# ORGANISATIONAL TRANSITION TO WORK PROGRAMS FOR NEW CAREER ENGINEERS


Sally Hawse

Faculty of Business and Economics

Department of Marketing and Management

Macquarie University


This dissertation is submitted for the degree of Doctor of Philosophy

October 2017

# DECLARATION

This dissertation is the result of my own work and includes nothing, which is the outcome of work done in collaboration except where specifically indicated in the text. It has not been previously submitted, in part or whole, to any university or institution for any degree, diploma, or other qualification.

The research presented in this dissertation was approved by the Macquarie University Ethics Committee as follows:

"Expertise and Wisdom: Socialising new professionals into their disciplines"

Ref: 5201300545, approved on 26/09/2013

Signed:________________________________________

Date: 14 October 2017

Sally Hawse BA (Hons), MA, PGAppLing

Student ID: 42812240

# ABSTRACT

Silvia Gherardi has famously noted that we are in the midst of a ‘practice turn’, and that new interpretations and forms of work, practice, student, and professional are emerging. This study explores the transition to work from an organisational perspective. Its aim is to inform induction programs that facilitate the successful transition of graduate engineers to the workplace. While the study asks the more routine question: “What capabilities enable successful transition to professional work for an engineering graduate?”, it addresses the broader issue of what it means to be between these worlds, and how learning models of ‘betweenness’, or co-production can assist the transition from university to work. The study acknowledges that this question is endemic to both engineering education and engineering practice, and that each are contributors to its knowledge base, and to the learning experiences that promote successful engineering outcomes. Inquiry is thus influenced by the literature from engineering education and organisational knowledge. Theories of knowledge forms, experts and novices, deliberative reflection, situational literacies, and distributed knowledge are interpretative lenses. The research method is statistical analysis of questionnaire responses. Study results help adjudicate theory-practice divisions. The study findings provide evidence-based confirmation that (1) universities and workplaces have complementary and interrelated roles in the transition from university to the workplace, (2) that the domains of knowledge, skills, and character comprise a professional persona uniquely weighted to the engineering discipline, and (3) that work experience is transformative, and contributes to developmental changes across the work lifespan. Formal study, situated and collaborative activities, and critical reconstruction of practice are catalysts for this transformation. The implication is that universities and workplaces ultimately co-produce learning experiences. This conclusion creates opportunities for the development of new models of collaboration and learning partnerships.

# Acknowledgements

In completing this study, I am grateful for the backing and direction of family and friends, and for the colleagues who have been the context for this project.

In particular, I thank my supervisor Professor Leigh Wood for her insights, counsel, and extraordinary guidance throughout this study. Leigh and her team provide the support structure to realise ideas. Many thanks to Antonia Dykes and Glyn Mather for being a part of this team. Malcolm Morgan and Kayla Friedman of the Centre for Sustainable Development, University of Cambridge, UK, created the look and feel on which this document is based.

Ultimately, this project could not have been completed without the generous patience of my family—Pete and Scott—and the steerage of “the Elizabeths”.

# CONTENTS

# List of Tables

# List of Figures

# List of Abbreviations and Acronyms

| | |
|---|---|
| ABET | Accreditation Board of Engineering and Technology |
| ASCE | American Society of Civil Engineers |
| BoK | Body of Knowledge |
| CASEL | Collaborative for Academic, Social, and Emotional Learning |
| CDIO | Conceive, Design, Implement, Operate |
| CPD | Continuous Professional Development |
| DP | Deliberate Professional |
| EFA | Exploratory Factor Analysis |
| FYE | First Year Experience |
| ICE | Institution of Civil Engineers, UK |
| KSA | Knowledge, Skills, Attitude |
| PBL | Problem/Project Based Learning |
| PCA | Principal Components Analysis |
| PY | Professional Year |
| SEL | Social and Emotional Literacies |
| SME | Small to Medium Sized enterprise |
| SOS | Self, Others, Situation |
| STEM | Science, Technology, Engineering, Mathematics |
| WBL | Work-based Learning |

# List of Appendices

# 1 Introduction

## Research Objectives

This study explores transition to work from the perspective of the engineering workplace. It views this transition through the lens of organisational development programs for career entrants, and asks: "What capabilities enable successful transition to professional work for an engineering graduate?" Extensive research has been undertaken around engineering curricular reform. In the context of economic and social need, the STEM (Science, Technology, Engineering, Mathematics) disciplines have received significant policy focus and program response. However, as this effort is largely aimed at development and provision of academic programs, there remains a gap in understanding the needs of employers as they address the work integration and further development of new career engineers. While most universities offer 'backpack to briefcase' programs and workplaces provide new career starter onboarding and induction, there is general acknowledgement that the transition process from university to the workplace is not well understood. Many of the challenges faced by novice professionals relate to the nature of knowledge, and how disciplinary knowledge operates in practice. Especially for engineers, the transition from university to practice is complex and important for career success (Baytiyeh & Naja, 2012). While recognising there are numerous career pathways for engineering graduates (Palmer, Tolson, Young, & Campbell, 2015), the purpose of this study is to explore transition to engineering work induction and development programs that are delivered by engineering firms to engineering graduates. It aims to contribute to articulating workplace expectations and to supporting socialisation to professional work. In particular, the study seeks to (1) identify areas where workplace programs can constructively impact the transition to work for new engineers, and (2) to understand the knowledge, skills, and attitudes which explicitly relate to the engineering workplace.

# SIGNIFICANCE AND BACKGROUND

Economic and social changes and the influence of digital and information technologies have broadly impacted the engineering profession. By consequence, this change extends to engineering education. At the practice level, increasingly distributed modes of work and interdisciplinary collaboration and cooperation have emerged. Developments in industry have compelled curricular reform as a tertiary program response. Educational change is being realised through bringing together influences from the learning sciences, digital and collaborative activities, and project focused curricular models. These efforts balance scholarship with the practical needs of a diverse discipline that is continually evolving the boundaries of its practice (ASCE, 2008; Vest, 2007).

Following Mukerji (2009), ‘distributed cognition’ or participatory and collaborative sense making characterises engineering work. Edgerton (2001) sees program completion, participant understanding, and acquisition of the literacies required for effective work, citizenship, and personal fulfilment as the quality standards against which educational programs should be evaluated. Similarly, Wood and Kaczynski (2007) summarise the dual role of higher education: it both develops generic, transferrable capabilities that enhance employment opportunities and provides preparation for specific disciplines, including their intellectual, philosophical, and methodological foundations. This two-fold role suggests there are knowledge forms specific to tertiary education and forms specific to navigating the workplace and engineering practice. While there is no fixed agreement as to what constitutes relevant generic and discipline-specific capabilities, research affirms that employers generally seek knowledge application and business skills, while universities focus on knowledge acquisition and civic or character-related capabilities (Hart Research Associates, 2015; Manoliu, 2005; Wood & Kaczynski, 2007). This difference in emphasis underlines the need for education and industry to create effective and ongoing partnerships that support successful transition to work experiences for engineering graduates.

## Overview of the Literature

This study takes a broadly systems and lifewide view of the learning journey. As such its theoretical influences intersect organisational knowledge and engineering education. Select statements and observational insights from the literature anchor this analysis and serve as conceptual signposts throughout the study. Organisational knowledge is a formative area of inquiry, with diverse disciplinary roots and conceptual approaches. It encompasses a wide range of theories and interpretive constructs that cross data and information management, situated learning and communities of practice, philosophies of knowledge and knowing, and organisations as learning entities (Saito, 2007). Organisational knowledge provides a conceptual medium for knowledge age sense-making, and for understanding engineering as a sociomaterial and distributed discipline (Fenwick, 2012; Orlikowski & Scott, 2008). This study takes a people-centric approach to knowledge as distributed amongst individuals, disciplinary practices, and tools. Knowledge is constituted at both individual and collective level. Individual knowledge relates to capability, experience, and world view, while collective knowledge is more about cooperation and collaborative effort to achieve shared outcomes. Professional and workplace learning connects formal bodies of knowledge with social and experience based “know-what, know-why, know-how, know-who” forms of knowing. Knowledge is thus a social practice that is developed through activities such as formal study, inquiry and reflection, and negotiated meaning. Boshuizen, Bromme, and Gruber (2004) observe that, “professional learning is both a process of change within an individual as well as of *enculturation* into a group. Enculturation has to be understood in two senses, namely as a process of change (acquisition of the skills, habits, attitudes of a certain profession) and as a process of becoming accepted and legitimised in a certain context” (p. 6). Adopting the view of Wood and Kaczynski (2007) that the role of tertiary education is both to provide transferrable capabilities that prepare students for life and work, and to prepare them for specific disciplines, this study references engineering education learning philosophies and delivery methodologies with touchpoints to practice, and which forge a middle ground between theory and practice. These include Problem/Project Based Learning (PBL), the CDIO initiative (Conceive, Design, Implement, Operate) which promotes learning design based on engineering methods, ontological analyses of disciplinary personas, and activities vested in the sociomateriality of engineering practice.

# Methodology

An established research instrument—The Tuning Process questionnaire—is the vehicle for analysis. Tuning is about designing, developing, implementing, and evaluating higher education programmes to incorporate and align views from industry, participants, and academia, with the objective to increase employment opportunities. Tuning asks participants to rate the degree to which general and discipline-specific skills are provided by university and required for work. These items are the result of input and consensus from key stakeholder groups, including students, academics, and industry associations and representatives. The thirty general skills items for this study are provided in Gonzélez and Wagenaar (2003). The eighteen engineering-specific items are provided in Manoliu (2005). The questionnaire was administered online following Tuning sampling protocol. Responses and commentary were sought from representatives from engineering organisations and from recent graduates. Participants represent cross-disciplinary (aerospace, biomedical, chemical, civil, electrical, mechanical, software), a cross-section of organisational roles and seniority, and geographical (Australia, Canada, India, United States) views.

The Tuning questionnaire was adapted to include free text responses and the insights offered by mixed methods approaches that combine qualitative and quantitative inputs. Participants were asked to nominate the three to five most important general and specific skills required for engineering. This change was implemented to capture emerging themes not accommodated by Tuning question items. Likert responses were analysed using data reduction and factor analysis techniques. Free text responses were interpreted and classified into themes using a grounded coding approach. These themes were summarised and interpreted using qualitative techniques.

# Organisation of the Study

This study is organised in eight chapters:

## 1. Introduction

Chapter one sets out the research question, and establishes the context for inquiry and its significance. This chapter summarises the framing literature and provides an overview of the research methodology and key findings.

## 2. Professional development for early-career engineers

Engineering is a ‘bridging discipline’ that brings together other domains beyond the technical. It has many publics, and engineering work is inherently practical, interactive, and multifaceted. The transition to work is therefore highly complex and critical for engineering graduates. Chapter two focuses on the transition of engineering graduates to work, and the role which disciplinary socialisation plays in this transition process. Its purpose is to investigate approaches and enabling activities which can be employed by organisational induction programs to support successful transition to practice for new-career engineers. The chapter introduces the Tuning Process methodology which is used as the research instrument for this study. The chapter concludes with a brief analysis of how engineering activities constitute disciplinary texts. Incorporating these texts in learning programs can help make tacit knowledge tangible and yield the usable knowledge that characterises engineering practitioners.

## 3. Fostering wise judgment: Professional decisions in development programs for early-career engineers

Professionals engage in complex and often unpredictable tasks on behalf of clients and stakeholders that require problem-solving skills and experience-based judgments. The interdisciplinary nature of their practice and its many stakeholders means that on graduation engineers are faced with situations that require professional judgments. The chapter reviews literature that explores the role of judgment in professional practice. This review of the literature is prompted by survey results inviting engineering graduates and professionals to identify the capabilities they believe are most significant to success in the engineering workplace. The requirement for sound professional judgment resonates throughout participant responses. However, there is little research that discusses developing professional judgment in transition to work programs. Chapter three inquires into the nature of problem-solving and decision-making. It asks: “How can workplace programs assist novice engineers to develop their capacity to exercise professional judgment?” This inquiry establishes linkages with social forms of knowing. It extends the theme of workplace socialisation to contexts of decision-making. The chapter proposes that sound, or wise judgments develop through deliberative, reflective practice and that 'wisdom' is a teachable quality. Activities for scaffolding wise practice in transition to work programs are summarised.

## 4. Professionalism, character, and skills: Leveraging the tuning process for the engineering workplace

Chapter four presents and discusses the research method, results data and findings. It details the study implementation of the Tuning Process methodology, mixed methods approach and analytical techniques for data reduction and interpretation. This chapter discusses in depth the research findings and their significance.

## 5. Transitioning to professional work: A view from the field

Chapter five interprets work-readiness through the insights of 'experienced graduates', who are outside of the scope of the Tuning Process sampling criteria and main dataset. It discusses similarities and differences of opinion between these experienced engineers and new graduates. This provides 'cross-generational' views and contributes explanatory richness from experienced professionals adopting the position of engineering graduates.

## 6. Co-creating knowledge experiences: Education and organisational partnerships in transition to work programs for new engineers

Chapter six analyses the Tuning Process quantitative survey results in view of knowledge theory. It summarises study findings that reveal stages of the career lifespan and the interdependent roles of tertiary education and places of work.

## 7. Components of the engineering professional persona: The transformative role of experience

Chapter seven interprets the results of adapting the Tuning Process questionnaire to capture free text responses. It discusses these qualitative results in relation to 'knowledge, skills, attitude' capability models. Analysis provides evidence-based support for these typologies. Results demonstrate the dimensions of the 'engineering professional persona'.

8. Conclusions

Chapter eight presents general conclusions from this study. It summarises key findings by answering the main and individual chapter research questions, examines research implications, and recommends possible future areas of investigation.

## FINDINGS

Findings affirm that education and industry are partners in knowledge and capability development, and have complementary roles in successful transition to work experiences for new career engineers. This nuances theory-practice debates and moves conversations towards paradigms of co-production, distributed cognition, interdisciplinary work, and to further developments in experiential learning (Vest, 2007). Analysis maps the transition from education to the workplace. It depicts patterns of interaction, or convergence, between universities and employing organisations during transition. Results additionally point to an ‘engineering professional persona’ marked by professionalism, a dimensional character, and technical proficiency. Factor analysis provides an evidence-based premise for the Bloom, Engelhart, Furst, Hill, and Krathwohl (1956) and related conceptualisations of ‘knowledge, skills, attitude’ domains.

## CONCLUSIONS

This study contributes to the transition to work research field and strengthens the argument for developing models of ‘learning experience co-production’. Analysis evidences a ‘division of labour’ or distinct and interdependent roles of education and industry across lifewide learning. It establishes that educational institutions and employing organisations are knowledge and learning partners, with complementary roles in co-creating successful transition to work experiences for new career engineers. The findings indicate that developing professional practices, and identities is an ongoing process, and that learning and work activities equally influence this process. The study results further illustrate key dimensions of the engineering professional persona and assert that qualities of attitude or character are the cornerstone of professional success. Opportunities for further research identified through this study include: the texts of engineering practice, relationship between problem-solving and decision-making, and approaches that promote co-production of transition to work learning experiences.

# REFERENCES


ASCE. (2008). *Civil engineering body of knowledge for the 21st century: Preparing the civil engineer for the future*. Retrieved from http://www.asce.org/uploadedFiles/Education_and_Careers/Body_of_Knowledge/Content_Pieces/body-of-knowledge.pdf

Baytiyeh, H., & Naja, M. (2012). Identifying the challenging factors in the transition from colleges of engineering to employment. *European Journal of Engineering Education, 37*(1), 3-14.

Bloom, B. S., Engelhart, M. D., Furst, E. J., Hill, W. H., & Krathwohl, D. R. (1956). *Taxonomy of educational objectives*. N.Y.: Longmans, Green.

Boshuizen, H., Bromme, R., & Gruber, H. (2004). On the long way from novice to expert and how travelling changes the traveller. In H. Boshuizen, R. Bromme, & H. Gruber (Eds.), *Professional Learning: Gaps and Transitions on the Way from Novice to Expert* (Vol. 2, pp. 3-8). Dordrecht, The Netherlands: Kluwer Academic Publishers.

Edgerton, R. (2001). *Education white paper*. Report prepared for the Pew Charitable Trusts, Pew Forum on Undergraduate Learning. Washington, DC.

Fenwick, T. (2012). Matterings of knowing and doing: Sociomaterial approaches to understanding practice. In P. Hager, A. Lee, & A. Reich (Eds.), *Practice, learning and change: Practice-theory perspectives on professional learning* (pp. 67-83). Dordrecht: Springer Netherlands.

