a knowledge base for engineering) questionnaires on (a) new graduate skill/ability at graduation, and (b) skill/ability requirements of a new graduate at the workplace.

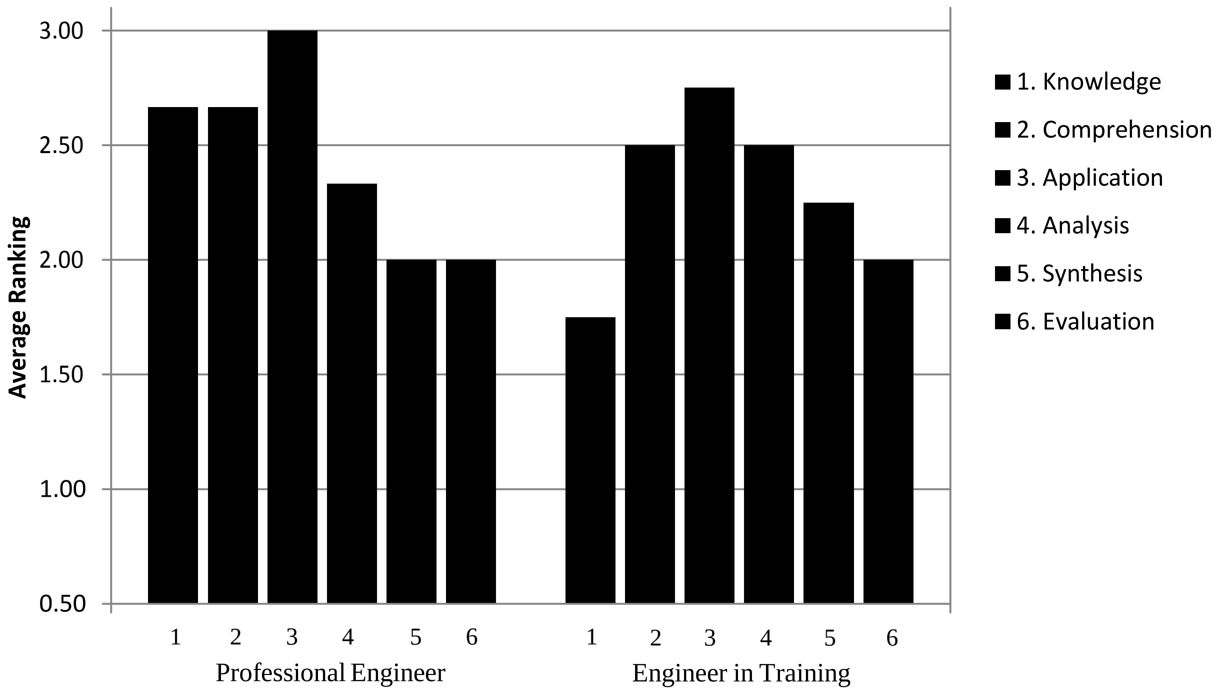
Problem Analysis

The definition for problem analysis is an ability to use appropriate knowledge and skills to identify, formulate, analyze and solve complex engineering problems in order to reach substantiated conclusions. This would be considered a technical area and so expectations would be that graduates had a good grasp of the knowledge. This was not representative of what the P.Eng's thought of the graduates they had supervised. The overall average rating dropped to 2.17 which is barely above an entry level of understanding (Figure 57a). They did assign a value of 2.67 to the learning objective level of knowledge but from there the values dropped down to 1.67 for the level of evaluation. The EIT's on the other hand evaluated themselves at a much higher level with an average of 2.38 (Figure 57a). These values are randomly distributed with a high of 2.75 for the application level and a low of 2.00 for the evaluation level.

Both groups evaluated the work environments at a higher level than the previous attribute. The big change was in the difference between the graduate's capabilities and the workplace requirements. P.Eng's felt that the graduates were below a level of knowledge that was required on the job. The EIT's though felt they were more than qualified for the work they had been assigned with a self assessment of 2.38 versus a work requirement of 2.29 (Figure 57b). By evaluating each individual learning objective it can be seen where each group felt there were excesses or deficiencies in the knowledge level. The professional group felt that graduates had sufficient knowledge in the two lower level learning objectives but then had deficiencies at an increasing rate for the upper level learning objectives. The EIT group in their self assessment felt adequate in the bottom level of knowledge with a value of 2.50 against a work requirement of 1.75. All the other levels were similar between the two ratings. Overall both groups had similar ratings for the work requirements with a discrepancy in the lower rating for graduate capabilities by the P.Eng's.



(a) Problem Analysis
University Graduation



(b) Problem Analysis
Work Environment

Figure 57(a&b): Average rankings from graduate attribute (problem analysis) questionnaires on (a) new graduate skill/ability at graduation, and (b) skill/ability requirements of a new graduate at the workplace.

Investigation

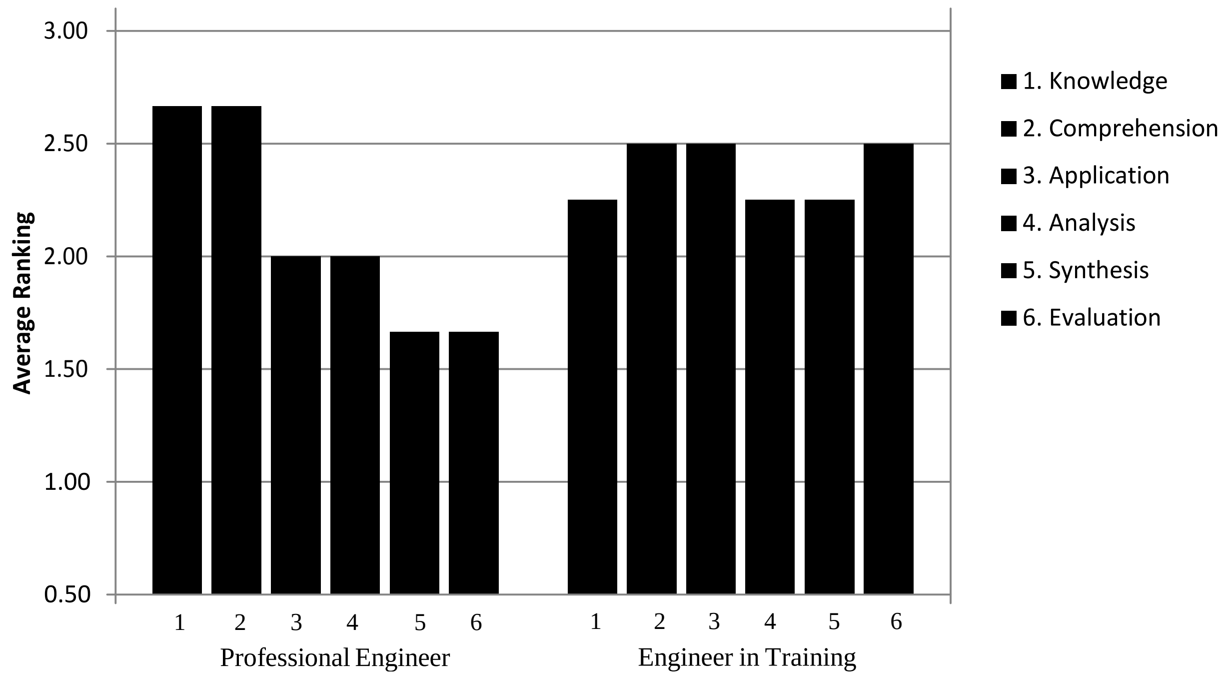
The definition for investigation is an ability to conduct investigations of complex problems by methods that include appropriate experiments, analysis, and interpretation of data and synthesis of information in order to reach valid conclusions. This is the third graduate attribute that would also have a more technical basis and so expectations are that this would be a strength of the graduate. Assessments by the P.Eng do not bear this out as this is ranked very similar to the last attribute. The average value from the senior group is 2.11 (Figure 58a). This is made up of values that range from 2.67 in the lower end learning objectives to 1.67 at the upper end. There is a nice distribution as this group feels the graduate has strong skills in the knowledge and comprehension areas but that this drops off rapidly to low abilities in the synthesis and evaluation areas.

The EIT's rated this graduate attribute (Figure 58a) equal to the previous one at 2.38 which again is slightly higher than the senior groups rating. The individual learning objectives were rated very consistently with a range of only 2.25 to 2.50. This would signify the information covered under this graduate attribute had been significantly covered in school and that they had attained a level of understanding half way to mastery.

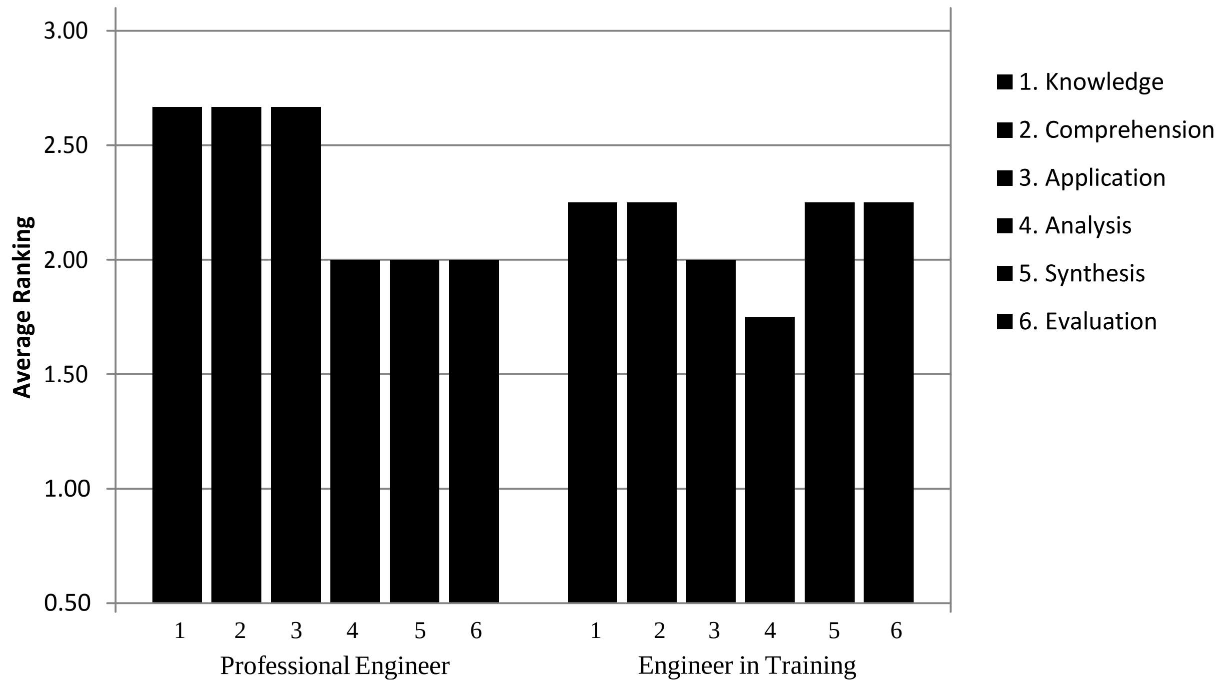
In an evaluation of the work environment ratings it was observed the P.Eng group had a similar rating to the previous attributes at 2.33 (Figure 58b). The professional group evaluation of the workplace for the first three graduate attributes was very consistent. This consistency was not only in average ratings but in the individual ratings of the learning objectives. This would be expected as these are all technical based attributes.

The EIT group evaluation for this attribute was slightly lower at 2.13 (Figure 58b). Therefore they believed that new graduates only needed slightly more than a basic understanding of the knowledge. The professional group showed a deficiency from the graduate capabilities at 2.13 to the work requirements at 2.33. The EITs on the other hand felt that their capabilities at 2.38 exceeded the requirements for the job at 2.13. The values for each learning objective in the professional evaluation showed a strong value of 2.67 for the first three and an introduced level of 2.00 for the higher level ones. This indicates that they feel new engineers need to have a good grasp of knowledge to application levels and only entry level skills at the analysis to evaluation levels.

The EIT reported that the learning objectives of application at 2.00 and analysis at 1.75 were areas in which knowledge levels at an entry level were all that was required in the workplace. They rated all the other learning objectives slightly higher at 2.25.



(a) Investigation
University Graduation



(b) Investigation
Work Environment

Figure 58(a&b): Average rankings from graduate attribute (investigation) questionnaires on (a) new graduate skill/ability at graduation, and (b) skill/ability requirements of a new graduate at the workplace.

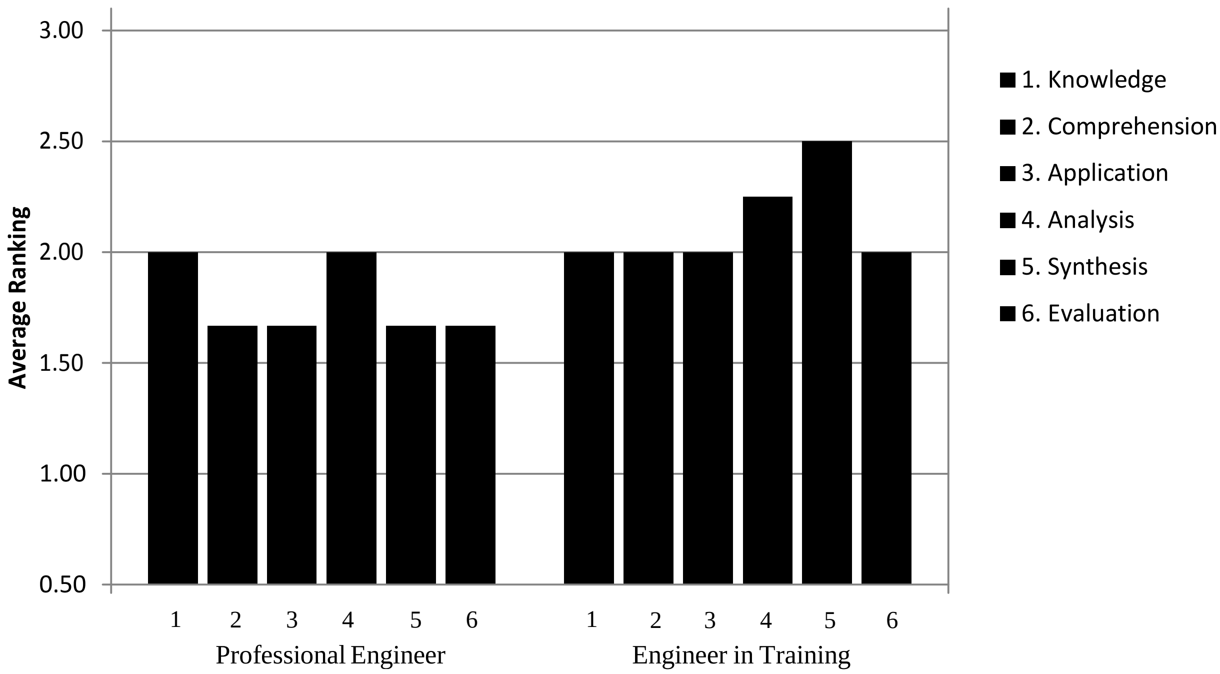
Design

The definition of design is an ability to design solutions for complex, open-ended engineering problems and to design systems, components or processes that meet specified needs with appropriate attention to health and safety risks, applicable standards, and economic, environmental, cultural and societal considerations. This is an area which would not be considered strictly technical. It does have technical aspects but also includes a variety of other skills and abilities. The ratings for this attribute by the P.Eng group is substantially lower than the previous ones. The average value for the attribute by the P.Eng's is 1.78 while the EIT's ratings are 2.13 (Figure 59a). In both cases the ratings are more in line with an introduced level of knowledge. The evaluation of each learning objective by the P.Eng's shows a value of 2.00 for the first and fourth one with the rest at 1.67. In comparison to the previous attributes where the P.Eng's ranked the graduates higher in the lower learning objectives, for this attribute the rating is lower in all learning objectives.

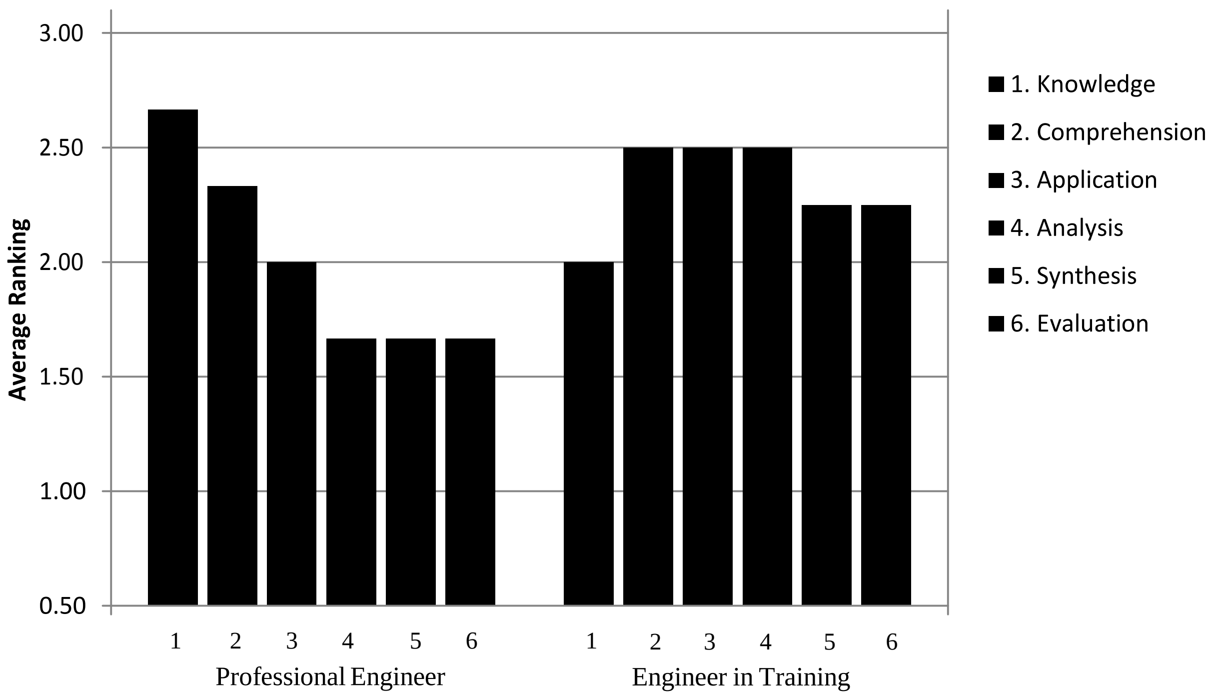
The EIT's self assessment is higher in their ratings with a range from 2.00 to 2.50. These ratings are consistent at the introduced level of 2.00 for most of the learning objectives other than analysis (4) at 2.25 and synthesis (5) at 2.50. Both groups were generally fairly consistent across all the learning objectives.

It is interesting to note that the ratings for the work environment are also at a lower level (Figure 59b). This would indicate that while new graduates were rated at an introductory level of knowledge, the requirements for the workplace were only slightly higher. The overall average ratings for this graduate attribute were 2.00 for the P.Eng and 2.33 for the EIT's (Figure 59b). While these averages are low they do show a deficiency of knowledge in the graduates' skill/ability in comparison to what is required in the workplace. The individual learning objectives show the professional group with a value of 2.67 for knowledge (1) and a decline in the value to 1.67 for the last three learning objectives. The

EIT group valued the first learning objective at 2.00, the next three at 2.50 and the last two at 2.25. This means the EIT's felt they had sufficient knowledge in the synthesis level, an adequate level in the knowledge level and deficiencies in the others. The P.Eng's reported deficiencies in the first three learning objectives, and adequate knowledge in the last three. The deficiency in the first level was substantial with a required value of 2.67 to a value of 2.1   for knowledge obtained.



(a) Design
University Graduation



(b) Design
Work Environment

Figure 59(a&b): Average rankings from graduate attribute (design) questionnaires on (a) new graduate skill/ability at graduation, and (b) skill/ability requirements of a new graduate at the workplace.

Use of Engineering Tools

The definition for use of engineering tools is an ability to create, select, apply, adapt, and extend appropriate techniques, resources, and modern engineering tools to a range of engineering activities, from simple to complex, with an understanding of the associated limitations. This is an area which is not necessarily a technical one but does have some technical attributes. It would be expected that graduates would have reasonable skills in some of the tools but with the range and variety they would not have skills in all the areas. Overall this attribute rated low from both the P.Eng's at 2.11 and the EIT's at 1.81 (Figure 60a). This graduate attribute was ranked fourth by the P.Eng group and only tenth by the EIT group as a self evaluation. The supervisors rated the new graduate at a higher level and rated the individual learning objectives from a low of 1.67 to a high of 2.67. They again rated the first two learning objectives of knowledge and comprehension the highest and the last three the lowest. The P.Eng group was very consistent in their evaluations with the lower learning objectives receiving a higher rating.

The EIT group rated the first learning objective the highest at 2.33 but then rated the next one comprehension (2) as the lowest at 1.33. Following that the rest of the objectives received low ratings with the highest learning objective of evaluation (6) at 1.50. Other than the first objective the EIT rated themselves at an introduction level or below for this graduate attribute. This is the first graduate attribute where the EIT's rated themselves not only lower but substantially lower than the ratings received by the P.Eng's.

What is interesting when evaluating the ratings for the work environment is that even though the evaluations were low they seem to be adequate for the workplace. The P.Eng's rated this attribute for the workplace at 2.22 which is only slightly above their rating of 2.11 for the new graduates (Figure 60b). The EIT's rated the workplace at 1.94 again slightly above the self assessment of 1.81. So even though both groups feel that graduating students are only at an entry level for education in this area, it is sufficient for the workplace. The P.Eng's rated the learning objectives from a low of 2.00 to a high of 2.67 with the objective application (3) receiving the high mark. They again rated the highest learning objectives with the lowest ratings. The EIT group had a range of ratings from 1.33 to 2.33. The low mark was for comprehension (2) with the others being consistent.

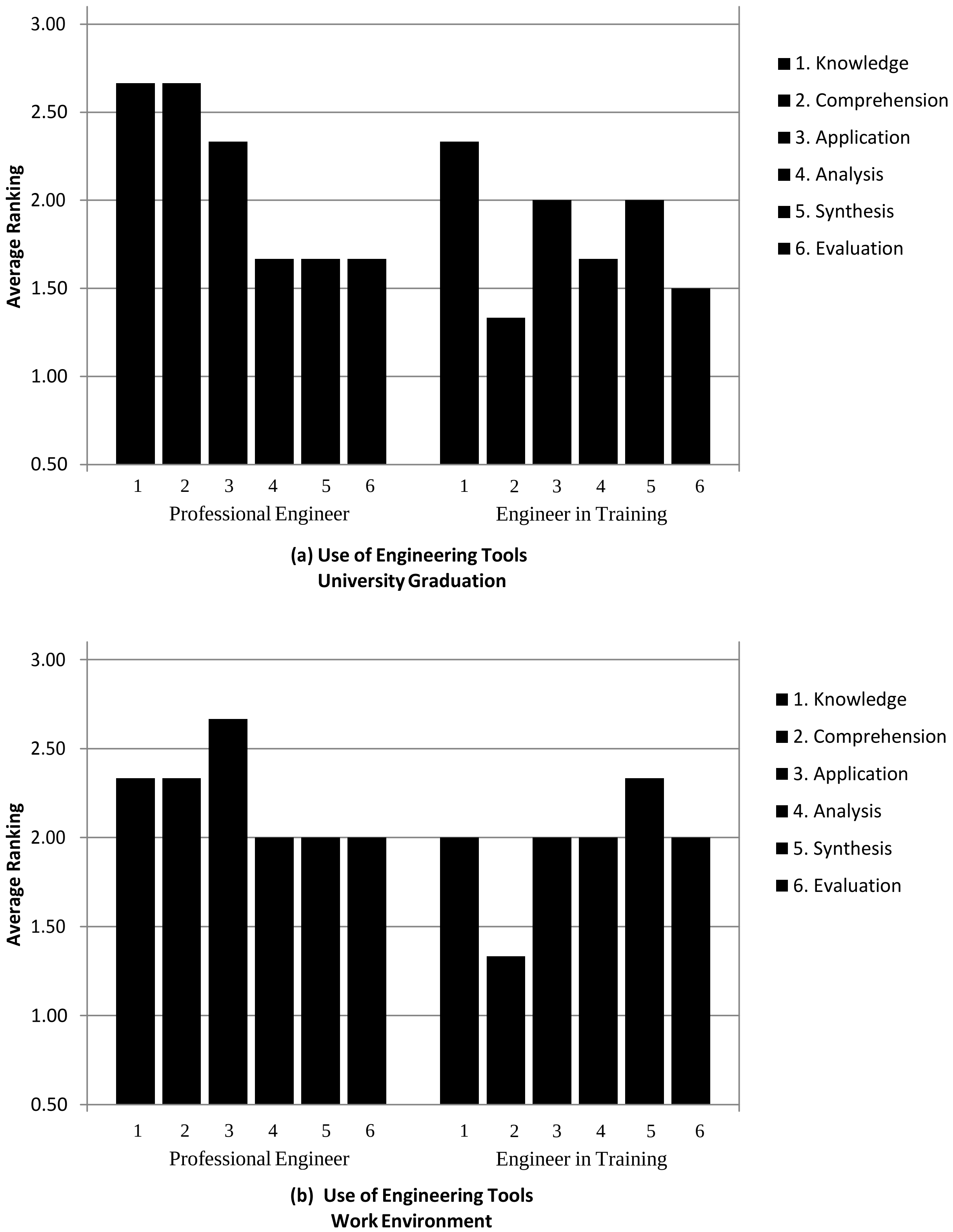
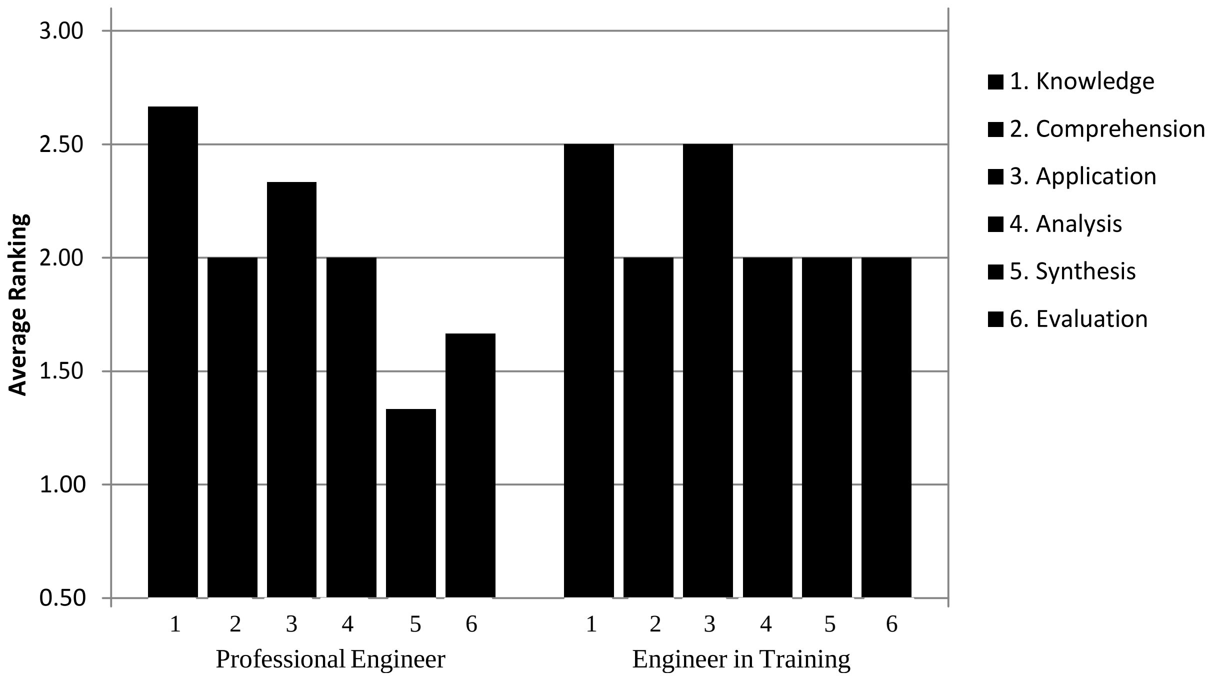


Figure 60(a&b): Average rankings from graduate attribute (use of engineering tools) questionnaires on (a) new graduate skill/ability at graduation, and (b) skill/ability requirements of a new graduate at the workplace.

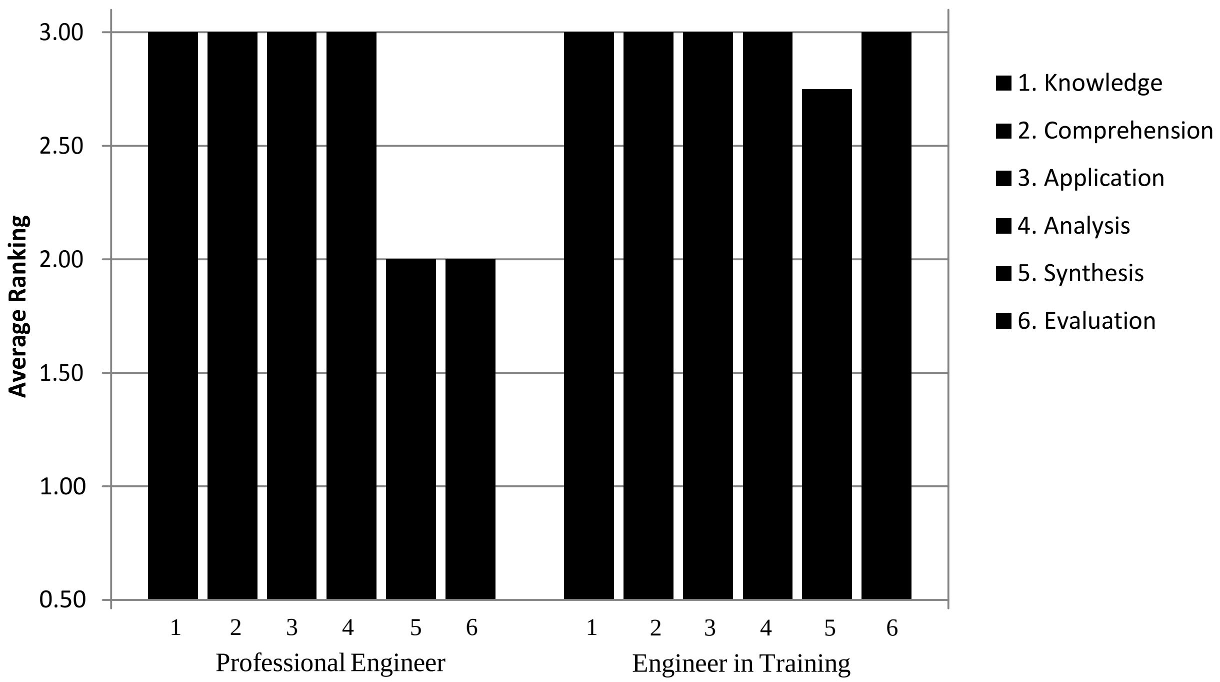
Individual and Team Work

The definition for individual and team work is an ability to work effectively as a member and leader in teams, preferably in a multidisciplinary setting. This is an area that was indicated as important in our interview discussions with the EIT group. The overall averages for this graduate attribute are consistent but low at a level of 2.00 for the P.Engs and at 2.17 for the EITs (Figure 61a). The P.Eng groups learning objective ratings range from a low of 1.67 to a high of 2.67. The high rating is for the lowest learning objective with the ratings dropping as you move to higher objectives.

The EIT self ratings range from a low of 2.00 to a high of 2.50. The high values were assigned to learning objective knowledge (1) and application (3). All of the other objectives received a rating of 2.00. This graduate attribute was ranked as sixth highest of all the attributes by the P.Eng groups and third by the EIT's. This ranking compares to the number one rank this attribute received in the Cicek study. The new graduates have a much higher opinion of their knowledge level at graduation than after a year of work experience.
This attribute was the top ranked one by both groups with respect to the work environment. The averages here were high at 2.67 for the P.Eng and 2.96 for the EITs (Figure 61b). The P.Eng group ratings ranged from a low of 2.00 to a high of 3.00. The first four learning objectives received the 3.00 rating while the other two received a rating of 2.00. The EIT group considered this graduate attribute even more important. They rated the learning objective synthesis (5) as a 2.75 and all the other learning objectives had a rating of 3.00. Both groups were consistent in their ratings indicating that new graduates were required to



(a) Individual and Teamwork
University Graduation



(b) Individual and Teamwork
Work Environment

Figure 61(a&b): Average rankings from graduate attribute (individual and teamwork) questionnaires on (a) new graduate skill/ability at graduation, and (b) skill/ability requirements of a new graduate at the workplace.

have mastered this graduate attribute at graduation. This fact along with the results that graduates were only introduced to this knowledge when entering the workplace produces a deficit of knowledge in this area. This deficit is the largest indicated by the P.Eng evaluations and the second largest by the EIT's. There may be a number of reasons for this with one being the small sample size. Other reasons could be related to the type of workplace or culture of the organization. With the small sample size some of the data can become skewed when one individual has an opinion that varies greatly from the others. One fact that can be assured of though, is the results of the ratings for the workplace. With virtually all the ratings sitting at the top of the scale, all of the individuals agreed this was the most important graduate attribute.