Gonzélez, J., & Wagenaar, R. (2003). *Tuning educational structures in Europe. Final report. Phase one*. Universidad de Deusto: Deusto. Retrieved from http://www.bolognakg.net/doc/Tuning_phase1_full_document.pdf

Hart Research Associates. (2015). *Falling short? College learning and career success*. Selected Findings from Online Surveys of Employers and College Students Conducted on Behalf of the Association of American Colleges & Universities. Washington DC. Retrieved from http://www.aacu.org/sites/default/files/files/LEAP/2015employerstudentsurvey.pdf

Manoliu, I. (2005). *First results of the Tuning Project with the participation of EUCEET and ECCE*. Paper presented at the 42nd ECCE meeting, Istanbul, Turkey. http://www.unideusto.org/tuningeu/images/stories/Summary_of_outcomes_TN/First_results_Civil_Engineering_PPT.ppt.

Mukerji, C. (2009). *Impossible engineering: Ttechnology and territoriality on the Canal du Midi*. Princeton, NJ: Princeton University Press.

Orlikowski, W. J., & Scott, S. V. (2008). Sociomateriality: Challenging the separation of technology, work and organization. *The Academy of Management Annals, 2*(1), 433-474. doi:10.1080/19416520802211644

Palmer, S., Tolson, M., Young, K., & Campbell, M. (2015). The relationship between engineering bachelor qualifications and occupational status in Australia. *Australasian Journal of Engineering Education, 20*(2), 103-112. doi:10.1080/22054952.2015.1092666

Saito, A. (2007). *Educating knowledge managers: A competence-based approach.* (PhD), Japan Advanced Institute of Science and Technology (JAIST), Nomi, Japan. Retrieved from https://dspace.jaist.ac.jp/dspace/bitstream/10119/3739/2/121paper.pdf

Vest, C. M. (2007). *Educating engineers for 2020 and beyond*. National Academy of Engineering, Grand Challenges Blog. Retrieved from http://www.engineeringchallenges.org/14373/GrandChallengesBlog/7639.aspx

Wood, L., & Kaczynski, D. (2007). University students in USA and Australia: Anticipation and reflection on the transition to work. *International Journal of Employment Studies, 15*(2), 91.

# 2 PROFESSIONAL DEVELOPMENT FOR EARLY-CAREER ENGINEERS

## OVERVIEW

This chapter has been submitted to the journal of *Higher Education, Skills and Work-based Learning*. The chapter is a literature review that focuses on the transition of engineering graduates to work, and the role which disciplinary socialisation plays in this transition process. Its purpose is to investigate approaches and enabling activities which can be employed by organisational induction programs to support successful transition to practice for new-career engineers. The chapter discusses research relating to 'becoming a professional' from the perspective of workplace development programs for early-career engineers. Competence (mastery of skills) and work-readiness (application in context, and the need to coordinate or synthesise multiple skills contribute to challenges new engineers face in the transition to work. The discussion in this chapter focuses on the expectations of the workplace, general or transferable versus specific skills, and philosophies of knowledge and practice. The review considers how tensions between higher education programs and workplace expectations have influenced the development of practice-influenced curriculum models, and how these models align with the Tuning Process research method used in this study. The Tuning Process seeks to align expectations across employers, academics, and students. Three broad knowledge domains or 'competences' underpin the Tuning methodology. These are: instrumental or 'foundational'; interpersonal; and systemic or 'combinatory' knowledge that builds on prior learning and experience. The chapter concludes with a brief analysis of how engineering methods and social and situated work activities constitute disciplinary texts. It recommends that centralising these texts in learning and organisational induction programs can help make experienced and work-based tacit 'know-how' more accessible, and yield the usable knowledge that typifies engineering practitioners.

## INTRODUCTION

This chapter investigates literature relating to 'becoming a professional' from the perspective of workplace development programs for early-career engineers. It discusses the expectations of the workplace, general or transferrable versus specific skills, and philosophies of knowledge and practice. The literature incorporates how professional identities are forged, and cognitive and social development models which may be leveraged in induction and development programs.

On graduation, engineers become practitioners. Degree courses provide the intellectual and scientific foundations of their discipline and the fundamentals of engineering principles and analysis. Thus, there is an argument that traditional university curricula develop 'expert students' or engineering researchers, rather than novice engineers (Crawley, C., Malmqvist, & Brodeur, 2008; Reid, Abrandt Dahlgren, Dahlgren, & Petocz, 2011). Vest (2007) summarises this as: "we educate and train the men and women who drive technological change, but we sometimes forget that they must work in a developing social, economic, and political context" (online).

## ALIGNING SKILLS WITH INDUSTRY AND SOCIAL NEED

Transferrable versus discipline-specific skills, philosophies of knowledge and practice, and the process of becoming a professional are anchor themes in transition to work research. Capabilities required for the future workplace include critical thinking, creativity, curiosity, and communication skills (Torii & O'Connell, 2017; World Economic Forum, 2016). Social and economic forces encourage innovation, and to apply, review, and extend existing knowledge to new domain boundaries and applications. This emphasises the ability of graduate engineers to make judgments, create solutions, and communicate results. The Motorola Corporation reveals that:

> We generally try to determine what an individual knows, how an individual can contribute, the perspective an individual brings to us, and how well the individual

> fits into the culture of our organisation. … We want deep technical expertise, but that expertise must have a context, and the individual needs to be able to work with others (cited in Crawley, Malmqvist, Östlund, Brodeur, & Edström, 2014, p. 18).

Employability requires broad and deep skills that are socially constituted. For engineering graduates, this entails science and engineering fundamentals, working knowledge of engineering practice, and awareness of how engineers contribute to society:

> They must develop a basic understanding of business processes, be adept at product development and high-quality manufacturing, and know how to *conceive*, *design*, *implement*, and *operate* complex engineering systems of appropriate complexity. They must increasingly do this within a framework of sustainable development, and be prepared to live and work as global citizens (Vest, 2014, pp. v-vi).

To be conversant in a field marks understanding of what it is those who work in the field do (Johnson, Watson, Delahunty, McSwiggen, & Smith, 2011). Learning frameworks such as the Conceive, Design, Implement, Operate Initiative (CDIO) align with the practical and situational knowledge of professional activity and address tensions between academia and industry (Kamstrup, 2016). CDIO incorporates industry-identified gaps and accrediting body expectations in the practice areas of: (1) disciplinary knowledge and reasoning, (2) personal and professional skills and attributes, (3) interpersonal skills of teamwork and communication, and (4) developing new knowledge through the process of conceiving, designing, implementing, and operating systems in business, social and environmental contexts. CDIO harmonises with efforts such as the Tuning Process, which identifies three broad knowledge domains:

- **Instrumental—**cognitive, methodological, technological, and linguistic abilities
- **Interpersonal—**individual abilities including social skills such as interaction and cooperation
- **Systemic—**abilities and skills which combine understanding and knowledge, and which leverage prior learning and experience (Tuning, 2000, online).

Tuning is a European higher education initiative to align or 'tune' student, tertiary institution, and employer reference points. Its aim is to achieve common understanding across a range of disciplines and key stakeholder groups for the purposes of increasing employability (Gonzélez & Wagenaar, 2003). Figure 2.1, adapted from Carvalho (2008,

p. 11), summarises employer, graduate, and academic views of the skills required for engineering.

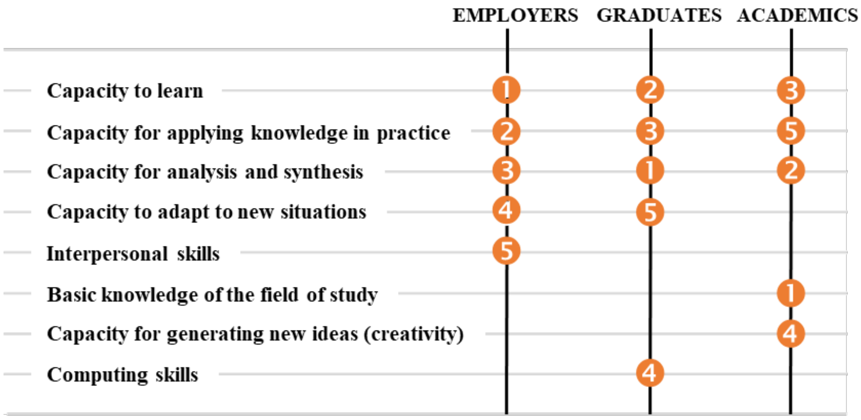



**Figure 2.1 Top five capabilities required for engineering**

Their priorities emphasise that employers value practical knowledge application and systemic or 'combinatory' knowledge. Beckett (2008) views this as 'holistic competence', which he associates with professional judgment, or judgments-in-context, and which are developed as part of engaging in work activities.

## BECOMING A PROFESSIONAL

There are various definitions and interpretations of the complex notions of 'capability' and 'competence'. Alberts and McIntire (2014) distinguish competency from workforce readiness. They summarise this distinction as:

> Workforce effectiveness relies on two critical characteristics: competence and readiness. *Competence* is the sufficient mastery of the knowledge, skills, and abilities—or competencies—needed to perform a given task. *Competence* reflects how well an individual understands subject matter or is able to apply a given skill. [C]ompetence is necessary, but not sufficient, to perform a job task successfully in a real-world work environment. In contrast to competence, *readiness* is the ability to apply a set of competencies required to perform a job task in a real-world environment with acceptable proficiency.

From an extensive literature database interrogation of the concepts of 'competence', 'engineering', 'practice', and 'importance' in engineering education, Passow and Passow (2017) conclude that, "engineers' technical work is inseparably intertwined with team-player collaboration. The most crucial skill is coordinating multiple competencies to accomplish a goal" (p. 475). The implications for engineering education and development are that technical and social capabilities are critical to project success; that technical capabilities cannot be disassociated from the context in which they are used; and that, "engineering education needs a greater connection to practice from the first day" (p. 503). Similarly, the active and 'combinatory' knowledge highlighted by Carvalho (2008) and Beckett (2008) as pivotal workplace skills is further emphasised by Baytiyeh and Naja (2012). From discussions with professional engineers, they observe that:

> While engineering curricula ensure that graduates possess the technical knowledge to begin a career, the transition from student to an employee is not well understood. Engineering students complete a highly-structured curriculum, but a professional engineer works in a highly unstructured environment and performs multi-dimensional tasks (Baytiyeh & Naja, 2012, p. 4).

Professional socialisation is "the process of learning a professional role and emerging as a member of an occupational culture" (Melrose, Miller, Gordon, & Janzen, 2012, p. 2). It links the worldview specific to disciplines with a professional sense of self. Socialisation is also a means by which we acquire the knowledge, skills, and disposition that enable us to become members of a profession. Johri (2012) points out that in a profession such as engineering, where technical competence is highly valued, the challenge for developmental programs is to identify "what newcomers do as they socialise and what this participation means to them" (p. 250). Reid et al. (2011) propose that the transition from student to professional lends itself to models of professional formation that interpret how contemporary work discourses, and discipline knowledge and professional dispositions interact and influence the development of professional identities. For Scanlon (2011), the journey to becoming a professional is characterised by 'continual becoming', as we shape, reshape and refine our professional selves:

> "Becoming" as a metaphor emphasises that learning, practice, and dispositional development are ongoing, and are never completed. This metaphor captures the iterative formation of a professional identity and encapsulates the concept of lifelong learning (Scanlon, 2011, p. 8).

Scanlon highlights the commitment to ongoing learning and development required of professionals, and directs attention towards programs that align learning, practice and development.

In an early developmental study of changes in student understanding, (Perry, 1970) proposes a four-stage evolutionary journey of intellectual and personal development that progresses from (1) accumulating rudimentary facts based on the authority of experts, to (2) perceiving diversity of opinion, through to (3) acknowledging that context and frames of reference underpin these diverse viewpoints, and ultimately to (4) holding one's own opinions. Systemic knowledge characterises this latter stage, which integrates information and knowledge learned from others with personal experience and reflection. Throughout, learners re-orient themselves as they adjust to new understandings and circumstances. Educational and professional development is therefore a continual journey for which key milestones are exposure to the domain, acquisition of domain knowledge, knowledge application, and ultimately and ideally, contribution to one's chosen field (Perry, 1970; Reid et al., 2011; Scanlon, 2011).

Theories of workplace socialisation reinforce developmental journey analogies. Interlinked with the view of professional 'becoming' is the Aristotelian belief that *what we do is who we are*—that is, practice and disciplinary values create professional personas. For Knorr-Cetina (1999), people working together are cultures whose collective knowledge exists as practice and evolves as a body of knowledge. Feldman and Orlikowski (2011) propose that "central to a practice lens is the belief that social life is an ongoing production and emerges through people's recurrent actions" (p. 2). Miller and Goodnow (1995) emphasise the centrality of work activity to personal identity creation; they argue that "the concept of *practice* recognises that the acquisition of knowledge or skill is part of the construction of an identity or a person" (p. 5). Professional identities are thus continually developed and refined based on feedback from peers, mentors, and role models, and this process is deeply social.

Trevelyan (2009) observes that engineers spend the majority of their time in communication with close associates. He makes the case for learning programs aimed at engineering practice as a social system in which people interact across discipline boundaries, and within the context of broad societal structures. Korte, Sheppard, and Jordan (2008) describe how early-career engineers approach tasks and problem-solving through finding people with useful information, and leveraging organisational experience networks. For workplace training and development, this means the focus is developing programs that foster networks, emphasising collaborative and cross-functional assignments, and providing graduates with authentic job tasks.

## APPROACHES TO SKILLS DEVELOPMENT

The American Society of Civil Engineers' (ASCE) *Body of Knowledge* (BoK) outlines "the necessary depth and breadth of knowledge, skills, and attitudes required of an individual entering the practice of civil engineering at the professional level in the 21st century" (ASCE, 2008, p. 8). The ASCE framework comprises foundational, technical, and professional dimensions of knowledge aligned to outcomes or areas of competency. It acknowledges that there are many developmental taxonomies, and that they describe:

> The same thing—the human person—and the educational process of human development. The purpose of a taxonomy is to break down this overall development process into smaller discernible 'chunks' within which goals can be articulated, metrics of achievement can be constructed, and achievement can be assessed (ASCE, 2008, p. 87).

Other contributors to theoretical models of development incorporate 'systemic' capabilities that integrate aspects of experience and socialisation into the learning journey. Table 2.1 summarises these taxonomies.

**Table 2.1 Key contributors to developmental taxonomies**

| Reference | Key Concepts | Key Variables | Key Contribution |
|---|---|---|---|
| (1956) Bloom et al. | Classification of learning objectives divided into three domains: cognitive, affective, and psychomotor, each of which has a staged model of acquisition | Cognitive—knowing/head (knowledge)<br>Affective—feeling/heart (attitude)<br>Psychomotor—doing/hands (skills) | Conceptual framework for curriculum development/assessment<br>Provides verbs for defining objectives |
| (1970) Perry | Learners go through staged intellectual growth | Dualism<br>Multiplicity<br>Relativism<br>Commitment | Framework for staged intellectual development<br>Reflection is the transition point between stages |
| (1979) Steinaker and Bell | Experiential Taxonomy<br>Underpinned by constructivist thinking<br>Offers a tool to plan, sequence, deliver and evaluate learning. | Exposure<br>Participation<br>Identification<br>Internalisation<br>Dissemination | Good model for socialisation into a profession.<br>Sequences the learning act. |
| (1980) Dreyfus and Dreyfus | Taxonomy of skills acquisition from novice to expert.<br>Concrete experience plays a paramount role. | Novice<br>Competent<br>Proficient<br>Expert<br>Master | Benchmark skills acquisition model.<br>Presents five cognitive and skill changes as one moves from novice to expert levels of mastery. |
| (1995) Hoffman et al. | Moves from no knowledge of discipline to mastery. | Naiveté<br>Novice<br>Initiate | Explores how experts are defined. |

| Reference | Key Concepts | Key Variables | Key Contribution |
|---|---|---|---|
| | Comprehensive suite of activities for eliciting expertise. | Apprentice<br>Journeyman<br>Expert<br>Master | Practical ideas for eliciting expertise.<br>Can be used for knowledge transfer and retention programs. |
| (2001) Anderson and Krathwohl | Bloom's nouns become verbs.<br>Shifts priority of evaluation and creativity. | Focus on higher order cognitive skills, including creativity | Updates Bloom to integrate with current skills and literacies.<br>Accommodates more active learning requirements. |
| (2003) Alexander | Expertise is 'domain acclimation'.<br>Characterised by systematic changes within and across stages of development. | Acclimation<br>Competence<br>Proficiency/Expertise | Considers interplay of these elements across the learning process.<br>Incorporates breadth and depth of learning. |

Perry (1970), Steinaker and Bell (1979), Alexander (2003) reinforce the view of Alberts and McIntire (2014) that work effectiveness combines mastery of knowledge and skills, within a context that encourages demonstrable capability. Steinaker and Bell's (1979) experiential taxonomy is guided by the view that knowledge is constructed or shaped by experience. They propose that learning progresses from initial exposure to a discipline to eventually contributing back to the discipline. Each of these stages of 'exposure, participation, identification, internalisation, and dissemination' is associated with introspection and knowledge processing. Similarly, for Alexander (2003), sharing or contributing knowledge signifies expertise. She notes that, "not only is the knowledge of experts broad and deep, but the experts are also contributing new knowledge to the domain" (p. 12).