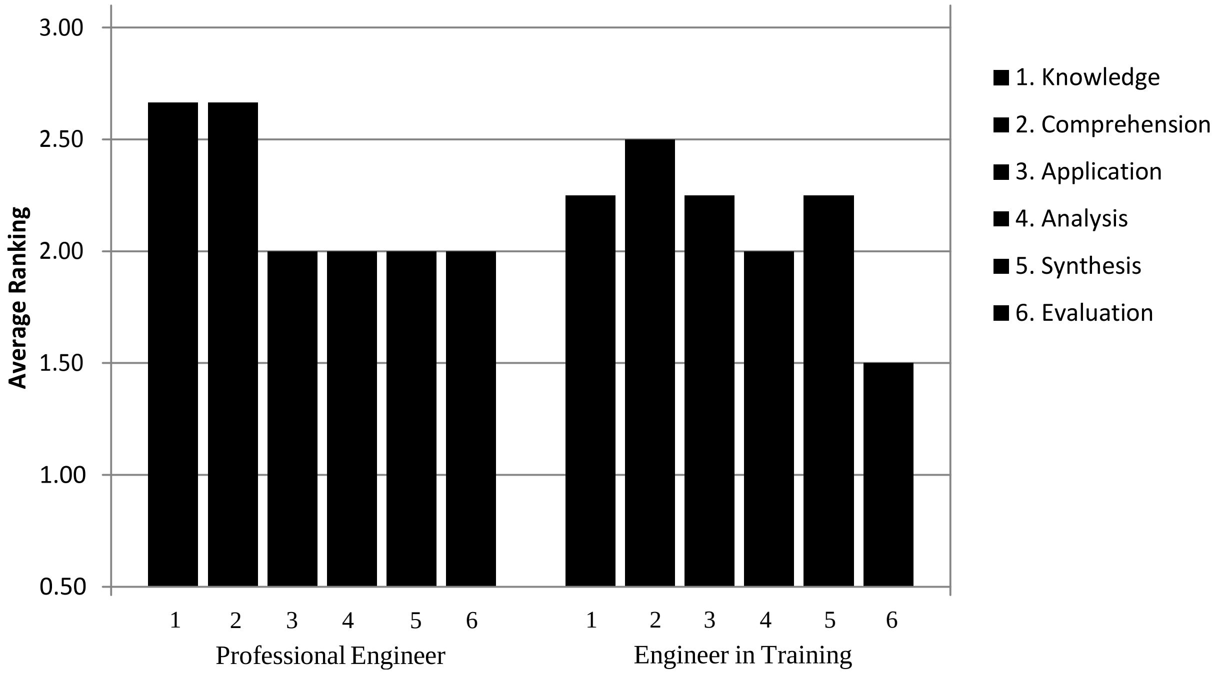
Communication Skills

The definition for communication skills is an ability to communicate complex engineering concepts within the profession and with society at large. Such ability includes, reading, writing, speaking and listening, and the ability to comprehend and write effective reports and design documentation, and give and effectively respond to clear instructions. This attribute is another one of the soft skills and is related to the previous one on team work. Working with others requires skills in communication. Overall this attribute had average ratings from the two groups that were extremely close together. The P.Engs rated this attribute at 2.22 which was their second highest rated attribute (Figure 62a). The EIT's rated it at 2.13 which was only their fifth highest overall (Figure 62a). In the Cicek study this attribute was rated as third highest and so there is consistency between these groups. The difference is that the ratings are much lower in this study.

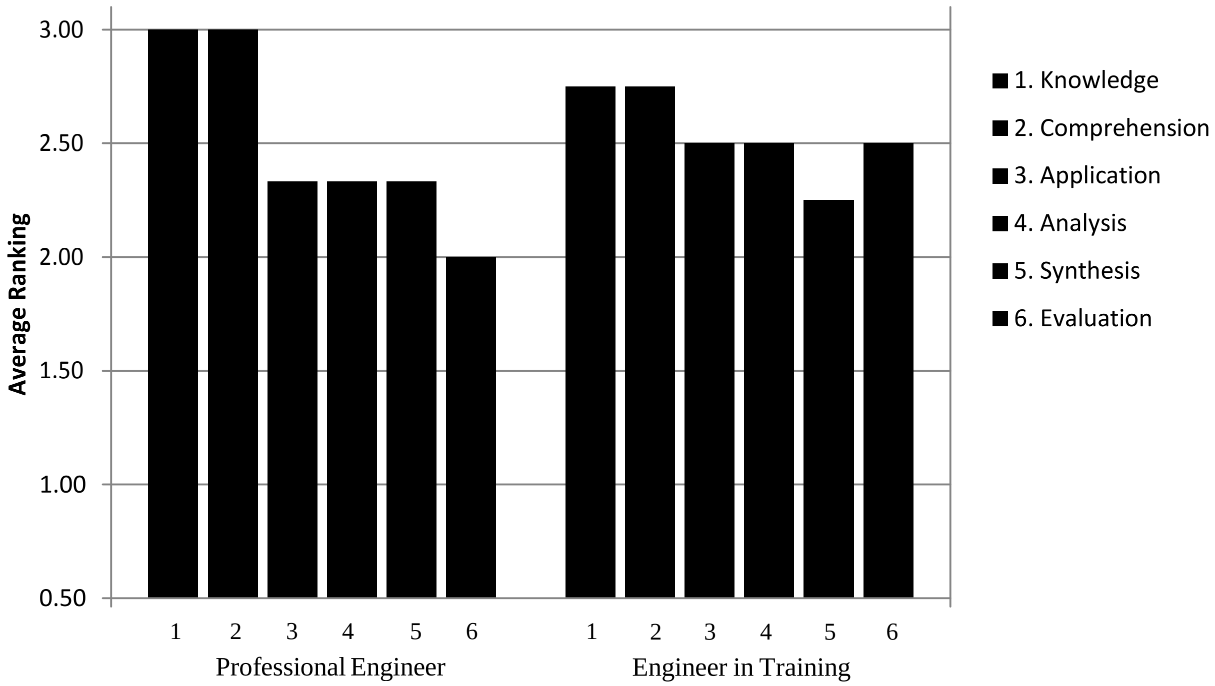
The P.Eng's had a range of ratings from 2.00 to 2.67 with the highest in the learning objectives knowledge (1) and Comprehension (2). The other four levels of learning objectives received the rating of 2.00. The EITs range of ratings varied from 1.50 to 2.50

(Figure 62a). The top learning objective evaluation (6) received the low rating of 1.50 with the high rating of 2.50 assigned to comprehension (2).

The ratings for these groups for the work environment were almost equal. The P.Eng's rated this graduate attribute at 2.50 while the EIT's rating was 2.54 (Figure 62b). These averages are substantially above the ratings for a new graduate and therefore there is a substantial deficit in this attribute between qualifications of a new entrant to the workforce and the job requirements. The P.Eng had a range of values for the learning objectives from 2.1 to 3.00. The high values of 3.00 were for the objectives knowledge (1), and comprehension (2). The lowest value was for the learning objective evaluation (6). The EIT group rated the objectives knowledge (1) and comprehension (2) at a value of 2.75 with the lowest being synthesis (5) at 2.25. There again is a difference between knowledge levels the new graduate enters the workplace and what is considered to be a requirement.



(a) Communication Skills
University Graduation



(b) Communication Skills
Work Environment

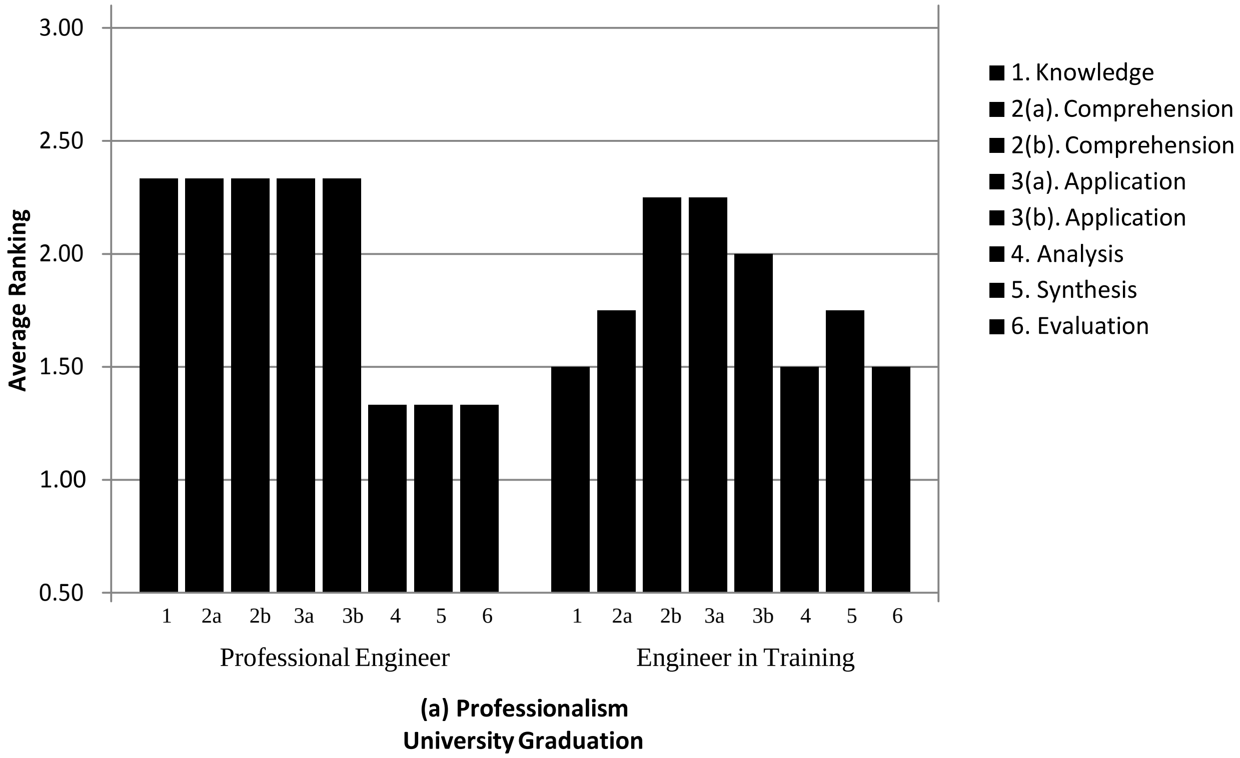
Figure 62(a&b): Average rankings from graduate attribute (communication skills) questionnaires on (a) new graduate skill/ability at graduation, and (b) skill/ability requirements of a new graduate at the workplace.

Professionalism

The definition for professionalism is an understanding of the roles and responsibilities of the professional engineer in society, especially the primary role of the protection of the public and the public interest. This is another attribute that is considered a soft skill. These are areas in which engineers seem to have difficulty with the definition. This is highlighted in the variability of responses in this area reported in the Cicek study. The results from this study show that the skill/ability level of graduating students was mediocre at best. The P.Eng's rated the new graduates at a level of 1.83 while the EIT's rated themselves at a value of 1.88 (Figure 63a). These are very consistent ratings between the two groups and they each had this attribute rated as the eighth highest overall.

This graduate attribute has two additional learning objectives. Two of the learning objectives are split into two parts. For objective comprehension (2) and application (3) the objectives were separated into an assessment of a general professional engineering role and a personal professional engineering role.

The P.Eng's individual assessment of the lower level learning objectives was consistent at 2.33. This indicates that they felt new graduates had this information introduced in their educational programs and that they were beginning to understand the professional roles. The last three of the higher level learning objectives receive a rating of 1.33 which indicates that this skill was not observed. The EIT's rated themselves in much the same manner except they rated the first two objectives of knowledge (1) and comprehension (2a) as somewhat low at 1.50 and 1.75 (Figure 63a). The objectives of comprehension (2b) and application (3a) were rated similar to the P.Eng's value at 2.25. The upper level learning objectives were also rated at a low level of less than an introduced level of education.



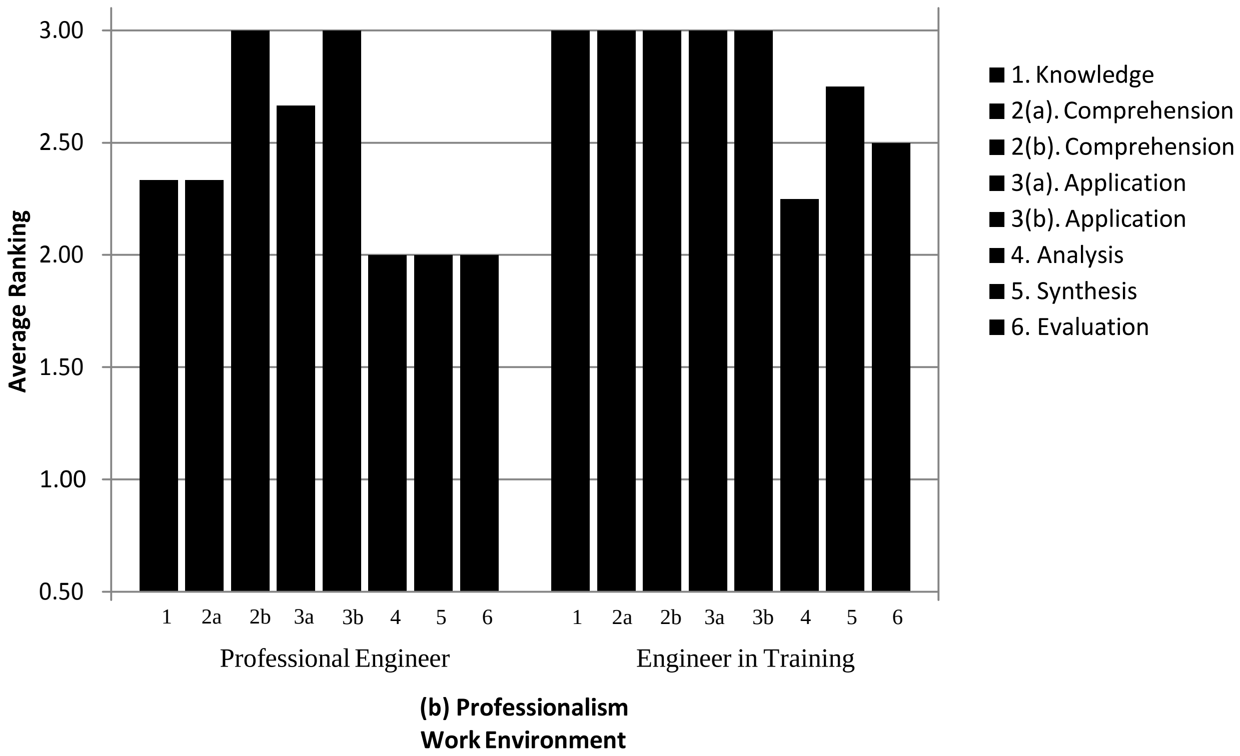


Figure 63(a&b): Average rankings from graduate attribute (professionalism) questionnaires on (a) new graduate skill/ability at graduation, and (b) skill/ability requirements of a new graduate at the workplace.

It was interesting that this EIT group rated the comprehension objective differently for the different aspects. They seemed to feel that they had a good introductory comprehension of their personal role as a professional but a much lower understanding of the general professional engineer's role in society.

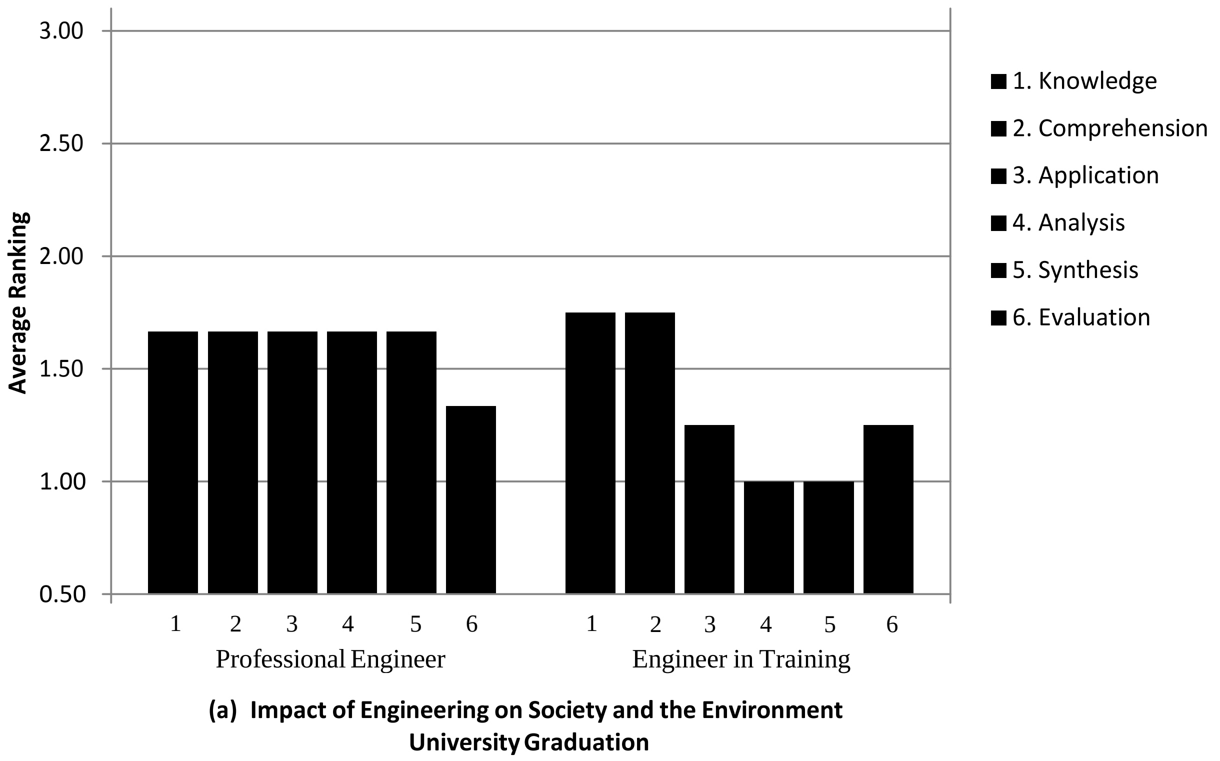
The results from the assessment of requirements in the work environment again were much higher than the level these engineers had entered the workplace. The P.Eng rated this category as third overall and the EIT's rated it as second. The average ratings for each group were 2.44 for the professional engineering assessment and 2.75 for the EIT's (Figure 63b). In both cases the skills are expected to be much above an introductory level with the EIT's considering that near mastery of this information is required. The individual learning objective ratings range from values of 2.00 to 3.00 for the P.Eng assessment. They classified objective comprehension (2b) and application (3b) with values of 3.00. These are the two additional objectives that evaluate the skill/ability of the individual engineer to understand and demonstrate their personal role as a professional engineer. This shows that they believe a new graduate should have a mastery level in how they act as a professional. The other levels were at slightly lower values with the three upper learning objectives receiving only a rating of 2.00.

The EIT's had a much higher opinion of the importance of professionalism. They rated the learning objectives of knowledge (1), comprehension (2) and application (3) all at a value of 3.00 (Figure 63b). They saw professionalism as one of the most important aspects of engineering in the workplace. They also rated the upper levels of the learning objectives at high values ranging from 2.25 to 2.75. In comparing the average ratings from each group we see that the P.Eng's indicated this was the area with the second largest deficit between the level of an engineering graduate and what is expected in the workplace. For the EIT's on their personal assessment they saw this as the attribute with the greatest deficit.

Impact of Engineering on Society and the Environment

The definition for this attribute is an ability to analyze social and environmental aspects of engineering activities. Such ability includes an understanding of the interactions that engineering has with the economic, social, health, safety, legal and cultural aspects of sustainable design and development and environmental stewardship. This graduate attribute is either poorly understood or is considered to be of little value as it ranked at the bottom of all attributes in the Cicek study. In this study the P.Eng's ranked this attribute in eleventh place with a rating of 1.61 while the EIT's placed it at the bottom with a rating of 1.33. These numbers would indicate that new graduates have had very little exposure to any of the knowledge required to attain skills in this area.

The individual ratings of each learning objective were fairly consistent (Figure 64a). The P.Eng group had values ranging from 1.33 to 1.67 with only the last learning objective evaluation (6) at the lower level. The EIT group had a little more variance with averages ranging from 1.00 to 1.75. They evaluated the lower learning objectives a little higher than the others. In all cases though both groups felt that engineering students had received very little exposure to knowledge for this attribute. Looking at the results for the ratings of the work environment the observation is that these are not much higher than the new graduate assessment. The overall average for the P.Eng's was 1.83 and for the EIT's was 1.71 (Figure 64b). So even though this skill/ability was not covered very well in the educational program, the requirement in



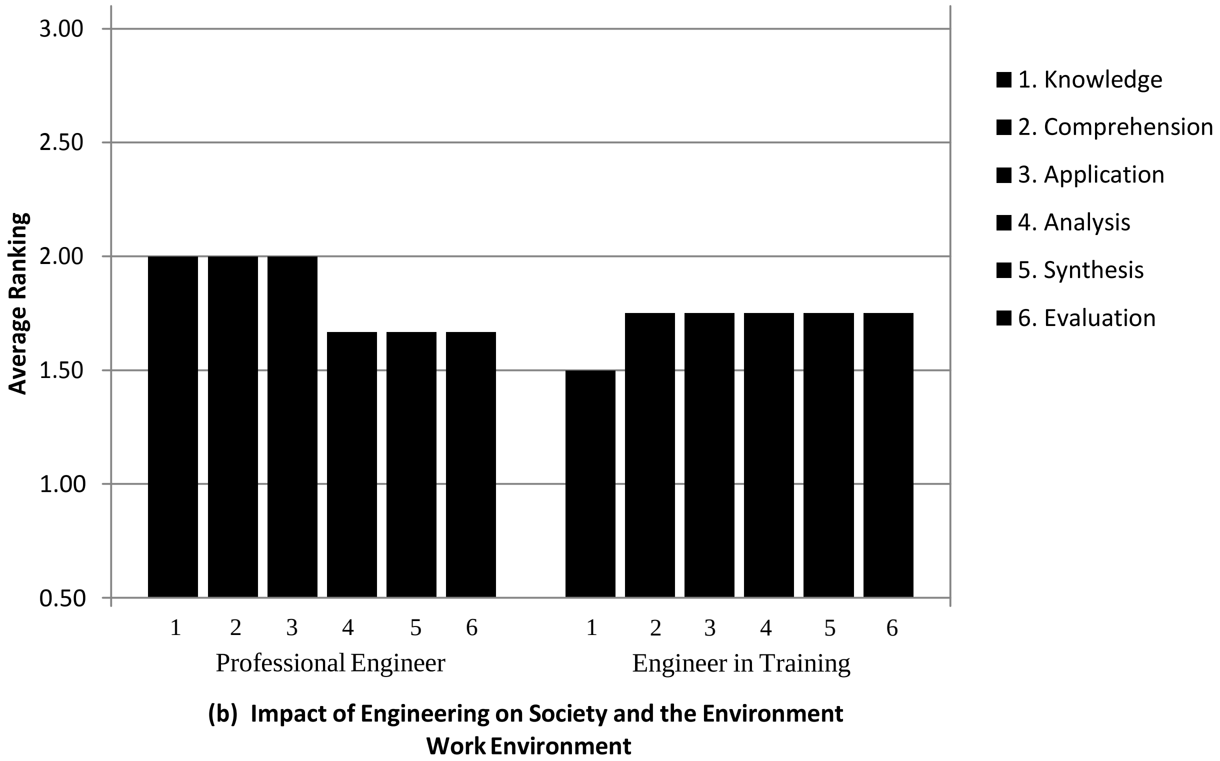


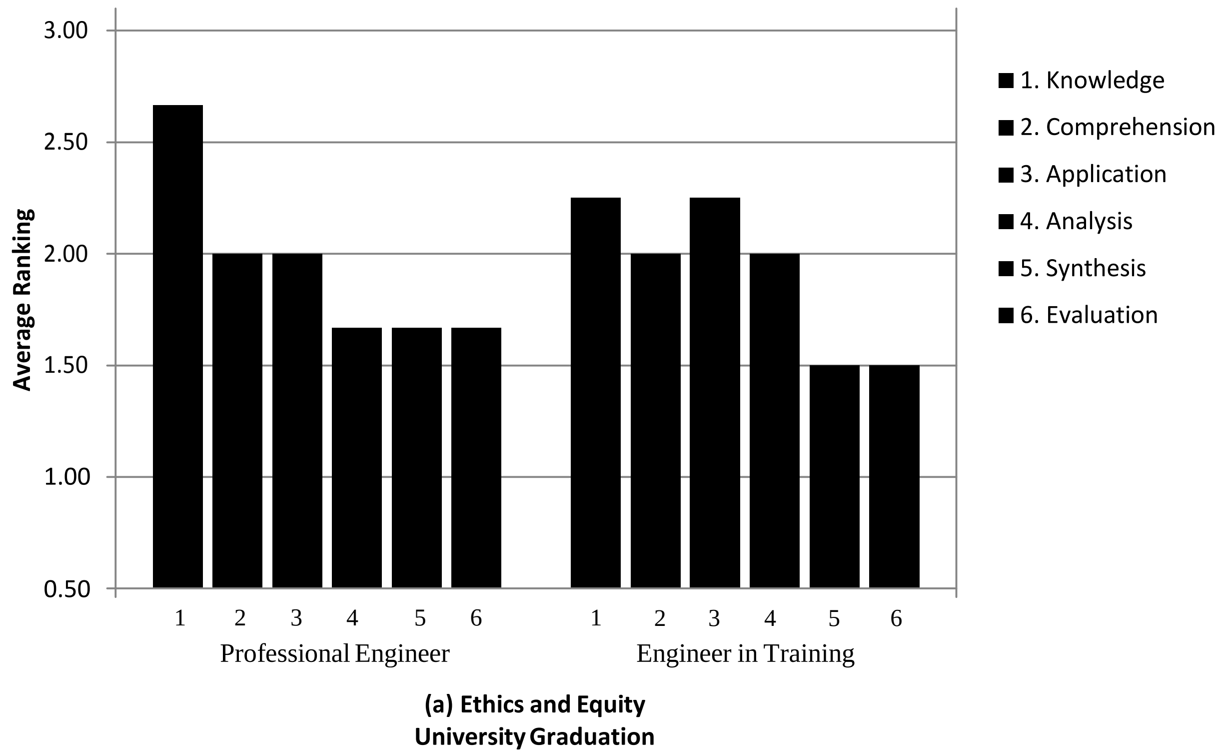
Figure 64(a&b): Average rankings from graduate attribute (impact of engineering on society and the environment) questionnaires on (a) new graduate skill/ability at graduation, and (b) skill/ability requirements of a new graduate at the workplace.

the workplace was also low. The P.Eng's individual learning objectives were rated between 1.67 and 2.00. The EIT group rated the objectives between 1.50 and 1.75. In both cases the ratings were very consistent across all learning objectives. The results indicate that while engineering students receive barely any introduction to this area, they are still not that much below a level required by the workplace.

Ethics and Equity

The definition of ethics and equity is an ability to apply professional ethics accountability, and equity. This is another of the soft skills in which the Cicek study showed a high level of variability in the ratings given by the participants. The results showed reasonable consistency in the ratings but at a fairly low level of skill/ability. The average ratings were 1.94 for the P.Eng's and 1.92 for the EIT group. This was a ranking of seventh place for both groups. In looking at the individual learning objective ratings the P.Eng group had a range from 1.67 to 2.67 (Figure 65a). The highest rating was for the learning objective knowledge (1) while the lowest were assigned to the upper three objectives. The EIT group had a range of ratings from 1.50 to 2.25 (Figure 65a). These were distributed in the same manner as the P.Eng group with high values assigned to lower level objectives. This was the attribute that showed the greatest consistency between the two groups in rating a new graduate's skill level at time of entry to the workplace.

An evaluation of the workplace showed different results as the EIT group ranked this much higher than the P.Eng's Figure 65b). The professional group ranked this attribute as their eighth highest with a rating of 2.06. This was not much different than their rating of the new graduate level. Therefore the supervisors think that for ethics and equity new engineering graduates may only have an introduced level of ability but that this is adequate for the workplace.



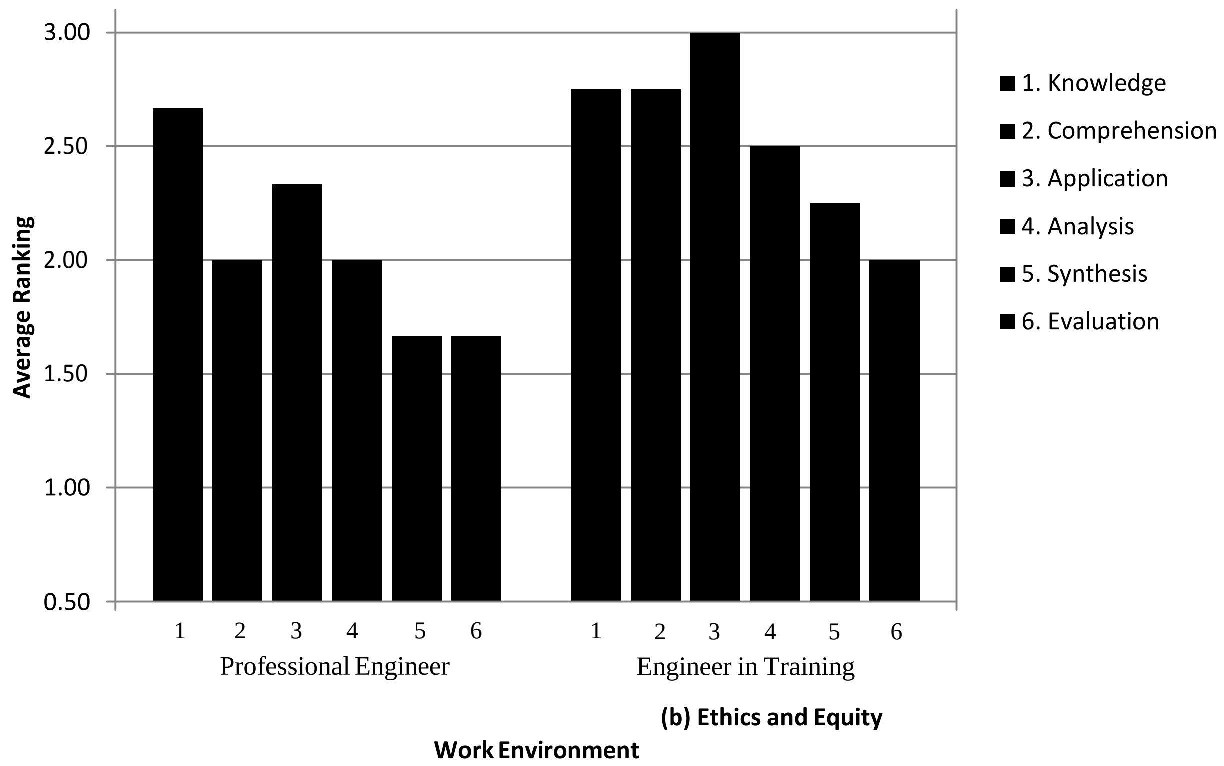


Figure 65(a&b): Average rankings from graduate attribute (ethics and equity) questionnaires on (a) new graduate skill/ability at graduation, and (b) skill/ability requirements of a new graduate at the workplace.

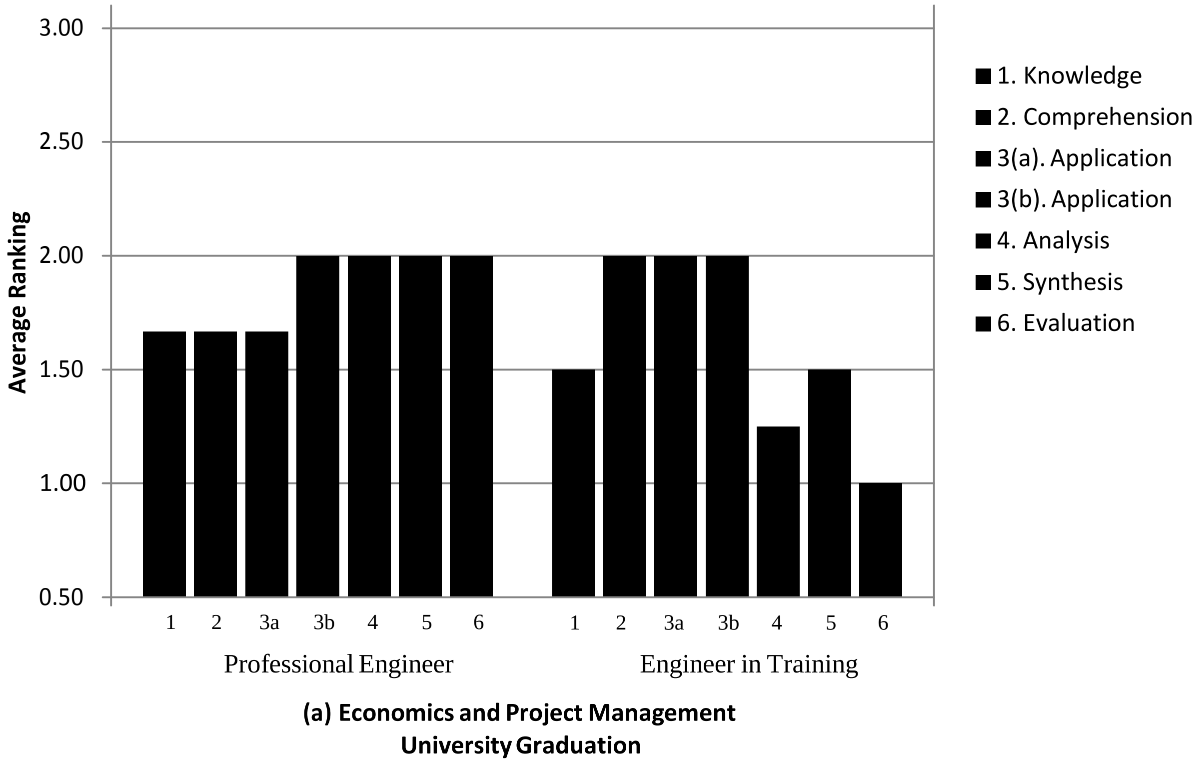
The EIT group had a different opinion as they ranked this attribute as their third highest with an average rating of 2.54. They felt that the requirement of the workplace were much greater than just an introduced level of ability. The ratings for the individual learning objectives were consistent for the P.Eng's with a range of values from 1.67 to 2.67. The highest values were assigned to the lower level objectives and the lower values to the upper objectives. The EIT group had individual objective averages assigned much higher values with a range of 2.00 to 3.00. The learning objectives knowledge (1), comprehension (2), and application (3) were assigned values of either 2.75 or 3.00. This indicates that these EITs felt that a mastery level was required in these levels of skill/ability. In all the results, levels this high seldom occur and therefore this was considered to be of high importance. The EIT's rated the upper level of learning objectives at a lower level but they still were on average rated at higher level than the senior group.