Vest (2014) underscores the importance of extending learning environments to authentic and empowering situations:

> Students, for example, are driven by passion, curiosity, engagement, and dreams. Although we cannot know exactly what they should be taught, we focus on the environment and context in which they learn, and the forces, ideas, inspirations, and empowering authentic situations to which they are exposed (Vest, 2014, p. iv).

The World Economic Forum (2016) similarly emphasises the role of social and emotional learning (SEL) skills, including collaboration, communication, and problem-solving. Bransford (2007) suggests that focusing on the context of how one learns, encourages resilience and develops behaviours that are receptive to uncertainty. This helps students learn about themselves as thinkers and as problem-solvers. It assists them to "develop an identity as a lifelong learner rather than as an expert who is supposed to know all the answers" (p. 3). Fink's (2003) taxonomy of significant learning addresses the call for important kinds of learning that do not emerge easily from traditional learning models. He proposes six transformational learning dimensions: (1) acquiring foundational knowledge or facts and ideas, (2) applying knowledge through various types of thinking and activities, (3) integrating ideas and seeing connections between things, (4) understanding the human dimension of knowledge by relating it to self and others, (5) becoming engaged and involved as a result of learning, and (6) becoming self-directed learners through the process of learning how to learn.

The UK Institution of Civil Engineers (ICE) *Competency Framework for Professional Development* sets out the knowledge, skills, and attitudes that are recognised and valued by the institution. Like the ASCE BoK, the ICE framework identifies the need for more holistic skills underpinned by a foundation of technical capability. It sees engineers through the broad lenses of self, citizenship, and the context of practice to "help engender those competencies attributed to a well-rounded practitioner at the heart of society" Institution of Civil Engineers (2011, p. 3). The ASCE reaches back into the curriculum and frames the capabilities required of graduates. ICE focuses on deepening and extending this foundational capability in practice. Behavioural, leadership/management and industry knowledge, and applied skills are "gained through experience and interaction and are cultivated, matured, and honed through continuing professional development" Institution of Civil Engineers (2011, p. 3).

## OPPORTUNITIES FOR THE WORKPLACE

Some universities such as the University of Western Australia (UWA, 2017) offer "professional practicums". Similarly, workplace development programs can provide structured pathways that assist career entrants to complete the mandatory work experience required by professional accrediting bodies. Examples of these types of organisational programs include apprenticeships, paraprofessional, and graduate programs (Arup, 2017; RMS, 2017). "The transition from university to an engineering career is highly complex and critically important for graduating engineers" (Baytiyeh & Naja, 2012, p. 12). Professional engineers work in increasingly unstructured environments and perform multi-dimensional tasks. Engineering work is also affected by transactional 'hidden' elements, such as awareness of human factors, socio-political influences, and environmental and economic considerations (Finkel & King, 2013;

Trevelyan, 2010). This highlights the ability of graduate engineers to make judgments, create solutions, to reflect on their decisions and solutions, and to communicate results. It emphasises the need for organisations to provide guided and authentic activities that develop these capabilities in new engineers.

“The process of learning a complex practice such as engineering necessarily shapes the perception, imagination, and deportment of anyone who undergoes it” (Sheppard, Macatangay, Colby, & Sullivan, 2009, p. 188). They present five guiding principles for engineering education, which are extensible as a design manifesto for workplace learning programs:

- Engineering work is inherently interactive and complex;
- Formulating problems and solving problems are interdependent activities;
- Engineering has many publics;
- Engineering incorporates many domains beyond the technical;
- Engineers affect the world (Sheppard et al., 2009, pp. 175-176).

Sheppard et al. (2009) suggest that a range of techniques from the learning sciences, such as mentoring, cognitive apprenticeship (modelling the processes that experts use to handle complex tasks), and scaffolding (guided ‘stretch’ tasks) can help to impart and to make visible the experience and knowledge of engineering practice. Solving complex workplace problems with conflicting goals, encouraging diverse and innovative ways to achieve solutions, and managing non-engineering constraints and success measures are activities that can be used to support the transition of early-career engineers to professional practice (Jonassen, Strobel, & Lee, 2006).

For Hays and Clements (2012) and Eraut (2007), work-related learning is *with, through*, and *in* work activities. Workplace induction and development programs for graduates blend practical on-the-job experience with academic or formal learning activities, adapted to provide personal and professional skills for program type and the knowledge needs of participants. Program elements include: on-campus residential studies, job rotations through projects and teams, discipline-specific site visits, work-based projects and stretch tasks, buddy and mentoring programs, networking / industry events, and defined career pathways that include further degrees, professional networks, and chartership (Arup, 2017; Exon, 2017; RMS, 2017). Other responses are personalised development plans that seek to develop whole individuals able to engage in knowledge transfer and knowledge production activities. For Saito, Salazar, Kreafle, and Grulke (2011), learning programs are developmental and should blend aspects of innovation or applied creativity with lifelong learning or reflective practice. Learning incorporates guidance from colleagues and work-group peers, and can involve structured learning and knowledge transfer activities, such as job shadowing. To respond to expectations of both graduates and of corporate members, the Australasian Institute of Mining and Metallurgy (AusIMM) *Graduate Program Best Practice Guidelines* outlines an industry standard for graduate induction and professional development (AusIMM, 2017). Its graduate program recommendations conform to the 70:20:10 model of many workplace development programs, adapted to the mining industry. The 70:20:10 model suggests the optimum balance for professional learning is: 70 percent for informal, practical and experiential 'stretch' tasks; 20 percent for coaching, mentoring and developing through others; and, 10 percent for formal learning, training, and structured courses (Kajewski & Madsen, 2012). The AusIMM guidelines combine general elements appropriate to all industry graduate development programs, and discipline-specific elements to shape graduate development program for individual minerals professions. The guidelines are framed as an agreement, with the program comprised of mentoring, being entrusted with meaningful responsibilities, and formal training.

The call for engineering education to yield practical or 'usable knowledge', is reiterated by Johnson et al. (2011), who approach professional activities via the *texts* of a discipline. They adopt Smagorinsky's broad interpretation of text, which encompasses "any configuration of signs that provide a potential for meaning" (Smagorinsky, 2001, p. 137). Engineering texts or meaning-making activities include interpreting client requirements, designing and evaluating technically and commercially effective solutions, and accessing the knowledge and experience of colleagues and related disciplines . Table 2.2 lists activities that correspond to engineering practice.

**Table 2.2 Conceive Design Implement Operate (CDIO) (Crawley et al., 2014, p. 26)**

| | |
|---|---|
| **C**onceive | Defining customer needs, considering technology, enterprise strategy and regulations, and developing conceptual, technical, and business plans. |
| **D**esign | Creating the detailed information description of the design; the plans, drawings, and algorithms that describe the system to be implemented. |
| **I**mplement | Transforming the design into the product, process, or system, including hardware manufacturing, software coding, testing, and validation. |
| **O**perate | Using the implemented product, process, or system to deliver the intended value, including maintaining, evolving, recycling, and retiring the system. |

# CONCLUSION

Engineering has become an expansive discipline. Its boundaries increasingly cross those of other disciplines and knowledge areas in a ‘landscape of practice’ (Trevelyan, 2014). As the scope of their discipline expands, the knowledge requirements for engineers increases. Professional learning in the form of shared activity connects these bodies of knowledge (curricula) with knowledgeability (social- and context-based experience). Vest (2014) urges engineering education to “find a new balance” (p. vi) that returns to the excitement of learning and engagement with knowledge. Research from engineering education and workplace learning affirms the role of tertiary learning and of organisational development programs in co-creating this new balance. The literature provides theoretical models of cognitive development and professional socialisation, and related good-practice examples in workplace induction programs. However, the expanding scope of the engineering profession suggest a need for further research in how education and industry can forge learning and knowledge partnership models that accommodate this growth. The literature reflects an emerging paradigm of learning design collaboration and co-production between universities and the workplace. While much work remains to be done in this area, it suggests new opportunities that can be used by workplace programs to support successful transition to practice. These opportunities include leveraging as a program design focus, insights into the practices and ‘texts’ of engineering work.

# References


Alberts, C. J., & McIntire, D. (2014). *A Systematic approach for assessing workforce readiness*. Technical Report. CERT Division. Carnegie Mellon University. Software Engineering Institute.

Alexander, P. A. (2003). The development of expertise: The journey from acclimation to proficiency. *Educational Researcher, 32*(8), 10-14.

Anderson, L. W., & Krathwohl, D. R. (Eds.). (2001). *A taxonomy for learning, teaching, and assessing: A revision of Bloom's Taxonomy of Educational Objectives*. Boston, MA: Allyn & Bacon (Pearson Education Group)

Arup. (2017). Graduate program. Retrieved from https://www.arup.com/careers/graduates-and-interns/australasia/graduate-program

ASCE. (2008). *Civil engineering body of knowledge for the 21st century: Preparing the civil engineer for the future*. Retrieved from http://www.asce.org/uploadedFiles/Education_and_Careers/Body_of_Knowledge/Content_Pieces/body-of-knowledge.pdf

AusIMM. (2017). *Graduate program best practice guidelines*. Australasian Institute of Mining and Metallurgy. Carlton, Victoria Australia. Retrieved from http://www.ausimm.com.au/content/docs/ausimm_graduate_guidelines.pdf

Baytiyeh, H., & Naja, M. (2012). Identifying the challenging factors in the transition from colleges of engineering to employment. *European Journal of Engineering Education, 37*(1), 3-14.

Beckett, D. (2008). Holistic competence: Putting judgements first. *Asia Pacific Education Review, 9*(1), 21-30.

Bloom, B. S., Engelhart, M. D., Furst, E. J., Hill, W. H., & Krathwohl, D. R. (1956). *Taxonomy of educational objectives*. N.Y.: Longmans, Green.

Bransford, J. (2007). Preparing people for rapidly changing environments. *Journal of Engineering Education, 96*(1), 1-3.

Carvalho, J. (2008). *International aspects of Bologna: The Tuning Project*. Paper presented at the BALANCE – Bologna: A long-term approach to new certification in Europe, University of Turku, Finland. http://www.coimbra-group.eu/balance/Docs/turku/International%20Aspect%20of%20Bologna%20Process%20-Tuning.ppt.

Crawley, E. F., C., J., Malmqvist, J., & Brodeur, D. R. (2008). *The context in engineering education*. Paper presented at the 4th International CDIO Conference, Hogeschool Gent, Gent, Belgium, . http://www.cdio.org/files/document/file/m1-crawley2008.pdf

Crawley, E. F., Malmqvist, J., Östlund, S., Brodeur, D. R., & Edström, K. (2014). *Rethinking engineering education: The CDIO approach* (2nd ed.). Heidelberg, Germany: Springer.

Dreyfus, S. E., & Dreyfus, H. L. (1980). *A five-stage model of the mental activities involved in directed skill acquisition*. Monograph. Operations Research Center. California University Berkeley. Retrieved from http://www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA084551&Location=U2&doc=GetTRDoc.pdf

Eraut, M. (2007). Learning from other people in the workplace. *Oxford Review of Education, 33*(4), 403-422.

Exon. (2017). *BEng Civil Engineering Site Management*. Engineering. University of Exeter. Retrieved from http://www.exeter.ac.uk/undergraduate/degrees/engineering/civil-engineering/

Feldman, M. S., & Orlikowski, W. J. (2011). Theorizing practice and practicing theory. *Organization Science, 22*(2011), 1240-1253.

Fink, L. D. (2003). *Creating significant learning experiences: An integrated approach to designing college courses*. San Francisco: Jossey-Bass.

Finkel, A., & King, R. (2013). *Innovative approaches to engineering education*. Paper presented at the CAETS, International Council of Academies of Engineering and Technological Sciences, Budapest, Hungary.

Gonzélez, J., & Wagenaar, R. (2003). *Tuning educational structures in Europe. Final report. Phase one*. Universidad de Deusto: Deusto. Retrieved from http://www.bolognakg.net/doc/Tuning_phase1_full_document.pdf

Hays, J., & Clements, M. (2012, 20-22 June, 2102). *Transition-bridging the gap between study and work.* Paper presented at the Proceedings of the 9th International Conference on Cooperative & Work-Integrated Education, Where East meets West and Theory meets Practice, Istanbul, Turkey.

Hoffman, R. R., Shadbolt, N. R., Burton, A. M., & Klein, G. (1995). Eliciting knowledge from experts: A methodological analysis. *Organizational Behavior and Human Decision Processes, 62*(2), 129-158.

Institution of Civil Engineers. (2011). *Competency framework for professional development*. Institution of Civil Engineers (ICE). Westminster, London. Retrieved from http://www.gedcouncil.org/sites/default/files/ICE-Competency-Framework.pdf

Johnson, H., Watson, P. A., Delahunty, T., McSwiggen, P., & Smith, T. (2011). What it is they do? Differentiating knowledge and literacy practices across content disciplines. *Journal of Adolescent & Adult Literacy, 55*(2), 100-109.

Johri, A. (2012). Learning to demo: The sociomateriality of newcomer participation in engineering research practices. *Engineering Studies, 4*(3), 249-269.

Jonassen, D. H., Strobel, J., & Lee, C. B. (2006). Everyday problem solving in engineering: Lessons for engineering educators. *Journal of Engineering Education, 95*(2), 139-151. doi:10.1002/j.2168-9830.2006.tb00885.x

Kajewski, K., & Madsen, V. (2012). Demystifying 70:20:10 White Paper. Retrieved from http://deakinprime.com/media/47821/002978_dpw_70-20-10wp_v01_fa.pdf

Kamstrup, A. K. (2016). CDIO Enacted: Tracing the multiplicity of an initiative in engineering education. In U. Jørgensen & S. Brodersen (Eds.), *Engineering professionalism: Engineering practices in work and education* (pp. 105-123). Rotterdam: SensePublishers.

Knorr-Cetina, K. (1999). *Epistemic cultures: How the sciences make knowledge*. Harvard: Harvard University Press.

Korte, R., Sheppard, S., & Jordan, W. (2008). *A qualitative study of the early work experiences of recent graduates in engineering.* Paper presented at the American Society for Engineering Education, June 22-26 2008, Pittsburgh, PA.

Melrose, S., Miller, J., Gordon, K., & Janzen, K. J. (2012). Becoming socialized into a new professional role: LPN to BN student nurses' experiences with legitimation. *Nursing Research and Practice, 2012*.

Miller, P. J., & Goodnow, J. J. (1995). Cultural practices: Toward an integration of culture and development. *New Directions for Child and Adolescent Development, 1995*(67), 5-16.

Passow, H. J., & Passow, C. H. (2017). What competencies should undergraduate engineering programs emphasize? A systematic review. *Journal of Engineering Education, 106*(3), 475-526. doi:10.1002/jee.20171

Perry, W. G., Jr. (1970). *Forms of intellectual and ethical development in the college years: A scheme*. New York: Holt, Rinehart, and Winston.

Reid, A., Abrandt Dahlgren, M., Dahlgren, L. O., & Petocz, P. (2011). *From expert student to novice professional* (Vol. 99). The Netherlands: Springer.

RMS. (2017). *Road designer in training*. Employment Services. Roads and Maritme Services. Sydney, NSW, Australia. Retrieved from http://www.rms.nsw.gov.au/about/careers/working-with-us/employment-programs/road-designer-in-training.html

Saito, K., Salazar, A. J., Kreafle, K. G., & Grulke, E. A. (2011). Hitozukuri and monozukuri: Centuries' old eastern philosophy to seek harmony with nature. *Interdisciplinary Information Sciences, 17*(1), 1-9.

Scanlon, L. (2011). 'Becoming' a professional. In L. Scanlon (Ed.), *"Becoming" a professional* (Vol. 16, pp. 13-32). The Netherlands: Springer.

Sheppard, S., Macatangay, K., Colby, A., & Sullivan, W. M. (2009). *Educating engineers: Designing for the future of the field* (Vol. 9). San Francisco, CA: Jossey-Bass.

Smagorinsky, P. (2001). If meaning is constructed, what is it made from? Toward a cultural theory of reading. *Review of Educational Research, 71*(1), 133-169.

Steinaker, N., & Bell, M. (1979). *The experiential taxonomy: A new approach to teaching and learning*. New York, NY: Academic Press.