Economics and Project Management

The definition for economics and project management is an ability to appropriately incorporate economics and business practices including project, risk, and change management into practice of engineering and to understand their limitations. This is a skill area in which expectations were for a high rating from the EIT group. This is due to the discussions during the interview process. When asked what additional training would be helpful the reply was "I'd probably take more project management." This type of response along with this group stating that most of their work was project management related led me to speculate that this would be an area of great importance. This graduate attribute was one that had an additional level of a learning objective included. The application level was split into two separate levels project management (3a) and economics (3b).

The overall average ratings for the level of skill for a new graduate were fairly low. The P.Eng rated this as the lowest of all graduate attributes at a value of 1.39 while the EIT group rating was eleventh overall at a value of 1.63 (Figure 66a). In both cases the skill level of the graduates was rated at less than an introductory level. The learning objective averages ranged from 1.00 to 2.00. The low rating was given to the upper level objectives with slightly higher ratings for the lower level objectives. The one value that stands out was for the level economics (3b) which received a rating of 2.00. The P.Eng group considered that this level had been introduced to the graduates but they had limited skills. The other levels were considered to be not evident. The EIT's also had the same range of ratings from 1.00 to 2.00. They classified the levels of learning objectives similar to the P.Eng group but gave a value of 2.1 to objectives comprehension (2), project management (3a), and economics (3b). They considered that they had at least an introduced level of knowledge in these areas but not in any of the other levels.

The work environment ratings had a larger gap between the two groups as the P.Eng's ranked this attribute as twelfth and the EIT's only ranked it as eighth (Figure 66b). The EIT group definitely felt that this attribute was more important to the workplace. The average rating for the P.Eng's was 1.61 which is only slightly higher than their rating of new graduates. Therefore even though new graduates lack these types of skills they are near the level needed for their employment. The EITs on the other hand rated this attribute at 2.25 for the workplace. This is substantially higher than their personal rating of 1.63. This ranks as one of the attributes with a high deficit between the skill level of the new employee to the requirements of the job.



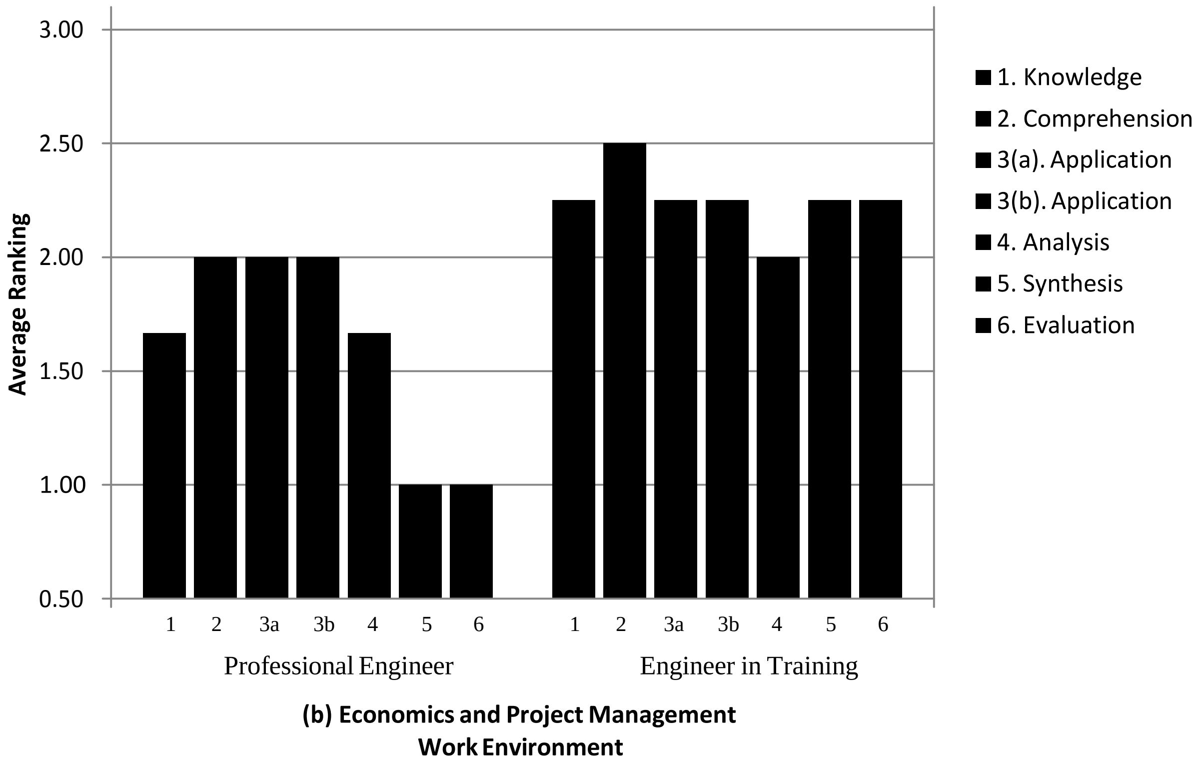


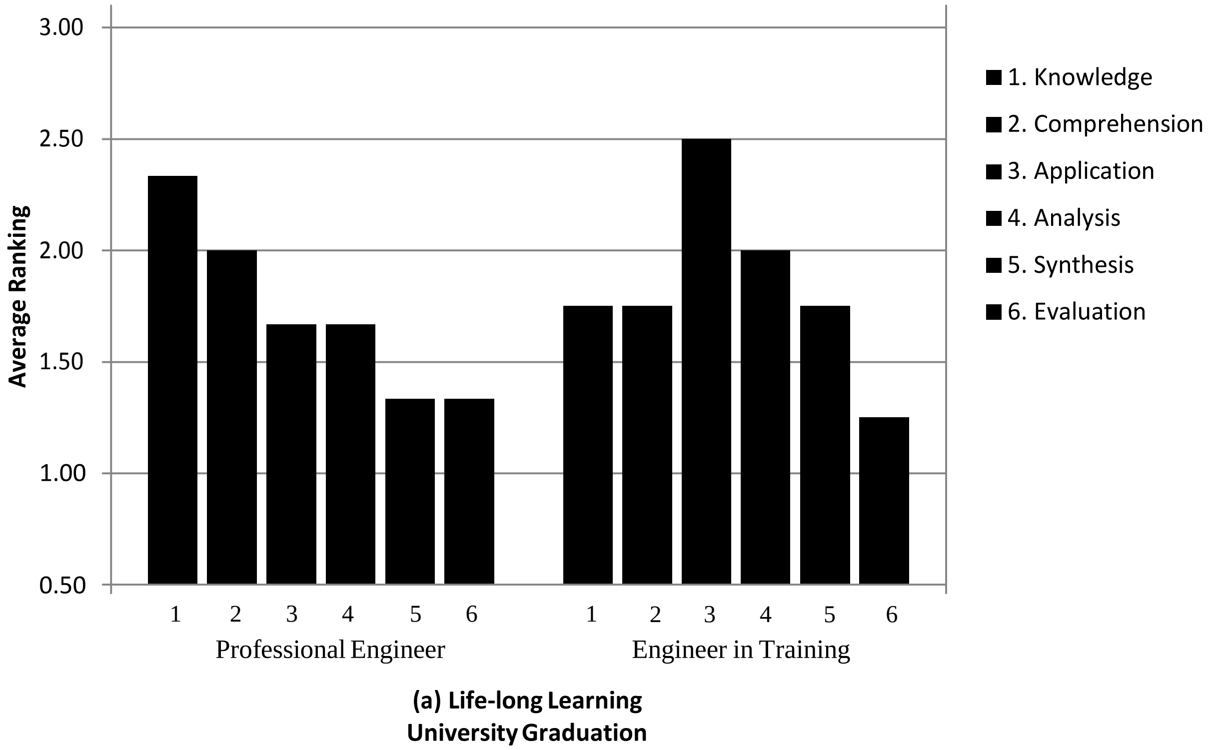
Figure 66(a&b): Average rankings from graduate attribute (economics and project management) questionnaires on (a) new graduate skill/ability at graduation, and (b) skill/ability requirements of a new graduate at the workplace.

The EIT rating of the individual learning objectives for the work environment were between 2.00 and 2.50. There was only one level analysis (4) at the rating of 2.00 while the others were all consistent between 2.25 and 3.00.

Life-Long Learning

The definition for life-long learning is an ability to identify and to address their own educational needs in a changing world in ways sufficient to maintain their competence and to allow them to contribute to the advancement of knowledge. This area is considered as a soft skill and one that can be hard to assess. This was an attribute that was ranked as one of the top ones in the Cicek study. In this study it ranked much lower with ranks of tenth and ninth from the two groups. The P.Eng average rating was at 1.72 while the EITs rated this attribute at 1.83 (Figure 67a). They are both fairly low and would be considered as not evident at the educational level. The P.Eng's individual learning objective ratings range between 1.33 to 2.33. The highest ratings were on the lower level objectives and the lower ratings were on the higher level learning objectives. This is consistent and would be expected. The EITs ratings had a somewhat wider range of values from 1.25 to 2.50. As expected the highest level objective received the lowest rating but the lowest levels also received a fairly low rating. They assigned the highest rating to the level application (3). There seems to be a consistent pattern with the EITs assigning the application and analysis levels with the higher ratings.

Results for the work environment showed the P.Eng group assigning an overall rating of 1.94 which is slightly above the rating of 1.72 for capabilities of new employees (Figure 67b). The EIT group rated the workplace with an overall value of 2.42 which is much above that of where they rated their own capabilities (Figure 67b).



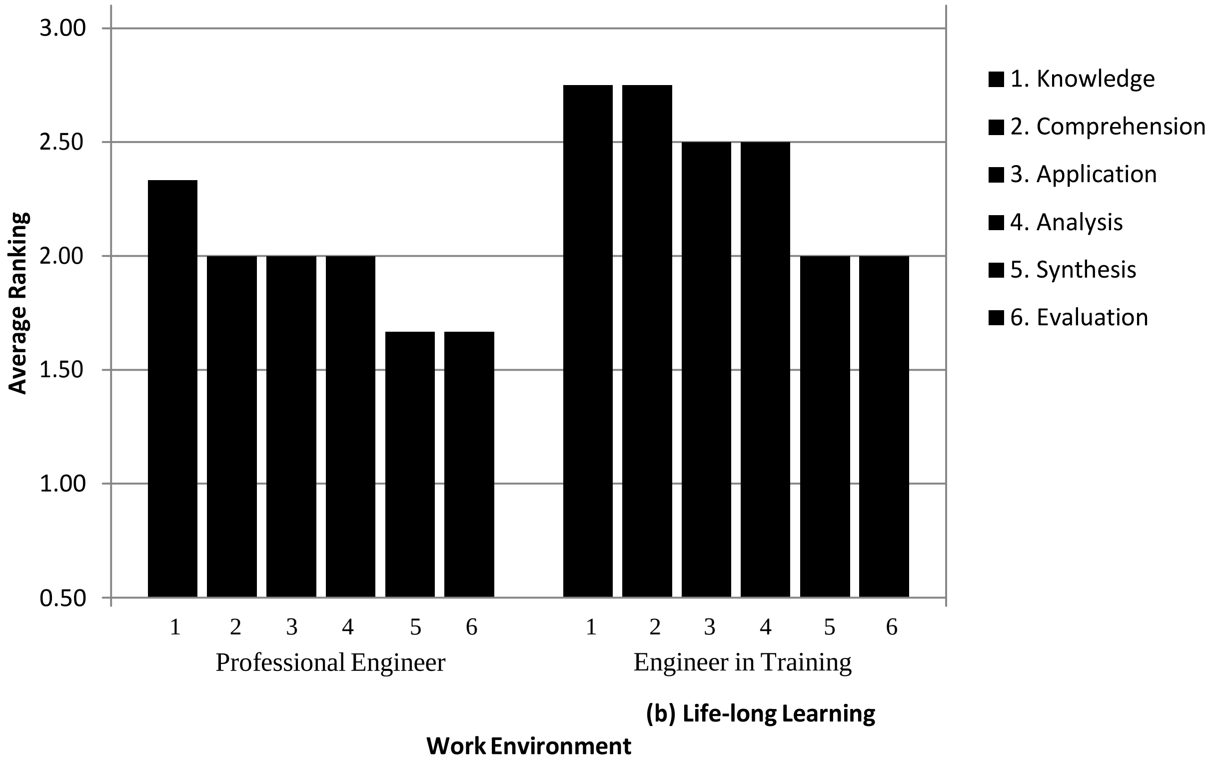


Figure 67(a&b): Average rankings from graduate attribute (life-long learning) questionnaires on (a) new graduate skill/ability at graduation, and (b) skill/ability requirements of a new graduate at the workplace.

The P.Eng's individual learning objective ratings varied from a low of 1.67 to a high of 2.33. These values were distributed as expected with the high level values assigned to the lower level learning objectives and low values to the upper level objectives. The EIT individual ratings on objectives had much higher values ranging from 2.00 to 2.75. This shows that this group was critical about their abilities and the importance they placed on learning opportunities in the workplace. The variability of the individual ratings for learning objectives for the EIT group was well distributed with low values to upper objectives and high values for lower objectives.

Summary of questionnaires on Graduate Attributes

The questionnaires on the graduate attributes were designed as a self assessment for the EIT's on their knowledge base at time of graduation and as an assessment of the knowledge required for their first job activities after graduation. They were also used for the P.Eng to assess the knowledge base of newly graduated engineers and to assess the level of knowledge required to complete assigned job tasks. Both groups came close to agreeing on which attributes were the strongest and the weakest for a new graduate engineer upon entry to the workplace. The attributes of problem analysis and knowledge base for engineering ranked high while project management and impact on society ranked lowest. Comparing the individual attributes for the two participant groups shows that there were differences in how they evaluated the knowledge levels. The P.Eng group felt the new graduates had a level between introduced and mastery in the knowledge and comprehension categories of most of the attributes. The EIT group ranked themselves having a higher level of knowledge in most attributes in the analysis, synthesis, and sometimes even in the evaluation categories. While the overall averages were comparable between the two groups the difference in depth of understand of activities was apparent. The senior group catergorized the new engineers knowledge in the more entry levels on Bloom's taxonomy while the new engineer saw these activities as more complex. This is understandable as the junior group does not have the experience to understand the depth of knowledge needed for complex tasks.

The second part of the questionnaire was to evaluate the knowledge required for a new engineering graduate to complete the tasks assigned. This again was evaluated by both the EIT and the P.Eng participants. Both groups rated the graduate attribute work requirements similarly. There was a difference in how both groups ranked the capabilities of a new engineer to that of the requirements of the workplace. They felt that the requirements of the workplace were above the capabilities of the new graduate engineer. The EIT group was especially hard on themselves when evaluating the difference in their abilities to the higher requirements of the job. What the two groups agreed upon was the graduate attributes which had the highest requirements. Both groups of participants agreed that teamwork, communication, and professionalism had the highest requirement in the workplace. These were the attributes that had the highest deficiency in knowledge for a newly graduating engineer. What is interesting is that both the EIT and P.Eng groups felt that a near mastery was needed in these areas for a newly graduating engineer.

Summary of Graduate Attributes

In evaluating the results the variability of the data can be seen within the learning objectives of each graduate attribute. Expectations are that students progress through the levels with the ability to master the upper levels of the learning objectives subsequent to mastery of lower levels. Therefore a decision was made to take an average of the learning objectives from all the graduate attributes to see this trend with these participants. Results show that the P.Eng's rated the new graduates overall from a high of 2.43 for learning objective knowledge to a low of 1.58 for evaluation. These ratings were distributed as expected from the lowest level learning objective to the upper level. The P.Eng assessment of the work environment showed a slightly different result with the range from 2.47 to 1.81

again from learning objective knowledge to evaluation. There was an upward shift in the values which is indicative of the requirements of the job being higher than the skill level of the new employees. The other point here is that this group rated the first three learning objectives at the same level. This would indicate that requirements for knowledge (1), comprehension (2) and application (3) are at an equal high level as a requirement for the workplace.

The results from the EIT group show that as a self assessment they rate all six of the learning objectives at an almost equal level. The range of values is from 1.71 to 2.18 with the lowest value assigned to evaluation (6). The other values seem to be randomly assigned to the other learning objectives. The ratings this group assigned to the graduate attributes for the work environment also had a narrow range. There were high values of 2.49 and 2.48 but they were assigned to learning objectives comprehension (2) and application (3). The other four learning objectives had assigned values of 2.19 to 2.29. Therefore the EIT group indicated that on average the work required their skill/abilities to be at the same level through all learning objectives. This could be explained somewhat by looking back at the results of the interview references assigned to the graduate attributes. Those references are based on the activities these individuals undertake on a regular basis. The vast majority of the interview references were assigned to the learning objectives comprehension (2), application (3), and analysis (4). If these are the areas of the major portion of their work assignments it would seem logical that they would assign a greater level of importance to these areas.

An evaluation of the results from the interview references assigned to the graduate attributes and the graduate attribute questionnaire was undertaken to determine if there was a correlation. Initially the P.Eng data from the interviews was evaluated and the graduate attributes with minimal data were eliminated. This left the following graduate attributes along with their ranking:

#2- Problem Analysis, ranked fifth.

#5- Use of Engineering Tools, ranked fourth.

#6- Individual and Team Work, ranked second.

#7- Communication Skills, ranked third.

#11- Economics and Project Management, ranked first.

The first obvious point is that while project management was the most discussed in the interviews it was listed with the lowest rating in the questionnaire in both new graduate capabilities and in requirement for the workplace. This could be explained by the fact that even though the employee's capabilities are not high they still meet the requirements. This area of work is a major one for the new employees and they are meeting the expectations of their supervisors.

The other four graduate attributes which had major discussion in the interviews were ranked as second, third, fourth and sixth in the P.Eng assessment of new graduate capabilities. Therefore in the areas that the supervisors discussed the work activities they also ranked the new graduates at the higher levels for capabilities. When comparing these four graduate attributes from the interviews with the P.Eng assessment of the work environment the rankings were observed as first, second, third and seventh. The areas rated as having higher requirements in the workplace were areas that the P.Engs pointed out as having the most assigned activities for new graduates.

The results for the EIT group in the interviews for graduate attribute had a larger volume of data as there were multiple interviews. Within this data, the attributes with limited results were eliminated which left the following attributes along with their rank:

#2- Problem Analysis, ranked sixth.

#5- Use of Engineering Tools, ranked fifth.

#6- individual Team Work, ranked second.

#7- Communication, ranked fourth.

#11- Economics and Project Management, ranked third.

#12- Life-Long Learning, ranked first.

In these results there are three attributes (#5, #11, #12) that had considerable discussion in the interviews and are rated as being low in skill/ability level. These attributes were also rated low in requirements at the workplace. The repeated references in the interviews should indicate that these were important aspects of their work. If they struggled at work the expectation would be that they would assess their own skills as inadequate and the work requirement at a higher level. The other attributes that were discussed in the interviews showed up as ranking high in the self assessment of capabilities and in the requirements in the workplace. The results of the interviews were then broken down further into each of the learning objectives within each graduate attribute. This only shows that most of the references are assigned to the application and analysis levels which are the active levels.

The results show that in the interview data, discussions are restricted to tasks undertaken and not to capabilities or requirement levels. The data for the questionnaires involves evaluating those capabilities and requirement levels and does not look at evaluating actual activities. Therefore the only correlation seen is that these individuals discuss the activities they undertake that they feel are important to the organization. These could also be their only activities.

The final data collected from the participants on the graduate attribute questionnaire was a ranking of the attributes. This was done in two ways, the first being as to the strongest in skill level for the new graduate and second in the most important to the workplace. The P.Eng rankings followed the list of the graduate attributes almost exactly. The top ranked one was #1- Knowledge, second ranked was #2- Problem Analysis, third ranked was #3- Investigation and so on. The only attribute that did not follow this pattern was #4- Design, which was pushed up to seventh place. When this group ranked which attribute was the most important to the workplace they again followed the same pattern. This time though the attribute #4- Design moved up one spot to the third position. Two of the other attributes, #9-Impact of Engineering and #10- Ethics, moved to the eleventh and twelfth positions. It was observed that the P.Eng group felt that both the strengths of the new graduate and the importance to the workplace were the graduate attributes on technical skills. The attributes for the soft skills were pushed to the position of lower importance. The only issue here is why design is considered a low skill area but a high requirement. By looking back at the results from the assessments of each graduate attribute, this group did assess design as a low skill area but did not assess the requirement to be much higher than the skill level of the new graduate.

Looking at the EIT results they do not assign rankings quite as consistently with the list of graduate attributes. Even so they are not that far removed from the rankings by the professional engineers. The observation for the EIT group is that the spread in the rating values is much smaller than that of the P.Eng group. These are averages of each individual's ratings so this low spread would indicate more variability between the individual ratings. The rankings of their own strengths come closest to the rankings of the P.Eng group. They follow the pattern of the graduate attribute list with two exceptions. First the attribute #6- Individual and Team work moves up to a tie for second and the other #9-Impact of Engineering moves down to last place. Looking at the results of an EIT assessment of the work environment there are completely different results. The EIT's have ranked #7-Communication as first, #6-Individual and Team Work as second, and #8-Professionalism as third. The other attributes are fairly equal with #9-Impact of Engineering again moving to last place. This is very different than the rankings by the P.Eng's and to their rankings of their own strengths. In looking back at the results of the assessment of each learning objective in each graduate attribute, the same three attributes were rated at the top and the same one was rated last. This would indicate that they feel very strongly about these three areas being the most important. They rated them as requiring mastery in skill level and then ranked them as most important.

5.5 Correlation of data

The final stage of the project was to determine if a correlation could be found between the graduate attributes and the aspects of engineering practice. During the initial phase of the study all of the interviews were coded to the aspects of engineering practice to determine the work activities of the participants. These same interviews were then coded to the graduate attributes to determine the knowledge level of the EIT's. The information was then evaluated with the software NVivo to determine if the new graduate's knowledge level (graduate attributes) was in any way related to their work activities. This information would only be valid for this group of participants.

The method used to evaluate the data was matrix coding in NVivo. This works by comparing the coded references and matching which ones were coded in both an aspect of engineering practice and a graduate attribute. From this matrix evaluation data the values were converted to a percentage of all the references assigned to that graduate attribute (Table 1). This produced a table which showed the percentage of the graduate attribute references which were also referenced to a particular aspect of engineering practice.

There were four of the graduate attributes; a knowledge base for engineering (1), professionalism (8), impact of engineering on society and the environment (9), and ethics and equity (10), which had such a limited number of data points that they were eliminated. The remaining data was evaluated and it was found that certain graduate attributes matched closely with one or more aspects of engineering practice. Each category of the aspects of engineering practice was then evaluated against each graduate attribute. The descriptors for each category were matched to the learning objectives of the graduate attributes. This showed which of the knowledge levels were used for each work activity.

Table 2: Interview references coded to a category of aspects of engineering practice and to a graduate attribute as a percentage of references coded to the same graduate attribute

Graduate Attributes / Aspects of Engineering Practice	1. Knowledge	2. P Analysis	3. Invest	4. Design	5. Tools	6. Team	7. Commun	8. Prof	9. Impact	10. Ethics	11. PM	12. Learning
1: Managing self & career development	0.0%	3.3%	0.0%	3.6%	9.7%	4.9%	5.9%	0.0%	0.0%	0.0%	4.5%	17.9%
2: Coordination, working with other people	0.0%	15.0%	13.8%	17.9%	9.7%	62.3%	35.3%	0.0%	0.0%	0.0%	21.8%	13.4%
3: Engineering management processes	0.0%	3.3%	3.4%	14.3%	4.2%	10.7%	10.8%	0.0%	0.0%	0.0%	26.4%	0.9%
4: Financial processes	0.0%	1.7%	3.4%	0.0%	2.8%	0.8%	5.9%	0.0%	0.0%	0.0%	9.1%	0.0%
5: Procurement	0.0%	1.7%	0.0%	0.0%	0.0%	0.8%	2.9%	0.0%	0.0%	0.0%	1.8%	0.0%
6: Human resources	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
7: Business development	0.0%	1.7%	0.0%	0.0%	0.0%	1.6%	2.0%	0.0%	0.0%	0.0%	3.6%	0.0%
8: Technical, creating new concepts, problem solving	0.0%	28.3%	34.5%	50.0%	59.7%	11.5%	34.3%	0.0%	0.0%	0.0%	13.6%	5.4%
9: Technical test, inspection, measurement, review, checking	0.0%	38.3%	69.0%	25.0%	15.3%	9.8%	19.6%	0.0%	0.0%	0.0%	12.7%	1.8%
10: Hands on work	0.0%	5.0%	17.2%	7.1%	4.2%	3.3%	4.9%	0.0%	0.0%	0.0%	2.7%	2.7%

Problem Analysis

This graduate attribute had a total of 66.6% of its references coded in the technical categories (technical, creating new concepts, problem solving and technical test, inspection, measurement, review) of the aspects engineering practice. This would be expected as this is an area of technical knowledge. The total number of references for the graduate attributes was only sixty. Therefore by expanding the analysis into a matrix consisting of the individual descriptors of the learning objectives, the data was found to be too diluted to show any trends. It is of note that the majority of references were in the application level of the graduate attribute, but were spread over a number of work activities.

Investigation

This data showed that 69% of all coded references were in the category of technical test, inspection, measurement, review, checking. There was also an additional 34.5% in the technical creating new concepts category. References at times overlap between related areas. That is the reason these percentages are so high. These two areas of activity are both technical and expectations are that they will be related. This graduate attribute only had a total of twenty-nine references and so any further breakdown in the data yielded little information.

Design

This graduate attribute is also a technical area but consists of more development tasks rather than analysis. The only work activity related to this attribute was the technical creating new concepts category with 50% of the references. The data was again limited and further breakdown only showed that the references were in the application learning objective.

Use of engineering tools

In this graduate attribute most of the references (59.7%) match up with the technical creating new concepts category. This category includes the activity of programming. As stated earlier the EIT's had indicated that they were required to work with programming and software. This is considered an engineering tool and fits into the programming activity. The majority of these references were in the application attribute either in the programming or sketching activities.

Individual and team work

This is one of four graduate attributes that had a substantial number of references. There were a total of 122 references with 76 or 62% in the coordination, working with other people category. These references were equally distributed in the knowledge, comprehension, and application learning objectives. They were most directly related to the activities of coordinate with insiders, receive mentoring and coordinate with outsiders. This is not surprising as team work consists of working with others.

Communication

This was another attribute that had a large number of references. They matched with engineering practice in two categories. The first as expected was with coordination, working with other people at 35.3%. The other was with technical creating new concepts, problem solving at 34.3%. The reason for this is that the communication attribute includes all forms including writing reports and documentation. This then fits into the technical category in the activities of documentation and work package instructions. These activities were documenting and work package instructions under the application learning objective.

Economics and project management

In this graduate attribute the largest match was with the attributes coordination working with other people at 21.8% and engineering management processes at 26.4%. This is as expected as project management is about working with others and managing projects. In breaking the data down into individual activities the largest concentration of references were in manage project and predict cost. These are two activities in which participants commented on working as part of a project.

Life-long learning

This last attribute also had a large number of references, but very few of them matched with any aspects of engineering practice. The largest match was with the category managing self and career development at 17.9%. This would be the obvious match as it includes activities such as training and personal research. The low percentage of matches would be a result of the definition of life-long learning including self awareness and self assessment of learning needs. These would not be considered an engineering activity in the workplace.

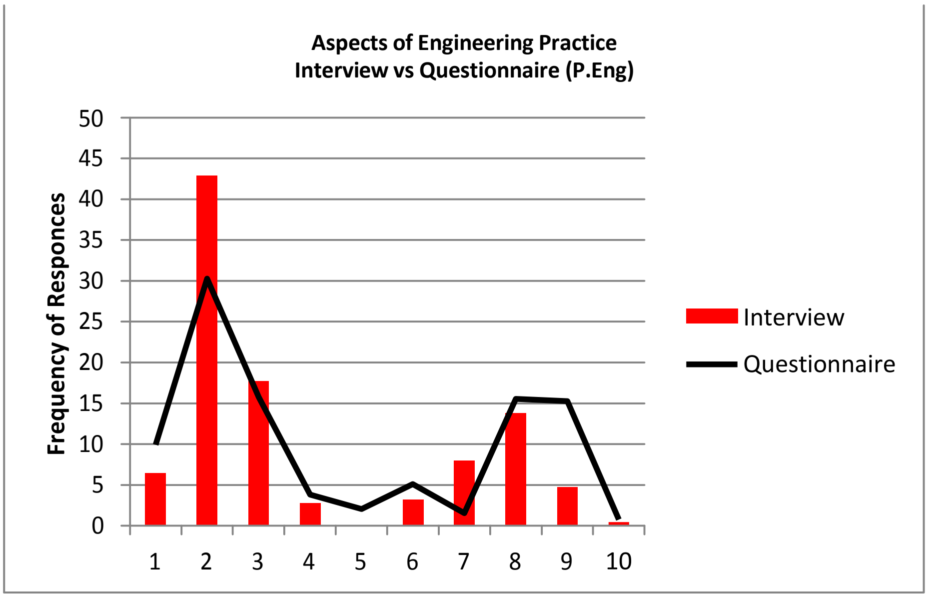
Summary of correlation of data

These results do show a correlation between the aspects of engineering practice and the graduate attributes. The technical areas of graduate knowledge match up with the technical activities. The areas of social knowledge match with the social activities in engineering practice. These are areas which are not difficult to match even without the interview data. The challenge is to find correlation for the attributes which had limited data. These are areas that will be difficult to correlate to any specific engineering activity. The attributes of professionalism and ethics are not activities to be completed. They are a mind set and a mental attitude of behaviour for an engineer.

5.6 Illustrative Summary of Results

This section is an illustrative analysis of the overall results. Figures have been compiled showing comparisons between P.Eng. and EIT results.

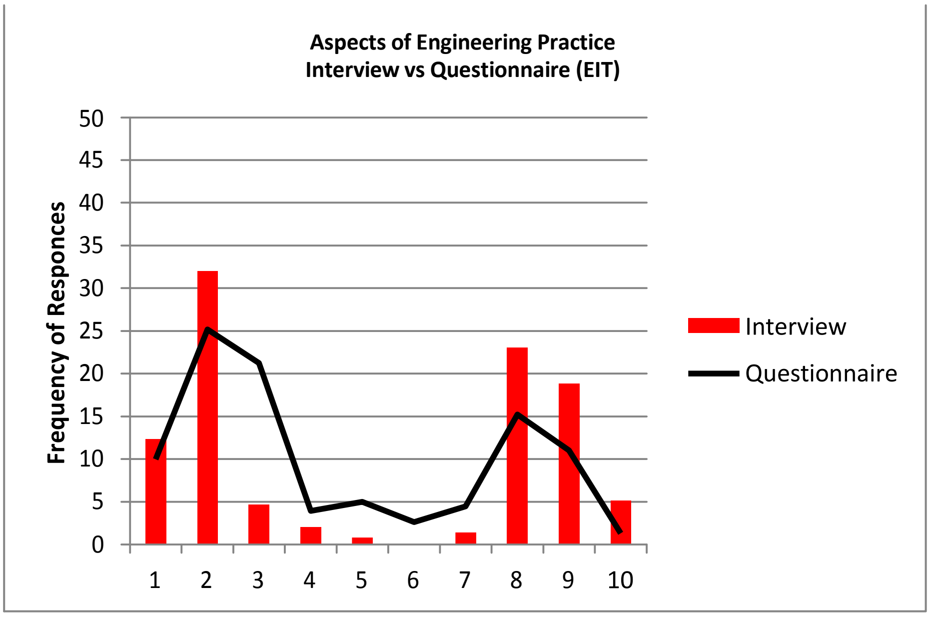
In Figure 68 the correlation of data between the P.Eng interviews and questionnaire can be seen in the overall categories of Aspects of Engineering Practice. The most prominent activity indicated by the P.Eng's was that of coordinating with others category #2. This category was indicated as the most prominent to their employment in the both methods of data collection. The other categories also coordinated well with the exception of category #9 technical test, inspection, measurement, review. This category was not indicated as a major work activity in the interview process but the P.Eng's classified it as a major activity in the questionnaires.



1. Managing self & career development
2. Coordination, working with other people
3. Engineering management processes
4. Financial processes
5. Procurement
6. Human resources
7. Business development
8. Technical, creating new concepts, problem solving
9. Technical test, inspection, measurement, review, checking
10. Hands on work

Figure 68: Comparison of results from the professional engineer's interviews and questionnaires for overall categories of the aspects of engineering practice.

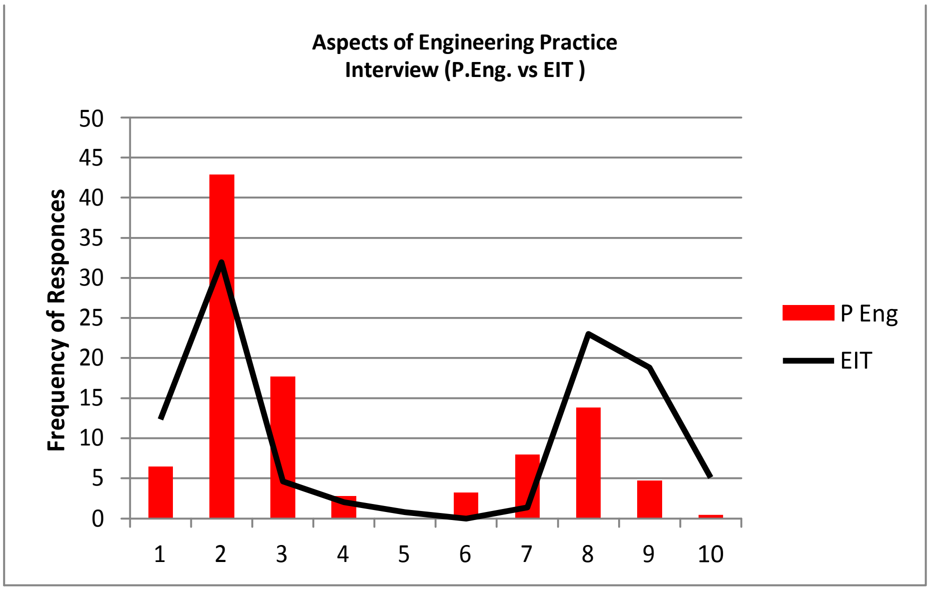
Figure 69 shows the correlation between the results of the interview and the questionnaires for the EIT group. These results are also closely related with the most prominent activity again being coordination working with others. The other activities with a high classification are the two technical areas in categories #8 and #9. These were seen as major activities for the EIT's in both the interviews and questionnaires. The one category with a large discrepancy was that of engineering management processes category #3. This is the activity of project management and did not show up in discussions during the interviews. The EIT's did indicate in the self assessment questionnaires that this was one of their major activities. In the analysis of the interviews of the P.Eng's on the activities of an EIT this was also not very prominent. There seems to be an interpretation issue with the EIT's feeling that their role has a more project management aspect then would be indicated by other interpretations. This did show up during the interviews in discussions on how the EIT's felt ill prepared for a project management role.



1. Managing self & career development
2. Coordination, working with other people
3. Engineering management processes
4. Financial processes
5. Procurement
6. Human resources
7. Business development
8. Technical, creating new concepts, problem solving
9. Technical test, inspection, measurement, review, checking
10. Hands on work

Figure 69: Comparison of results from the engineers in training interviews and questionnaires for overall categories of the aspects of engineering practice.

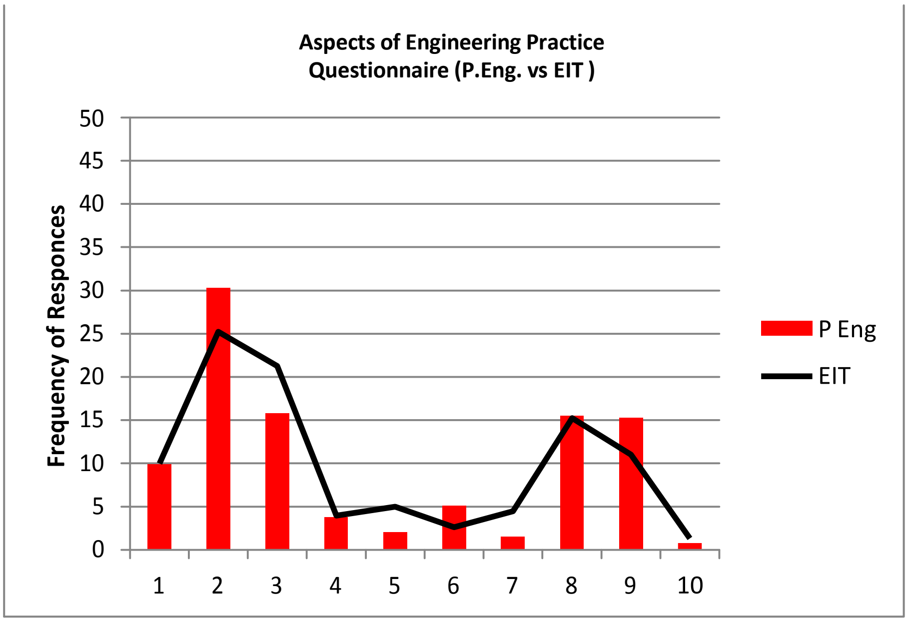
A comparison of results between the P.Eng group and the EIT's from the interviews is seen in Figure 70. Both groups were seen to have the greatest activity in the coordinating with others category #2. The differences between the two groups showed up in category #3 engineering management processes and in categories #8 and #9 the technical aspects. The engineering management processes was seen to be a large responsibility for the P.Eng's and played a small role in the duties of an EIT. The technical activities showed up as a major responsibility for the EIT's with lesser activity for the more senior P.Eng's.



1. Managing self & career development
2. Coordination, working with other people
3. Engineering management processes
4. Financial processes
5. Procurement
6. Human resources
7. Business development
8. Technical, creating new concepts, problem solving
9. Technical test, inspection, measurement, review, checking
10. Hands on work

Figure 70: Comparison of interview results between the professional engineers and engineers in training for overall categories of the aspects of engineering practice.

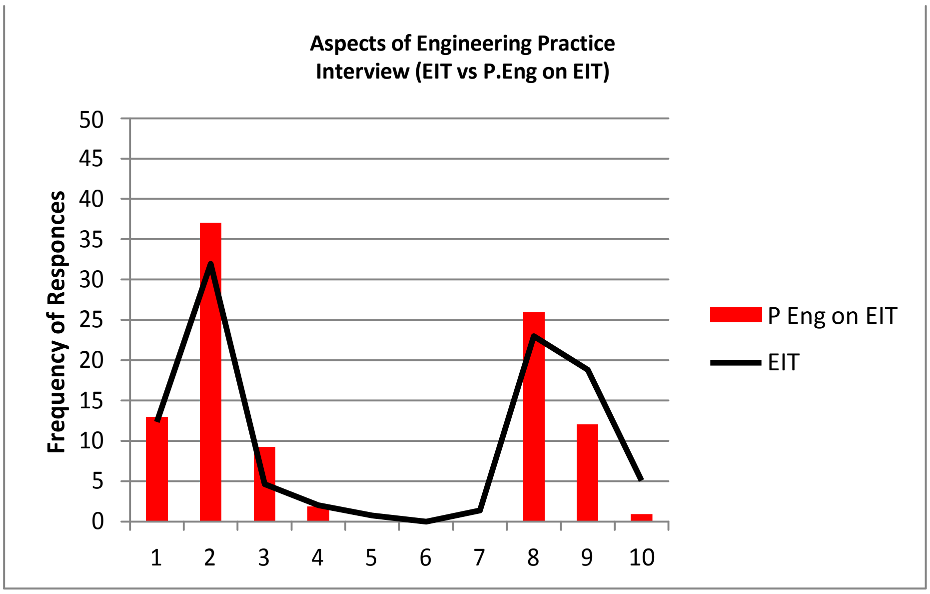
Figure 71 shows the comparison of results for P.Eng's and EIT's from the self assessment on the questionnaire. These again show similar results to the interview data with the most prominent activities being category #2 coordinating with others and categories #8 and #9 the technical activities. The one major aspect that can be observed from this figure is that the EIT's consider engineering management processes category #3 to be a more prominent activity for themselves than the P.Eng's in their self evaluation.



1. Managing self & career development
2. Coordination, working with other people
3. Engineering management processes
4. Financial processes
5. Procurement
6. Human resources
7. Business development
8. Technical, creating new concepts, problem solving
9. Technical test, inspection, measurement, review, checking
10. Hands on work

Figure 71: Comparison of questionnaire results between the professional engineers and engineers in training for overall categories of the aspects of engineering practice.

Figure 72 shows the comparison of the EIT interview with the P.Eng's discussion on EIT activities. This shows that both groups evaluate the role of an EIT to include the same general activities. There are no discrepancies between each of these evaluations.



11. Managing self & career development
12. Coordination, working with other people
13. Engineering management processes
14. Financial processes
15. Procurement
16. Human resources
17. Business development
18. Technical, creating new concepts, problem solving
19. Technical test, inspection, measurement, review, checking
20. Hands on work

Figure 72: Comparison of interview results between the engineers in training and the professional engineer's discussion of engineers in training for overall categories of the aspects of engineering practice.

This evaluation of the roles of a P.Eng and an EIT within Manitoba Hydro show that in a broad sense their activities are in the same categories. It also shows that additional preparation is needed to define terms between the groups and the analyst. Calibration of terms and definitions is required between all participants.

Once the overall category data for the Aspects of Engineering Practice was evaluated it was determined that a more in-depth study was warranted for the three most prominent categories. A illustrative comparison was then completed on category #2, Coordination Working with Other People, category #8, Technical, Creating New Concepts, Problem Solving, and category #9, Technical, Test, Inspection, Measurement, Review, Checking. Results were compared between the two participant groups and the two methods of data collection. The remaining seven categories were found to have limited data and therefore comparisons between groups were not meaningful. This is an indication that activities in these categories are not a major part of the work activities of this engineering cohort at Manitoba Hydro.

Figure 73 shows the correlation between the data collection methods of interviews and questionnaires for the P.Eng's in category #2. The two main activities for P.Eng's from both methods are coordinating insiders, mentoring, and supervise staff. Two activities that were discussed in the interviews but not highly indicated on the questionnaire were build teamwork and coordinating outsiders. The activities of delegate supervision and delegate technical work were indicated as very important in the questionnaire but did not show up in the interviews. By evaluating these activities it can be seen that these definitions have a measure of overlap especially since each method of data collection had the activities defined by different individuals. The interviews were defined by the researcher and the questionnaire by the participant. Overall though, the two data collection methods show a related pattern of job activities for the P.Eng group.

1. Advocacy / compromise
2. Build team work
3. Coordinate insiders, mentoring
4. Coordinate outsiders
5. Coordinate with client
6. Coordinate with insiders receive mentoring
7. Delegate supervision
8. Delegate technical work
9. Networking
10. Organize socials
11. Report progress
12. Reverse mentoring
13. Review procedures
14. Site engineer
15. Supervise contractors
16. Supervise staff

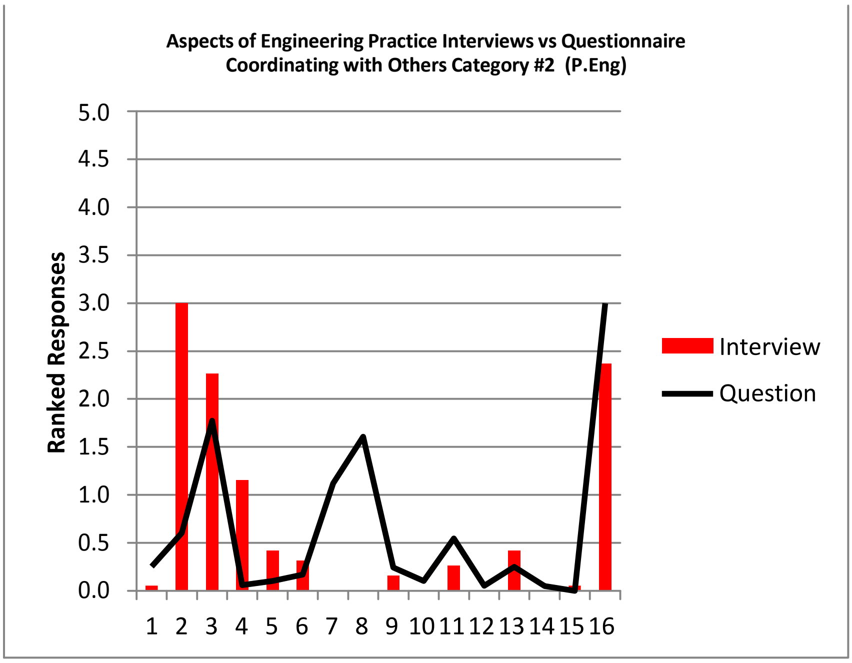


Figure 73: Comparison of results from the professional engineer's interviews and questionnaires for category #2 (Coordination, Working with Other People) of the aspects of engineering practice.

Comparing the results of the two data collection methods for the EIT participants shows a close correlation in Figure 74. The same activities at similar levels are indicated with the exception of networking and report progress. These two activities were indicated as important to the EIT's in the self assessment questionnaire but not so in the interviews. One reason for this was that one individual placed a very high value on networking on a daily basis. This behaviour would have been recorded as an activity of working with others in the interviews. Even though the activity was similar the definition difference between the researcher and the participant would place the activity in different categories. This would also be the case with the activity of reporting progress. During the interviews project information was discussed but no mention was made of progress reports. While in the self assessment questionnaire the EIT's indicated that this was an important activity. Overall the two methods of data collection correlate well for the EIT participants.

1. Advocacy / compromise
2. Build team work
3. Coordinate insiders, mentoring
4. Coordinate outsiders
5. Coordinate with client
6. Coordinate with insiders receive mentoring
7. Delegate supervision
8. Delegate technical work
9. Networking
10. Organize socials
11. Report progress
12. Reverse mentoring
13. Review procedures
14. Site engineer
15. Supervise contractors
16. Supervise staff

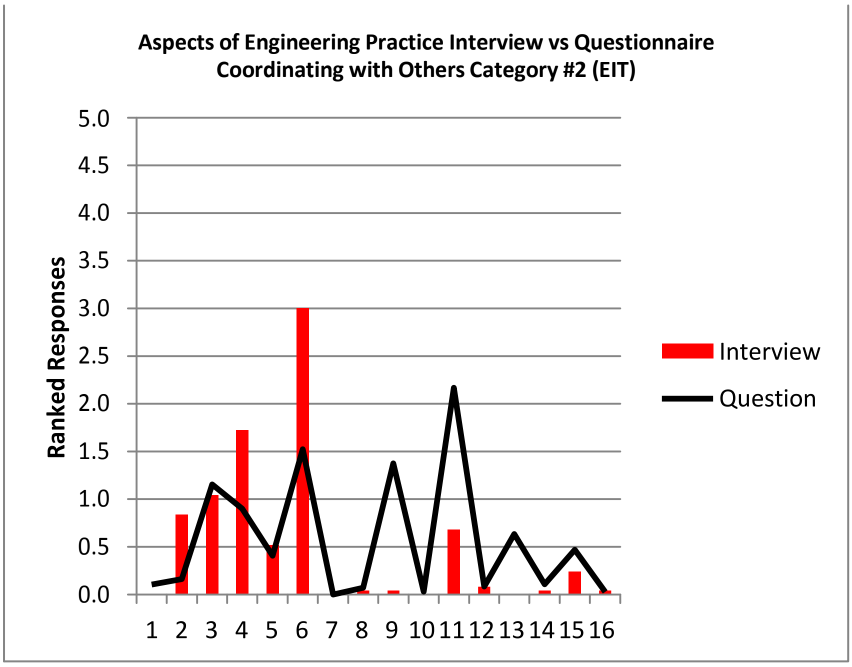


Figure 74: Comparison of results from the engineers in training interviews and questionnaires for category #2 (Coordination, Working with Other People) of the aspects of engineering practice.

Figure 75 shows the difference between the activities of the P.Eng and the EIT's in category #2. This interview data shows that the P.Eng's are mainly involved in the activities of team building, mentoring, and supervision. The EIT's are involved in coordinating with others and receiving mentoring.

1. Advocacy / compromise
2. Build team work
3. Coordinate insiders, mentoring
4. Coordinate outsiders
5. Coordinate with client
6. Coordinate with insiders receive mentoring
7. Delegate supervision
8. Delegate technical work
9. Networking
10. Organize socials
11. Report progress
12. Reverse mentoring
13. Review procedures
14. Site engineer
15. Supervise contractors
16. Supervise staff

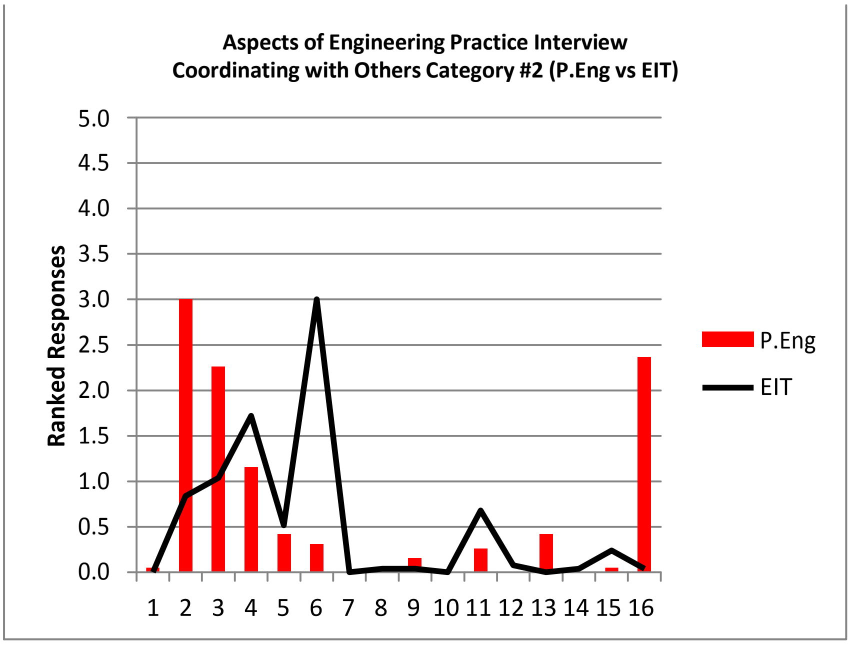


Figure 75: Comparison of interview results between the professional engineers and engineers in training for category #2 (Coordination, Working with Other People) of the aspects of engineering practice.

Figure 76 shows the same the difference between the activities of the P.Eng and the EIT's in category #2 from the self assessment questionnaires. This shows that the P.Eng's are mainly involved in mentoring, delegating tasks, and supervising staff. The EIT's are receiving mentoring, networking, and reporting progress. Both of these sets of data show a distinct difference in the activities of these two groups which require different skill sets.

1. Advocacy / compromise
2. Build team work
3. Coordinate insiders, mentoring
4. Coordinate outsiders
5. Coordinate with client
6. Coordinate with insiders receive mentoring
7. Delegate supervision
8. Delegate technical work
9. Networking
10. Organize socials
11. Report progress
12. Reverse mentoring
13. Review procedures
14. Site engineer
15. Supervise contractors
16. Supervise staff

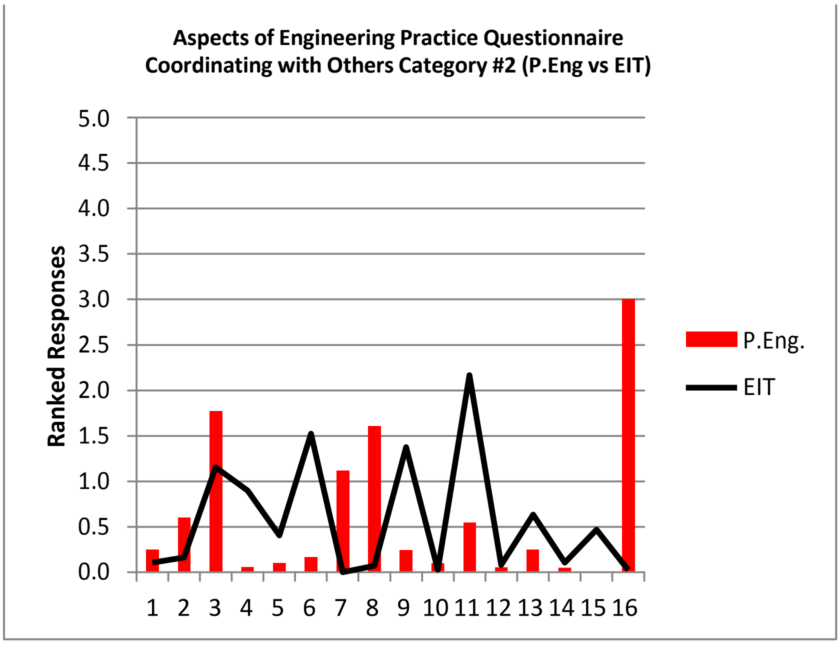


Figure 76: Comparison of questionnaire results between the professional engineers and engineers in training for category #2 (Coordination, Working with Other People) of the aspects of engineering practice.

The last set of data in category #2 is the comparison of an EIT's description of their workday with that of a P.Eng's description of an EIT's responsibility seen in Figure 77. This shows that both groups have the same view of the activities of an EIT. The only real difference is that the P.Eng's put even a higher value on the EIT's requirement for reporting progress.

1. Advocacy / compromise
2. Build team work
3. Coordinate insiders, mentoring
4. Coordinate outsiders
5. Coordinate with client
6. Coordinate with insiders receive mentoring
7. Delegate supervision
8. Delegate technical work
9. Networking
10. Organize socials
11. Report progress
12. Reverse mentoring
13. Review procedures
14. Site engineer
15. Supervise contractors
16. Supervise staff

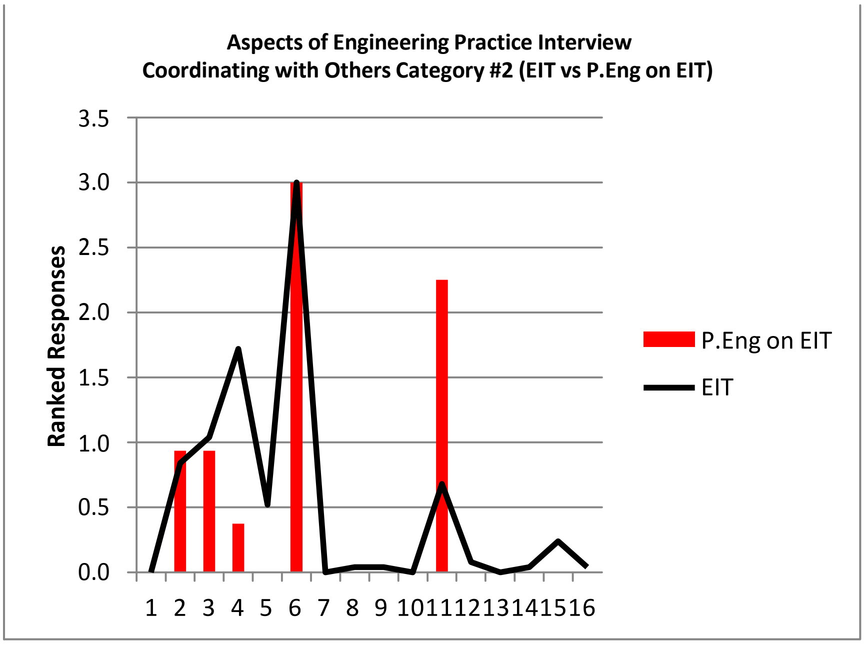


Figure 77: Comparison of interview results between the engineers in training and the professional engineer's discussion of engineers in training for category #2 (Coordination, Working with Other People) of the aspects of engineering practice.

The second category for more in depth evaluation is category #8 Technical, Creating New Concepts, Problem Solving. Figure 78 shows a comparison of the P.Eng responses from the interview and questionnaire. The major activities noted from the interviews were design, document, research standards, and scoping. In their self assessment from the questionnaire the P.Eng's indicated detailing, document, research, and solution for client as their major activities. There are some areas that compare well such as documenting and research but the other activities are not well coordinated. The activity listed as solution for client was indicated in the questionnaire but did not appear in the interviews. While it is an important activity on a list, it is not mentioned in the interview discussion as finding the solution was implied. As for the activities of design and detailing, definitions for these activities can be varied. This is another area where calibration of consistent definitions would be necessary.

1. Design
2. Detailing
3. Document
4. Predict failure modes
5. Predict performance
6. Programming
7. Reduce costs
8. Research
9. Research standards & solutions
10. Scoping
11. Sketch or outline
12. Solution for client
13. Work package instructions

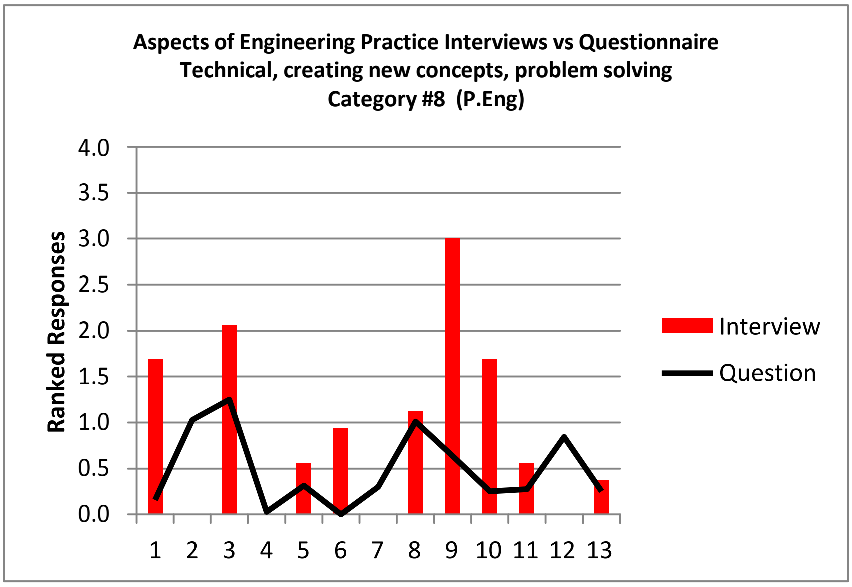


Figure 78: Comparison of results from the professional engineer's interviews and questionnaires for category #8 (Technical, Creating New Concepts, Problem Solving) of the aspects of engineering practice.

Figure 79 shows the comparison of results from interviews and questionnaires from the EIT participants. The interviews showed the main activities were document and programming. The self assessment questionnaire showed the EIT's felt that design and researching standards were their main activities in this category. Discrepancies in some of these activities would again be due to some differing definitions. The activity of design is the first one to question as this group of EIT's considered a large part of their workload to be defined as design. This seems to be counterintuitive for a new engineering graduate as design is generally a more senior activity. The activity of programming can be explained by the inclusion of any reference to working with computer programs from the interviews. This was the most logical activity to store these references. The EIT's in their questionnaires would only include instances where they were involved in the actual programming.

1. Design
2. Detailing
3. Document
4. Predict failure modes
5. Predict performance
6. Programming
7. Reduce costs
8. Research
9. Research standards & solutions
10. Scoping
11. Sketch or outline
12. Solution for client
13. Work package instructions

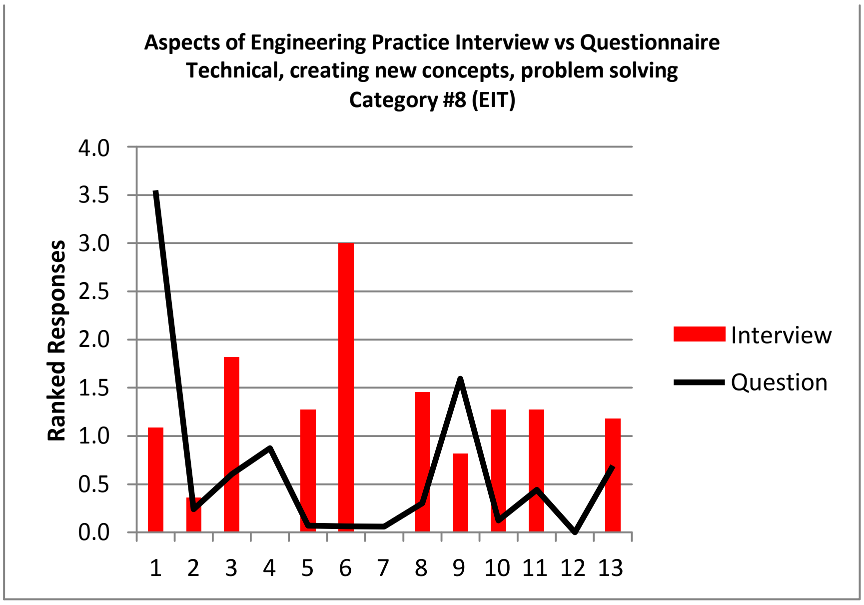


Figure 79: Comparison of results from the engineers in training interviews and questionnaires for category #8 (Technical, Creating New Concepts, Problem Solving) of the aspects of engineering practice.

In comparing the interview results of the P.Eng's to the EIT's most activities are quite similar. Figure 80 shows that only programming for the EIT's and researching standards for the P.Eng's are major differences between the two groups responsibilities. The programming aspect was discussed previously and the researching standards are overrepresented in the P.Eng group due to one participant's responsibility in setting up some new standards.

1. Design
2. Detailing
3. Document
4. Predict failure modes
5. Predict performance
6. Programming
7. Reduce costs
8. Research
9. Research standards & solutions
10. Scoping
11. Sketch or outline
12. Solution for client
13. Work package instructions

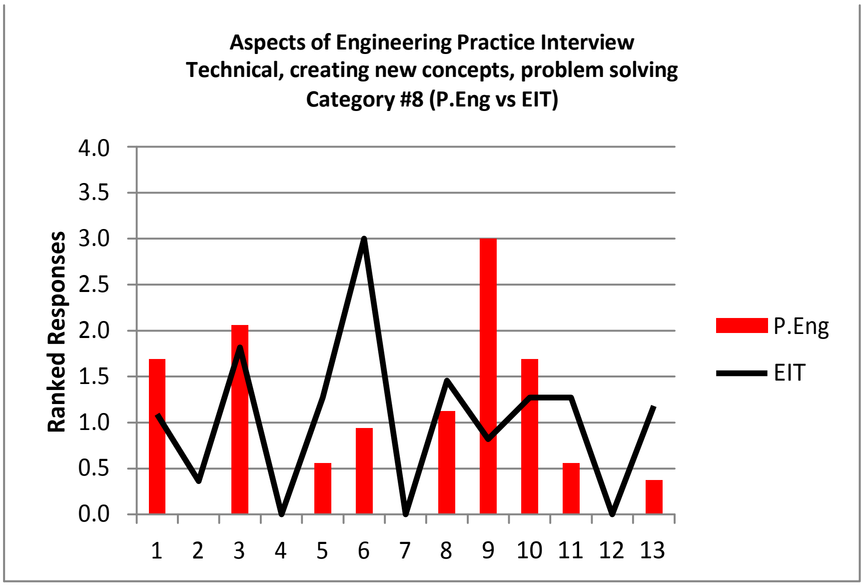


Figure 80: Comparison of interview results between the professional engineers and engineers in training for category #8 (Technical, Creating New Concepts, Problem Solving) of the aspects of engineering practice.

The questionnaire results for the two group's shows very little difference in Figure 81. There is only one major difference between the two groups activities which is the previously discussed design activity for the EIT's.

1. Design
2. Detailing
3. Document
4. Predict failure modes
5. Predict performance
6. Programming
7. Reduce costs
8. Research
9. Research standards & solutions
10. Scoping
11. Sketch or outline
12. Solution for client
13. Work package instructions

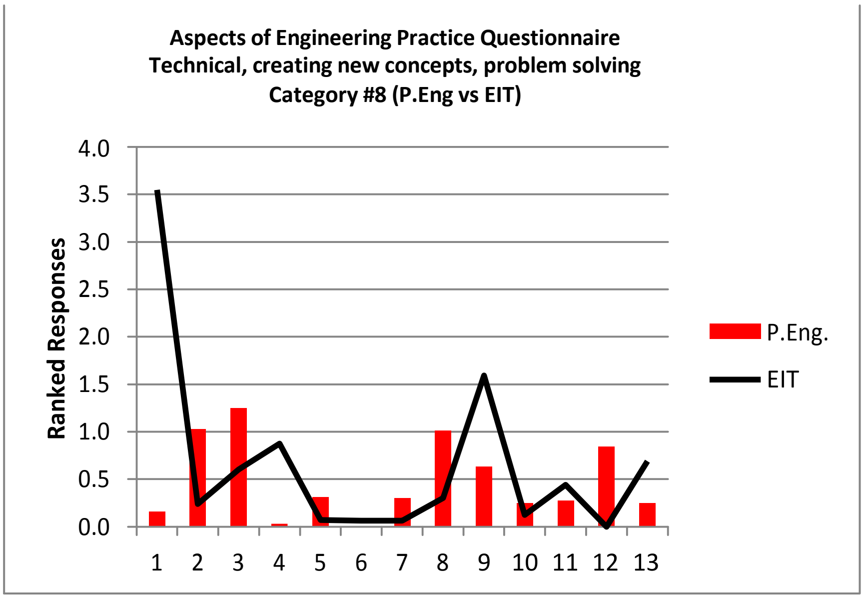


Figure 81: Comparison of questionnaire results between the professional engineers and engineers in training for category #8 (Technical, Creating New Concepts, Problem Solving) of the aspects of engineering practice.

Figure 82 shows the comparison of an EIT's activities with the P.Eng understanding of an EIT's activities. The major difference in these results is that the EIT's feel they play a role in the activities of design and research in which the P.Eng's did not indicate the EIT's had any role. The additional activities of scoping and work package instructions also had a higher incidence for the EIT's than that of the P.Eng's. The other areas of activity were well matched between the two groups.

1. Design
2. Detailing
3. Document
4. Predict failure modes
5. Predict performance
6. Programming
7. Reduce costs
8. Research
9. Research standards & solutions
10. Scoping
11. Sketch or outline
12. Solution for client
13. Work package instructions

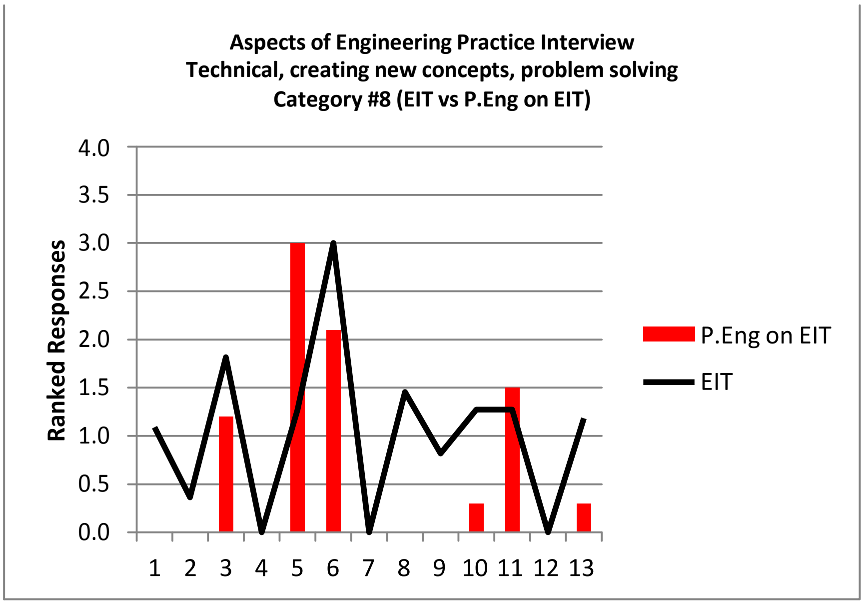


Figure 82: Comparison of interview results between the engineers in training and the professional engineer's discussion of engineers in training for category #8 (Technical, Creating New Concepts, Problem Solving) of the aspects of engineering practice.