Torii, K., & O'Connell, M. (2017). *Preparing young people for the future of work*. Mitchell Institute. Melbourne. Retrieved from http://www.mitchellinstitute.org.au/reports/preparing-young-people-for-the-future-of-work/

Trevelyan, J. P. (2009). *Engineering education requires a better model of engineering practice.* Paper presented at the Research in Engineering Education Symposium 2009, Palm Cove, QLD, Australia.

Trevelyan, J. P. (2010). Reconstructing engineering from practice. *Engineering Studies, 2*(3), 175-195.

Trevelyan, J. P. (2014). *The making of an expert engineer*. Leiden, The Netherlands: CRC Press.

Tuning. (2000). *Tuning educational structures in Europe*. Retrieved from http://www.unideusto.org/tuningeu/

UWA. (2017, 7 July 2017). Professional practicum. *Faculty of engineering and mathematical sciences, University of Western Australia.* Retrieved from http://www.ecm.uwa.edu.au/students/professional-practicum

Vest, C. M. (2007). *Educating engineers for 2020 and beyond*. National Academy of Engineering, Grand Challenges Blog. Retrieved from http://www.engineeringchallenges.org/14373/GrandChallengesBlog/7639.aspx

Vest, C. M. (2014). Forward: Educating engineers for 2020 and beyond. In E. F. Crawley, J. Malmqvist, S. Östlund, D. R. Brodeur, & K. Edström (Eds.), *Rethinking engineering education: The CDIO approach* (2nd ed.). Heidelberg, Germany: Springer.

World Economic Forum. (2016). *New vision for education: Fostering social and emotional learning through technology*. Retrieved from https://www.weforum.org/reports/new-vision-for-education-fostering-social-and-emotional-learning-through-technology

# 3 Fostering Wise Judgment

*Fostering wise judgment: Professional decisions in development programs for early-career engineers*

## Overview

This chapter has been submitted to the *Journal of Vocational Education & Training*. The chapter reviews literature that explores the role of judgment in professional practice. This investigation is prompted by survey results inviting engineering graduates and professionals to identify the capabilities they believe are most significant to success in the engineering workplace. Sound professional judgment resonates throughout participant responses. However, there is little research that discusses developing professional judgment in transition to work programs. The chapter poses the question "How can workplace programs assist novice engineers to develop their capacity to exercise professional judgment?" Although engineering graduates may have technical expertise, be inclined to innovate, and be schooled in the need for social accountability, engineering projects require decisions based on uncertainty and time constraints. The chapter discusses how reflecting on the decisions made in response to day-to-day work activities, and on the outcomes of these decisions may contribute to the development of wise judgments, or 'practical wisdom'. Foundational to this discussion is Aristotle's concept of *phronesis*, which translates as "practical wisdom". The literature review establishes connections between professional judgment and practical wisdom and the role of deliberative, reflective practice in developing professional judgment. This analysis is set against a list of ten principles which interpret professional judgment through the lens of how they promote transformational practice, and activities which help realise these principles. The chapter highlights the importance of organisational culture and of designing work experiences that are pathways to learning. It summarises different approaches to workplace induction programs, and discusses how these programs provide opportunities to link everyday work activities with the structured, critical reflection that promotes continuous improvement of practice, and helps develop sound professional judgments.

## INTRODUCTION

Professionals engage in complex and often unpredictable tasks involving problem-solving skills and experience-based decisions. Particularly for engineers, the interdisciplinary nature of their practice and its many stakeholders means that on graduation, they are faced with professional challenges demanding sound judgment. The knowledge required for these judgments involves navigating project based environments with multi-disciplinary teams, cultures, and diverse stakeholder groups (Baytiyeh & Naja, 2012). Results of a survey that invited engineering graduates and experienced professionals to identify the most important skills required for engineering work highlight that problem-solving, decision-making, and teamwork are fundamental to work activities, and to the disciplinary character of an engineer. Survey analysis shows there are reciprocal interactions between educational institutions and workplaces, and that each informs scholarship and practice. Analysis additionally identifies judgment as a significant factor in engineering professional capability.

Reflection or critical reconstruction of practice is tendered as a means whereby abstract or conceptual knowledge becomes knowledge grounded in experience. Professional judgments and decision-making are associated with this transformational process. This chapter focuses on fostering decision making, or professional judgment for new career engineers. The chapter poses the question: “How can workplace programs assist novice engineers to develop their capacity to exercise professional judgment?” This inquiry establishes linkages with social forms of knowing. It presents the view that sound, or wise judgments develop through deliberative, reflective practice and that ‘wisdom’ or practical professional knowledge is a ‘teachable’ quality. Frameworks which can be leveraged to scaffold wise practice in transition to work programs are summarised. These encompass taxonomies of professional judgment (Coles, 2002), workplace learning *with*, *through*, and *in* work processes (Eraut, 2007), and the broader contribution of expansive and participatory learning environments (Fuller & Unwin, 2004).

Coles (2002) offers the following definition of professional judgment:

> At the foundation of professional judgment is a form of knowledge—called practical wisdom—which is not formally taught and learnt but is acquired largely through experience and informal conversations with respected peers. Wisdom develops through "the critical reconstruction of practice," including deliberation, which is distinguished from mere reflection. Professionals need to engage in the appreciation of their practice—not just to understand what informs their own practice but to consider critically the contestable issues endemic to practicing as a professional (Coles, 2002, p. 3).

To critical reflection, Beckett (1996) includes discretionary judgments, or decisions with defensible epistemological and ethical dimensions. These decisional moments and judgments-in-context are accountable to professional peer groups, and thereby advance communal knowledge. Beckett (1996) and Coles (2002) bring together complex concepts of 'knowledge' and 'wisdom'. These concepts have as foundation Aristotle's *phronesis*, which translates as "practical wisdom. In Figure 3.1, Coles reframes his definition of professional judgment as ten lessons that promote transformational practice.

1. Professionals engage, on society's behalf, with people who present them with complex, indeterminate problems.
2. Professionals work with high levels of uncertainty.
3. Professional practice fundamentally involves making judgements.
4. Professional judgement is based on "practical wisdom".
5. Professional judgement is acquired through experience and conversations with respected peers.
6. The learning process that underpins this is the critical reconstruction of practice.
7. This involves "deliberation," which is more than "reflection".
8. Deliberation involves consideration of the contestable issues endemic to practicing as a professional.
9. Professional education and development require professionals to engage in the appreciation of their practice through deliberation.
10. The assessment of practice should focus on the judgements that professionals make and will inevitably involve making judgements about them, which, in turn, requires deliberation.

**Figure 3.1 Lessons for practice (Coles, 2002, p. 9)**

Sheppard, Macatangay, Colby, and Sullivan (2009) present similar maxims for engineering education: (1) Engineering work is inherently interactive and complex; (2)

formulating problems and solving problems are interdependent activities; (3) engineering has many publics; (4) engineering incorporates many domains beyond the technical; and (5) engineers affect the world. Novice engineers face unstructured real-world knowledge application that requires teamwork, informed decision making, and problem-solving abilities. Transferring knowledge from an education setting to the workplace is "particularly difficult, because of the considerable differences in context, culture and modes of learning" (Eraut, 2009, p. 7). Hays and Clements (2012) outline key differences in formal and workplace learning that include: (1) work related learning is *with*, *through*, and *in* work activities; (2) learning is generally from colleagues and peers and gradually moves towards shared learning experiences and mentoring; (3) knowledge is generated through experience and all workgroup members are expected to have and contribute knowledge and skill. Specifically, tailoring learning environments and learning programs to accommodate these differences in knowledge forms and how knowledge is acquired and applied in the workplace can help acclimatise new engineers to workplace social systems, to the complexities of moving from theory to practice, and to the expectations of the workplace.

## ENGINEERING IN PRACTICE

On graduation, engineers become practitioners. Engineering is a complex applied social system in which knowledge is distributed amongst group members:

> Engineers rarely work alone; they rely on the knowledge of many people to solve workplace problems.... different team members contribute their skills and knowledge to the solutions of engineering problems (Jonassen, Strobel, & Lee, 2006, p. 144).

Gordon (1984) similarly frames the professional engineering persona as individual capability that is dynamic, relational, and reflective, within a discipline construct with touchpoints across multiple social, technical, practical, and economic dimensions. A professional engineer is one who:

> Has attained and continuously enhances technical, communications, and human relations knowledge, skills, and attitudes, and who contributes effectively to society by theorizing, conceiving, developing, and producing reliable structures and machines of practical and economic value (Gordon, 1984, p. 4).

This is supported by Fenwick's (2012a) view that disciplinary competencies are constituted in a participatory network of knowing. Trevelyan (2009) observes that engineering is a collaborative discipline, where "engineers typically spend 60% of their time on communication with other people, mainly close associates" (p. 1). When practicing engineers are asked to recommend strategies to assist newcomers to the profession, they therefore highlight the importance of developing practical and interpersonal skills, leadership and decision-making, and skills in applied creativity or innovation (Crawley, Malmqvist, Östlund, Brodeur, & Edström, 2014). For Litzinger, Lattuca, Hadgraft, and Newstetter (2011), this manifests as the provision of learning experiences that build adaptable knowledge and skills.

Solving complex workplace problems with conflicting goals, employing diverse ways to achieve successful solutions, and managing non-engineering success measures and constraints are activities that can be utilised to support the transition of early-career engineers to professional practice (Jonassen et al., 2006; Litzinger et al., 2011). Extrapolating from Filliettaz's (2011) study of good practice in guidance and support for apprentices distributed across workgroups and teams, there are high levels of ambiguity in real-world engineering, and what new engineers perceive and learn about engineering work often depends on the quality of their interactions with co-workers and work groups. A range of 'know-what, know-why, know-how, know-who' knowledge forms thus impact the transition process. Beckett's (1996, 2008) notions of 'substantial judgments made in the heat of practice', judgments-in-context, and holistic competence, and Fenwick's (2012b) 'situational' literacies of practice articulate related viewpoints.

Socialisation in the form of collective guidance from managers and peers is an important aspect of how novice engineers acquire the habits of practice, or the signature epistemologies of their profession (Lucas & Spencer, 2015). For Beckett (2008) "work is literally embodied in workers" (p. 23), from which communal self-correction or work done in socio-culturally significant ways leads to collective practice. Professional socialisation is "the process of learning a professional role and emerging as a member of an occupational culture" (Melrose, Miller, Gordon, & Janzen, 2012, p. 2). Knowledge is in the heads and in the conversations and social relations between collaborators; it is distributed amongst people, their tools and communication media, history, and the institutions and artefacts they create (Knorr-Cetina, 1999). Engineers "design not just technical artefacts but socio-technical systems" (Johri 2010, p. 278). Greeno, Collins, and Resnick (1996) take a sociomaterial stance; they see knowledge as "distributed among people and their environments, including objects, artefacts, tools, books, and the communities of which they are a part” (p. 17). Guided support activities such as mentoring, distributed work groups, guided tasks, and reflection activities that leverage work experiences and tasks scaffold the formation of professional values, skills, and personas.

## STRUCTURING WORKPLACE TRANSITION TO WORK PROGRAMS

Graduate programs at professional engineering firms provide a one to two year structured induction into work culture, professional practices, and disciplinary values. These offer pathways to professional work, with programs available for apprentices, internships/summer placements, school leavers/paraprofessionals, university graduates. The programs blend practical on-the-job experience with academic or formal learning activities, adapted to provide personal and professional skills for program type and the knowledge needs of participants. An emerging paradigm is knowledge partnerships with specialist knowledge providers, industry associations, and educational institutions. For example, Laing O’Rourke has partnered with the University of Exeter to design and deliver a BEng Civil Engineering Site Management as part of its *Degree Apprenticeships* program (Exon, 2017). Similarly, an Australian Roads and Maritime Services Road Designer in Training program (RMS, 2017) has been delivered in partnership with the University of Southern Queensland. Elements of these programs include: on-campus residential studies, job rotations through projects and teams, discipline-specific site visits, work-based projects and stretch tasks, buddy programs, peer networks, mentoring, and defined career pathways that include further degrees, professional networks, and chartership.

## VIEWS OF EXPERTISE

Korte (2013) quotes a new engineer as saying: “I’m working on my technical niche [to] become the expert” (p. 46). Alternative views include that expertise emerges from socialisation into workplaces and disciplinary conventions (Ibarra, 1999; Van Maanen & Schein, 1979), and that expert practitioners advance knowledge frontiers through sharing or contributing new knowledge to their domain (Alexander, 2003). Eraut (2005) affiliates expertise with rich experience, and with peer collaboration and consensus. He queries whether the concept of ‘expert’ has become synonymous with ‘professional’:

> The adjective "expert" now means "trained by practice" or "skilled"; and the noun "expert" carries the additional meaning: "One whose special knowledge causes him to be an authority" or "a specialist".... There is also a suggestion of a social process (training) and a social role (an authority). Becoming an expert entails not only learning, but socialisation (Eraut, 2005, p. 173).

Similarly, McCauley (2016) contrasts industrial age certainty where "if a problem was encountered, an expert was called in to 'solve' it" with the current work landscape of unknowns, ambiguity, and collective solution finding. The skills that now need to be cultivated in response require "a development paradigm that embraces the discomforts of ambiguity, uncertainty, and complexity" (p. 27). Fuller and Unwin (2004) amplify this necessity. From case-study research on workplace apprenticeship programs, they conclude that organisations which engender 'expansive' and participatory approaches to learning are more likely to foster learning at work and to promote synergies between personal and organisational development, with discernible productivity and economic benefits. From a knowledge building approach, Bereiter and Scardamalia (1993) maintain that expertise is not a final state but involves a propensity to solve problems at the edge of one's competence and to push the boundaries of one's understanding of important and increasingly complex problems, solutions, and formal knowledge.

While newcomer literature is dominated by discussions of socialisation and assimilation, it devotes less attention to the details of what newcomers *do* as they integrate into the workplace, and how this participation helps establish professional identities (Johri, 2012). Eraut's (2007) study of workplace learning experiences for early-career engineers, accountants and nurses foresees this gap. It highlights workplace learning is fundamentally about learning through work. What is being learned, how it is being learned, and factors such as constructive feedback or "created confidence" and workplace culture affect the quality and degree of learning uptake. This 'learning in the flow of work' is summarised in Table 3.1.

**Table 3.1 Workplace learning processes (Eraut, 2007)**

| Work processes with learning as a by-product | Learning actions located within work or learning processes | Learning experiences at or near the workplace |
|---|---|---|
| Participating in group processes<br>Working alongside others<br>Consultation<br>Tackling challenging tasks and roles | Asking questions<br>Listening<br>Observing<br>Getting information<br>Learning from mistakes | Being supervised<br>Being coached<br>Being mentored<br>Shadowing<br>Visiting other sites |

| Work processes with learning as a by-product | Learning actions located within work or learning processes | Learning experiences at or near the workplace |
|---|---|---|
| Solving problems<br>Trying things out<br>Consolidating, extending, and refining skill | Reflecting<br>Locating resource people<br>Giving and receiving feedback | Studying based on individual needs/planning<br>Going to conferences<br>Taking courses |

Similarly, McCall (2010) situates experience at the centre of workplace development programs. Work-related circumstances that are formative include early work experiences, short-term assignments, stretch tasks, working with very good or very bad managers, meeting challenges and solving problems, and to a lesser extent, training programs. McCall (2010) contends that these experiences are powerful because they present a panorama of challenges. Identifying the different challenges that make these experiences resonant become opportunities to reflect and learn how to handle tests of ability, capacity, and character. Enablers comprise training interventions, progressive problem-solving, and scaffolding or “stretch” tasks (Bereiter & Scardamalia, 1993); analysing and discussing critical incidents (Tripp, 1993; Villachica, 2013); and outcomes-oriented work tasks (Kuhlmann & Ardichvili, 2015). Vygotsky (1927) underscores the importance of anchoring these activities in practice: “Practice sets the tasks and serves as the supreme judge of theory, as its truth criterion. It dictates how to construct the concepts” (p. 1).

## FOSTERING PRACTICAL WISDOM

Business adviser Ram Charan (2015) alleges that “taking control of uncertainty is the fundamental leadership challenge of our time” (p. 1). This imperative is not limited to leadership. Arguably, dealing with uncertainty and ambiguitity is the core contemporary *workplace* challenge. Industry requires those capable of making judgments knowing that these decisions are influenced by context, fluid circumstances, and the need for timely outcomes. Meacham (1990) views the essence of wisdom is in balancing knowing and doubting. He defines wisdom as an attitude towards the beliefs, values, knowledge, information, abilities, and skills one holds. The meaning and value of this knowledge is mutable and derives from the context in which it is known. He aligns with Bereiter & Scardamalia’s (1993) ‘propensity’ concept of expertise, which looks to extend capabilities and knowledge boundaries:

> The challenge of wisdom is to avoid this easy course of merely acquiring more and more knowledge and instead to strive simultaneously to construct new uncertainties, doubts, and questions about what might be known (Meacham, 1990, p. 183).

Reflecting on one's actions and responses cultivates reflection as a professional habit, underpinning informed or wise behaviours (Deepwell, 2017). Arlin for example, approaches wisdom through "problem finding". She suggests that "knowing what one does not know can be represented by the questions one asks, the doubts one has, and the ambiguities one tolerates. This type of knowing is the gift of one who has thought deeply in a domain and has a substantial knowledge based within that domain" (Arlin, 1990, p. 230).

Reflection is an activity in which people "recapture their experience, think about it, mull it over and evaluate it" (Boud, Keogh, & Walker, 1985, p. 19). Three key aspects of this process are: (1) recalling or detailing significant events; (2) emotional associations; and (3) re-examining or evaluating experiences. Eraut (2004) sees these as *deliberative* activities. He borrows the notion of "deliberate" learning from Tough (1971): "Time is set aside for acquiring new knowledge, and engagement in deliberative activities such as planning and problem-solving, for which there is a clear work-based goal with learning as a probable by-product" (Eraut, 2004, p. 250). Correspondingly, Schön (1983) discusses "reflection-in-action" as a mechanism to reflect on actions while carrying them out, to adapt and optimise performance. Gibbs' reflective cycle (1998, 2013) models this process. The cross-functional after-action-reviews and post-completion-reviews used by engineering and project teams to bookend activity and to consider lessons learned, reflect this process. Figure 3.2 illustrates how linking experience and reflection improves practice.

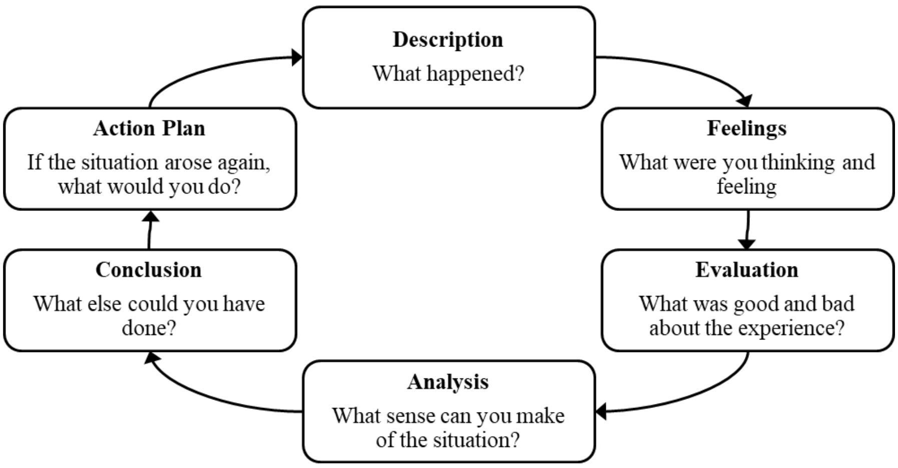



**Figure 3.2 Reflective cycle (Gibbs, 1998, 2013)**

From experience guiding disparate startup business groups towards mutual understandings, Guille, Abraham, and Patel (2010) suggest that interdisciplinarly project teams can engage in 'constuctively aligning' experiential learning across the project lifecycle, and share issues and learnings among project and business or support staff. These learnings, and the process of appreciative reflection cross project and team boundaries to enhance communal knowledge. They foster a holistic learning experience to inform subsequent actions and guide decision-making.

Critical reflectivity is transformational (Brookfield, 1986). Hinett (2002) interprets this as: "What gets us from experience to understanding is reflection" (p. 1). Appreciation of practice is purposeful and deliberative; it provides opportunities to constructively evaluate what we did, what we did well, and what we could do better next time (Coles, 2002; Day, 2010). MacIntyre (2007) argues that wisdom is related to options and to how to judge what we should do in different circumstances, and with the resources available. For Litzinger et al. (2011) these alternatives provide for "effective learning experiences" (p. 126). Participating in structured activities such as lessons learnt promotes reflection on practice, and can serve the transition towards wise practice.

Aristotle distinguishes between *techne* (technical or knowledge of how to make things) and *phronesis* (practical wisdom). Sternberg (2001) differentiates between a domain and a field: A *domain* is a formal body of knowledge that is learned, such as mathematics or physics, whereas a *field* is the social dynamics of how this knowledge is created and transmitted. Professionals combine specialised knowledge and how to apply this knowledge in practice. In response to Korte's graduate engineer, while deep domain knowing may promise expertise, assimilated tacit or experience-based and socially-exchanged insights underpins professional wisdom. This reiterates the question: How can workplaces foster the qualities required in broad (wise) and deep (expert) practices?

Wisdom unites experiential knowledge, cognition, affect, and social action. It is thus the territory of all (Clayton & Birren, 1980; Sternberg, 1998). Gates and Higgs (2013) frame wisdom as an individual and personal characteristic that transcends the boundaries of formal and higher education programs. Wisdom "sits comfortably within the realm of lifelong and lifewide education" (p. 43). As with Guille et al.'s (2010) project learnings, accounts of diverse life experiences, and ill-defined problems can be debated and analysed to help surface wise thinking or practices. Reflecting on these stories and the experiences they embody can help create personal wise narratives. Table 3.2 outlines techniques which assist expert practice, and can help to encourage wise behaviours.

**Table 3.2 Techniques to foster wisdom**

| Technique | Citation |
|---|---|
| Analysing quandaries and 'wicked problems' that present threshold moments | Bassett (2011) |
| Recalling and detailing significant events, establishing emotional associations, and reviewing or evaluating experiences | Boud et al. (1985) |
| Reflective journal writing based on SOS (Self, Others, Situation) | Dye (2011) |
| Work processes that have learning as a by-product, learning as part of a task or activity, and learning experiences that are part of the process of being at work. These include: solving problems, giving and receiving feedback, and reflecting | Eraut (2007) |
| Collective guidance—a form of distributed mentorship and support, where novice workers are guided and supported by more experienced colleagues, and this guidance and support is distributed collectively in work teams | Filliettaz (2011) |
| Structured reflection process of: (1) describing what happened, (2) associating the event with feelings, (3) evaluating good and bad aspects of the experience, (4) analysing the experience, (5) asking what alternatives could be implemented, and (6) establishing an action plan for similar situations | Gibbs (1998, 2013) |
| Reflective learning experiences at each stage of the project lifecycle that encompass: affective (empathy and engagement), metacognitive (structured reflection based on feedback), cognitive (guided/mentored 'stretch') tasks that promote deeper knowledge and proficiency | Litzinger et al. (2011) |
| Includes mentors as a critical piece of the reflective process for professionals | Schön (1983) |
| Critical incident review at workplace onboarding and in the first year | Villachica (2013) |

Korte (2013) points out that, "by narrating their experiences new engineers transformed a relatively disorganised set of experiences into a more meaningful and coherent series of events" (p. 46). The events we evaluate and share contribute to sense-making. They help establish the boundaries and opportunities of complex work environments, and ultimately contribute to creating individual capacity, and the collective professional philosophies.

## DEVELOPING PROFESSIONAL JUDGMENT

Judgment is the nexus of expertise and wisdom. Arlin (1990) attributes wisdom to the "decisions, judgments, and practices that are made in the face of uncertainty, ambiguity, and complexity". She further suggests that "wisdom can be represented as a set of conceptual moves" (p. 237). Following Coles (2002), professional judgment develops as a series of conceptual stages that progress from routine judgments vested in policy, to problem-solving, and to complex decisions influenced by moral considerations or possible outcomes. Judgment sets professional practice apart from more routinely technical work; practice is based in reasoning and making choices. These choices and the thinking behind them are what ultimately constitute practical wisdom and professional judgment. Coles (2002) emphasises the importance of judgment in the practical professions, noting that, "a huge challenge for us today concerns whether we deal adequately with this as part of professional development" (p. 5). To meet this challenge, he outlines a typology of judgment influenced by reflecting on critical incidents (Tripp,

1993) and by approaching curricula more through the lens of process or practice more than endpoints (Fish & Coles, 2005). Figure 3.3 shows this typology.

| Type of Judgement | Description | Defining Question |
|---|---|---|
| Intuitive | • Is concerned with urgent practical questions needing an immediate response<br>• Focus is on the practitioner, and how to do something and what skills to call on | What do I do now? |
| Strategic | • Most often seen in routine situations, where the problem is fairly clear cut<br>• Focus is on the practitioner, and making decisions based on policy and protocol | What might I do now? |
| Reflective | • Relates to situations where there are uncertainties<br>• Focus is on the practitioner/workgroup, and on making decisions based on skills, abilities, and experience in relation to the situation | What could I/we do now? |
| Deliberative | • Relates to the complexity of decision-making in context<br>• Involves an aspect of morality as it seeks to balance competing or conflicting agendas, priorities, and ideologies<br>• Incorporates the notion of critical reconstruction of practice<br>• Focus is on the client or stakeholders | What ought I/we to do now? |

**Figure 3.3 Four areas of professional judgment (Adapted from Coles, 2002)**

Coles' taxonomy of judgment (2002) provides a developmental and transformational approach to decision-making that moves from the individual to the workgroup, and then to the distributed and contextual. It progresses from (1) triage and the process-driven "What do I do now?" to (2) the choices and selecting appropriate options of "What might I do now?" to (3) lessons learned or reflecting on alternatives in "What could I/we do now?" to (4) outward looking balancing of competing forces, incorporating the ethical imperative of the common good, and principled deliberation in "What ought I/we to do now"? Following Yunxia, Rooney, and Phillips (2016), these questions comprise a developmental process that leads to practical wisdom, which:

> [N]ot only drives action that is intentional, it also uses tacit knowledge and experience, considers the long-term future, and incorporates a broad spectrum of ways of knowing and perspectives. In doing this, a wise person can generalise beyond what narrow expertise can, and know what to do in specific instances (Yunxia et al., 2016, p. 610).

"What is it that turns experience into learning? What specifically enables learners to gain the maximum benefit from the situations they find themselves in? How can they apply their experiences in new contexts? Why can some learners appear to benefit more than others?" (Boud et al., 1985, p. 7). Part of the answer is in the differences in how novices and experts classify and order their knowledge. Novices group things based on surface features, while experts group things based on patterns of experience, meaningful context and conditions of relevance (Boud et al., 1985; Cropp, Banks, & Elghali, 2011; Litzinger et al., 2011). At the intuitive, strategic, and reflective stages of Coles' taxonomy of professional judgment, the focus is on the practitioner. Through appreciation of practice, and critical reconstruction of the context in which decisions are made, reflection shifts to broader epistemological and ethical aspects of professional activity.

Fuller and Unwin (2004) provide a learning experience framework that integrates organisational and personal development. Based on case-study evidence of the relationship between work and learning, they outline three participatory dimensions that contribute towards extending knowledge and capability. These are analogous to Beckett's (2008) judgments-in-context and Eraut's (2007) knowledge in the flow of work. These dimensions are: (1) opportunities for engaging in multiple/overlapping communities of practice at and beyond the workplace; (2) access to a multidimensional approach to the acquisition of expertise through the organisation of work and job design; and (3) the opportunity to pursue knowledge-based courses and qualifications relating to work (p. 126). Fuller and Unwin's (2004) framework encompasses a range of learning opportunities, and organisational and cultural factors that contribute towards expansive, or meaningful workforce development. Figure 3.4, adapted from Fuller & Unwin (2004, p. 130), lists these factors.

**Expansive Approaches to Workforce Development**

- Participation in multiple communities of practice inside and outside the workplace
- Primary community of practice has shared 'participatory memory'—cultural inheritance of workforce development
- Breadth—access to learning fostered by cross-company experiences
- Access to range of qualifications including knowledge-based vocational qualifications
- Planned off-the-job time, including for knowledge-based courses and for reflection
- Gradual transition to full, rounded participation
- Talent development pathways—vision for career progression
- Organisational recognition of, and support for employees as learners
- Workforce development is used as a vehicle for aligning the goals of individual and organisational development
- Workforce development fosters cross-functional opportunities to extend professional identity

- Workplace curriculum is tangible (through documents, language, symbols, tools), and is accessible to apprentices
- Widely distributed skills
- Technical skills valued
- Knowledge and skills of whole workforce developed and valued
- Team work valued
- Cross-functional communication encouraged
- Managers as facilitators of workforce and individual development
- Changes to learn new skills / jobs
- Innovation is important
- Multidimensional view of expertise

**Figure 3.4 Expansive approaches to workforce development**

In marking out their participatory, dimensional, and expansive framework for learning environments, Fuller and Unwin (2004) generate opportunities for learning that integrates *with*, *through*, and *in* work processes and contexts. What is being learned, how it is being learned, and cultural, philosophical, and practical influences are incorporated into a learning ecosystem.

## CONCLUSION

The goal of engineering education is to prepare students to participate and to lead in devising and implementing engineering solutions. While engineering graduates may have technical expertise, innovative capabilities, and be socially accountable, engineering outcomes increasingly require decisions based on uncertainty. This chapter has responded to the question: “How can workplace programs assist novice engineers to develop their capacity to exercise professional judgment?” A review of the literature reinforces that ‘know-what, know-why, know-how, know-who’ experiential and ethically grounded knowledge forms are foundational to professional judgments, and that wisdom is cultivated in critical reflection of contestable issues, with activities and conversations about and through work. Professional wisdom is realised in decisions that combine experience and specialist knowledge with ethical considerations. Workplaces can guide the propensity for wise decisions by providing the range of environments and opportunities that reflect the uncertain nature of ‘substantial judgments made in the heat of practice’.

# References


Alexander, P. A. (2003). The development of expertise: The journey from acclimation to proficiency. *Educational Researcher, 32*(8), 10-14.

Arlin, P. K. (1990). Wisdom: The art of problem finding. In R. J. Sternberg (Ed.), *Wisdom: Its nature, origins, and development* (pp. 230-243). Cambridge: Cambridge University Press.

Bassett, C. L. (2011). Understanding and teaching practical wisdom. *New Directions for Adult and Continuing Education, 2011*(131), 35-44. doi:10.1002/ace.419

Baytiyeh, H., & Naja, M. (2012). Identifying the challenging factors in the transition from colleges of engineering to employment. *European Journal of Engineering Education, 37*(1), 3-14.

Beckett, D. (1996). Critical judgment and professional practice. *Educational Theory, 46*(2), 135-149.

Beckett, D. (2008). Holistic competence: Putting judgements first. *Asia Pacific Education Review, 9*(1), 21-30.

Bereiter, C., & Scardamalia, M. (1993). *Surpassing ourselves: An inquiry into the nature and implications of expertise*. Chicago: Open Court.

Boud, D., Keogh, R., & Walker, D. (1985). *Reflection: Turning experience into learning*. Oxford, UK: Routledge.

Brookfield, S. (1986). *Understanding and facilitating adult learning: A comprehensive analysis of principles and effective practices*. Milton Keynes, UK: Open University Press.

Charan, R. (2015). *The attacker's advantage: Turning uncertainty into breakthrough opportunities*. New York: Public Affairs.

Clayton, V. P., & Birren, J. E. (1980). The development of wisdom across the life span: A re-examination of an ancient topic. *Lifespan Development and Behavior, 3*, 103-135.

Coles, C. (2002). Developing professional judgment. *Journal of Continuing Education in the Health Professions, 22*(1), 3-10. doi:10.1002/chp.1340220102

Crawley, E. F., Malmqvist, J., Östlund, S., Brodeur, D. R., & Edström, K. (2014). *Rethinking engineering education: The CDIO approach* (2nd ed.). Heidelberg, Germany: Springer.

Cropp, N., Banks, A., & Elghali, L. (2011). Expert decision making in a complex engineering environment: A comparison of the lens model, explanatory coherence, and matching heuristics. *Journal of Cognitive Engineering and Decision Making, 5*(3), 255-276. doi:10.1177/1555343411415795

Day, D. V. (2010). The difficulties of learning from experience and the need for deliberate practice. *Industrial and Organizational Psychology, 3*(1), 41-44. doi:10.1111/j.1754-9434.2009.01195.x

Deepwell, M. (2017). #CMALT 1 year on: #edtech reflection & professional practice. Retrieved from http://marendeepwell.com/cpd/cmalt-1-year-on-edtech-reflection-professional-practice/

Dye, V. (2011). Reflection, Reflection, Reflection. I'm thinking all the time, why do I need a theory or model of reflection? In D. McGregor & L. Cartwright (Eds.), *Developing reflective practice: A guide for beginning teachers*. Maidenhead, Berkshire, UK: Open University Press, McGraw-Hill Education.

Eraut, M. (2004). Informal learning in the workplace. *Studies in Continuing Education, 26*(2), 247-273. doi:10.1080/158037042000225245

Eraut, M. (2005). Expert and expertise: Meanings and perspectives. *Learning in Health and Social Care, 4*(4), 173-179. doi:10.1111/j.1473-6861.2005.00102.x

Eraut, M. (2007). Learning from other people in the workplace. *Oxford Review of Education, 33*(4), 403-422.