The third category for in depth evaluation is category #9, technical test, inspection, measurement, review, checking. Figure 83 shows a comparison of the P.Eng responses from the interview and the questionnaire. In the questionnaire the P.Eng's indicated that their major responsibilities were in the areas of respond to query, check details, and technical standards. The interview results showed their main responsibilities in the areas of diagnose problem, survey measurement, and technical standards. Only one of these activities is a complete match and this area has been discussed previously with one P.Eng working on a standards project. Another of these mismatches could be as a result of interpretation. The

P.Eng's in their self assessment indicated that they check details while the interpretation from the interviews was diagnose problem. These two activities are closely related and could be mistaken as the same activity. The respond to query activity was important as an activity to the P.Eng's but was not evident in the interviews. This is an area where the interpretation from the interviews was that of communication with the client, contractors, or others. A re examination of information and redefinition of terms would result in a better understanding of these differences. The last discrepancy was in the large number of references to survey measurement in the interviews by the P.Eng participants. This was not anticipated as this activity is generally considered a task for more junior members of a team.

1. Acceptance test
2. Check details
3. Diagnose problem
4. R&D testing
5. Respond to query
6. Review costs
7. Review design change
8. Review tech solution
9. Survey, measurement
10. Technical standards

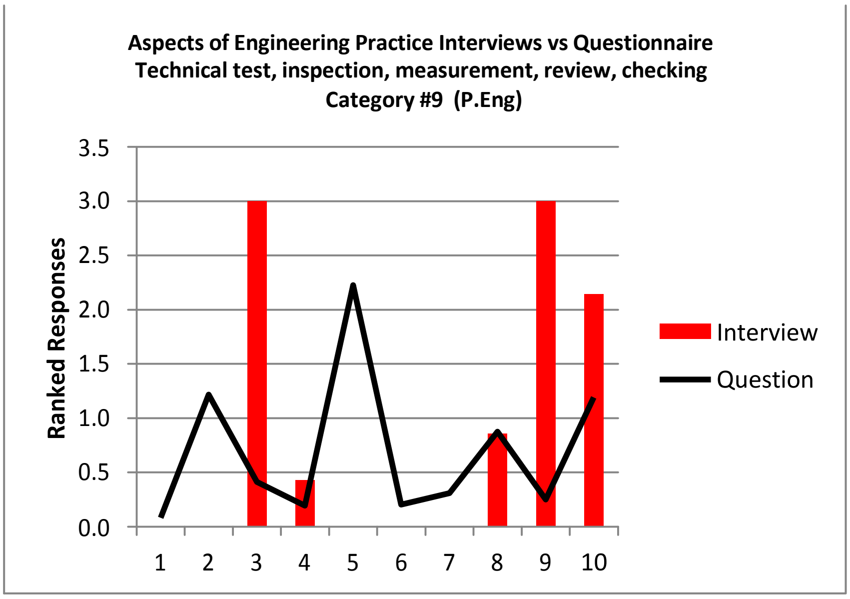


Figure 83: Comparison of results from the professional engineer's interviews and questionnaires for category #9 (Technical Test, Inspection, Measurement, Review, Checking) of the aspects of engineering practice.

Figure 84 shows the comparison of the interviews to the questionnaires of the EIT participants. This shows a close match between the two sets of data. The activities the EIT's indicated were most important, also showed up in the interviews as being most often undertaken. The one difference was that the last three activities, while being indicated as having some importance to the EIT work role in the questionnaire, showed up as being the largest portion of their work tasks in the interviews.

1. Acceptance test
2. Check details
3. Diagnose problem
4. R&D testing
5. Respond to query
6. Review costs
7. Review design change
8. Review tech solution
9. Survey, measurement
10. Technical standards

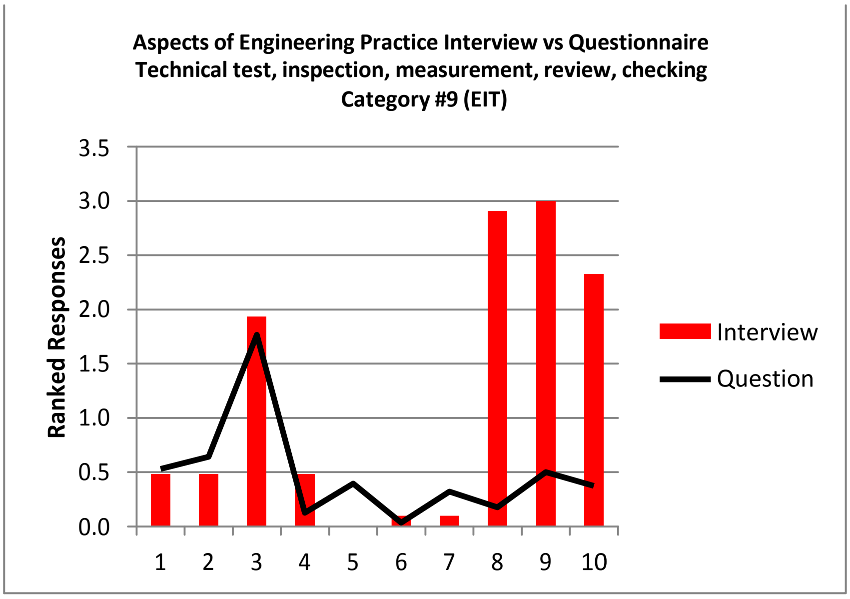


Figure 84: Comparison of results from the engineers in training interviews and questionnaires for category #9 (Technical Test, Inspection, Measurement, Review, Checking) of the aspects of engineering practice.

The comparison of P.Eng to EIT activities from the interviews is seen in Figure 85. This data shows that both groups perform the same tasks to the same levels. The one difference is that EIT's spent a large portion of their time reviewing technical solutions while this was not a major role of the P.Eng. The interviews indicated that this was a task given to new employees as a training tool to help them understand the process.

1. Acceptance test
2. Check details
3. Diagnose problem
4. R&D testing
5. Respond to query
6. Review costs
7. Review design change
8. Review tech solution
9. Survey, measurement
10. Technical standards

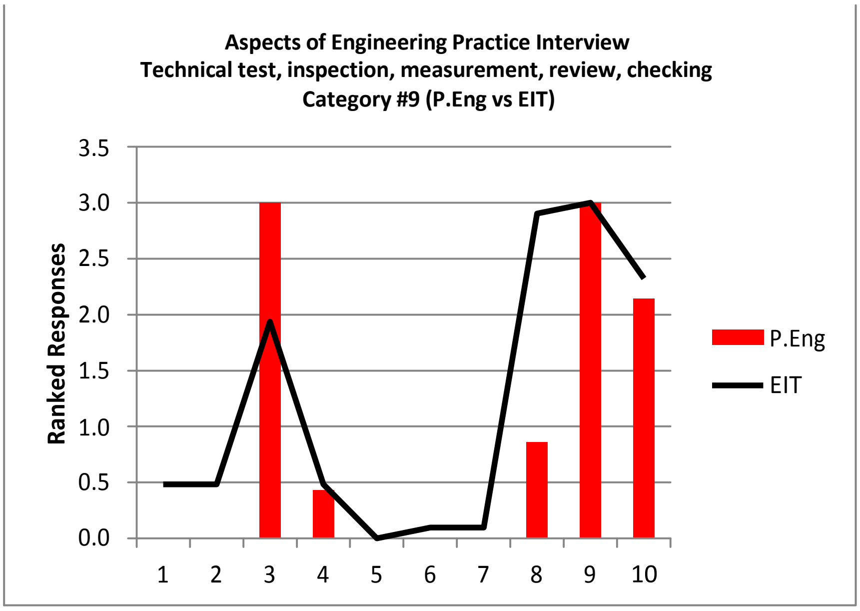


Figure 85: Comparison of interview results between the professional engineers and engineers in training for category #9 (Technical Test, Inspection, Measurement, Review, Checking) of the aspects of engineering practice.

Figure 86 shows the comparison of P.Eng to EIT in their self assessment. There are two major differences in the activities of the two groups. The EIT's consider the activity of diagnosing problems as their most important while the P.Eng's was responding to queries. The other activities were not considered to be as important by either group.

1. Acceptance test
2. Check details
3. Diagnose problem
4. R&D testing
5. Respond to query
6. Review costs
7. Review design change
8. Review tech solution
9. Survey, measurement
10. Technical standards

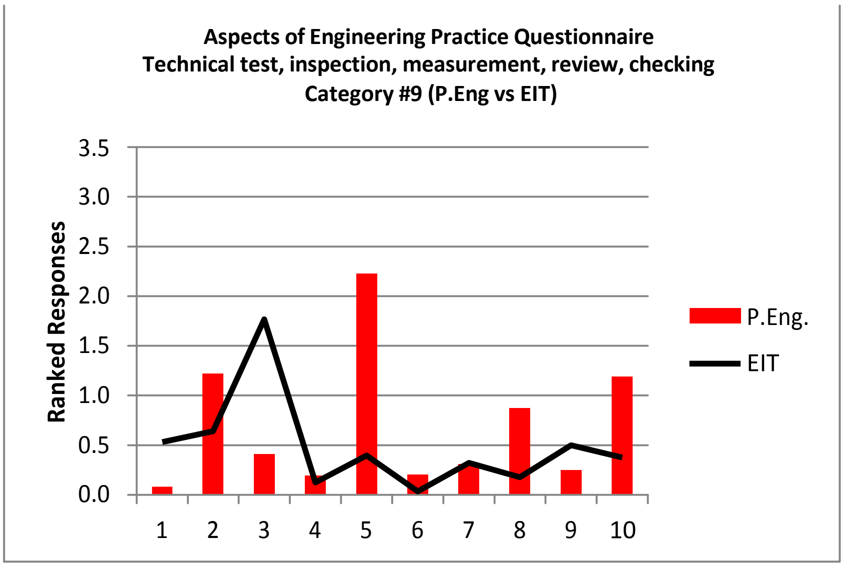


Figure 86: Comparison of questionnaire results between the professional engineers and engineers in training for category #9 (Technical Test, Inspection, Measurement, Review, Checking) of the aspects of engineering practice.

In Figure 87 a comparison is displayed between the EIT's and the P.Eng understanding of the EIT role from the interview data. Three of the activities were indicated by both groups as important to the EIT work role. These activities were the same in both cases and included diagnose problem, review technical solution, and survey measurement. The EIT's also discussed other areas such as technical standards that were not indicated by the P.Eng's.

1. Acceptance test
2. Check details
3. Diagnose problem
4. R&D testing
5. Respond to query
6. Review costs
7. Review design change
8. Review tech solution
9. Survey, measurement
10. Technical standards

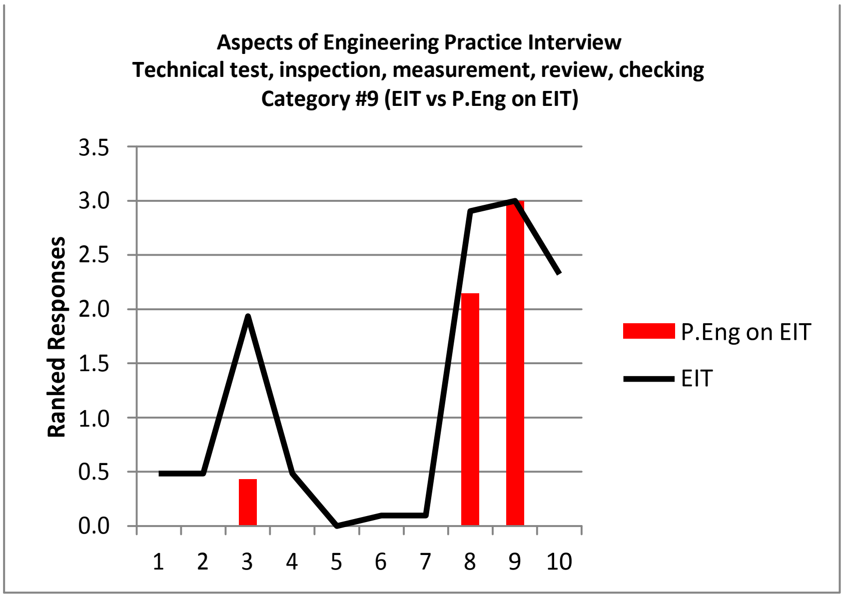


Figure 87: Comparison of interview results between the engineers in training and the professional engineer's discussion of engineers in training for category #9 (Technical Test, Inspection, Measurement, Review, Checking) of the aspects of engineering practice.

This final section is an evaluation of the responses to the graduate attribute questionnaires. The responses given by each group of participants was averaged for each graduate attribute. These values were then compared between the P.Eng and the EIT participants. Comparisons were conducted for each group between the responses for new graduates capabilities and the requirements of the workplace.

Figure 88 shows the results of a new graduate's capability between the P.Eng's and the EIT participants. The value of this information is in the comparison of gaps in the results between each group. It shows that this group of EIT's considered their knowledge base at graduation to be very similar to what the P.Eng's felt was the knowledge base of all the new graduates they had encountered.

1. A Knowledge Base for Engineering
2. Problem Analysis
3. Investigation
4. Design
5. Use of Engineering Tools
6. Individual and Teamwork
7. Communication Skills
8. Professionalism
9. Impact of Engineering on Society and the Environment
10. Ethics and Equity
11. Economics and Project Management
12. Life-long Learning

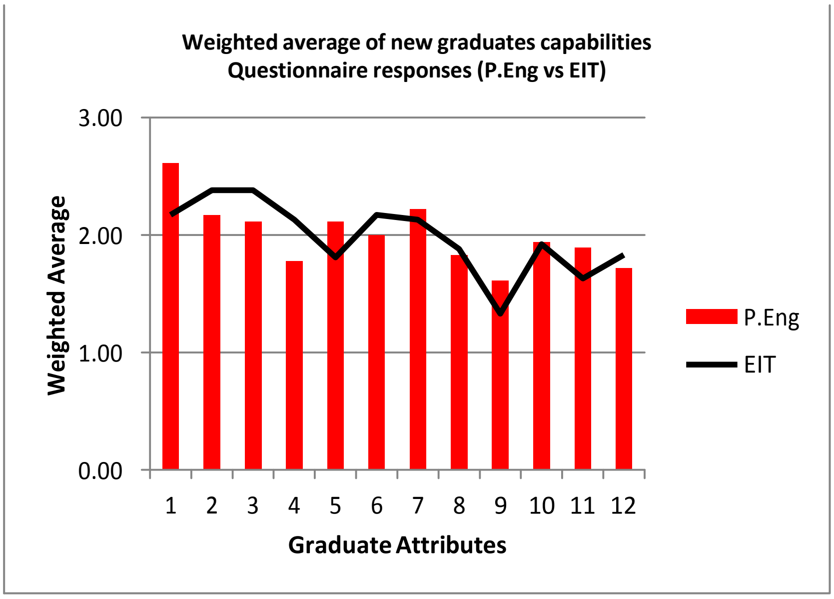


Figure 88: Comparison of graduate attribute questionnaire results between the professional engineers and engineers in training on new graduate capabilities.

Figure 89 shows the results of the workplace requirements at Manitoba Hydro for a new graduate engineer. This is a comparison between the results from the P.Eng's and the EIT's. This comparison shows that both groups had a similar opinion on the workplace requirements for a new graduate engineer. The only real discrepancy in the data was in the last three attributes. These include Ethics, Project Management, and Life Long Learning. In these three areas the EIT participants felt that the workplace requirements were greater than that indicated by the P.Eng's. The one attribute with the largest gap was project management. While this requirement was ranked the lowest by the P.Eng group it was considered much higher by the EIT's. The interview discussions pointed out that the P.Eng's felt new graduates has little involvement in the area of project management. The EIT's had the opposite understanding in that they felt project management was important to their activities. They also felt that they were not well prepared for the role of project management.

Another point from this figure is that both the P.Eng's and the EIT's indicated that the same three attributes ranked the highest with respect to workplace requirements. These attributes were Teamwork, Communication, and Professionalism. The graduate attributes as represented are not ranked against each other and therefore this information alone does not represent each attributes relative importance. But along with this information is the response from the individuals ranking of the attributes. Both of these groups ranked these three attributes as the most important to the workplace requirements for a new graduate. This is a strong indication that these three attributes are very important in the workplace.

1. A Knowledge Base for Engineering
2. Problem Analysis
3. Investigation
4. Design
5. Use of Engineering Tools
6. Individual and Teamwork
7. Communication Skills
8. Professionalism
9. Impact of Engineering on Society and the Environment
10. Ethics and Equity
11. Economics and Project Management
12. Life-long Learning

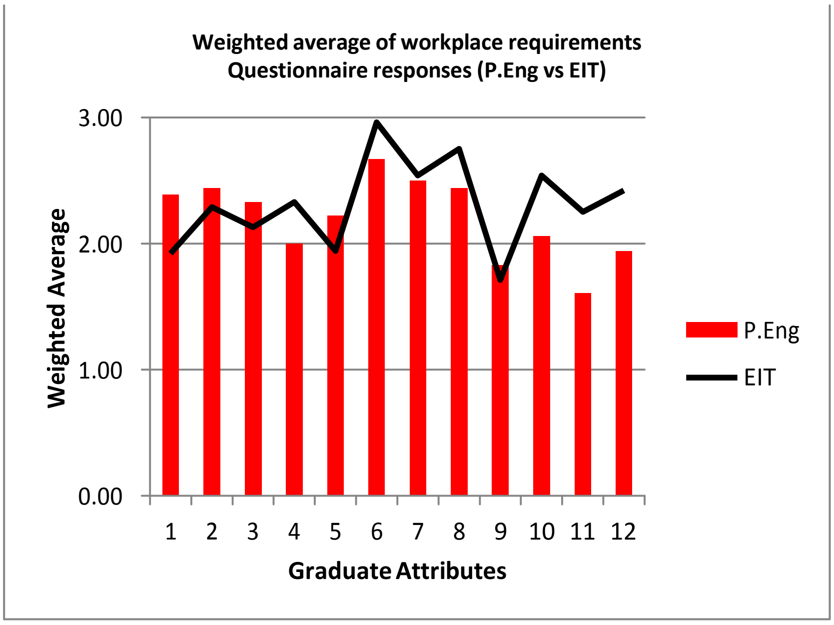


Figure 89: Comparison of graduate attribute questionnaire results between the professional engineers and engineers in training on new workplace requirements for new graduates.

Figure 90 shows the comparison of the P.Eng's responses of the new graduate's capabilities to the workplace requirements. This information shows a close relationship with the workplace requirements being slightly greater than the capabilities of the new graduates. The technical attributes of Problem Analysis, Investigation, and Design show a slight gap in a new graduates capabilities to the requirements of the workplace. The largest gap is in the Teamwork, Communication, and Professionalism attributes. The P.Eng's indicated that these were the areas in which the new graduates' capabilities did not meet the requirements of the workplace.

13. A Knowledge Base for Engineering
14. Problem Analysis
15. Investigation
16. Design
17. Use of Engineering Tools
18. Individual and Teamwork
19. Communication Skills
20. Professionalism
21. Impact of Engineering on Society and the Environment
22. Ethics and Equity
23. Economics and Project Management
24. Life-long Learning

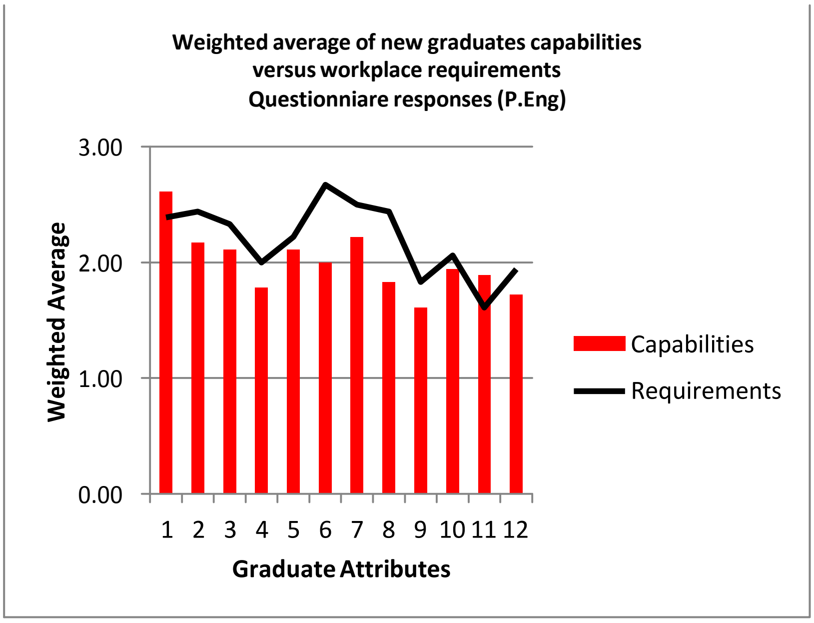


Figure 90: Comparison of graduate attribute questionnaire results by the professional engineer's between a new graduate's capability and the workplace requirements of a new graduate.

The comparison of the EIT's response of their own capabilities at graduation to the workplace requirements they experienced is shown in Figure 91. This information indicates that the EIT's felt they met the workplace requirements in the technical areas. It also shows that they felt they did not meet the requirements of the professional skill attributes. There was a substantial gap in capabilities to requirements in the following attributes; Teamwork, Communication, Professionalism, Impact on Society and the Environment, Ethics, Project Management, and Life Long Learning.

1. A Knowledge Base for Engineering
2. Problem Analysis
3. Investigation
4. Design
5. Use of Engineering Tools
6. Individual and Teamwork
7. Communication Skills
8. Professionalism
9. Impact of Engineering on Society and the Environment
10. Ethics and Equity
11. Economics and Project Management
12. Life-long Learning

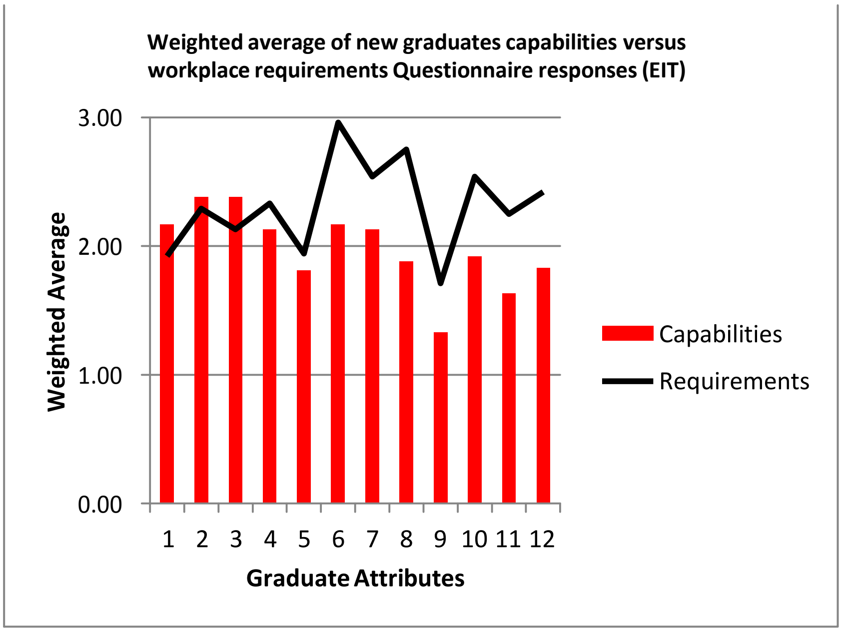


Figure 91: Comparison of graduate attribute questionnaire results by the engineers in training between a new graduate's capability and the workplace requirements of a new graduate.

5.7 Limitations of This Mixed Method Study

This study was a mixed method study using interviews and questionnaires. It was a quantitative study which fit well with the information from the questionnaires. The interviews are more commonly used in a qualitative format. They allowed for in-depth study of a select group of participants. The use of the interviews in this, a quantitative study, allowed for a real depth of of understanding of not only what but how engineers complete activities in the workplace. This method allowed the researcher and the participant to reflect on what they do each day and provided an ability for them to give detailed descriptions. Another advantage of using these two methods is the ability to triangulate the data. Information from the interviews was used to enhance the activity descriptions and to cross reference with the results of the questionnaire.

There are also disadvantages to using interviews in this study. There use limits the size of the participant group in two ways. First, because of the time involved and amount of data collected, there is a limit to the size of the participant group. Secondly, for the same reasons, it limits who is available and who is willing to participate. The limitation of the size of the participant group restricts the results to this particular group. Some of the results could be indicative of the Manitoba Hydro organization. Due to culture and structure, certain activities would be common. Other aspects would be more representative of the individual's personality and of their department. Results would be difficult to take outside of the organization due to differences in organizational culture, structure, type of work, and type of organization.

Another limitation is in the analysis of the data from the interviews. A questionnaire is completed by the participant and the results can be easily compiled. The interviews must first be defined and coded to uncover the meaning. The participant discusses their activities but it is the analyst who uncovers the meaning. Each analyst will have a different interpretation based on their own personal biases and history. Each participant describes their experience in a different way. The analyst must then also interpret each individual's interviews in a consistent manner. The challenge is to find the correct definitions to allow for consistency between the participants and their understanding of the questionnaire. This will allow the researcher to analyze the complete data set with a common understanding of the participants.

6 CONCLUSIONS

This was an exploratory study of engineers in the workplace to form a basis on how engineering education translates to the activities in the workplace. It was conducted as a mixed method study within a large energy corporation in the Province of Manitoba. A number of professional engineers and engineers in training were interviewed and asked to complete questionnaires. In the first stage, research questions were developed to understand the role an engineer undertakes in the workplace and the activities they complete. The second stage questions were developed to determine the role of engineering education in the workplace. These questions inquired into an assessment of the level of knowledge a new engineering graduate has at time of entry to the workplace. A second inquiry was to the level of knowledge required by a new engineering graduate to complete the workplace duties as assigned.

The first objective of this study was to identify the role of a professional engineer. Data collected through interviews and questionnaires gave an in-depth understanding of the activities these four professional engineers conducted on a daily basis. This information matched comparative data from a more extensive study by Trevelyan (2008). Individual tasks and responsibilities differ among the participants but the overall role was consistent between the participants. The conclusion from the interview data was that this group of professional engineers spend one-third of their time in supervising and coordinating the activities of other staff. Earlier the importance of the social aspect of engineering was discussed. This group of engineers spent more than 40% of their time on these social aspects in coordinating efforts with staff, administration, consultants, and clients. They additionally were involved in engineering management processes at nearly 18% of their time with the technical aspects of their employment only encompassing a total 14%. In the questionnaire data the professional engineers results were distributed more evenly across the range of activities. The results showed the most prominent activity being the coordination of activities with staff, followed by engineering management, and technical problem solving. These three activities were the most prominent in both sets of collected data which gives credibility to these being the prominent role for this group of professional engineers.

The second objective was to identify the role of an engineer in training. The interviews and questionnaires showed that these individuals also fit closely to the aspects of engineering practice in Trevelyan's study. The EIT's most prominent role was that of coordination working with others at a total of 32%. Within this category this group indicated that they spent the largest proportion of their time receiving mentoring. The other areas indicated by the EIT group were the technical areas of problem solving (23%) and testing (18%). They also indicated more than 12% of their time was involved in personal development which would include training and personal improvement. The self assessment questionnaire showed that the EIT's had a slightly different assessment than the analysis of the interviews. The most prominent category was the coordination efforts with others as in the interview data. The change was in the second most prominent category of engineering management. The EIT's classified a large proportion of their efforts in this category under the project management activities. The next two categories were the technical categories which matched the technical categories from the interview data. With the exception of the engineering management category there was coordination of data between the interview and questionnaire with respect to the EIT's role at Manitoba Hydro. The difference of that one category can be attributed to subjective analysis of data between the researcher and the EIT's. There can be a fine line between classification of activities as project management or technical tasks. The overall conclusion is that EIT's spend the majority of their time in coordinating with others and in the technical aspects of projects.

An evaluation of the two groups of engineers shows that the EIT's tasks matched the professional engineers when grouped into categories. On more detailed analysis the work activities between the two groups had more variance. While both groups spent the majority of time working on tasks in the same category, individual work differed. The professional group spent the majority of their time supervising and making decisions. The EIT group spent more time in the technical details and working on projects. What the data did show is that a large portion of all engineers time is spent on communication with various parties.

The third and fourth objectives were to determine the knowledge of a newly graduated engineer and to identify the knowledge requirements of the workplace with respect to the CEAB graduate attributes. The information was compiled through the interviews and questionnaires from both P.Eng's and EIT's on the activities of newly graduated engineers. The interview data had some limitations as discussions centred around certain graduate attributes with minimal data in the other attributes. Data was coded into the six levels of Blooms Taxonomy for each of the graduate attributes. The analysis of the interview data showed that the EIT's discussed their role as being in the comprehension and application levels of the graduate attributes; team work, communication, project management, and life-long learning. The P.Eng assessment of EITs placed the activities in the comprehension and application levels of the graduate attributes; engineering tools, team work, communication, and project management. Assessment of the EITs was consistent between the two groups in both the level of Bloom's Taxonomy and category of graduate attribute.

The second method of collecting information was with a questionnaire. The P.Eng's were asked to evaluate the capabilities and the job requirements for a newly graduated engineer. The EIT's were asked to give a self evaluation of their own capabilities at graduation and an assessment of their first job activities. The evaluation of the data showed consistency among the members of the groups and between the groups. It showed that the skill/ability level of new graduates was assessed at a much lower level than of graduating students self assessments as discussed by Cicek (2008). EIT's self assessment was slightly above an introduced level of knowledge. The P.Eng assessment of the EIT abilities was equal to or higher than the EIT self assessment in all graduate attributes except one. In the graduate attribute Design the P.Eng assessment was slightly lower. The main difference between the two group ratings was the P.Eng assessed the knowledge levels of the EITs higher in the lower levels of Bloom's Taxonomy with progressively lower assessments in the upper levels. The EIT's self evaluation saw a random distribution of assessment through the six levels of Bloom's Taxonomy.

The second aspect of the questionnaire was the assessment of the job requirements of a new graduate based on the graduate attributes. The P.Eng group assessed the graduate attributes; team work, communication, and professionalism as the three top attributes for knowledge requirements for new graduate engineers. These three attributes were also assessed as having the greatest knowledge deficit for a new graduate with respect to the job requirements. The attributes of problem analysis and design were considered to have slight deficits in knowledge as require by new graduates with all other attributes requirements met by the knowledge of a new graduate. The EIT's classified themselves as having large knowledge deficits in the graduate attributes team work, communication, professionalism, and project management which closely matches the ratings by the P.Eng group. EIT's were critical of certain areas they felt they lacked knowledge required for their assigned activities. Other areas of concern for the EIT's were in design, ethics and life-long learning. The interesting information is that both groups felt that the highest requirements for the workplace were in the social aspects. Knowledge areas of communication, teamwork, and professionalism were classified as having the highest knowledge requirements along with the highest deficit in the knowledge attained by a new engineering graduate.

The last objective was to determine the links or gaps between the knowledge requirements of a newly graduated engineering and a professional engineer. The goal was to find any gaps and see if they are due to knowledge deficits in education or are filled normally in the workplace over time. There were definite differences in the activities and responsibilities between the two groups of engineers. The P.Eng participants' activities were in the supervisory and decision making areas while the EIT responsibilities were the coordinating and technical activities. An EIT would transition to a more senior role over time through knowledge gained with experience and training. The deficit shown in knowledge for the EIT participants was in the areas of team work, communication, and professionalism. These would be important not only to a new engineering graduate but also to the supervisory role a P.Eng undertakes. This would be an area of concern and considered a gap in the knowledge required by a new graduate. The EIT's had an adequate knowledge base in the other graduate attributes, especially the technical areas. Since these areas were not shown to be important areas of responsibilities for the P.Eng participants would indicate that they are not considered to be a gap in knowledge for a new graduate engineer.

This study was on four professional engineers and four engineers in training within one corporation. This small sample size means that the conclusions are of a general nature and will be used as a guide for future research.

6.1 Recommendations for Future Research

This study was successful but the small number of participants and the fact that they worked in one organization limits the results to an understanding of the general aspects rather than specific conclusions. The study did show that questionnaires on both the aspects of engineering practice and on graduate attributes can be valuable tools to gather information.

My recommendation is that to increase the database of information a questionnaire on the aspects of engineering practice be refined and sent out as an online tool to a broad audience of engineers. This would give a much broader understanding of the activities and requirements of the engineering community. As a follow up, a random selection of participants could be interviewed to verify the data.

The second recommendation would be to update the graduate attribute questionnaire for participant clarification. This could then also be used as an online questionnaire. This should be directed to a broad audience of engineers that are recently graduated. This would give a broad perspective from individuals in different industries with varying responsibilities. This could also be used for supervising engineers as an assessment tool. Follow-up interviews with a random selection of participants would be used as a verification of the process.

REFERENCES

Ahmed, S., K.M. Wallace, and L.T.M. Blessing. 2003. Understanding the differences between how novice and experienced designers approach design tasks. Research in Engineering Design 14: 1-11.

Akin, O.O. 1989. A paradigm for problem structuring in design. Pages 127-144 in Proceedings of the NSF engineering Design Research Conference. University of Massachusetts.

American Society of Civil Engineers. 2008. ‘‘Civil Engineering Body of Knowledge for the 21st, Century,’’. http://www.asce.org/uploadedFiles/Leadership_Training_-_New/BOK2E_%28ASCE_2008%29_ebook.pdf

Anderson, K., S. Courter, T. McGlamery, T. Nathans-Kelly and C. Nicometo. 2009. Understanding the Current Work and Values of Professional Engineers: Implications for Engineering Education. Engineering Education. http://www.engr.wisc.edu/services/elc/ASEE_09_Engr_work_values.pdf

Anderson, K.J.B., S.S. Courter., T. McGlamery, T.M. Nathans-Kelly. and C.G. Nicometo. 2010. Understanding engineering work and identity: a cross-case analysis of engineers within six firms. Engineering Studies 2(3): 153–174.

Archer, L.B. 1964 Systematic Method for Designers, (Council for Industrial Design, London).

Atman, C.J., J.R. Chimka, K.M. Bursic and H.L. Nachtmann. 1999. A Comparison of Freshman and Senior Engineering Design Processes. Design Studies 20(2): 131–152.