Eraut, M. (2009). Transfer of knowledge between education and workplace settings. In H. Daniels, H. Lauder, & J. Porter (Eds.), *Knowledge, values and educational policy: A critical perspective* (pp. 65-84). Abingdon, Oxon, UK: Routledge.

Exon. (2017). *BEng Civil Engineering Site Management*. Engineering. University of Exeter. Retrieved from http://www.exeter.ac.uk/undergraduate/degrees/engineering/civil-engineering/

Fenwick, T. (2012a). Co-production in professional practice: a sociomaterial analysis. *Professions and Professionalism, 2*(2), 1-16.

Fenwick, T. (2012b). Matterings of knowing and doing: Sociomaterial approaches to understanding practice. In P. Hager, A. Lee, & A. Reich (Eds.), *Practice, learning and change: Practice-theory perspectives on professional learning* (pp. 67-83). Dordrecht: Springer Netherlands.

Filliettaz, L. (2011). Collective guidance at work: A resource for apprentices? *Journal of Vocational Education & Training, 63*(3), 485-504. doi:10.1080/13636820.2011.580359

Fish, D., & Coles, C. (2005). *Medical education: Developing a curriculum for practice*. Maidenhead, Berkshire, UK: Open University Press, McGraw-Hill Education.

Fuller, A., & Unwin, L. (2004). Expansive learning environments: Integrating organisational and personal development. In A. Fuller, H. Rainbird, & A. Munro (Eds.), *Workplace learning in context* (pp. 126-144). London, UK: Routledge.

Gates, A., & Higgs, J. (2013). Realising wise practitioners. In J. Higgs, D. Sheehan, J. Currens, W. Letts, & G. Jensen (Eds.), *Realising exemplary practice-based education* (Vol. 7, pp. 43-56). Rotterdam, The Netherlands: Sense Publishers.

Gibbs, G. (1998, 2013). *Learning by doing: A guide to teaching and learning methods*. Oxford Brookes University, UK: Oxford Centre for Staff and Learning Development.

Gordon, B. M. (1984). *What is an engineer? Invited keynote presentation.* Paper presented at the European Society for Engineering Education (SEFI) Annual Conference, Nürnberg, Germany.

Greeno, J. G., Collins, A. M., & Resnick, L. B. (1996). Cognition and learning: Handbook of educational psychology. In (pp. 15-46). New York, NY: Simon & Shuster, MacMillan.

Guille, J., Abraham, N., & Patel, U. (2010). *Designing an educational experience of relevance to real world situations*. Northumbria Research Link. Northumbria University. Newcastle, UK. Retrieved from http://nrl.northumbria.ac.uk/id/eprint/9837

Hays, J., & Clements, M. (2012, 20-22 June, 2102). *Transition-bridging the gap between study and work.* Paper presented at the Proceedings of the 9th International Conference on Cooperative & Work-Integrated Education, Where East meets West and Theory meets Practice, Istanbul, Turkey.

Hinett, K. (2002). *Improving learning through reflection–part one*. The Higher Education Academy. Retrieved from http://jisctechdis.ac.uk/assets/documents/resources/database/id485_improving_learning_part_one.pdf

Ibarra, H. (1999). Provisional selves: Experimenting with image and identity in professional adaptation. *Administrative Science Quarterly, 44*(4), 764-791.

Johri, A. (2010). Open organizing: Designing sustainable work practices for the engineering workforce. *International Journal of Engineering Education, 26*(2), 278.

Johri, A. (2012). Learning to demo: The sociomateriality of newcomer participation in engineering research practices. *Engineering Studies, 4*(3), 249-269.

Jonassen, D. H., Strobel, J., & Lee, C. B. (2006). Everyday problem solving in engineering: Lessons for engineering educators. *Journal of Engineering Education, 95*(2), 139-151. doi:10.1002/j.2168-9830.2006.tb00885.x

Knorr-Cetina, K. (1999). *Epistemic cultures: How the sciences make knowledge*. Harvard: Harvard University Press.

Korte, R. (2013). The formulation of engineering identities: Storytelling as philosophical inquiry. In *Philosophy and Engineering: Reflections on Practice, Principles and Process* (pp. 39-50). The Netherlands: Springer.

Kuhlmann, D. O., & Ardichvili, A. (2015). Becoming an Expert: Developing expertise in an applied discipline. *European Journal of Training and Development, 39*(4), 262-276. doi:doi:10.1108/EJTD-08-2014-0060

Litzinger, T., Lattuca, L. R., Hadgraft, R., & Newstetter, W. (2011). Engineering education and the development of expertise. *Journal of Engineering Education, 100*(1), 123-150.

Lucas, B., & Spencer, E. (2015). *Remaking apprenticeships: Powerful learning for work and life*. University of Winchester. Centre for Real-World Learning. Retrieved from http://www.winchester.ac.uk/aboutus/lifelonglearning/CentreforRealWorldLearning/Publications/Documents/Lucas%20and%20Spencer%20(2015)%20Remaking%20Apprenticeships.pdf

MacIntyre, A. (2007). *After virtue: A study in moral theory* (3rd ed. Vol. 99). Notre Dame, Indiana: University of Notre Dame Press.

McCall, M. W. (2010). Recasting leadership development. *Industrial and Organizational Psychology, 3*(1), 3-19. doi:10.1111/j.1754-9434.2009.01189.x

McCauley, D. H. (2016). Rediscovering the art of strategic thinking. *National Defense University Press, Joint Force Quarterly 81 (JFQ)*(2nd Quarter, April 2016).

Meacham, J. A. (1990). The loss of wisdom. In R. J. Sternberg (Ed.), *Wisdom: Its nature, origins, and development* (pp. 181-211). Cambridge, UK: Cambridge University Press.

Melrose, S., Miller, J., Gordon, K., & Janzen, K. J. (2012). Becoming socialized into a new professional role: LPN to BN student nurses' experiences with legitimation. *Nursing Research and Practice, 2012*.

RMS. (2017). *Road designer in training*. Employment Services. Roads and Maritme Services. Sydney, NSW, Australia. Retrieved from http://www.rms.nsw.gov.au/about/careers/working-with-us/employment-programs/road-designer-in-training.html

Schön, D. A. (1983). *The reflective practitioner: How professionals think in action*. New York, NY: Basic Books.

Sheppard, S., Macatangay, K., Colby, A., & Sullivan, W. M. (2009). *Educating engineers: Designing for the future of the field* (Vol. 9). San Francisco, CA: Jossey-Bass.

Sternberg, R. J. (1998). A balance theory of wisdom. *Review of General Psychology, 2*(4), 347.

Sternberg, R. J. (2001). Why schools should teach for wisdom: The balance theory of wisdom in educational settings. *Educational Psychologist, 36*(4), 227-245.

Tough, A. (1971). *The adult's learning projects. A fresh approach to theory and practice in adult learning*. Toronto, Ontario: Institute for Studies in Education.

Trevelyan, J. P. (2009). *Engineering education requires a better model of engineering practice.* Paper presented at the Research in Engineering Education Symposium 2009, Palm Cove, QLD, Australia.

Tripp, D. (1993). *Critical incidents in teaching: Developing professional judgement*. Oxford, UK: Routledge.

Van Maanen, J., & Schein, E. H. (1979). Toward a theory of organizational socialization. *Research in Organizational Behavior, 1*, 209-264.

Villachica, S. (2013). *When performance is fuzzy: The critical incident technique*. Paper presented at the International Society for Performance Improvement (ISPI) Conference 2014, Reno, Nevada.

Vygotsky, L. S. (1927). *The historical meaning of the crisis in psychology: A methodological investigation* (R. van der Veer, Trans. 1987 ed.). New York: Plenum.

Yunxia, Z. H. U., Rooney, D., & Phillips, N. (2016). Practice-based wisdom theory for integrating institutional logics: A new model for social entrepreneurship learning and education. *Academy of Management Learning & Education, 15*(3), 607-625. doi:10.5465/amle.2013.0263

# 4 PROFESSIONALISM, CHARACTER, AND SKILLS

*Professionalism, character, and skills: Leveraging the Tuning Process for the engineering workplace*

## OVERVIEW

Considerable research has been undertaken around generic and specific skills and capabilities and their role in contemporary engineering curricula. As much of this research focuses on development and provision of academic programs, there remains a gap in understanding how well it facilitates the transition of new career engineers to the workplace. This chapter summarises the qualitative and quantitative data analysis of a study to design organisational development programs for new graduates entering the engineering workplace. Chapters four to seven each discuss different aspects of this analysis. The study utilises the Tuning Process methodology, which is a higher education initiative aimed at supporting the development of learning programs that incorporate and align or 'tune' the views of employers, academics, and students. Tuning asks these groups to rate the skills provided by university study and required for work in a profession. Analysis of responses helps benchmark, and identify congruences and gaps in the general and discipline-specific skills provided by formal study and required for work. For this study, engineering survey questions were administered to engineering graduates and representatives from employing organisations. Participants represent a range of geographical locations, engineering disciplines and workplace seniority. The Tuning questionnaire was adapted to include free text responses for the purposes of qualitative analysis. This change was implemented to capture emerging themes not accommodated by Tuning question items. Likert responses were analysed using data reduction and factor analysis techniques. Free text responses were interpreted and classified into themes using a grounded coding approach. These free text themes were summarised and interpreted using qualitative techniques. Analysis of survey responses suggests it may be possible to identify or ‘map’ aspects of the transition to the workplace, and that this provides opportunities for both universities and places of work. Results additionally point to an ‘engineering professional persona’ with attributes of professionalism, character, and proficiency in engineering skills. Although directed at workplace learning and development, study results also have application to the instructional sciences, particularly for university to workplace pathway programs.

# CHAPTER CONTENTS

## 4.1 Introduction

### 4.1.1 Research question

This study is situated in transition to work research. It explores the question: 'What capabilities enable successful transition to professional work for an engineering graduate'? To answer this question, it considers the responses of employers and recent graduates to a skills evaluation questionnaire. Study results are intended for workplace development programs that support the entry of engineering graduates to the workplace. The dataset that forms the basis of this analysis adapts an established questionnaire instrument (the Tuning Process) to assess employer and graduate views of the skills required for engineering work.

## 4.2 Purpose

Considerable research has been undertaken around skills and capabilities for career success, and how to embed these competencies in contemporary engineering curricula (ASCE, 2008; Crawley, Malmqvist, Östlund, Brodeur, & Edström, 2014; Vest, 2007). However, as this research addresses the development and provision of academic programs, there remains a gap in understanding how well it supports employers in understanding the workplace learning and development needs of new career engineers. Exploring this gap can benefit organisational continuing professional development (CPD) or induction programs for career entrants. Study results also have application to the instructional sciences, internships, and university-workplace pathway programs.

Tuning is a European higher education initiative to create diversity, cooperation, and academic exchange. Tuning Process methodology focuses on establishing and 'tuning' student, academic, and employer reference points, and encouraging common understanding across a range of disciplines and key stakeholder groups for the purposes of increasing employability (Gonzélez & Wagenaar, 2003). Edvardsson Stiwne and Jungert (2007) recognise that the concept of employability "indicates that an employable person holds knowledge, skills and characteristics that makes that person useful and valuable in a specific context" (p. 1). The Tuning project addresses two capability areas: generic (instrumental, interpersonal and systemic) and subject-specific (including skills and knowledge). Manoliu (2005) points out that the general capabilities Tuning has identified and measures help determine those which are most important for the professional development of university graduates, independent of their degree and field of study. The Tuning Process asks: ‘What are the most important competences to be employable independent of one’s subject area?’ and ‘Are these actually taught and to what extent?’ (p. 7)

While Tuning incorporates employer and professional body input, and acknowledges that industry is a key stakeholder and client, it focuses on university curricula. Adopting the Tuning Process for workplace learning program design may help to bring the process full cycle and close this gap. Reid, Abrandt Dahlgren, Dahlgren, and Petocz (2011) acknowledge there is a lack of “information regarding the relationships between graduates’ expectations of working life and their employers’ explicit expectations of them” (p. 54). They also concede that a shared problem for both institutions and individual students is the “lack of real knowledge about the expectations and requirements of particular professions” (Reid et al., 2011, p. 54). Many of the challenges faced by these novice professionals relate to the nature of knowledge, and the ways in which discipline-specific knowledge is enacted in practice. This study aims to contribute to articulating these expectations and in supporting transition to professional practice. In particular, it seeks to understand if there is an explicitly engineering workplace dimension of the Tuning competencies, or skills that signpost opportunities adopt Tuning outcomes in organisational induction and development programs.

## 4.3 Summary of the method

The Tuning Process asks graduate, employer, and academic participants to rate a selection of general and specific skills for how well they are provided by university and are required for work. Questionnaire items represent industry, academia, and student contributions and consensus. The general skill items used for this study are provided in Gonzélez and Wagenaar (2003). The engineering-specific items are discussed in Manoliu (2005). Appendix 1 shows the questionnaire items. Tuning methodology is matched through purposeful sampling (Gonzélez & Wagenaar, 2003, pp. 73-75). Table 4.1 summarises the Tuning procedure and participant sampling. Although Tuning incorporates responses across employers, graduates, and academics, input from academics is not included in this analysis.

**Table 4.1 Tuning Process sampling (Adapted from Gonzélez & Wagenaar, 2003)**

| Respondents | Tuning Methodology | Study Sample Size |
|---|---|---|
| Employers | At least 30 employers<br>The criterion of selection was that they should be organisations known to employ engineering graduates. | $n$=94 |
| Graduates | A minimum of 150 graduates.<br>The graduates selected are to have graduated within the last 3 to 5 years.<br>The criterion of selection of the graduates was at random. | $n$=121 |

Representatives from engineering organisations and recent graduates participated in the questionnaire. Their responses represent cross-disciplinary (aerospace, biomedical, chemical, civil, electrical, mechanical, software), organisational (management, engineers, technical specialists), and geographical (Australia, Canada, India, United States) views. As the study sample size is smaller than the Tuning preferred sample size of 150, the t-statistic was used to calculate the confidence level for the study sample using the formula: $\mu = M \pm t\ (s_M)$, where:

$M$ = sample mean
$t$ = $t$ statistic determined by confidence level
$s_M$ = standard error = $\sqrt{(s^2/n)}$

Using this formula, and the results from the control question, "Has university provided adequate preparation for engineering?" the calculation below provides a confidence level of 95% (3.62 ± 0.18):

$M = 3.62$
$t = 1.98$
$s_M = \sqrt{(1.002^2/121)} = 0.09$
$\mu = M \pm t(s_M)$
$\mu = 3.62 \pm 1.98*0.09$
$\mu = 3.62 \pm 0.1804$

## 4.4 Data collection

The survey was administered online. It consisted of five mandatory questions: (1) demographic information, (2) thirty general competences rated according to a Likert-type scale, ranging from 1='None', 2='Weak', 3='Some', 4='Strong' for the degree to which they were developed at university and are required for work, (3) opinion statements of the most important general capabilities required for engineering, (4) eighteen engineering-specific competences rated using the same Likert-type scale (1='None', 2='Weak', 3='Some', 4='Strong') for how they were developed at university and are required for work, and (5) opinion statements of the most important technical or specific capabilities required for engineering. Survey questions are provided in Appendix 1.

# 4.5 Survey respondents

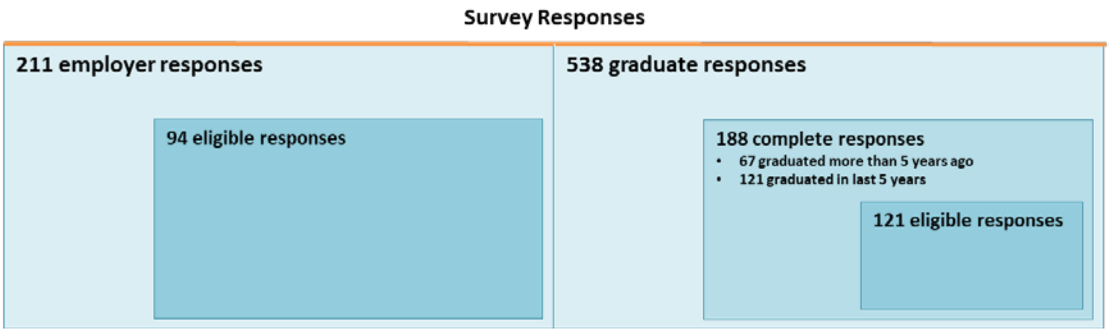
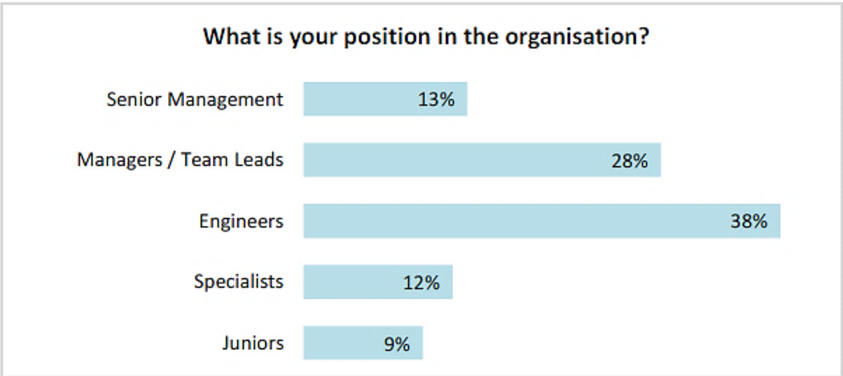



**Figure 4.1 Survey responses from employers and graduates**

A total of 215 respondents (121 graduates and 94 employers) completed the questionnaire. Following Tuning sampling methodology, selection criteria was that employers should represent organisations known to employ engineering graduates and that graduates should have completed an engineering degree in the last three to five years.

## 4.5.1 Employers

Employer responses represent balanced organisational demographics. They comprise 41% from management, 50% from engineers and technical specialists, and 9% from junior staff. Figure 4.2 summarises employer responses by role.



| Roles | Role Groups |
|---|---|
| Director, Executive, Co-Founder, Managing Executive, General Manager, Senior Manager | Senior Management (13%) |
| Team Lead, Supervisor, Manager, Technical Manager, Project Manager | Managers/Team Leads (28%) |
| Site Engineer, Design Engineer, Assistant Engineer, Technical Engineer, Junior and Senior Engineer, Engineer | Engineers (38%) |
| Designer, Draftsman, IT Trainer and Developer, Analyst, Research Assistant | Specialists (12%) |
| Junior Engineer, Junior Research Fellow | Juniors (9%) |

**Figure 4.2 Employer responses by role**

Over half (55%) of survey responses were from small to medium sized engineering firms (SMEs) of 10-100 employees. Both SMEs and larger firms of 1000-10000+ employees positively assess the preparation provided by university. These groups collectively rate work-readiness for ‘Very Much’, ‘Much’ and ‘Some’ at 88%. Figure 4.3 shows the distribution of responses by organisation size.

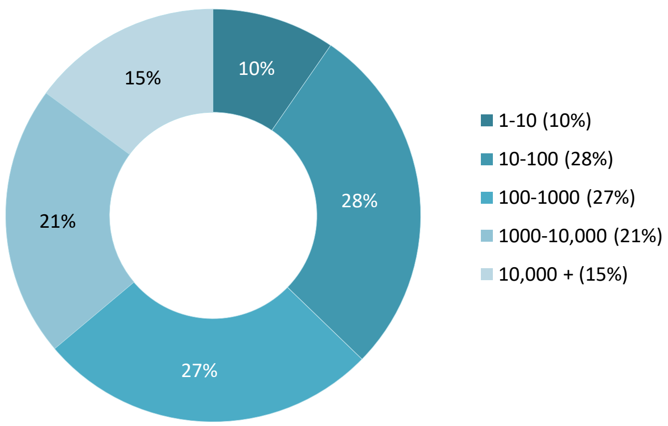



**Figure 4.3 Employer responses by organisation size**

Compared to larger firms, at 47%, the slightly lower SME appraisal of university preparation suggests that for smaller organisations, onboarding, induction, or greater need to decrease time to competency may influence results. These factors may not have the same visibility in larger firms. Figure 4.4 shows how SMEs and larger organisations rate graduate preparation.

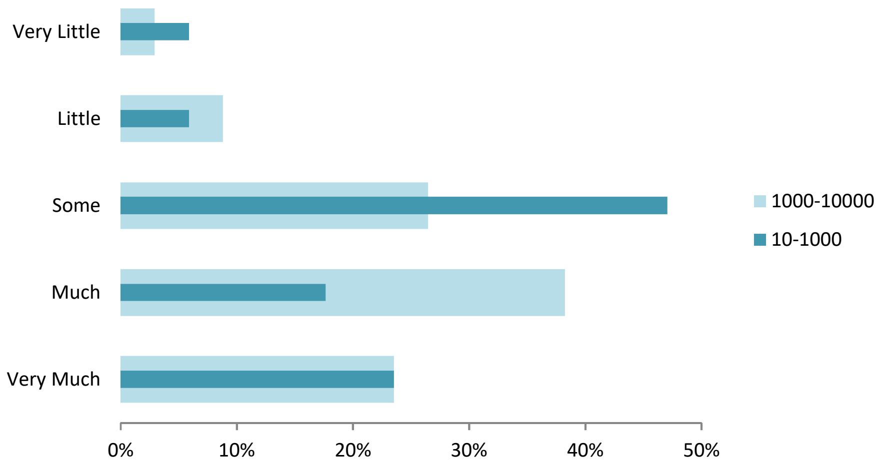



**Figure 4.4 SME views of adequacy of university preparation**

## 4.5.2 Graduates

Over 50% of graduates indicated they are working in a position related to their degree. 62% rated the employment potential of their degree as either ‘Very Good’ or ‘Good’. Figure 4.5 shows graduate views of career opportunities.

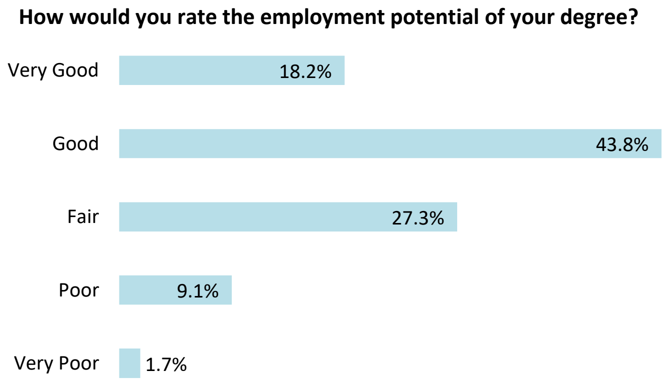



**Figure 4.5 Employment potential of an engineering degree**

## 4.5.3 Adequate preparation for work

Employers (66%) and graduates (68%) generally agree on how well university prepares students for work. Figure 4.6 illustrates these views.

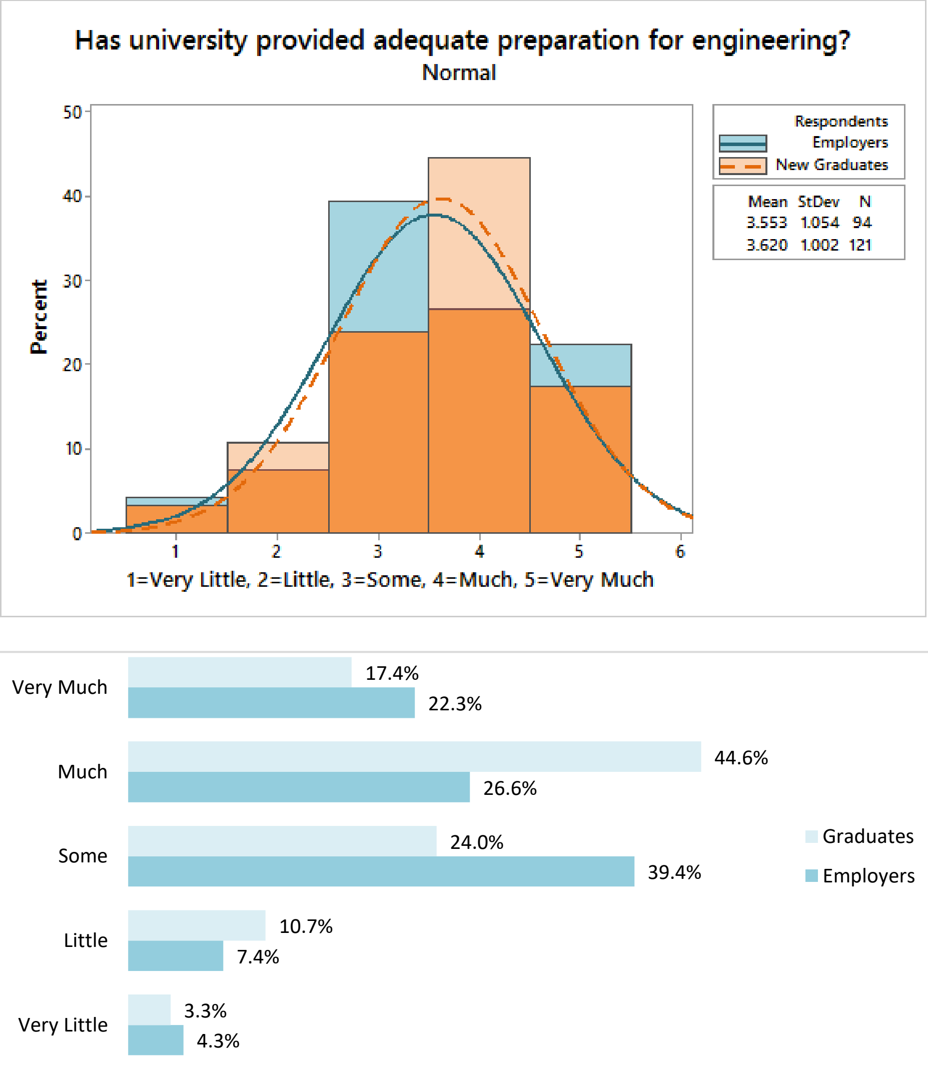



**Figure 4.6 Adequacy of university preparation for work**

## 4.5.4 Top five responses

Using top-two-box calculations (Sauro, 2010, 2011), the combined percentage results for ‘Considerable’ and ‘Strong’ represent the five most important university and work outcomes. Figure 4.7 through Figure 4.9 illustrate these results. Chart data is presented by employer rankings of the top five capabilities. While there are overlaps, study findings do not align with those presented by Carvalho (2008). Particularly Figure 4.8, which shows skills required for work, this variation suggests that although workplace priority areas of teamwork, collaboration, interpersonal skills, and the more technically-oriented skills of analysis and decision-making may shift in detail, they remain materially significant to engineering.

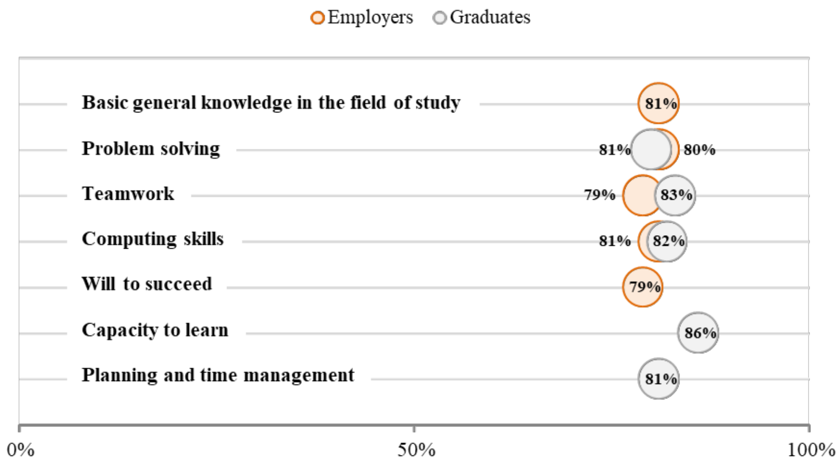



**Figure 4.7 Top five general skills provided by university**

Employers and graduates have similar views of the most important transferrable skills provided by university. For employers these are: 'Basic general knowledge in the field of study', and 'Problem-solving'. Graduates also rate 'Problem-solving' highly, along with the transferrable skills of 'Teamwork', 'Computing skills', 'Capacity to learn', and 'Planning and time management'. Graduates rate highest skills in information literacy, leadership, working in teams, and communication. Employers are generally biased towards discipline fundamentals, and nominate mathematics, engineering concepts, the culture and values of engineering, and knowledge application. By way of explanation, Faulkner (2007) points out that "engineers have two types of stories about what constitutes 'real' engineering" (p. 331). These stories largely divide into *technicist* or *sociotechnical* anecdotes. That is, 'nuts and bolts and people' views of engineering work. Similarly, a technical, analytical, problem-solving versus participatory, collaborative, interpersonal tension is manifest in the results of this study. Faulkner's (2007) observation that much of the technical emphasis of formal engineering training "stands in stark contrast to the huge importance of 'social' expertise in engineering jobs, which engineers soon learn is actually vital to their work (p. 332) emerges through analysis of survey responses.

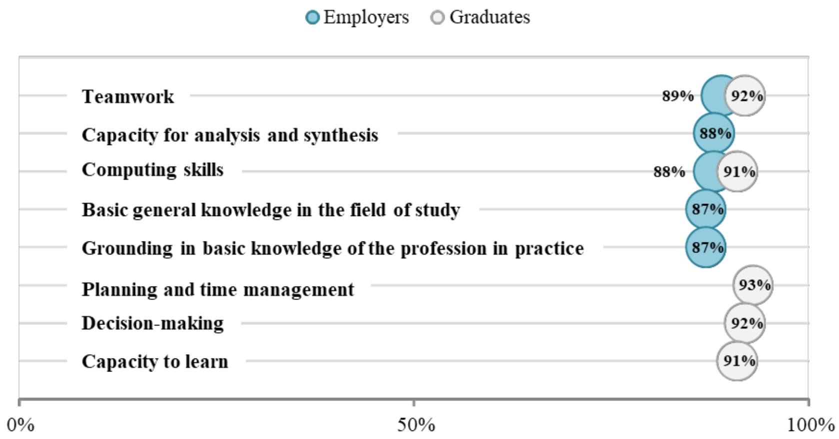
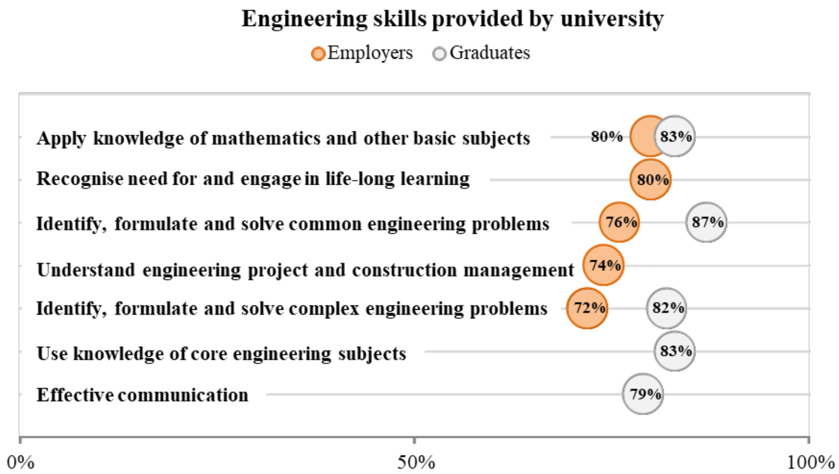



**Figure 4.8 Top five general skills required for work**

Employers value university grounding in discipline-specific knowledge and skills of collaboration, information analysis and synthesis, technical capability, and knowledge of engineering practice. Graduates highlight navigating the workplace, and the development of a professional identity. Their top rated 'Planning and time management', 'Decision making', 'Teamwork', and 'Capacity to learn' underline the need to translate these abstract skills to the environment of work.



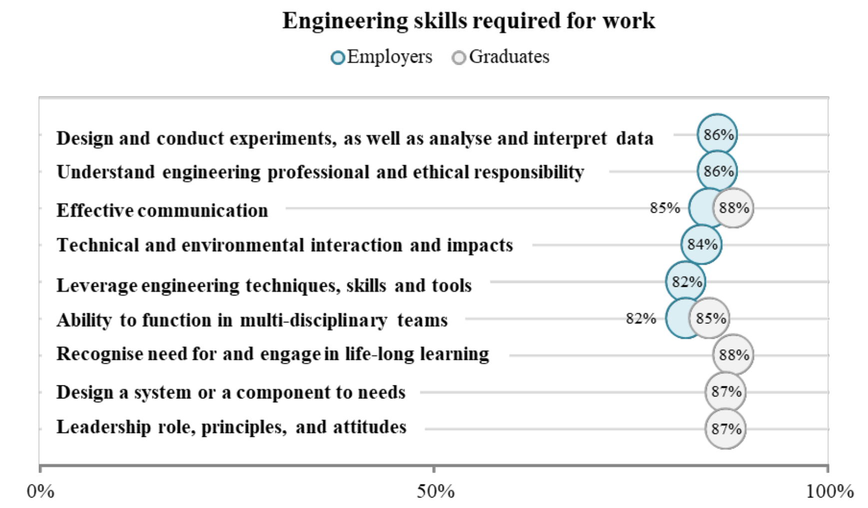



**Figure 4.9 Top five specific skills provided by university and required for work**

'Design and conduct experiments, as well as analyse and interpret data' and 'Understand engineering professional and ethical responsibility' are equally top rated at 86%. This affirms the social context of engineering knowledge application. For field-specific skills, employers emphasise knowledge application and interdisciplinary work. Graduates focus on professional socialisation. These analogous views suggest engineering education reforms to include interdisciplinary and practice based influences have been successful (Goldberg, 2010; Trevelyan, 2009, 2010). Results also indicate there remain opportunities to align employer and graduate expectations. For example, 'Planning and time management' (graduates, 93%) and 'Capacity for analysis and synthesis' (employers, 88%) suggest different expectations of similar skills.