Badke-Schaub, P. And E. Frankenberger. 1999. Analysis of design projects. Design Studies 20: 465-480.

Baird, F., C.J. Moore, and A.P. Jagodzinski. 2000. An ethnographic study of engineering design teams at Roll-Royce Aerospace. Design Studies 21: 333-355.

Ball, L.J., T.C. Ormerod. and N.J. Morley. 2004. Spontaneous analogising in engineering design: a comparative analysis of experts and novices. Design Studies 25: 495-508.

Benner, P. 1982. From novice to expert. American Journal of Nursing. 82(3): 402-407

Benner, P.A., Tanner, C.A., and Chesla, C.A., 1996. Expertise in Nursing Practice: Caring, Clinical Judgement, and Ethics. Springer Publishing Company, New York, NY.

Beitz,W. 1994. Design science – the need for a scientific basis for engineering design methodology. Journal of Engineering Design 5(2): 129-133.

Borrego, M., E.P. Douglas, and C.T. Amelink. 2009. Quantitative, qualitative, and mixed method research methods in engineering education. Journal of Engineering Education 98(1): 53-66.

Brock, H.R., S.S. Condoor. and C.P. Burger. 1993. Development of design skills through employment of open-ended problems. Design Theory and Methodology 53: 207-121.

Bucciarelli, L.L. 1984. Reflective practice in engineering design. Design Studies 5(3): 185-190.

Bucciarelli L.L. 1988. An ethnographic perspective on engineering design. Design Studies 9(3): 159–168

Bucciarelli, L.L. 1994. Designing Engineers, Cambridge, Mass: MIT Press, 1994.

Bucciarelli, L.L. 2002. Between thought and object in engineering design. Design Studies 23: 219-231.

Busby, J.S. 1998. The neglect of feedback in engineering design organizations. Design Studies 19: 103-117.

Busby, J.S. 2001. Error and distributed cognition in design. Design Studies 22(3): 233-254.

Cicek, J.S., P. Labossiere and D. Mann. 2013. Surveying fourth year engineering student perceptions of graduate attribute competencies. Proceedings of Canadian Engineering Education Association Conference, Montreal, QC.

Court, A.W., D.G. Ullman. and S.J. Culley. 1998. A comparison between the provision of information to engineering designers in UK and the USA. International Journal of Information Managment 18: 409-425.

Creswell, J.W., V.L. Plano Clark, M.L. Gutmann, and W.E Hanson. 2003. Advanced mixed methods research designs. In Handbook of mixed methods in social and behavioral research, eds. A. Tashakkori and C. Teddlie, 209-240. Thousand Oaks, CA: Sage Publications.Cross, N. 1981a. Design methods and learning methods. Pages 281-296 In Proceedings of the 1980 design research society conference. Design Research Society.

Cross, N., J. Naughton. and D. Walker. 1981. Design method and scientific method. Design Studies 2(4): 195–201

Cross, N. 1986. Understanding design: the lessons of design methodology. Design Methods and Theories 20(2): 409-438.

Cross, N., 1987. Anyone For Design? Participation and Performance in Designing, Pages 35-39 in proceedings of the International Congress on Planning and Design Theory: Plenary and Interdisciplinary Lectures, Boston, MA, USA, ASME.

Cross, N. and A.C. Cross. 1995. Observations of teamwork and social processes in design. Design Studies 16: 143-170.

Cross, N. 1997. Descriptive models of creative design: application to an example. Design Studies 18: 427-440.

Cross, N. 2002. Creative cognition in design: processes of exceptional designers. Pages 14-19 in Proceedings of the 4th Creativity and Cognition Conference, Association for Computing Machinery.

Cross, N. 2004. Expertise in design: an overview. Design Studies 25: 427-441.

Cross, N. 2006. Designerly ways of knowing, London, UK: Springer-Verlag,

Darke, J. 1979. Design creativity and the understanding of objects. Design Studies 1(1): 36-44

Darlington, M.J. and S.J. Culley. 2004. A model of factors influencing the design requirement. Design Studies 25: 329-350.

Deken, F., M. Aurisicchio., M. Kleinsmann. and K. Lauche. 2009. Novice-Expert Design Consultations: Findings from a Field Study. International Conference on Research into Design, ICoRD'09.

Dieter, G.E. 1983. Engineering design: a materials and processing approach. New York, New York: McGraw-Hill.

Dorner, D. 1999. Approaching design thinking research. Design Studies 20: 407-415.

Domal, V., B. Stappenbelt. and J. Trevelyan. 2008. Professional development at university: student perceptions of professional engineering practice. Proceedings of the 2008 AAEE Conference, Yeppoon, Copyright © Domal, Stappenbelt & Trevelyan.

Dorst, K. and J. Dijkhuis. 1995. Comparing paradigms for describing design activity. Design Studies 16: 261-274.

Dorst, K. and I. Reymen. 2004. Levels of expertise in design education., International Engineering and Product Design Education Conference. Delft the Netherlands.

Dym, C.L. 1994. Engineering Design: A Synthesis of Views. London, England: Cambridge University Press.

Dym, C.L. 2006. Engineering design: So much to learn. International Journal of Engineering Education 22(3): 422-428.

Eastman, C.M. 1999. Representation of design processes. Keynote address in Conference on Design Thinking, MIT.

Eckert, C.M. N. Cross. and J.H. Johnson. 2000. Intelligent support for communication in design teams: garment shape specifications in the knitwear industry. Design Studies 21: 99-112.

Eisentraut, R. 1999. Styles of problem solving and their influence on the design process. Design Studies 20: 431-437.

Engineering Accreditation Commission. Engineering Criteria 2000, 2nd ed. Baltimore, MD: Accreditation Board for Engineering and Technology, 1996.

Engineers Canada, Graduate attributes, Accreditation Criteria and Procedures 2011, Canadian Engineering Accreditation Board, Accreditation Criteria and Procedures, Section 3.1 page 12. http://www.engineerscanada.ca/files/w_Accreditation_Criteria_Procedures_2011.pdf

Eris, O. 2003. Asking Generative Design Questions: A Fundamental Cognitive Mechanism in Design Thinking, In the proceedings of the International Conference on Engineering Design, Stockholm, Sweden.

Faste, Rolf A., 2001. The human challenge in engineering design. International Journal of Engineering Design 17(4): 327-331.

Felder, R.M., D.R. Woods, J.E. Stice, and A. Rugarcia. 2000. The future of engineering education II Teaching methods that work. Chemical Engineering Education 34(1):26-39.

Fruchter, R. 2001. Dimensions of teamwork education. International Journal of Engineering Education 17: 426-430.

Gainsburg, J., C. Rodriguez-Lluesma. and D.E. Bailey. 2010. A ‘‘knowledge profile’’ of an engineering occupation: temporal patterns in the use of engineering knowledge. Engineering Studies 2(3): 197–219.

Geisler, C. 1991. Writing about the material world: Communication tasks in engineering design. Pages 128-133 in Proceedings of the International Professional Communication Conference, IEEE.

Goldschmidt, G. 1995. The designer as a team of one. Design Studies 16: 189-209.

Hales C. 1993. Managing engineering design. Harlow, UK: Longman Scientific & Technical.

Hight, T.K., L. Hornberger. and L.A. Sanchez. 1993. Toward critical thinking mechanical designers. Design Theory and Methodology 53: 189-193.

Hirsch, P.L., B.L. Shwom, C. Yarnoff, J. C. Anderson, D. M. Kelso, G. B. Olson, and J. E. Colgate, 2001. Engineering design and communication: the case for interdisciplinary collaboration. International Journal of Engineering Education 17: 342-348.

http://www.engineerscanada.ca/sites/default/files/w_Accreditation_Criteria_Procedures_2012.pdf

Ishino, Y. And Y. Jin. 2002. Acquiring engineering knowledge from design processes. Artificial Intelligence for Engineering Design, Analysis and Manufacturing 16: 73-91.

Jonassen, D., J. Strobel. and C.B. Lee. 2006. Everyday Problem Solving in Engineering: Lessons for Engineering Educators. Journal of Engineering Education: 139-151.

Jones, J.C. 1966. Design Methods Reviewed. Pages 295-310 in Gregory, S.A. (ed.), The Design Method, London: Butterworths.

Koen B.V. 2003. Discussion of the Method. London, England: Oxford University Press.

Korte, R., S. Sheppard. and W. Jordan. 2008. A Qualitative Study of the Early Work Experiences of Recent Graduates in Engineering. Proceedings of 2008 American Society for Engineering Education Conference.

Kruger, C. and N. Cross. 2006. Solution driven versus problem driven design: strategies and outcomes. Design Studies 27: 527-548.

Kurakawa, K. 2004. A scenario-driven conceptual design information model and its formation. Research in Engineering Design 15: 122-137.

Larsson, A., P. Törlind., A. Mabogunje. and A. Milne. 2002. Distributed Design Teams: Embedded One-on-One Conversations in One-to-Many. Pages 1-11 in Proceedings of the Common Ground: Design Research Society International Conference, London, UK.

Lawson, B. 1997. How designers think: the design process demystified. London, England: Architectural Press.

Linder, B., and W.C. Flowers. 2001. Integrating engineering science and design: a definition and discussion. International Journal of Engineering Education 17: 436-439.

Lloyd, P. and P. Scott. 1994. Discovering the design problem. Design Studies 15(2): 125-140.

MacDonnell, J. 1997. Descriptive models for interpreting design. Design Studies 18: 457-473.

Macmillan, S., J. Steele, S. Austin, P. Kirby, and R. Spence. 2001. Development and verification of a generic framework for conceptual design. Design Studies 22: 169-191.

Maier, A.M., C.M. Eckert and P.J. Clarkson. 2005. A meta-model for communication in engineering design. CoDesign 1(4): 243-254.

Martin, R., B. Maytham., J. Case. and D. Fraser. 2005. Engineering graduates' perceptions of how well they were prepared for work in industry. European Journal of Engineering Education 30(2): 167–180.

Milne, A., and T. Winograd. 2003. The iLoft Project: A Technologically Advanced Collaborative Design Workspace as Research Instrument. In Proceedings of the 13th Annual Intenational Conference on Engineering Design (ICED'03), Stockholm, Sweden.

Morley, I. E. and S. Pugh. 1987. The organisation of design: an interdisciplinary approach to the study of people, process and contexts. Pages 210-222 in Proceedings of the International Conference on Engineering Design. Boston, MA.

Nicolai, L.M., 1998. Viewpoint: an industry view of engineering design education. International Journal of Engineering Education 14: 7-13.

Palys, T., C. Atchison. 2008. Research Decisions Quantitative, Qualitative, and Mixed Method Approaches. Toronto, Ont: Nelson Education Ltd.

Patel, A., C.S. Nair and G. Codner. 2008. Global Accreditation for the Global Engineering Attributes: A Way Forward. Proceedings of 2008 Australasian Society for Engineering Education Conference. Yeppoon, Australia.

Pilottea, M. and D. Evangelou. 2012. Building bridges – identifying generational communication characteristics to facilitate engineering collaboration and knowledge transfer across field-practicing engineers. Engineering Studies 4(1): 79–99.

Purcell, A.T. and J.S. Gero. 1996. Design and other typed of fixation. Design Studies 17: 363-383.

Roozenburg, N. and N. Cross. 1991. Models of the design process: integrated across the disciplines. Design Studies 12(4): 215-220.

Salustri, F.A., and N.L. Eng. 2007. Design as...: Thinking about what design might be. Design Principles and Practices: An International Journal 1(1): 19-27.

Schensul, S. L., J.J. Schensul, and M.D. LeCompte. 1999. Essential Ethnographic Methods. Walnut Creek, CA.: Altamira Press.

Schunn, C. and Nelson, M. Role of Expert-Novice Studies in Educational Research. The Gale Group, http://www.education.com/reference/article/expert-novice-studies/

Sheppard, S., A. Colby., K. Macatangay. and W. Sullivan. 2006. What is Engineering Practice? International Journal of Engineering Education 22(3): 429-438.

Sivaloganathan, S., A. Jebb and H.P. Wynn. 1995. Design function deployment – a design system for the future. Design Studies 16: 447-470.

Smith, K.A. 1988. The Nature and Development of Engineering Expertise. European Journal of Engineering Education 13(3):317-330.

Sobek, II, D.K., 2002. Use of journals to evaluate student design processes. In Proceedings of the 2002 American Society for Engineering Education Annual Conference & Exposition. Montreal, QC, June 16-19.

Sonnenwald, D. H. 1996. Communication roles that support collaboration during the design process. Design Studies 17: 277-301.

Suh, Nam P. 1990. The Principles of Design, New York, New York: Oxford University Press.

Thomas, J.C. and J.M. Carroll. 1979. The psychological study of design. Design Studies 1(1): 5-11.

Trevelyan, J. P. 2007. Technical Coordination in Engineering Practice. Journal of Engineering Education: 191-204.

Trevelyan, J. P. 2008. A Framework for Understanding Engineering Practice. Paper presented at the American Society for Engineering Education Annual Conference, Pittsburgh.

Trevelyan, J. 2009a. Engineering Education Requires a Better Model of Engineering Practice. Proceedings of the Research in Engineering Education Symposium. Palm Cove, QLD.

Trevelyan, J. 2009b. Steps Toward a Better Model of Engineering Practice, James Trevelyan, Proceedings of the Research in Engineering Education Symposium. Palm Cove, QLD.

Trevelyan, J. 2010. Reconstructing engineering from practice. Engineering Studies 2(3): 175–195.

Ullman, D.G. 2001. Robust decision-making for engineering design. Journal of Engineering Design 12: 3-13.

Vincenti, Walter G. 1990. What Engineers Know and How They Know It: Analytical Studies from Aeronautical History. Baltimore: Johns Hopkins University Press.

Voland , G. 2004. Engineering by Design. Upper Saddle River, NJ: Pearson Prentice Hall.

Wallace, K.M. and C. Hales. 1987. Detailed analysis of an engineering design project. Pages 94-101 in Proceedings of the international conference on engineering design (ICED'87), Boston, Massachusetts, ASME.

Wood, W. H. 2003. Integrating social issues into design theory. International Journal of Engineering Education 19(1): 35-40.

Yilmaz, S. and C.M. Seifert. 2011. Creativity through design heuristics: a case study of expert product design. Design Studies 32: 384-415.

Zeiler, Wim., 2007. Methodical design 1972-2006: A historical overview about a design model. Design principle and practices: An International Journal 1(1): 59-68.

APPENDIX A

ASPECTS OF ENGINEERING PRACTICE

1: Managing self & career development	
apply for job	Apply for positions outside organization, register with employment agencies, maintain current resumé and portfolio of achievements.
formal training	Attend formal training courses, further education.
internal transfer	Apply for internal transfers to provide opportunities for skill improvement and work experience on particular projects or assignments.
network contacts	Networking contacts in relevant industries to act as referees or potential alternative employers.
personal research	Background research, not for immediate work needs, on technology developments, organizational and planning methods, business approaches, components and alternatives: when one type of material or component is not available which ones can be used instead, all to build personal knowledge and expertise.
promotion	Apply for promotion, provide knowledge of achievements to people who influence promotion opportunities.
time planning	Plan personal time allocation, maintain diary and appointment schedule.
trade shows & conferences	Attend trade shows, conferences, exhibitions, supplier seminars and presentations, develop knowledge of suppliers and capabilities.
2: Coordination, working with other people	
advocacy / compromise build and lead team	Advocacy for a particular technical or commercial view, setting out to change the framework in which a problem is considered. Compromise is probably essential for securing eventual agreement. Build and lead a project team. Create shared vision, objective, monitor team members, provide care for team members.
coordinate insiders, mentoring	Coordinate work of peers, subordinates and superiors. Perform technical checks on work, watch for roadblocks, may provide advice and feedback, may review technical competence, may assess training needs, provide informal training when appropriate.
coordinate outsiders	Coordinate with outside organizations such as other contractors working on same project, community organizations, etc.
coordinate with client	Liaise with client, expedite solution review and acceptance, coordinate installation, commissioning, monitor acceptance testing.
coordinate with insiders, receive mentoring	Working with more senior engineers to receive technical checks on work, receive advice and feedback, review of technical competence, assessment of training needs, informal training when appropriate.
delegate supervision	Allocate appropriate technical supervision capacity for a given activity to ensure that required performance and quality standards are measured, maintained and recorded.
delegate technical work	Allocate responsibility for technical work: balance technical expertise and experience against cost and availability, decide whether to employ additional staff or contractors etc. Select appropriate working methods and tools.
networking	Networking: develop and maintain network of contacts to help with performance of job.
organize socials	Organise recreational and social activities within organization.
report progress	Report to supervisor, team leaders, peers on project progress, solutions, financial and resource consumption. Verbal, written or in meetings.
reverse mentoring	Providing mentoring, guidance, coordination, training and supervision to more senior or experienced personnel.
review procedures	Review and develop standard organizational procedures or organizational structures.
site engineer	Coordinate and supervise work on site: ensure that work performed according to drawings and specifications, plan site work, coordinate with foremen.

supervise contractors	Coordinate and supervise work performed by contractors - ensure that work is performed according to specifications and requirements.
supervise staff	Supervise staff for which engineer has line management responsibility.
3: Engineering management processes	
assess progress	Monitor technical progress. Decide whom to contact and when, whom to believe, decide which evidence is needed to assess actual progress.
assess risks	Assess risks associated with any activity, including safety risks, commercial risks, supplier risks, early completion etc. Assess likely causes, consequences, relative importance and treatment options such as insurance, protection equipment, financial safeguards, safety warnings, training etc.
completion report	Report completion (check punch lists), prepare payment requests, prepare documentation, file test reports, installation logs.
configuration management	Configuration management (records of design documentation, changes, inventory of completed parts, stock lists etc.)
follow org'n procedures	Learn and practise standard organizational procedures (eg purchasing, tender preparation, design review, configuration management, safety risk assessment, quality measurement, quality control and quality management, etc.)
inspect work	Inspect work in progress, visit site or factory, conduct informal discussions. Also part of site engineer's work.
logistics	Plan and manage procurement, transport and storage of materials, components, and completed product, manage inventory and stock levels.
manage information	Manage internal documentation, drawings, and other information resources; maintain indexing/filing system, ensure safe storage and/or backup.
manage maintenance	Plan maintenance, condition monitoring, maintenance and asset management plan for components and systems with high failure costs and/or consequences.
manage production	Manage production capacity and resources for product delivery (product is the output of resources being managed: can be people, plant or machines or combination).
manage project plan project	Manage project: review budget and plans, time and resource estimates, progress data, resource allocation, re-plan where dependencies can be 'relaxed' (eg combining manufacture with testing, concurrent engineering etc). Plan project taking into account activity constraints (eg design completed before starting construction). Gather data such as time and resource requirements for individual activities. Perform critical path and similar analysis.
project structure	Devise appropriate structure for engineering project and/or team based on previous experience of organization and individuals involved, and the nature of technical issues likely to be encountered.
4: Financial processes	
invoicing & debt collection	Manage invoicing and debt collection, payments to contractors, maintain background knowledge on contractor financial status.
negotiate	Negotiate contract price and conditions, payment schedule, completion criteria, technical specifications, cost of changes.
negotiate internal resources	Negotiate for internal resources; prepare business case for investment: perform technical performance analysis; perform a safety/hazard risk assessment; calculate costs (labour, materials, etc.) and consumption or raw materials, fuel and energy, determine emissions and waste management costs, determine maintenance requirements and cost, perform discounted cash flow analysis, calculate internal rate of return.
predict cash flow	Predict cash flow requirements for a project, predict delivery lead times, take payment deadlines into account.

predict costs	Predict costs, prepare accurate bills of materials, reliably estimate labor, accommodation, training, equipment hire, transport, consumable material and capital equipment costs.
research regulations	Research government regulations and legislation, environmental laws, employment laws, contract law, occupational health and safety.
5: Procurement	
procurement, evaluate tenders research supplier	Evaluate tenders, quotations and specifications from contractors / suppliers, check against specification and requirements, check costs. Research, get help on component and service supplier products (reliability, quality, cost, availability, technical support capabilities), includes using network of peers for obtaining background information on suppliers or contractors.
review contract terms	Review contractual terms and conditions, both when taking on a project and when sub-contracting work for the project. Suggest changes.
6: Human resources	
evaluate performance	Evaluate job performance (both technical and non-technical aspects) of self, peers and subordinates.
provide training	Formal training for engineers, contractors, clients to perform required activities. Prepare support materials, case studies, learning plans etc.
recruit staff	Assess qualifications, knowledge, skills and experience of engineers and technical staff from resumé, curriculum vitae, referees and employment reports for a given job description. Interview engineering and technical/administrative job applicants for given job description, assess suitability.
research HR rules	Research, learn, get help on employment conditions and rules, pay rates, basic HR policies and procedures especially for subordinate staff.
7: Business development	
accreditation	Accreditation, establish pre-qualification status to enable tender participation.
analyze client requirements	Analyze client requirements, may be tender specifications and drawings, prepare preliminary technical solutions and designs, prepare preliminary bills of materials and cost estimates.
business development	Planning for new business, develop strategy for developing new types of business or retaining present direction. Plan resources for tendering.
check satisfaction	Follow-up clients to assess satisfaction with work, prepare feedback reports
influence clients	Participate in marketing and sales presentations, functions, research potential client needs, client knowledge and expertise, in relation to industry norms, visit and assist potential clients develop projects, explore potential financing options and resources for client, possibly assist client obtain finance for project work by preparing technical specifications and performance studies.
prepare tender or quote	Prepare tender bidding documents, quotations etc.
pre-position resources	Pre-position resources, contacts etc. in order to help win bids, and execute them efficiently.
proposals, brochures, presentations	Prepare proposals, brochures, presentations that can be used for marketing or business development purposes.
research client rules	Research potential/actual client-specific business rules and contract laws.
research competitors	Analyze capabilities of competitors, analyze performance of competitor in similar contracts, compare competing products.
research environment	Research government and policy changes and major players in economy to help forecast business opportunities.
8: Technical, creating new concepts, problem solving	

design	Create technical solutions to meet client needs from available resources and commercial off-the-shelf (COTS) components using specific technology expertise, design of new systems or components to meet client needs constrained by need to use available materials, production technologies and expertise.
detailing	Document details, prepare and issue technical specifications, drawings, software code, circuit layouts and designs, etc.
document	Document existing systems, components, processes, conduct tests where necessary to determine performance, material properties etc.
predict failure modes	Predict component and system failure modes and probabilities, determine consequences and costs of failure.
predict performance	Predict performance (feasibility study, technical or commercial) of solutions using modeling and simulation of proposed technical solutions and/or designs, including modeling of different business approaches. (Often much time spent on gathering information to construct models and verifying model accuracy).
programming	Create software code from specifications and outlines.
reduce costs	Reduce costs (either in design, construction, operations or maintenance) use detailed technical and business knowledge to achieve required cost reductions while minimizing performance loss.
research	Research, get help on relevant technologies, solutions, and costs in response to technical suggestions from peers, clients, contractors, superiors or subordinates (or even self).
research standards & solutions	Research, get help on applicable standards for design, test, operations, safety etc. Develop ways to exploit the 'corners' in standards to maximize performance within allowable design limits. Includes referring to previous designs or calculations.
scoping	Resolving complex technical areas into discrete areas for design work that can be performed relatively independently. May also require resolution of difficult technical problems into simpler design tasks.
sketch or outline	Prepare sketches and outline design information for technical staff (e.g. drafting staff, programmers etc.) to produce detailed designs, software, CAD models and drawings. Issue change requests.
solution for client	Develop technical or business solution that provides qualitative and quantitative satisfaction for clients.
work package instructions	Design and write instructions, construction, installation, maintenance and operating procedures and instructions, preparing work packages.
9: Technical test, inspection, measurement, review, checking	
acceptance test	Perform (or supervise) acceptance or commissioning tests on purchased (or in-house produced and/or installed) equipment, software, systems and materials, to ensure compliance with specifications.
check details	Check documents, assumptions, drawings, code, check calculations, performance specifications: are they realistic?
diagnose problem	Diagnose performance issues (may be partial or total failure, or sub-optimal or sub-specification performance), check with databases, consult experts, gather appropriate evidence, perform measurements, locate the root cause, and possibly devise alternative technical solutions.
R&D testing	Design and testing of prototypes, pilot plants, experimentation and data collection to confirm designs, resolve design problems, provide data for full-scale or production designs.
respond to query	Respond to technical, business or financial questions from peers, subordinates, sub-contractors and clients on construction, installation, maintenance and operating procedures. Suggest repair and maintenance procedures when unexpected operating conditions result in failure to achieve required results.

	review costs	Review / Check technical solutions and check costs and bills of materials (requires experience of operations, construction, commissioning, knowledge of prices etc., compromises between technical performance and cost, which technical features contribute how much to the cost, how necessary they are.)
	review design change	Review design change proposals from peers or other contractors. Prepare response detailing consequence of design changes.
	review tech solution	Review / check technical solution; check documents and specifications against design codes, design requirements and client needs, quality, safety and environmental standards etc.
	survey, measurement	Performing measurements, surveys to gather data for documentation or design.
	technical standards	Review and check technical aspects of design or techniques (especially when design has been contracted out) to ensure compliance with design standards and relevant technical specifications. Design or develop technical and quality standards for organization, monitor compliance with standards, provide training and guidance. Includes creating design procedures and/or software.
10: Hands on work		
	hands-on tech work	Hands-on technical work; production or maintenance.

Modified from Trevelyan, J. P. 2008. A Framework For Understanding Engineering Practice. Paper Presented At The American Society For Engineering Education Annual Conference, Pittsburgh.

APPENDIX B

Pre-Interview surveys

B.1 Pre-Interview Survey for Engineering in Training

Pre -interview survey for Junior Engineers:

- What is your title with Manitoba Hydro?
- How long have you had this position?
- What has your professional career path been?
  - ✓ Within Manitoba Hydro
  - ✓ Prior to Manitoba Hydro
- How long since you graduated from your engineering program?
- What would you describe your position to be?
- What are your formal duties?
- How has your role changed over the time?
- What experiences preceded your role as an engineer?
- What would you describe the role of an engineer to entail?

B.2 Pre-Interview Survey for Professional Engineer

<u>Pre -interview survey for Senior Engineers:</u>

- What is your title with Manitoba Hydro?

- How long have you had this position?

- What has your professional career path been?
    - ✓ Within Manitoba Hydro

    - ✓ Prior to Manitoba Hydro

- How long have you been a Professional Engineer?

- How many people do you supervise?

- What would you describe your position to be?

- What are your formal duties?

- How has your role changed over the years?

- What experiences preceded your role as an engineer?

- What would you describe the role of an engineer to entail?

APPENDIX C

Interview Guides for Data Collection

C.1 Interview Guide for first interviews.

The following questions and probes will guide the interview:

- Tell me something about yourself.

    What has your professional career path been?

    What experiences preceded your role as an engineer?

- Describe the typical engineering activities you undertake each day.

    How much of each day is spent working on engineering activities?

- How do you define engineering?

    What are key components of [a definition of] engineering?

- How do you understand your involvement as an engineer?

    What are your most important needs in terms of engineering?

    What is your role as an engineer?

    Describe the work you do as an engineer?

C.2 Interview Guide for second interviews.

The following questions and probes will guide the interview:

- I need to better understand how departments at Manitoba Hydro carry out their work.

    How did you learn to do your work?

    What are the resources you use to get your job done?

    What are the differences in how departments at Manitoba Hydro carry out their work?

    How do you define success in your work?

    Who do you interact with and what form do these interactions take place.

    What are engineering tasks at your level of within the organization?

    What are your expectations of your job?

    Describe a job that was not routine.

C.3 Interview Guide for third interview with Engineers in Training.

Questions for Engineers in Training on their experiences.

What I want you to think about is when you first started work, when you first came and started with Hydro, what are the first things they got you to do?

What are the jobs they gave you, or what did they ask you to do?

What type of responsibility were you given?

What areas have you seen that you're not asked to take responsibility?

Are there any areas where you can tell me where you felt really comfortable in what you were given, or uncomfortable in some of the responsibilities you were given?

What additional training have you completed?

What additional training do you feel you require?

What strengths do you feel you've brought here... You bring to Hydro, to the job?

How has your education contributed to your success in completing your job?

C.4 Interview guide for third interview with Professional Engineers.

Questions for senior engineers on experiences of junior engineers.

What would be your expectations of a newly graduating engineer in the tasks they undertake?

What would be your expectations of a newly graduating engineer in the roles they undertake?

What would be your expectations of a newly graduating engineer in the areas of responsibility assigned?

In what areas would you expect them to take a lead in getting a job done?

In what areas would you expect them to follow the lead of a mentor?

What are some of the basic strengths you see in the new graduates?

What about weaknesses?

Where would you expect them to receive additional training?

So tell me about any training programs you have for these people?

What would you not ask a new graduate to do and from a perspective they wouldn’t have the skill to do that, they wouldn’t have the knowledge or skill?

C.5 Interview guide for focus group interview with Professional Engineers.

The following questions and probes will guide the interview:

How do you decide what to do each day?
Tell me about the most demanding aspects of your position.
Which part of your job makes you work the hardest?
Over the past few years have you had to receive training on some new skills?
As a group you play different roles in the organization. What do you think are some of the similarities and differences in your roles?

What would be your expectations of a newly graduating engineer in the tasks they undertake?
What work role do you expect of a graduating engineer?
In what areas would you expect them to take a lead in getting a job done?
What skills do you consider necessary for graduating engineers?
What skills do new graduates need to learn on the job that they do not have when they graduate?
Can you provide examples?
In what areas would you expect them to receive additional training?
What are some of the strengths you have seen in new graduates?
What are some of the weaknesses you have seen in new graduates?

What did you think of the questionnaires I asked you to complete?

C.6 Interview guide for focus group interview with Engineers in Training.

The following questions and probes will guide the interview:

How do you decide what to do each day?

Tell me about the most demanding aspects of your position.

Which part of your job makes you work the hardest?

Over the past few years what training have you had on some new skills?

What is the most important or helpful training you received?

Do you regularly use the new skills for which you received training?

As a group you play different roles in the organization. What do you think are some of the similarities and differences in your roles?

How do you participate in decisions that affect the way your work is conducted?

What were your expectations when you first graduated and started the job?

How did the actual job differ from these expectations?

What skills do you consider necessary for graduating engineers?

What skills do new graduates need to learn on the job that they do not have when they graduate?

Can you provide examples?

What type of training would you suggest for a new graduate working at Hydro?

What are some of the strengths you brought to the job?

What are some of the weaknesses you brought to the job?

What did you think of the questionnaires I asked you to complete?

APPENDIX D

Follow-up questionnaires on Aspects of Engineering Practice

D.1 Questionnaire on Aspects of Engineering Practice.

Instructions: Mark each question (each row) by checking the appropriate box based on your duties in the past year. **Daily** - refers to work you would expect to be involved in on a regular basis. **Weekly** - refers to work you have been involved in but not expected as your main duties. **Monthly** - refers to work you have completed in the past, on more than one occasion, but that you see only intermittently. **Occasionally** - work that you have completed in the past year but not something you would normally be expected to complete. **Not applicable** - Refers to work you have never done or would be expected to complete. **Rank** - please rank the items under each category from the most to least likely you are involved in during your work day. (ie. 1, 2 ...) **Overall Rank** - please rank the 10 major categories from most to least importance in your current position. (ie. 1, 2, ..., 10)

Name: ____________________________		Daily	Weekly	Monthly	Occasionally	Not Applicable	Rank	Overall Rank
1: Managing self & career development								
personal research	Background research, not for immediate work needs, on technology developments, organizational and planning methods, business approaches, components and alternatives: to build personal knowledge and expertise.							
trade shows & conferences	Attend trade shows, conferences, exhibitions, supplier seminars and presentations, develop knowledge of suppliers and capabilities.							
formal training	Attend formal training courses, further education.							
network contacts	Networking contacts in relevant industries to act as referees or potential alternative employers.							
internal transfer	Apply for internal transfers to provide opportunities for skill improvement and work experience on particular projects or assignments.							

promotion	Apply for promotion, provide knowledge of achievements to people who influence promotion opportunities.						
apply for job	Apply for positions outside organization, register with employment agencies, maintain current resumé and portfolio of achievements.						
time planning	Plan personal time allocation, maintain diary and appointment schedule.						
2: Coordination, working with other people							
coordinate insiders, mentoring	Coordinate work of peers, subordinates and superiors. Perform technical checks on work, watch for roadblocks, may provide advice and feedback, may review technical competence, may assess training needs, provide informal training when appropriate.						
Coordinate with insiders, receive mentoring	Working with more senior engineers to receive technical checks on work, receive advice and feedback, review of technical competence, assessment of training needs, informal training when appropriate.						
supervise staff	Supervise staff for which engineer has line management responsibility.						
coordinate outsiders	Coordinate with outside organizations such as other contractors working on same project, community organizations, etc.						
coordinate with client	Liaise with client, expedite solution review and acceptance, coordinate installation, commissioning, monitor acceptance testing.						
advocacy / compromise	Advocacy for a particular technical or commercial view, setting out to change the framework in which a problem is considered. Compromise is probably essential for securing eventual agreement.						

site engineer	Coordinate and supervise work on site: ensure that work performed according to drawings and specifications, plan site work, coordinate with foremen.						
supervise contractors	Coordinate and supervise work performed by contractors - ensure that work is performed according to specifications and requirements.						
reverse mentoring	Providing mentoring, guidance, coordination, training and supervision to more senior or experienced personnel.						
report progress	Report to supervisor, team leaders, peers on project progress, solutions, financial and resource consumption. Verbal, written or in meetings.						
delegate technical work	Allocate responsibility for technical work: balance technical expertise and experience against cost and availability, decide whether to employ additional staff or contractors etc. Select appropriate working methods and tools.						
delegate supervision	Allocate appropriate technical supervision capacity for a given activity to ensure that required performance and quality standards are measured, maintained and recorded.						
review procedures	Review and develop standard organizational procedures or organizational structures.						
team work	Build and lead a project team. Create shared vision, objective, and work with others on a team.						
networking	Networking: develop and maintain network of contacts to help with performance of job.						
organize socials	Organise recreational and social activities within organization.						
3: Engineering management processes							

plan project	Plan project taking into account activity constraints. Gather data such as time and resource requirements for individual activities. Perform critical path and similar analysis.							
assess risks	Assess risks associated with any activity, including safety risks, commercial risks, supplier risks, early completion etc. Assess likely causes, consequences, relative importance and treatment options such as insurance, protection equipment, financial safeguards, safety warnings, training etc.							
manage project	Manage project: review budget and plans, time and resource estimates, progress data, resource allocation, re-plan where dependencies can be 'relaxed' (eg combining manufacture with testing, concurrent engineering etc).							
assess progress	Monitor technical progress. Decide whom to contact and when, whom to believe, decide which evidence is needed to assess actual progress.							
manage maintenance	Plan maintenance, condition monitoring, maintenance and asset management plan for components and systems with high failure costs and/or consequences.							
logistics	Plan and manage procurement, transport and storage of materials, components, and completed product, manage inventory and stock levels.							
manage information	Manage internal documentation, drawings, and other information resources; maintain indexing/filing system, ensure safe storage and/or backup.							

follow org'n procedures	Learn and practise standard organizational procedures (eg purchasing, tender preparation, design review, configuration management, safety risk assessment, quality measurement, quality control and quality management, etc.)						
project structure	Devise appropriate structure for engineering project and/or team based on previous experience of organization and individuals involved, and the nature of technical issues likely to be encountered.						
inspect work	Inspect work in progress, visit site or factory, conduct informal discussions. Also part of site engineer's work.						
completion report	Report completion, prepare payment requests, prepare documentation, file test reports, installation logs.						
manage production	Manage production capacity and resources for product delivery (product is the output of resources being managed: can be people, plant or machines or combination).						
configuration management	Configuration management (records of design documentation, changes, inventory of completed parts, stock lists etc.)						
4: Financial processes							
predict costs	Predict costs, prepare accurate bills of materials, reliably estimate labor, accommodation, training, equipment hire, transport, consumable material and capital equipment costs.						
predict cash flow	Predict cash flow requirements for a project, predict delivery lead times, take payment deadlines into account.						
research regulations	Research government regulations and legislation, environmental laws, employment laws, contract law, occupational health and						

	safety.						
invoicing & debt collection	Manage invoicing and debt collection, payments to contractors, maintain background knowledge on contractor financial status.						
negotiate internal resources	Negotiate for internal resources; prepare business case for investment: perform technical performance analysis; perform a safety/hazard risk assessment; calculate costs (labour, materials, etc.) determine emissions and waste management costs, determine maintenance requirements and cost, perform discounted cash flow analysis, calculate internal rate of return.						
negotiate	Negotiate contract price and conditions, payment schedule, completion criteria, technical specifications, cost of changes.						
5: Procurement							
research supplier	Research, get help on component and service supplier products (reliability, quality, cost, availability, technical support capabilities), includes using network of peers for obtaining background information on suppliers or contractors.						
procurement, evaluate tenders	Evaluate tenders, quotations and specifications from contractors / suppliers, check against specification and requirements, check costs.						
review contract terms	Review contractual terms and conditions, both when taking on a project and when sub-contracting work for the project. Suggest changes.						
6: Human resources							

research HR rules	Research, learn, get help on employment conditions and rules, pay rates, basic HR policies and procedures especially for subordinate staff.						
recruit staff	Assess qualifications, knowledge, skills and experience of engineers and technical staff from resumé for a given job description. Interview engineering and technical/administrative job applicants for given job description, assess suitability.						
provide training	Formal training for engineers, contractors, clients to perform required activities. Prepare support materials, case studies, learning plans etc.						
evaluate performance	Evaluate job performance (both technical and non-technical aspects) of self, peers and subordinates.						
7: Business development							
research competitors	Analyze capabilities of competitors, analyze performance of competitor in similar contracts, compare competing products.						
accreditation	Accreditation, establish pre-qualification status to enable tender participation.						
analyze client requirements	Analyze client requirements, may be tender specifications and drawings, prepare preliminary technical solutions and designs, prepare preliminary bills of materials and cost estimates.						
proposals, brochures, presentations	Prepare proposals, brochures, presentations that can be used for marketing or business development purposes.						

influence clients	Participate in marketing and sales presentations, functions, research potential client needs, client knowledge and expertise, in relation to industry norms, visit and assist potential clients develop projects, explore potential financing options and resources for client, possibly assist client obtain finance for project work by preparing technical specifications and performance studies.					
pre-position resources	Pre-position resources, contacts etc. in order to help win bids, and execute them efficiently.					
prepare tender or quote	Prepare tender bidding documents, quotations etc.					
research environment	Research government and policy changes and major players in economy to help forecast business opportunities.					
business development	Planning for new business, develop strategy for developing new types of business or retaining present direction. Plan resources for tendering.					
research client rules	Research potential/actual client-specific business rules and contract laws.					
check satisfaction	Follow-up clients to assess satisfaction with work, prepare feedback reports					
8: Technical, creating new concepts, problem solving						
document	Document existing systems, components, processes, conduct tests where necessary to determine performance, material properties etc.					

design	Create technical solutions to meet client needs from available resources and commercial off-the-shelf (COTS) components using specific technology expertise, design of new systems or components to meet client needs constrained by need to use available materials, production technologies and expertise.						
scoping	Resolving complex technical areas into discrete areas for design work that can be performed relatively independently. May also require resolution of difficult technical problems into simpler design tasks.						
detailing	Document details, prepare and issue technical specifications, drawings, software code, circuit layouts and designs, etc.						
programming	Create software code from specifications and outlines. Work with programming and software.						
sketch or outline	Prepare sketches and outline design information for technical staff (e.g. drafting staff, programmers etc.) to produce detailed designs, software, CAD models and drawings. Issue change requests.						
research	Research, get help on relevant technologies, solutions, and costs in response to technical suggestions from peers, clients, contractors, superiors or subordinates (or even self).						
research standards & solutions	Research, get help on applicable standards for design, test, operations, safety etc. Develop ways to exploit the 'corners' in standards to maximize performance within allowable design limits. Includes referring to previous designs or calculations.						
predict failure modes	Predict component and system failure modes and probabilities, determine consequences and costs of failure.						

predict performance	Predict performance (feasibility study, technical or commercial) of solutions using modeling and simulation of proposed technical solutions and/or designs, including modeling of different business approaches. (Often much time spent on gathering information to construct models and verifying model accuracy).				
work package instructions	Design and write instructions, construction, installation, maintenance and operating procedures and instructions, preparing work packages.				
reduce costs	Reduce costs (either in design, construction, operations or maintenance) use detailed technical and business knowledge to achieve required cost reductions while minimizing performance loss.				
solution for client	Develop technical or business solution that provides qualitative and quantitative satisfaction for clients.				
9: Technical test, inspection, measurement, review, checking					
survey, measurement	Performing measurements, surveys to gather data for documentation or design.				
acceptance test	Perform (or supervise) acceptance or commissioning tests on purchased (or in-house produced and/or installed) equipment, software, systems and materials, to ensure compliance with specifications.				
diagnose problem	Diagnose performance issues (may be partial or total failure, or sub-optimal or sub-specification performance), check with databases, consult experts, gather appropriate evidence, perform measurements, locate the root cause, and possibly devise alternative technical solutions.				

R&D testing	Design and testing of prototypes, pilot plants, experimentation and data collection to confirm designs, resolve design problems, provide data for full-scale or production designs.						
review tech solution	Review / check technical solution; check documents and specifications against design codes, design requirements and client needs, quality, safety and environmental standards etc.						
check details	Check documents, assumptions, drawings, code, check calculations, performance specifications: are they realistic?						
review design change	Review design change proposals from peers or other contractors. Prepare response detailing consequence of design changes.						
review costs	Review / Check technical solutions and check costs and bills of materials (requires experience of operations, construction, commissioning, knowledge of prices etc., compromises between technical performance and cost, which technical features contribute how much to the cost, how necessary they are.)						
respond to query	Respond to technical, business or financial questions from peers, subordinates, sub-contractors and clients on construction, installation, maintenance and operating procedures. Suggest repair and maintenance procedures when unexpected operating conditions result in failure to achieve required results.						

	technical standards	Review and check technical aspects of design or techniques (especially when design has been contracted out) to ensure compliance with design standards and relevant technical specifications. Design or develop technical and quality standards for organization, monitor compliance with standards, provide training and guidance. Includes creating design procedures and/or software.						
10: Hands on work								
	hands-on tech work	Hands-on technical work; production or maintenance.						

Adapted from Trevelyan, J. P. 2008. A Framework for Understanding Engineering Practice. Paper Presented At The American Society For Engineering Education Annual Conference, Pittsburgh.

APPENDIX E

Follow-up questionnaires on Graduate Attributes

D.1 Engineer in Training Questionnaire on Graduate attributes.

Educational Knowledge Questionnaire

Preamble

As a conclusion to my research into how engineering education has contributed to your success in the workplace I would like to ask you to fill out the following survey.

The new Canadian engineering accreditation system requires that institutions demonstrate that their students possess 12 specific attributes upon graduation. My research study is to determine how these attributes fit into the work experience of a new graduate and the learning experiences after graduation. Attributes are measured by indicators, which are the skills and abilities associated with each attribute. Each of the twelve graduate attributes is described according to the six levels of Bloom's Taxonomy of Knowledge:
1-Knowledge, 2-Comprehension, 3-Application, 4-Analysis, 5-Synthesis, and 6-Evaluation.
Initially I would ask you to please consider each indicator carefully and check the box that most closely describes your experience at the completion of your engineering education under the heading labeled "University Graduation". At a second level I would like you to consider each indicator carefully and check the box that most closely describes the level you feel would have been the most appropriate to the level of work you have been asked to complete under the heading labeled "Work Environment".

Instructions:

Under the heading "University Graduation" for each indicator, check the appropriate box.
The "o" indicates that the skill/ability was not developed within the Engineering curriculum.
The "+" indicates that the skill/ability was introduced within the Engineering curriculum, but the coverage was insufficient for it to be mastered.
The "++" indicates that the skill/ability was covered in sufficient depth within the Engineering curriculum that it could be mastered.

Please remember that "the curriculum" includes: lectures, laboratories, tutorials, assignments, midterms, exams, projects, and tours. If coverage was related to an extra-curricular activity, co-op work experience, or summer work experience that is separate from the curriculum, please indicate in the "additional" column.

Under the heading "Work Environment" for each indicator, check the appropriate box.
The "o" indicates that the skill/ability was not used in any of the work I have been asked to complete.
The "+" indicates that the skill/ability was used but I needed support or additional training when completing these tasks.
The "++" indicates that the skill/ability was used in my work and felt comfortable completing these tasks.

Please remember that as you answer these questions I want you to consider the work you have completed from the time you graduated with your engineering degree and started your position within the organization. Remember that even though the questions are related to your learning experience in university, I want you to relate that skill/ability to the tasks you are completing at the workplace.

1. A knowledge base for engineering: Demonstrated competence in university level mathematics, natural sciences, engineering fundamentals, and specialized engineering knowledge appropriate to the program.

		University Graduation				Work Environment		
Bloom's Taxonomy Level	**Indicator**	**o**	+	++	**Additional**	**o**	+	++
1	Ability to recall/select/describe/ identify/recognize the appropriate engineering formula and reproduce/repeat well-structured textbook problems on homework, tests and exams.							
2	Ability to describe the underlying physical principles and/or assumptions behind engineering formulae.							
3	Ability to select and apply the appropriate engineering formula and solve well-structured textbook problems.							
4	Ability to analyze/calculate/model algebraic relations derived from simple expressions, which describe relationships or expected theoretical trends.							
5	Ability to construct/devise/ formulate/generate more complex equations and/or algebraic expressions by combining principles learned in more than one subject area.							
6	Ability to compare analytical results with either experimental or numerical results and evaluate the applicability and accuracy of the analytical results.							

2. Problem analysis: An ability to use appropriate knowledge and skills to identify, formulate, analyze, and solve complex engineering problems in order to reach substantiated conclusions.

		University Graduation				Work Environment		
Bloom's Taxonomy Level	**Indicator**	**o**	**+**	**++**	**Additional**	**o**	**+**	**++**
1	Ability to identify classes of problems and recall key equations and procedures used in their solutions.							
2	Ability to describe the problem applicability of engineering formulae and the corresponding underlying assumptions and limitations.							
3	Ability to identify, organize and solve problems based on available information, and check conclusions against objectives.							
4	When solving complex engineering problems, able to make valid assumptions and grounded approximations, clarify objectives, and appraise and analyze solutions.							
5	Ability to assemble information and resources, and combine scientific and engineering principles to formulate models of processes and systems.							
6	Ability to evaluate validity and reliability of models/results as well as information and resources.							

3. Investigation: An ability to conduct investigations of complex problems by methods that include appropriate experiments, analysis and interpretation of data and synthesis of information in order to reach valid conclusions.

		University Graduation				Work Environment		
Bloom's Taxonomy Level	**Indicator**	**o**	+	++	**Additional**	**o**	+	++
1	Ability to recognize the characteristics of experimental investigations and theory. Can label machinery and instruments.							
2	Ability to explain the characteristics of, and distinguish between experimental investigations and theory. Can describe how machinery and instruments operate.							
3	Ability to understand and operate machinery and instruments in a competent manner. Ability to collect raw data following standard laboratory/experimental protocols that ensure their traceability, and ability to use the collected data to illustrate/compute a desired property based on established fundamentals.							
4	Ability to analyze/examine/infer/question mathematical relationships, conduct error analysis in measurement and instrumentation and test hypothesis.							
5	Ability to draw on knowledge from outside the discipline and synthesize information to make decisions when conducting investigations, develop mathematical relationships and reach valid conclusions.							
6	Ability to choose/select solutions that achieve system requirements and specifications and defend/justify effectiveness of solutions in terms of practicality and constructability. Ability to predict outcomes and demonstrate multiple interpretations of the data.							

4. Design: An ability to design solutions for complex, open-ended engineering problems and to design systems, components or processes that meet specified needs with appropriate attention to health and safety risks, applicable standards, and economic, environmental, cultural and societal considerations.

		University Graduation				Work Environment		
Bloom's Taxonomy Level	**Indicator**	**o**	+	++	**Additional**	**o**	+	++
1	Ability to list the steps and tools used in the design decision-making process.							
2	Ability to explain the design process including the importance of needs, specifications, concept generation, selection and evaluation. Can describe the presented problem using engineering principles consistent with information and constraints.							
3	Ability to use a convergent decision-making and a systematic evaluation protocol to produce a suitable solution to an open-ended problem. Ability to demonstrate the process by which the project outcome will be reproducible and manufactured in a reliable, responsible and efficient manner.							
4	Ability to use a formal methodology to test a proposed solution in the full context of its application to ensure that all stakeholders' needs and product specifications are satisfied. Ability to compare the design solution against the functional specifications, standards and codes.							
5	Ability to summarize and explain competing values in the decision-making process.							
6	Ability to assess possibilities for further improvement and conduct design reviews to evaluate performance of the overall process.							

5. Use of engineering tools: An ability to create, select, apply, adapt, and extend appropriate techniques, resources, and modern engineering tools to a range of engineering activities, from simple to complex, with an understanding of the associated limitations.

		University Graduation				Work Environment		
Bloom's Taxonomy Level	**Indicator**	**o**	+	++	**Additional**	**o**	+	++
1	Ability to describe appropriate measurement devices, testing methodologies or techniques to accomplish a task.							
2	Ability to explain the principles behind and applicability of measurement devices, testing methodologies or techniques.							
3	Ability to implement/employ relevant techniques, tools and protocols/technology to apply to a range of engineering activities and in the solution of engineering problems. Ability to produce simple tools (sensory, software, etc.).							
4	Ability to analyze/appraise/examine the accuracy and limitations of tools (apparatus or techniques) and assumptions inherent in their use.							
5	Ability to combine the use of techniques, resources and tools to optimize results.							
6	Ability to evaluate techniques, skills, and tools, assess their strengths and limitations with respect to the project needs, and justify decisions.							

6. Individual and team work: An ability to work effectively as a member and leader in teams, preferably in a multi-disciplinary setting.

		University Graduation				Work Environment		
Bloom's Taxonomy Level	**Indicator**	**o**	**+**	**++**	**Additional**	**o**	**+**	**++**
1	Ability to recognize the importance of responsible individual and teamwork.							
2	Ability to recognize a variety of learning and working preferences, and cultural values in individuals and teams. Ability to understand the importance of organizational behaviors and the need to be consistent with and adapt to organizational and professional values.							
3	Ability to actively participate in team meetings and collaborate with others to achieve agreed upon goals. Ability to demonstrate self-direction, manage own time, and proceed effectively and responsibly to achieve personal and team goals.							
4	Ability to examine and question impact of own/others' contributions to group work. Ability to discriminate constructive from unconstructive criticism; ability to point out mentorship opportunities.							
5	Ability to arrange/develop/design mentorship opportunities. Ability to create initiatives and develop capacity for technical or team leadership while respecting others' roles. Ability to integrate engineering with other professional inputs on multidisciplinary teams to achieve project goals.							
6	Ability to assess/evaluate team effectiveness and justify status quo/argue for improvements. Can apply principles of conflict management to resolve team conflicts. Ability to choose diplomacy.							

7. Communication skills: An ability to communicate complex engineering concepts within the profession and with society at large. Such ability includes reading, writing, speaking and listening, and the ability to comprehend and write effective reports and design documentation, and to give and effectively respond to clear instructions.

		University Graduation				Work Environment		
Bloom's Taxonomy Level	**Indicator**	**o**	+	++	**Additional**	**o**	+	++
1	Ability to identify standard written, spoken, and visual expressions/formats and conventions; ability to recall and reproduce standard written, spoken, and visual conventions (grammar and mechanics).							
2	Ability to read, listen and view technical and non-technical instructions and responds conventionally/appropriately. Ability to identify and explain standard formats and conventions in written, spoken, and visual/graphical expressions (drawings, plots, legends).							
3	Ability to produce and paraphrase written, spoken or visual documents with appropriate format, content, organization, style and mechanics for a variety of audiences. Ability to effectively integrate clear and appropriate illustrations to complement texts or presentations. Ability to use proper documentation.							
4	Ability to critique written, spoken or visual documents for appropriate format, content, organization, style, mechanics and documentation for a variety of audiences. Ability to examine use of illustrations to complement texts or presentations.							
5	Ability to assemble and combine information and viewpoints from other sources when creating written, spoken or visual texts.							
6	Ability to critically evaluate the work of others. Ability to explain and interpret written, spoken and visual texts for various audiences. Ability to predict and explain audiences' reactions to written, spoken and visual texts.							

8. Professionalism: An understanding of the roles and responsibilities of the professional engineer in society, especially the primary role of protection of the public and the public interest.

		University Graduation				Work Environment		
Bloom's Taxonomy Level	**Indicator**	**o**	+	++	**Additional**	**o**	+	++
1	Ability to identify the roles and responsibilities of professional engineers, especially the protection of public health and safety.							
2a	Ability to explain the professional role of engineers in society, including protection of the public and the public interest. Ability to understand there are legal requirements governing engineering activities and personnel, health, safety, and risk issues to consider.							
2b	Ability to understand the expected professional behavior of engineers, including the importance of etiquette, appropriate communication, punctuality, and on-time delivery of work. Ability to recognize the importance of ethics and equity.							
3a	Ability to demonstrate professional engineering conduct, including the practice to protect the public and ability to operate under the understanding of the legal requirements governing engineering activities and personnel, health, safety, and risk issues.							
3b	Ability to demonstrate appropriate/professional behavior and communication, including punctuality and on-time delivery of work. Is guided by ethics and equity.							
4	Ability to calculate public interest considerations, codes and standards in decision-making and analyzes risks and safety concerns.							
5	Ability to design protocols and procedures to minimize risks to the public in engineering practices and projects.							
6	Ability to anticipate and evaluate risks associated with engineering projects, including technical risks and risks in relation to clients, the public and the public interest.							

9. Impact of engineering on society and the environment: An ability to analyze social and environmental aspects of engineering activities. Such ability includes an understanding of the interactions that engineering has with the economic, social, health, safety, legal, and cultural aspects of sustainable design and development and environmental stewardship.

		University Graduation				Work Environment		
Bloom's Taxonomy Level	**Indicator**	**o**	+	++	**Additional**	**o**	+	++
1	Ability to describe earth systems and recognize the relationship between human activity and earth systems.							
2	Ability to recognize the effects of human activities on earth systems and identify the types of approaches required for sustainable design, development and environmental stewardship.							
3	Ability to consider economic, social, and environmental factors in decision-making. Ability to make decisions that demonstrate sustainable design, development and environmental stewardship.							
4	Ability to analyze social and environmental aspects of engineering activities. Ability to examine the interactions between engineering and the economic, social, health, safety, legal, and cultural aspects of sustainable design, development and environmental stewardship.							
5	Ability to summarize/explain and develop/create/construct interactions between technical systems and economic, social, health, safety, legal, and cultural aspects of sustainable design, development and environmental stewardship.							
6	Ability to evaluate management techniques and engineering activities. Ability to defend the economic, social, health, safety, legal, and cultural aspects of sustainable design, development and environmental stewardship.							

10. Ethics and equity: An ability to apply professional ethics, accountability, and equity.

		University Graduation				Work Environment		
Bloom's Taxonomy Level	**Indicator**	**o**	+	++	**Additional**	**o**	+	++
1	Ability to identify items from the university and professional codes of conduct.							
2	Ability to distinguish academic and professional ethical issues and describe how they affect individuals, stakeholders, companies and the public.							
3	Ability to use a professional code of ethics in decision-making. Ability to use information to act ethically, legally and equitably. Ability to adhere to guidelines dictating use of intellectual property and contractual issues.							
4	Ability to analyze ethical issues and examine how they affect individuals, stakeholders, companies and the public. Ability to illustrate the consequences of deviating from university/professional codes of conduct.							
5	Ability to categorize/explain professional ethics, accountability and equity, and construct/design/formulate engineering plans that take ethical risk components into account.							
6	Ability to critically evaluate ethical decisions and information for authority, currency, accuracy, reliability, validity and objectivity. Ability to defend judgments on ethical, social, equitable and legal issues including open access, privacy, intellectual property, etc.							

11. Economics and project management: An ability to appropriately incorporate economics and business practices including project, risk and change management into the practice of engineering and to understand their limitations.

		University Graduation				Work Environment		
Bloom's Taxonomy Level	**Indicator**	**o**	+	++	**Additional**	**o**	+	++
1	Ability to identify the role of economic and business practices in engineering.							
2	Ability to understand and explain an engineer's role in structured and economic decision-making; understands intellectual property.							
3a	**Project Management**: Ability to establish appropriate project scope based on consultation with client and available resources. Ability to map out project with clear milestones and budget and apply appropriate project management tools.							
3b	**Economics**: Ability to apply basic economic principles in decision-making, including one-time and recurring costs and return on investments. Ability to incorporate sustainability in project constraints and apply economic tools in engineering analysis.							
4	Ability to identify and analyze economic and managerial threats to project success. Ability to distinguish risks from threats and identify ways to reduce risk. Ability to calculate limitations.							
5	Ability to create a management structure for a multidisciplinary team that integrates engineering with other professional inputs and design a management plan with sound economic practices to achieve project goals. Ability to explain limitations.							
6	Ability to evaluate economics and business practices including project, risk and change management in the practice of engineering.							

12. Life-long learning: An ability to identify and to address their own educational needs in a changing world in ways sufficient to maintain their competence and to allow them to contribute to the advancement of knowledge.

		University Graduation				Work Environment		
Bloom's Taxonomy Level	**Indicator**	**o**	+	++	**Additional**	**o**	+	++
1	Ability to describe connections between past engineering experience and the future. Ability to recognize responsibility for own learning.							
2	Ability to understand the dynamic nature of engineering knowledge and continuous advancement of engineering technology. Ability to identify personal learning needs or knowledge gaps.							
3	Ability to describe/discover own learning style and use resources and activities to address own learning needs. Ability to employ steps in information gathering including those outside engineering discipline.							
4	Ability to analyze own information/learning needs or knowledge gaps to select optimal resources. Ability to analyze information from a variety of sources and makes accurate use of them. Ability to identify resources and professional associations that address own ongoing professional development.							
5	Ability to create learning opportunities and manage own educational needs in changing circumstances. Ability to synthesize information from a variety of sources to advance own knowledge. Ability to arrange participation in professional associations that address own professional development.							
6	Ability to critically evaluate own learning efficacy. Ability to appraise procured information for authority, currency, accuracy, reliability, validity and objectivity.							

From your perspective, rank the graduate attributes in order of strongest in your engineering education and the most important to your employment.

Graduate Attribute	Strongest in my engineering education	Most important to my employment
Knowledge base for engineering		
Problem analysis		
Investigation		
Design		
Use of engineering tools		
Individual and team work		
Communication skills		
Professionalism		
Impact of engineering on society and the environment		
Ethics and equity		
Economics and project management		
Lifelong learning		

D.2 Professional Engineer Questionnaire on Graduate attributes.

Educational Knowledge Questionnaire

Preamble

As a conclusion to my research into how your engineering education has contributed to success in the workplace I would like to ask you to fill out the following survey.

The new Canadian engineering accreditation system requires that institutions demonstrate that their students possess 12 specific attributes upon graduation. My research study is to determine how these attributes fit into the work experience of a new graduate and the learning experiences after graduation. Attributes are measured by indicators, which are the skills and abilities associated with each attribute. Each of the twelve graduate attributes is described according to the six levels of Bloom's Taxonomy of Knowledge:
1-Knowledge, 2-Comprehension, 3-Application, 4-Analysis, 5-Synthesis, and 6-Evaluation.
Initially I would ask you to please consider each indicator carefully and check the box that most closely describes the level you would consider new graduates are entering the workplace under the heading labeled "University Graduation". At a second level I would like you to consider each indicator carefully and check the box that most closely describes the level you feel would be the most appropriate for a new graduate at the time of entry to the workplace under the heading labeled "Work Environment".

Instructions:

Under the heading "University Graduation" for each indicator, check the appropriate box.
The "o" indicates that the skill/ability was not evident in the new Engineering graduate.
The "+" indicates that the skill/ability was evident in the new Engineering graduate, but that they had not yet mastered the skill or needed additional support and training.
The "++" indicates that the skill/ability was evident in the new Engineering graduate and they could readily use the skill in the workplace.

Please remember that I would like you to only consider new graduates with which you have had personal experience.

Under the heading "Work Environment" for each indicator, check the appropriate box.
The "o" indicates that the skill/ability would not be expected to be used by a new engineering graduate.
The "+" indicates that the skill/ability would be expected to be used by a new engineering graduate with additional training or support.
The "++" indicates that the skill/ability would be expected to be used readily by a new engineering graduate.

Please remember that as you answer these questions I want you to consider the work that would be expected by any new engineering graduate.

1. A knowledge base for engineering: Demonstrated competence in university level mathematics, natural sciences, engineering fundamentals, and specialized engineering knowledge appropriate to the program.

		University Graduation				Work Environment		
Bloom's Taxonomy Level	**Indicator**	**o**	+	++	**Additional**	**o**	+	++
1	Ability to recall/select/describe/ identify/recognize the appropriate engineering formula and reproduce/repeat well-structured textbook problems on homework, tests and exams.							
2	Ability to describe the underlying physical principles and/or assumptions behind engineering formulae.							
3	Ability to select and apply the appropriate engineering formula and solve well-structured textbook problems.							
4	Ability to analyze/calculate/model algebraic relations derived from simple expressions, which describe relationships or expected theoretical trends.							
5	Ability to construct/devise/ formulate/generate more complex equations and/or algebraic expressions by combining principles learned in more than one subject area.							
6	Ability to compare analytical results with either experimental or numerical results and evaluate the applicability and accuracy of the analytical results.							

2. Problem analysis: An ability to use appropriate knowledge and skills to identify, formulate, analyze, and solve complex engineering problems in order to reach substantiated conclusions.

		University Graduation				Work Environment		
Bloom's Taxonomy Level	**Indicator**	**o**	+	++	**Additional**	**o**	+	++
1	Ability to identify classes of problems and recall key equations and procedures used in their solutions.							
2	Ability to describe the problem applicability of engineering formulae and the corresponding underlying assumptions and limitations.							
3	Ability to identify, organize and solve problems based on available information, and check conclusions against objectives.							
4	When solving complex engineering problems, able to make valid assumptions and grounded approximations, clarify objectives, and appraise and analyze solutions.							
5	Ability to assemble information and resources, and combine scientific and engineering principles to formulate models of processes and systems.							
6	Ability to evaluate validity and reliability of models/results as well as information and resources.							

3. Investigation: An ability to conduct investigations of complex problems by methods that include appropriate experiments, analysis and interpretation of data and synthesis of information in order to reach valid conclusions.

		University Graduation				Work Environment		
Bloom's Taxonomy Level	**Indicator**	**o**	+	++	**Additional**	**o**	+	++
1	Ability to recognize the characteristics of experimental investigations and theory. Can label machinery and instruments.							
2	Ability to explain the characteristics of, and distinguish between experimental investigations and theory. Can describe how machinery and instruments operate.							
3	Ability to understand and operate machinery and instruments in a competent manner. Ability to collect raw data following standard laboratory/experimental protocols that ensure their traceability, and ability to use the collected data to illustrate/compute a desired property based on established fundamentals.							
4	Ability to analyze/examine/infer/question mathematical relationships, conduct error analysis in measurement and instrumentation and test hypothesis.							
5	Ability to draw on knowledge from outside the discipline and synthesize information to make decisions when conducting investigations, develop mathematical relationships and reach valid conclusions.							
6	Ability to choose/select solutions that achieve system requirements and specifications and defend/justify effectiveness of solutions in terms of practicality and constructability. Ability to predict outcomes and demonstrate multiple interpretations of the data.							

4. Design: An ability to design solutions for complex, open-ended engineering problems and to design systems, components or processes that meet specified needs with appropriate attention to health and safety risks, applicable standards, and economic, environmental, cultural and societal considerations.

		University Graduation				**Work Environment**		
Bloom's Taxonomy Level	**Indicator**	**o**	+	++	**Additional**	**o**	+	++
1	Ability to list the steps and tools used in the design decision- making process.							
2	Ability to explain the design process including the importance of needs, specifications, concept generation, selection and evaluation. Can describe the presented problem using engineering principles consistent with information and constraints.							
3	Ability to use a convergent decision-making and a systematic evaluation protocol to produce a suitable solution to an open-ended problem. Ability to demonstrate the process by which the project outcome will be reproducible and manufactured in a reliable, responsible and efficient manner.							
4	Ability to use a formal methodology to test a proposed solution in the full context of its application to ensure that all stakeholders' needs and product specifications are satisfied. Ability to compare the design solution against the functional specifications, standards and codes.							
5	Ability to summarize and explain competing values in the decision-making process.							
6	Ability to assess possibilities for further improvement and conduct design reviews to evaluate performance of the overall process.							

5. Use of engineering tools: An ability to create, select, apply, adapt, and extend appropriate techniques, resources, and modern engineering tools to a range of engineering activities, from simple to complex, with an understanding of the associated limitations.

		University Graduation				Work Environment		
Bloom's Taxonomy Level	**Indicator**	**o**	+	++	**Additional**	**o**	+	++
1	Ability to describe appropriate measurement devices, testing methodologies or techniques to accomplish a task.							
2	Ability to explain the principles behind and applicability of measurement devices, testing methodologies or techniques.							
3	Ability to implement/employ relevant techniques, tools and protocols/technology to apply to a range of engineering activities and in the solution of engineering problems. Ability to produce simple tools (sensory, software, etc.).							
4	Ability to analyze/appraise/examine the accuracy and limitations of tools (apparatus or techniques) and assumptions inherent in their use.							
5	Ability to combine the use of techniques, resources and tools to optimize results.							
6	Ability to evaluate techniques, skills, and tools, assess their strengths and limitations with respect to the project needs, and justify decisions.							

6. Individual and team work: An ability to work effectively as a member and leader in teams, preferably in a multi-disciplinary setting.

		University Graduation				Work Environment		
Bloom's Taxonomy Level	**Indicator**	**o**	+	++	**Additional**	**o**	+	++
1	Ability to recognize the importance of responsible individual and teamwork.							
2	Ability to recognize a variety of learning and working preferences, and cultural values in individuals and teams. Ability to understand the importance of organizational behaviors and the need to be consistent with and adapt to organizational and professional values.							
3	Ability to actively participate in team meetings and collaborate with others to achieve agreed upon goals. Ability to demonstrate self-direction, manage own time, and proceed effectively and responsibly to achieve personal and team goals.							
4	Ability to examine and question impact of own/others' contributions to group work. Ability to discriminate constructive from unconstructive criticism; ability to point out mentorship opportunities.							
5	Ability to arrange/develop/design mentorship opportunities. Ability to create initiatives and develop capacity for technical or team leadership while respecting others' roles. Ability to integrate engineering with other professional inputs on multidisciplinary teams to achieve project goals.							
6	Ability to assess/evaluate team effectiveness and justify status quo/argue for improvements. Can apply principles of conflict management to resolve team conflicts. Ability to choose diplomacy.							

7. Communication skills: An ability to communicate complex engineering concepts within the profession and with society at large. Such ability includes reading, writing, speaking and listening, and the ability to comprehend and write effective reports and design documentation, and to give and effectively respond to clear instructions.

		University Graduation				Work Environment		
Bloom's Taxonomy Level	**Indicator**	**o**	+	++	**Additional**	**o**	+	++
1	Ability to identify standard written, spoken, and visual expressions/formats and conventions; ability to recall and reproduce standard written, spoken, and visual conventions (grammar and mechanics).							
2	Ability to read, listen and view technical and non-technical instructions and responds conventionally/appropriately. Ability to identify and explain standard formats and conventions in written, spoken, and visual/graphical expressions (drawings, plots, legends).							
3	Ability to produce and paraphrase written, spoken or visual documents with appropriate format, content, organization, style and mechanics for a variety of audiences. Ability to effectively integrate clear and appropriate illustrations to complement texts or presentations. Ability to use proper documentation.							
4	Ability to critique written, spoken or visual documents for appropriate format, content, organization, style, mechanics and documentation for a variety of audiences. Ability to examine use of illustrations to complement texts or presentations.							
5	Ability to assemble and combine information and viewpoints from other sources when creating written, spoken or visual texts.							
6	Ability to critically evaluate the work of others. Ability to explain and interpret written, spoken and visual texts for various audiences. Ability to predict and explain audiences' reactions to written, spoken and visual texts.							

8. Professionalism: An understanding of the roles and responsibilities of the professional engineer in society, especially the primary role of protection of the public and the public interest.

		University Graduation				Work Environment		
Bloom's Taxonomy Level	**Indicator**	**o**	+	++	**Additional**	**o**	+	++
1	Ability to identify the roles and responsibilities of professional engineers, especially the protection of public health and safety.							
2a	Ability to explain the professional role of engineers in society, including protection of the public and the public interest. Ability to understand there are legal requirements governing engineering activities and personnel, health, safety, and risk issues to consider.							
2b	Ability to understand the expected professional behavior of engineers, including the importance of etiquette, appropriate communication, punctuality, and on-time delivery of work. Ability to recognize the importance of ethics and equity.							
3a	Ability to demonstrate professional engineering conduct, including the practice to protect the public and ability to operate under the understanding of the legal requirements governing engineering activities and personnel, health, safety, and risk issues.							
3b	Ability to demonstrate appropriate/professional behavior and communication, including punctuality and on-time delivery of work. Is guided by ethics and equity.							
4	Ability to calculate public interest considerations, codes and standards in decision-making and analyzes risks and safety concerns.							
5	Ability to design protocols and procedures to minimize risks to the public in engineering practices and projects.							
6	Ability to anticipate and evaluate risks associated with engineering projects, including technical risks and risks in relation to clients, the public and the public interest.							

9. Impact of engineering on society and the environment: An ability to analyze social and environmental aspects of engineering activities. Such ability includes an understanding of the interactions that engineering has with the economic, social, health, safety, legal, and cultural aspects of sustainable design and development and environmental stewardship.

		University Graduation				Work Environment		
Bloom's Taxonomy Level	**Indicator**	**o**	**+**	**++**	**Additional**	**o**	**+**	**++**
1	Ability to describe earth systems and recognize the relationship between human activity and earth systems.							
2	Ability to recognize the effects of human activities on earth systems and identify the types of approaches required for sustainable design, development and environmental stewardship.							
3	Ability to consider economic, social, and environmental factors in decision-making. Ability to make decisions that demonstrate sustainable design, development and environmental stewardship.							
4	Ability to analyze social and environmental aspects of engineering activities. Ability to examine the interactions between engineering and the economic, social, health, safety, legal, and cultural aspects of sustainable design, development and environmental stewardship.							
5	Ability to summarize/explain and develop/create/construct interactions between technical systems and economic, social, health, safety, legal, and cultural aspects of sustainable design, development and environmental stewardship.							
6	Ability to evaluate management techniques and engineering activities. Ability to defend the economic, social, health, safety, legal, and cultural aspects of sustainable design, development and environmental stewardship.							

10. Ethics and equity: An ability to apply professional ethics, accountability, and equity.

		University Graduation				Work Environment		
Bloom's Taxonomy Level	**Indicator**	**o**	+	++	**Additional**	**o**	+	++
1	Ability to identify items from the university and professional codes of conduct.							
2	Ability to distinguish academic and professional ethical issues and describe how they affect individuals, stakeholders, companies and the public.							
3	Ability to use a professional code of ethics in decision-making. Ability to use information to act ethically, legally and equitably. Ability to adhere to guidelines dictating use of intellectual property and contractual issues.							
4	Ability to analyze ethical issues and examine how they affect individuals, stakeholders, companies and the public. Ability to illustrate the consequences of deviating from university/professional codes of conduct.							
5	Ability to categorize/explain professional ethics, accountability and equity, and construct/design/formulate engineering plans that take ethical risk components into account.							
6	Ability to critically evaluate ethical decisions and information for authority, currency, accuracy, reliability, validity and objectivity. Ability to defend judgments on ethical, social, equitable and legal issues including open access, privacy, intellectual property, etc.							

11. Economics and project management: An ability to appropriately incorporate economics and business practices including project, risk and change management into the practice of engineering and to understand their limitations.

		University Graduation				Work Environment		
Bloom's Taxonomy Level	**Indicator**	**o**	+	++	**Additional**	**o**	+	++
1	Ability to identify the role of economic and business practices in engineering.							
2	Ability to understand and explain an engineer's role in structured and economic decision-making; understands intellectual property.							
3a	**Project Management**: Ability to establish appropriate project scope based on consultation with client and available resources. Ability to map out project with clear milestones and budget and apply appropriate project management tools.							
3b	**Economics**: Ability to apply basic economic principles in decision-making, including one-time and recurring costs and return on investments. Ability to incorporate sustainability in project constraints and apply economic tools in engineering analysis.							
4	Ability to identify and analyze economic and managerial threats to project success. Ability to distinguish risks from threats and identify ways to reduce risk. Ability to calculate limitations.							
5	Ability to create a management structure for a multidisciplinary team that integrates engineering with other professional inputs and design a management plan with sound economic practices to achieve project goals. Ability to explain limitations.							
6	Ability to evaluate economics and business practices including project, risk and change management in the practice of engineering.							

12. Life-long learning: An ability to identify and to address their own educational needs in a changing world in ways sufficient to maintain their competence and to allow them to contribute to the advancement of knowledge.

		University Graduation				Work Environment		
Bloom's Taxonomy Level	**Indicator**	**o**	+	++	**Additional**	**o**	+	++
1	Ability to describe connections between past engineering experience and the future. Ability to recognize responsibility for own learning.							
2	Ability to understand the dynamic nature of engineering knowledge and continuous advancement of engineering technology. Ability to identify personal learning needs or knowledge gaps.							
3	Ability to describe/discover own learning style and use resources and activities to address own learning needs. Ability to employ steps in information gathering including those outside engineering discipline.							
4	Ability to analyze own information/learning needs or knowledge gaps to select optimal resources. Ability to analyze information from a variety of sources and makes accurate use of them. Ability to identify resources and professional associations that address own ongoing professional development.							
5	Ability to create learning opportunities and manage own educational needs in changing circumstances. Ability to synthesize information from a variety of sources to advance own knowledge. Ability to arrange participation in professional associations that address own professional development.							
6	Ability to critically evaluate own learning efficacy. Ability to appraise procured information for authority, currency, accuracy, reliability, validity and objectivity.							

From your perspective, rank the graduate attributes in order of strongest in your engineering education and the most important to your employment.

Graduate Attribute	Strongest in my engineering education	Most important to my employment
Knowledge base for engineering		
Problem analysis		
Investigation		
Design		
Use of engineering tools		
Individual and team work		
Communication skills		
Professionalism		
Impact of engineering on society and the environment		
Ethics and equity		
Economics and project management		
Lifelong learning		

APPENDIX F

Letters of Informed Consent

F.1 Letter of Introduction and Informed Consent for Professional Engineer.

<u>Letter to Engineers at Manitoba Hydro</u>:

Project Title:	A Mixed Method Study on Transitioning Engineering Graduate Attributes into the Workplace
Researcher:	Donald S. Petkau, B.Sc. (Agricultural Engineering), P.Eng., MBA, PhD. student
Sponsor:	Manitoba Hydro. This research is being conducted as part of a PhD thesis in Engineering (Post-Secondary Studies).

[Date]

[Participant's Name]
[Participant's Address]

Dear [Participant's Name]:

Thank you for considering participation in this research study, as expressed in your recent communication with Kevin Zink P.Eng. Fibre Optics Engineer, Communications Department, Transmission System Operations and our subsequent [phone / email] communication. This letter is provided to you to outline the purpose and nature of the study, to formally request your participation in the study, and to obtain your written informed consent as a participant.

This consent form, a copy of which will be left with you for your records and reference, is only part of the process of informed consent. It should give you the basic idea of what the research is about and what your participation will involve. If you would like more detail about something mentioned here, or information not included here, you should feel free to ask. Please take the time to read this carefully and to understand any accompanying information.

This research is being conducted as part of a PhD thesis in Biosystems Engineering (Post-Secondary Studies). Allow me to introduce myself as the researcher in this project. I am a 1985 graduate of Agricultural Engineering at the University of Manitoba. I spent 1985 – 2005 as a design engineer in engineering consulting, as a research engineer in the areas of environment, agriculture and agri-business, and as a managing engineer in processing and manufacturing. In 1994, I returned to the university to pursue Master of Business Administration on a part time basis (completed 1999). In 2001 I was given the opportunity to teach a Design Trilogy course in Biosystems Engineering. I still currently teach design courses to first year engineering students. My work in developing and instructing design courses has stirred an interest in understanding the design process and engineering education. Discussions with Dr. M.G. (Ron) Britton, former NSERC Chair Design Engineering have led to an opportunity to further my studies in the engineering education field. In addition to graduate work, I continue to teach as an Instructor II in Biosystems Engineering.

The following is a brief context for this research. Nationally and internationally, undergraduate engineering programs have been criticized for the perceived lack of design skills and design competencies of engineering graduates. The University of Manitoba (U of M), like other universities in Canada and U.S., has taken these criticisms seriously and has implemented a number of new initiatives to enhance and improve design education for engineering undergraduates. Such new initiatives include the NSERC Design Chair, the Design Engineering department, the Engineer-in-Residence program, and curriculum modifications to introduce design into the first year. The individual engineering departments also have various design courses from a three-year Design Trilogy program to individual Design Capstone programs. The instruction of these courses captures basic design tasks but fails to incorporate the intangibles used by senior designers. We had the opportunity to meet with Manitoba Hydro officials and discuss design procedures. We found that Manitoba Hydro was experiencing the same frustration in defining exactly how the design process worked. Manitoba Hydro expressed an interest in a better understanding in order to train junior engineers.

I am interested in exploring how the engineering is conceptualized and carried out within a corporate environment. Specifically, my purpose in this study is to understand how individual engineers move from a newly graduate of an engineering degree to that of a senior professional engineer. The objectives of the study are to (1) understand the activities senior professional engineers undertake; (2) to understand the activities undertaken by newly hired engineering graduates; (3) how a new engineer transitions to a professional engineer and; (4) how engineering education compliments and contributes to the transition. To fulfill these objectives, I am recruiting members from a number of engineering teams at Manitoba Hydro.

Should you agree to participate, you and I will engage in two face-to-face interview of approximately one hour duration each. The interviews will be scheduled for spring and summer 2013 at a time and location suitable for you. The interview strategy will follow qualitative interviewing norms; as opposed to a structured question and answer session, the format will be conversational and relaxed. I will make reference to a prepared interview guide with open-ended questions to guide our conversation. My role in the interview will be to provide an atmosphere in which you feel comfortable disclosing your feelings, perceptions, and opinions relative to design and your design experience.

I also anticipate conducting a focus group involving a group of senior engineers within Manitoba Hydro. This would be a face-to-face discussion exploring how the engineering activities undertaken by senior engineers fit into a standard model of engineering practice. There will also be a discussion on how junior engineers transition into senior members of the profession and how engineering education transitions into an engineering career. The focus group will be scheduled for 2013 at a time and location suitable for you. The interview strategy will follow qualitative interviewing norms; as opposed to a structured question and answer session, the format will be conversational and relaxed. I will make reference to a prepared interview guide with open-ended questions to guide the conversation. My role in the interview will be to provide an atmosphere in which you feel comfortable discussing your opinions relative to engineering design and your design experience.

Consistent with qualitative interviewing norms, I will audiotape the interview and transcribe the audiotape immediately after the interview (within 24 hours). The transcript will also include notes about non-verbal features of the situation (such as location, atmosphere, tone, body language) taken from my written notes during the interview session. A copy of the transcript will be provided to you in either hard copy or electronic form (as per your preference), for your review. You will be invited to make additions and deletions to the transcript and return your comments to me. Should you desire, drafts of the thesis can also be provided to you for review and comment.

Given the nature of the study, I anticipate only minimal potential of risk to participants. Before providing written consent, however, you should be aware that you have the right to withdraw any of your comments or withdraw completely from this study at any time, and that any disclosures or data you provide are held in complete confidence. . If you wish to withdraw comments or withdraw from the study you are only required to inform the researcher of your intent verbally or through email. Any comments you wish to withdraw will be destroyed and not used as part of the study. If you withdraw from the study all of your information will be excluded from the study and destroyed immediately. Paper copies of information will be shredded and electronic copies deleted and storage devices (usb) will be destroyed. To preserve confidentiality, pseudonyms will be used in all notes, transcripts, and reports associated with the study. An explicit assurance of confidentiality will be given prior to the interview session. In the final report, all quotations, citations, or paraphrases will be made generic with respect to unique personal features or identifiers, including but not limited to your gender, age, ethnicity, and exact position in the organization. All data collected in the course of the study will be held at my office. Transcripts of our audiotaped interview will be shared only with yourself. At the completion of the study, all audiotapes will be destroyed. I anticipate completing this study by the end of 2013. Interview transcripts will be kept in a secure location at my office, under lock and key, until any articles arising out the research have been accepted for publication; this period will not exceed five years, after which all interview transcripts will be destroyed. Electronic copies of interview transcripts will be password protected, until any articles arising out the research have been accepted for publication; this period will not exceed five years, after which all interview transcripts will be destroyed. Paper copies of information will be shredded and electronic copies deleted and storage devices (usb) will be destroyed. I should also let you know that no compensation is being offered for your participation.

Your signature on this form indicates that you have understood to your satisfaction the information regarding participation in the research project and agree to participate as a subject. In no way does this waive your legal rights nor release the researchers, sponsors, or involved institutions from their legal **and professional responsibilities. You are free to withdraw from the study at any time, and /or refrain from answering any questions you prefer to omit, without prejudice or consequence. Your continued**

participation should be as informed as your initial consent, so you should feel free to ask for clarification or new information throughout your participation.

The University of Manitoba may look at your research records to see that the research is being done in a safe and proper way.

This research has been approved by the Education/Nursing Research Ethics Board. If you have any concerns or complaints about this project you may contact any of the above-named persons or the Human Ethics Coordinator (HEC) at 474-7122. A copy of this consent form has been given to you to keep for your records and reference.

I can be contacted as follows:

Don Petkau, P.Eng.	Tel 474-7443;
E1-358 Engineering Building	Fax 474-7512
Faculty of Engineering, University of Manitoba	Email Don.Petkau@ad.umanitoba.ca

My thesis supervisor can be contacted as follows:

Dr. M.G. (Ron) Britton, P.Eng., Ph.D.	Tel 474-6059
E1-387 Engineering Building	Fax 474-7676
University of Manitoba	Email Ron_Britton@umanitoba.ca

Other committee members are:

Dr. D.D. (Danny) Mann, P.Eng.	Tel 474-7149
E2-376 Engineering Building	Fax 474-7512
University of Manitoba	Email danny_mann@umanitoba.ca
Dr. James Blatz, P.Eng.	Tel 474-9568
E1 - 338 Engineering Building	Fax 474-7513
University of Manitoba	Email james.blatz@ad.umanitoba.ca
Dr. Marcia Friesen, PhD.	Tel 474-7873
E3 – 571 Engineering Building	Fax 474-7676
University of Manitoba	Email marcia_friesen@umanitoba.ca

Sincerely,

Donald S. Petkau, P.Eng.

PhD. Student

Please sign below to indicate your informed written consent to participate in this study:

Participant’s signature Date

Researcher and/or Delegate’s Signature Date

- -

If you wish to receive a copy of the results of the study please fill out the following form. A copy of the study will be sent at the completion of the project.

Participant’s Name:	
Address:	
Address:	
Phone number:	

F.2 Letter of Introduction and Informed Consent for Engineer in Training

Letter to Engineers at Manitoba Hydro:

Project Title: A Mixed Method Study on Transitioning Engineering Graduate Attributes into the Workplace

Researcher: Donald S. Petkau, B.Sc. (Agricultural Engineering), P.Eng., MBA, PhD. student
Sponsor: Manitoba Hydro. This research is being conducted as part of a PhD thesis in Engineering (Post-Secondary Studies).

[Date]

[Participant's Name]
[Participant's Address]

Dear [Participant's Name]:

Thank you for considering participation in this research study, as expressed in your recent communication with Kevin Zink P.Eng. Fibre Optics Engineer, Communications Department, Transmission System Operations and our subsequent [phone / email] communication. This letter is provided to you to outline the purpose and nature of the study, to formally request your participation in the study, and to obtain your written informed consent as a participant.

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This research is being conducted as part of a PhD thesis in Biosystems Engineering (Post-Secondary Studies). Allow me to introduce myself as the researcher in this project. I am a 1985 graduate of Agricultural Engineering at the University of Manitoba. I spent 1985 – 2005 as a design engineer in engineering consulting, as a research engineer in the areas of environment, agriculture and agri-business, and as a managing engineer in processing and manufacturing. In 1994, I returned to the university to pursue Master of Business Administration on a part time basis (completed 1999). In 2001 I was given the opportunity to teach a Design Trilogy course in Biosystems Engineering. I still currently teach design courses to first year engineering students. My work in developing and instructing design courses has stirred an interest in understanding the design process and engineering education. Discussions with Dr. M.G. (Ron) Britton, former NSERC Chair Design Engineering have led to an opportunity to further my studies in the engineering education field. In addition to graduate work, I continue to teach as an Instructor II in Biosystems Engineering.

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I am interested in exploring how the engineering is conceptualized and carried out within a corporate environment. Specifically, my purpose in this study is to understand how individual engineers move from a newly graduate of an engineering degree to that of a senior professional engineer. The objectives of the study are to (1) understand the activities senior professional engineers undertake; (2) to understand the activities undertaken by newly hired engineering graduates; (3) how a new engineer transitions to a professional engineer and; (4) how engineering education compliments and contributes to the transition. To fulfill these objectives, I am recruiting members from a number of engineering teams at Manitoba Hydro.

Should you agree to participate, you and I will engage in three face-to-face interviews of approximately one hour duration each. The interview will be scheduled for spring and summer 2013 at a time and location suitable for you. The interview strategy will follow qualitative interviewing norms; as opposed to a structured question and answer session, the format will be conversational and relaxed. I will make reference to a prepared interview guide with open-ended questions to guide our conversation. My role in the interview will be to provide an atmosphere in which you feel comfortable disclosing your feelings, perceptions, and opinions relative to design and your design experience.

I also anticipate conducting a focus group involving a group of junior engineers within Manitoba Hydro. This would be a face-to-face discussion exploring how engineering education transitions into an engineering career. The focus group will be scheduled for spring 2013 at a time and location suitable for you. The interview strategy will follow qualitative interviewing norms; as opposed to a structured question and answer session, the format will be conversational and relaxed. I will make reference to a prepared interview guide with open-ended questions to guide the conversation. My role in the interview will be to provide an atmosphere in which you feel comfortable discussing your opinions relative to engineering design and your design experience.

Consistent with qualitative interviewing norms, I will audiotape the interview and transcribe the audiotape immediately after the interview (within 24 hours). The transcript will also include notes about non-verbal features of the situation (such as location, atmosphere, tone, body language) taken from my written notes during the interview session. A copy of the transcript will be provided to you in either hard copy or electronic form (as per your preference), for your review. You will be invited to make additions and deletions to the transcript and return your comments to me. Should you desire, drafts of the thesis can also be provided to you for review and comment.

Given the nature of the study, I anticipate only minimal potential of risk to participants. Before providing written consent, however, you should be aware that you have the right to withdraw any of your comments or withdraw completely from this study at any time, and that any disclosures or data you provide are held in complete confidence. If you wish to withdraw comments or withdraw from the study you are only required to inform the researcher of your intent verbally or through email. Any comments you wish to withdraw will be destroyed and not used as part of the study. If you withdraw from the study all of your information will be excluded from the study and destroyed immediately. Paper copies of information will be shredded and electronic copies deleted and storage devices (usb) will be destroyed. To preserve confidentiality, pseudonyms will be used in all notes, transcripts, and reports associated with the study. An explicit assurance of confidentiality will be given prior to the interview session. In the final report, all quotations, citations, or paraphrases will be made generic with respect to unique personal features or identifiers, including but not limited to your gender, age, ethnicity, and exact position in the organization. All data collected in the course of the study will be held at my office. Transcripts of our audiotaped interview will be shared only with yourself. At the completion of the study, all audiotapes will be destroyed. I anticipate completing this study by the end of 2013. Interview transcripts will be kept in a secure location at my office, under lock and key, until any articles arising out the research have been accepted for publication; this period will not exceed five years, after which all interview transcripts will be destroyed. Electronic copies of interview transcripts will be password protected, until any articles arising out the research have been accepted for publication; this period will not exceed five years, after which all interview transcripts will be destroyed. Paper copies of information will be shredded and electronic copies deleted and storage devices (usb) will be destroyed. I should also let you know that no compensation is being offered for your participation.

Your signature on this form indicates that you have understood to your satisfaction the information regarding participation in the research project and agree to participate as a subject. In no way does this waive your legal rights nor release the researchers, sponsors, or involved institutions from their legal and professional responsibilities. You are free to withdraw from the study at any time, and /or refrain from answering any questions you prefer to omit, without prejudice or consequence. Your continued participation should be as informed as your initial consent, so you should feel free to ask for clarification or new information throughout your participation.

The University of Manitoba may look at your research records to see that the research is being done in a safe and proper way.

This research has been approved by the Education/Nursing Research Ethics Board. If you have any concerns or complaints about this project you may contact any of the above-named persons or the Human Ethics Coordinator (HEC) at 474-7122. A copy of this consent form has been given to you to keep for your records and reference.

I can be contacted as follows:

Don Petkau, P.Eng.	Tel 474-7443; Fax 474-7512
E1-358 Engineering Building	Tel (home)
Faculty of Engineering, University of Manitoba	Email Don.Petkau@ad.umanitoba.ca

My thesis supervisor can be contacted as follows:

Dr. M.G. (Ron) Britton, P.Eng., Ph.D.	Tel 474-6059
E1-387 Engineering Building	Fax 474-7676
University of Manitoba	Email Ron_Britton@umanitoba.ca

Other committee members are:

Dr. D.D. (Danny) Mann, P.Eng.	Tel 474-7149
E2-376 Engineering Building	Fax 474-7512
University of Manitoba	Email danny_mann@umanitoba.ca
Dr. James Blatz, P.Eng.	Tel 474-9568
E1 - 338 Engineering Building	Fax 474-7513
University of Manitoba	Email james.blatz@ad.umanitoba.ca
Dr. Marcia Friesen, PhD.	Tel 474-7873
E3 – 571 Engineering Building	Fax 474-7676
University of Manitoba	Email marcia_friesen@umanitoba.ca

Sincerely,

Donald S. Petkau, P.Eng.
PhD. Student

Please sign below to indicate your informed written consent to participate in this study:

Participant's signature Date

Researcher and/or Delegate's Signature Date

If you wish to receive a copy of the results of the study please fill out the following form. A copy of the study will be sent at the completion of the project.

Participant's Name:	
Address:	
Address:	
Phone number:	

F.3 Letter of Informed Consent for Pilot Study Interviews

Letter to Design Team Members

Project Title: Understanding the Design Process

Researcher: Donald S. Petkau, B.Sc. (Agricultural Engineering), P.Eng., MBA, PhD. student
Sponsor: Manitoba Hydro. This research is being conducted as part of a PhD thesis in Engineering (Post-Secondary Studies).

Allow me to introduce myself as the researcher in this project. I am a 1985 graduate of Agricultural Engineering at the University of Manitoba. I spent 1985 – 2005 as a design engineer in engineering consulting, as a research engineer in the areas of environment, agriculture and agri-business, and as a managing engineer in processing and manufacturing. In 1994, I returned to the university to pursue Master of Business Administration on a part time basis (completed 1999). In 2001 I was given the opportunity to teach a Design Trilogy course in Biosystems Engineering. I currently still teach that course along with numerous others in Biosystems, Civil, and Design Engineering. My work in developing and instructing Design courses has stirred an interest understanding the design process. Discussions with Dr. M.G. (Ron) Britton, NSERC Chair Design Engineering has led to an opportunity to further my studies in the Design field. In addition to graduate work, I continue to teach sessionally in the Faculty of Engineering.

The following is a brief context for this research. Nationally and internationally, undergraduate engineering programs have been criticized for the perceived lack of design skills and design competencies of engineering graduates. The University of Manitoba (U of M), like other universities in Canada and U.S., has taken these criticisms seriously and has implemented a number of new initiatives to enhance and improve design education for engineering undergraduates. Such new initiatives include the NSERC Design Chair, the Design Engineering department, the Engineer-in-Residence program, and curriculum modifications to introduce design into the first year. The individual engineering departments also have various design courses from a three-year Design Trilogy program to individual Design Capstone programs. The instruction of these courses captures basic design tasks but fails to incorporate the intangibles used by senior designers. We had the opportunity to meet with Manitoba Hydro officials and discuss design procedures. We found that Manitoba Hydro was experiencing the same frustration in defining exactly how the design process worked. Manitoba Hydro expressed an interest in a better understanding in order to train junior designers.

Should you agree to participate, you will participate in design group observation sessions. I will be joining your design group meetings to observe the design process in action. The observation sessions will be scheduled for May 2006 inclusive to the completion of all design groups meetings or until January 2008. I will be attending design group meetings for a number of design groups within Manitoba Hydro. I will not be participating in the group discussion or interfering with the process in any way. My role is to observe the regular design group meetings to better understand the design process.

The design group observation sessions will be held at a time and location at Manitoba Hydro determined by the design group. This is expected to be regularly scheduled design meetings. The observation strategy will follow qualitative group observation norms. My role as the observer will be to provide an atmosphere in which you feel comfortable disclosing your perceptions, and opinions relative to design. I will have an assistant present to take detailed notes during the observation session. My analysis of the session will be based on the assistant's written notes. As a back-up only, I will also audiotape the observation session. Should you desire, drafts of the thesis can also be provided to you for review and comment. The assistant moderator and myself will keep the identity of group participants confidential. In the notes made during the group session, each participant will be identified only by a letter or number corresponding to your seating arrangement in the group.

Given the nature of the study, I anticipate only minimal potential of risk to participants. Before providing written consent, however, you should be aware that you would have the right to withdraw any of your comments or withdraw completely from the study at any time, and that any disclosures or data you provide are held in complete confidence. To preserve confidentiality, pseudonyms will be used in all notes, transcripts, and reports associated with the study. An explicit assurance of confidentiality will be given prior to the observation group session. Neither the researcher, the assistant moderator, nor the group members will reveal the identity of other group participants. In the final report, all quotations, citations, or paraphrases will be made generic with respect to unique personal features or identifiers, including but not limited to your gender, age, ethnicity, and exact position in the organization. All data collected in the course of the study will be held at my office. At the completion of the study, all audiotapes will be destroyed. I anticipate completing this study in summer, 2008. Observation group notes will be kept in a secure location at my office until any articles arising out the research have been accepted for publication; this period will not exceed five years, after which all focus group notes will be destroyed.

I should also let you know that no compensation is being offered for your participation, although I will likely provide refreshments during the observation group sessions. You should also be aware that your participation in this study is completely independent of (unrelated to) your employment at Manitoba Hydro. You will not be rewarded nor penalized for your decision to participate or not to participate in the focus group sessions. You are free to withdraw from the study at any time, and/or refrain from answering any questions you prefer to omit, without prejudice or consequence. If you wish to withdraw from the study, at any time, you need only to contact the researcher, verbally or in writing indicating that you will no longer participate. Your name will then be removed from the list of participants and you will no longer be a part of the study.

Should you have questions at any point, you are encouraged to contact me (e-mail and home phone given below), or my thesis advisor.

Don Petkau, P.Eng.	Tel 479-4084; Fax 474-7676
E2-519 Engineering Building	Tel (home)
Faculty of Engineering, University of Manitoba	Email dpetkau@shaw.ca

My thesis supervisor can be contacted as follows:

Dr. M.G. (Ron) Britton, P.Eng., Ph.D.	Tel 474-6059
E2-262 Engineering Building	Fax 474-7676
University of Manitoba	Email Ron_Britton@umanitoba.ca

Other committee members are:

Dr. D.D. (Danny) Mann, P.Eng.	Tel 474-7149
E2-376 Engineering Building	Fax 474-7512
University of Manitoba	Email danny_mann@umanitoba.ca
Dr. James Blatz, P.Eng.	Tel 474-9816
E3 - 380D Engineering Building	Fax 474-7513
University of Manitoba	Email blatzja@cc.umanitoba.ca
Dr. Sandra Ingram, PhD.	Tel 474-9698
E3 – 503C Engineering Building	Fax 474-7676
University of Manitoba	Email ingram@ee.umanitoba.ca

This research has been approved by the Education/Nursing Research Ethics Board. If you have any concerns or complaints about this project, you may contact the above-named persons or the Human Ethics Secretariat at 474-7122. A copy of this consent form has been given to you to keep for your records.

Sincerely,

Donald S. Petkau, P.Eng.

PhD. Student

Please sign below to indicate your informed written consent to participate in this study:

____

Participant’s signature   Date

____

Researcher and/or Delegate’s Signature   Date

If you wish to receive a copy of the results of the study please fill out the following form. A copy of the study will be sent at the completion of the project.

Participant’s Name:	
Address:	
Address:	
Phone number:	

APPENDIX G

Approval Certificates for Human Subjects Research

G.1 Protocol E2012:092 for Interviews Focus Groups and follow-up questionnaires: Original approval.

UNIVERSITY OF MANITOBA | Research Ethics and Compliance
Office of the Vice-President (Research and International)

Human Ethics
208-194 Dafoe Road
Winnipeg, MB
Canada R3T 2N2
Phone +204-474-7122
Fax +204-269-7173

APPROVAL CERTIFICATE

May 28, 2013

TO:	**Donald S. Petkau** Principal Investigator	(Advisor R. Britton)
FROM:	**Stan Straw, Chair** Education/Nursing Research Ethics Board (ENREB)	
Re:	**Protocol #E2012:092** **"A Mixed Method Study on Transitioning Engineering Graduate Attributes into the Workplace"**	

Please be advised that your above-referenced protocol has received human ethics approval by the **Education/Nursing Research Ethics Board**, which is organized and operates according to the Tri-Council Policy Statement (2). **This approval is valid for one year only.**

Any significant changes of the protocol and/or informed consent form should be reported to the Human Ethics Secretariat in advance of implementation of such changes.

Please note:

- **If you have funds pending human ethics approval, the auditor requires that you submit a copy of this Approval Certificate to the Office of Research Services, fax 261-0325 - please include the name of the funding agency and your UM Project number. This must be faxed before your account can be accessed.**

- **if you have received multi-year funding for this research, responsibility lies with you to apply for and obtain Renewal Approval at the expiry of the initial one-year approval; otherwise the account will be locked.**

The Research Quality Management Office may request to review research documentation from this project to demonstrate compliance with this approved protocol and the University of Manitoba *Ethics of Research Involving Humans.*

The Research Ethics Board requests a final report for your study (available at: http://umanitoba.ca/research/orec/ethics/human_ethics_REB_forms_guidelines.html) **in order to be in compliance with Tri-Council Guidelines.**

umanitoba.ca/research

G.2 Protocol E2006:006 For Pilot Study Interviews: Original Approval and renewals.

UNIVERSITY OF MANITOBA | OFFICE OF RESEARCH SERVICES
Office of the Vice-President (Research)

CTC Building
208 - 194 Dafoe Road
Winnipeg, MB R3T 2N2
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www.umanitoba.ca/research

RENEWAL APPROVAL

26 June 2009

TO:	**Donald S. Petkau** Principal Investigator
FROM:	**Lorna Guse, Chair** Education/Nursing Research Ethics Board (ENREB)
Re:	**Protocol #E2006:006** **"Understanding the Design Process"**

Please be advised that your above-referenced protocol has received approval for renewal by the **Education/Nursing Research Ethics Board**. This approval is valid for one year only.

Any significant changes of the protocol and/or informed consent form should be reported to the Human Ethics Secretariat in advance of implementation of such changes.

Please be advised that this is the final renewal allowed. Subsequently a full application must be submitted.

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Winnipeg, MB R3T 2N2
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www.umanitoba.ca/research

RENEWAL APPROVAL

25 June 2008

TO:	**Donald S. Petkau** Principal Investigator
FROM:	**Stan Straw, Chair** Education/Nursing Research Ethics Board (ENREB)
Re:	**Protocol #E2006:006** **"Understanding the Design Process"**

Please be advised that your above-referenced protocol has received approval for renewal by the **Education/Nursing Research Ethics Board.** This approval is valid for one year only.

Any significant changes of the protocol and/or informed consent form should be reported to the Human Ethics Secretariat in advance of implementation of such changes.

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www.umanitoba.ca/research

RENEWAL APPROVAL

26 June 2007

TO: **Donald S. Petkau**
Principal Investigator

FROM: **Stan Straw, Chair**
Education/Nursing Research ~~Ethics Board~~ (ENREB)

Re: **Protocol #E2006:006**
"Understanding the Design Process"

Please be advised that your above-referenced protocol has received approval for renewal by the **Education/Nursing Research Ethics Board.** This approval is valid for one year only.

Any significant changes of the protocol and/or informed consent form should be reported to the Human Ethics Secretariat in advance of implementation of such changes.

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APPROVAL CERTIFICATE

26 June 2006

TO: **Donald S. Petkau** (Advisor R. Britton)
Principal Investigator

FROM: **Stan Straw, Chair**
Education/Nursing Research Ethics Board (ENREB)

Re: **Protocol #E2006:006**
"Understanding the Design Process"

Please be advised that your above-referenced protocol has received human ethics approval by the **Education/Nursing Research Ethics Board**, which is organized and operates according to the Tri-Council Policy Statement. This approval is valid for one year only.

Any significant changes of the protocol and/or informed consent form should be reported to the Human Ethics Secretariat in advance of implementation of such changes.

Please note:

- **if you have funds pending human ethics approval, the auditor requires that you submit a copy of this Approval Certificate to Kathryn Bartmanovich, Research Grants & Contract Services (fax 261-0325), including the Sponsor name, before your account can be opened.**

- **if you have received multi-year funding for this research, responsibility lies with you to apply for and obtain Renewal Approval at the expiry of the initial one-year approval; otherwise the account will be locked.**

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