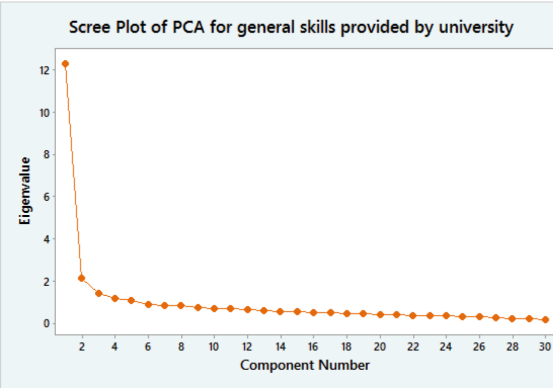
## 4.6 Factor analysis of questionnaire responses

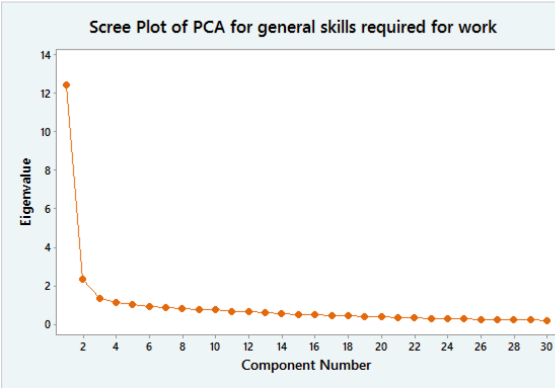
Participant responses are generally in agreement. This consensus counters related studies that find significant differences in employer and graduate expectations of work life (Baytiyeh & Naja, 2012; Nadelson, McGuire, Davis, Farid, & Hardy, 2015; Reid et al., 2011; Stevens, Johri, & O'Connor, 2014). Differences between survey results and comparable research indicate there may be alternate explanatory possibilities. Factor analysis was selected as the analytical methodology best suited to surfacing these possibilities.

### 4.6.1 Data reduction and analysis

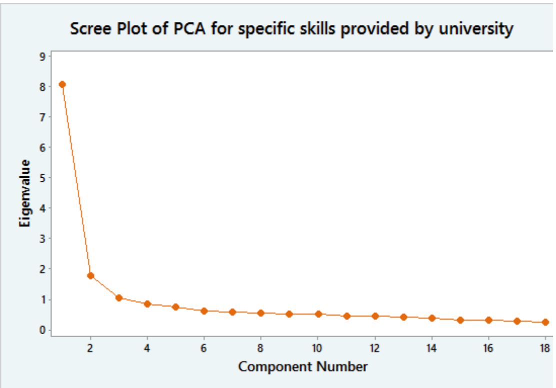
Principal components analysis (PCA) is a statistical method used to reduce a large number of variables to a smaller and more meaningful dataset. Exploratory factor analysis (EFA) is an approach that looks to explore the data to find meaningful commonalities in a set of variables. The goal is “to discover likely factors that will account for at least 50% of the common variation in the observed factors” (Fricker Jr, Appleget, & Kulzy, 2012, p. 30). Using Kaiser rule and Scree plot techniques, PCA identified that five principal components for general skills, and three principal components for specific skills contributed meaningfully to analysis. Table 4.2 displays these findings.

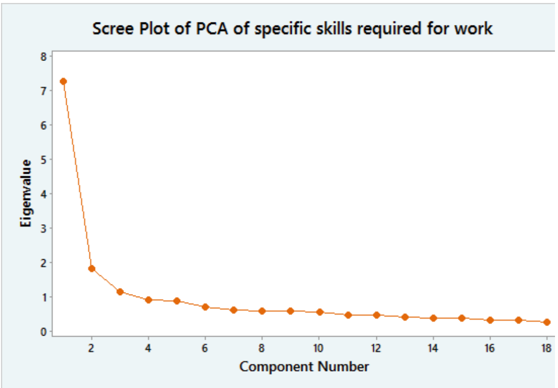
**Table 4.2 Eigenanalysis of Likert responses**




| Eigenvalues (provided by university) | | | | Eigenvalues (required for work) | | | |
|---|---|---|---|---|---|---|---|
| **Component** | **Total** | **% Variance** | **% Cumulative** | **Component** | **Total** | **% Variance** | **% Cumulative** |
| 1 | 12.28 | 41% | 41% | 1 | 12.44 | 42% | 42% |
| 2 | 2.11 | 7% | 48% | 2 | 2.36 | 8% | 49% |
| 3 | 1.38 | 5% | 53% | 3 | 1.31 | 4% | 54% |
| 4 | 1.18 | 4% | 57% | 4 | 1.12 | 4% | 57% |
| 5 | 1.04 | 4% | 60% | 5 | 1.02 | 3% | 61% |




| Eigenvalues (provided by university) | | | | Eigenvalues (required for work) | | | |
|---|---|---|---|---|---|---|---|
| **Component** | **Total** | **% Variance** | **% Cumulative** | **Component** | **Total** | **% Variance** | **% Cumulative** |
| 1 | 8.0939 | 45% | 45% | 1 | 7.253 | 40% | 40% |
| 2 | 1.7784 | 10% | 55% | 2 | 1.8239 | 10% | 50% |
| 3 | 1.0497 | 6% | 61% | 3 | 1.1373 | 6% | 57% |

The Maximum Likelihood method of factor distribution provided optimal 'face value' for initial factor groupings. Osborne and Costello (2005) advise that:

> Fabrigar, Wegener, MacCallum and Strahan (1999) argued that if data are relatively normally distributed, Maximum Likelihood is the best choice because "it allows for the computation of a wide range of indexes of the goodness of fit of the model [and] permits statistical significance testing of factor loadings and correlations among factors and the computation of confidence intervals" (p. 277).

Factor loadings, communality, and factor score coefficients were examined. Appendix 4 summarises these calculations. Factor communalities were for the most part above 0.3, confirming that each item shared some common variance with other items. Factor loadings with scores ranging between -0.4 and 0.4 were included for analysis. Factor loading scores were originally set at -0.5 to 0.5, but this excluded/isolated items from factors where they might be expected to group. As adding factors did not substantively change these groupings, the minimum factor score was updated to between -0.4 and 0.4. Given these overall indicators, factor analysis was conducted with the thirty general items and the eighteen specific items.

### 4.6.2 General skills provided by university

The eigenvalues in Table 4.2 show that for general skills provided by university, the first factor explains 41% of the variance, the second factor 7%, the third factor 5%, the fourth factor 4%, and the fifth factor 4% of the variance. The sixth factor eigenvalue of just under one, explained 3%. Three, four, and five factor solutions were examined, using a Varimax rotation of the factor loading matrix. The selected five factor solution explains 60% of the variance, with twenty-five residuals (40%).

Two items ('Ability to work in an international context' and 'Understanding of cultures and customs of other countries') were cross loaded, and were assigned to the factor where their primary loading was higher. These items load with 'Knowledge of a second language', signifying they contribute to a construct around the notion of a 'global citizen'. Two variables did not meet the minimum factor loading criteria of 0.40 or above, but did have a cross-loading of 0.03. Following Aron and Aron (2003, p. 629), "variables have loadings on each factor but usually have high loadings on only one". In this factor solution, the item 'Problem-solving' loads highest with factor 1 loadings, and the item 'Planning and time management' loads highest with factor 3 loadings. Mertler and

Vannatta (2002) acknowledge that "by its very nature, interpretation of components or factors involves much subjective decision making on the part of the researcher" (p. 254). Acknowledging this subjectivity, factor components and contributing variables for this five factor extraction are shown in Table 4.3, where the percentages are based on averaged absolute values of the loadings for each factor construct.

**Table 4.3 Factor components and variables (general skills—university)**

| **Component Loadings** | | |
|---|---|---|
| **Construct 1: Outlook** | | **36%** |
| Ability to communicate with non-experts (in the field) | 0.502 | |
| Ability to work autonomously | 0.580 | |
| Ability to work in an interdisciplinary team | 0.552 | |
| Appreciation of diversity and multiculturality | 0.513 | |
| Concern for quality | 0.666 | |
| Ethical commitment | 0.699 | |
| Initiative and entrepreneurial spirit | 0.664 | |
| Problem-solving | 0.393 | |
| Project design and management | 0.705 | |
| Will to succeed | 0.622 | |
| **Construct 2: Foundational knowledge** | | **29%** |
| Basic general knowledge in the field of study | 0.430 | |
| Capacity for analysis and synthesis | 0.577 | |
| Capacity for applying knowledge in practice | 0.551 | |
| Capacity to learn | 0.458 | |
| Computing skills | 0.618 | |
| Critical and self-critical abilities | 0.437 | |
| Grounding in basic knowledge of the profession in practice | 0.616 | |
| Oral and written communication in your native language | 0.548 | |
| Research skills | 0.549 | |
| **Construct 3: Adaptiveness** | | **12%** |
| Capacity for generating new ideas (creativity) | 0.592 | |
| Capacity to adapt to new situations | 0.483 | |
| Information management skills | 0.599 | |
| Planning and time management | 0.364 | |
| **Construct 4: Collaboration and consensus** | | **13%** |
| Decision making | 0.478 | |
| Interpersonal skills | 0.673 | |
| Leadership | 0.438 | |
| Teamwork | 0.483 | |
| **Construct 5: Global awareness** | | **11%** |
| Ability to work in an international context | -0.623 | |
| Knowledge of a second language | -0.536 | |
| Understanding of cultures and customs of other countries | -0.614 | |

'Outlook' encapsulates the self-awareness, personal, and interpersonal characteristics that embody civic capacity and engender reflective and constructive behaviours. Aspects of these qualities are defined by the Collaborative for Academic, Social, and Emotional

Learning (CASEL) as “Social and Emotional Literacies (SEL), which are the processes through which individuals “acquire and effectively apply the knowledge, attitudes, and skills necessary to understand and manage emotions, set and achieve positive goals, feel and show empathy for others, establish and maintain positive relationships, and make responsible decisions” (CASEL, 2017, online). At 36%, these qualities represent a significant outcome of an engineering degree. Field-specific knowledge is the substance of engineering studies: ‘Foundational knowledge’ (29%) incorporates working knowledge of engineering with grounding in its history, values, and the ability to advance the discipline by further learning and knowledge application. ‘Adaptiveness’ (12%) acknowledges the need to manage, review, and renew personal knowledge stores. In ‘Collaboration and consensus’ (13%), working collaboratively, and in workgroups or teams is balanced with personal accountability for task deadlines and work standards. ‘Global awareness’ (11%) recognises the importance of diversity and cultural difference in an increasingly intercultural world and workplace (Hoffmann, Jørgensen, & Christensen, 2011; Mansilla & Jackson, 2011). All ‘Global awareness’ factor components are negatively loaded, which suggests opportunities for tertiary institutions to enhance the intercultural dimension of program offerings.

### 4.6.3 General skills required for work

The eigenvalues in Table 4.2 show that for general skills required for work, the first factor explains 42% of the variance, the second factor 8%, the third factor 4%, the fourth factor 4%, and the fifth factor 3% of the variance. The sixth factor eigenvalue of just under one, explained 3%. Three, four, and five factor solutions were examined, using a Varimax rotation of the factor loading matrix. The selected five factor solution explains 61% of the variance, with twenty-five residuals (39%). Three items (‘Appreciation of diversity and multiculturality’, ‘Planning and time management’, and ‘Will to succeed’) were cross loaded. The variable, ‘Planning and time management’ was assigned to factor 1, and ‘Will to succeed’ and ‘Appreciation of diversity and multiculturality’ were assigned to factor 2, where they loaded highest. The factor components and contributing variables for this five-factor extraction are shown in Table 4.4, where the percentages are based on averaged absolute values of the loadings for each factor construct.

**Table 4.4 Factor components and variables (general skills—work)**

| **Component Loadings** | | |
|---|---|---|
| **Construct 1: Work skills** | | **45%** |
| Basic general knowledge in the field of study | 0.664 | |
| Capacity for analysis and synthesis | 0.436 | |
| Capacity for applying knowledge in practice | 0.551 | |
| Capacity for generating new ideas (creativity) | 0.484 | |
| Capacity to adapt to new situations | 0.47 | |
| Capacity to learn | 0.577 | |
| Computing skills | 0.583 | |
| Critical and self-critical abilities | 0.596 | |
| Grounding in basic knowledge of the profession in practice | 0.56 | |
| Information management skills | 0.546 | |
| Knowledge of a second language | 0.462 | |
| Oral and written communication in your native language | 0.448 | |
| Planning and time management | 0.509 | |
| Research skills | 0.594 | |
| **Construct 2: Professionalism** | | **27%** |
| Ability to communicate with non-experts (in the field) | -0.402 | |
| Ability to work autonomously | -0.622 | |
| Appreciation of diversity and multiculturality | -0.443 | |
| Concern for quality | -0.61 | |
| Ethical commitment | -0.633 | |
| Initiative and entrepreneurial spirit | -0.697 | |
| Project design and management | -0.673 | |
| Will to succeed | -0.484 | |
| **Construct 3: Presence** | | **9%** |
| Ability to work in an interdisciplinary team | 0.428 | |
| Interpersonal skills | 0.468 | |
| Leadership | 0.674 | |
| **Construct 4: Outcomes oriented** | | **10%** |
| Problem-solving | -0.437 | |
| Decision making | -0.6 | |
| Teamwork | -0.704 | |
| **Construct 5: Global citizenship** | | **8%** |
| Ability to work in an international context | 0.667 | |
| Understanding of cultures and customs of other countries | 0.715 | |

‘Work skills’ (45%) encapsulates the notion of a workforce equipped with functional literacies, able to perform tasks, and achieve organisational outcomes: academic skills, concepts, job specific methodologies, and the ability to increase these attributes. ‘Professionalism’ (27%) synthesises qualities associated with self-directedness, initiative, civic capacity, concern for quality, and the ability to work with diverse groups. All variables that contribute to ‘Professionalism’ are negatively loaded, suggesting the importance of experience to work skills. ‘Presence’ (9%) conveys the interpersonal qualities of self-assurance, equanimity, and ability to lead and work as part of a team. ‘Outcomes oriented’ (10%) is comprised of negatively loaded variables, which signals that problem-solving, decision making, and teamwork are developed progressively. ‘Global citizenship’ (8%) expresses the capacity to work in an international context, with appreciation of other cultures and customs.

### 4.6.4 Specific skills provided by university

The eigenvalues in Table 4.2 show that for specific skills provided by university, the first factor explains 45% of the variance, the second factor 10%, and the third factor 6% of the variance. The fourth factor eigenvalue of just under one explained 5% of the variance. Three and four factor solutions were examined, using a Varimax rotation of the factor loading matrix. The selected three factor solution explains 61% of the variance, with fifteen residuals (39%). Four variables were cross-loaded (‘Technical and environmental interaction and impacts’, ‘Identify research needs and necessary resources’, ‘Specialist engineering knowledge application’, and ‘Understanding complex engineering project and construction management’). Each of these items was assigned to the factor where it demonstrated the highest loading. The factor components and contributing variables for this three-factor extraction are shown in Table 4.5, where the percentages are based on averaged absolute values of the loadings for each factor construct.

**Table 4.5 Factor components and variables (specific skills—university)**

| **Component Loadings** | | |
|---|---|---|
| **Construct 1: Engineering values** | | **38%** |
| Understand engineering professional and ethical responsibility | 0.612 | |
| Understanding social and global impacts of engineering | 0.665 | |
| Effective communication | 0.643 | |
| Leadership role, principles, and attitudes | 0.711 | |
| Recognition of the need for, and the ability to engage in, life-long learning | 0.697 | |
| Ability to function in multi-disciplinary teams | 0.81 | |
| **Construct 2: Domain knowledge** | | **42%** |
| Apply knowledge of mathematics and other basic subjects | -0.596 | |
| Use knowledge of core engineering subjects | -0.641 | |
| Design a system or a component to needs | -0.586 | |
| Identify, formulate and solve common engineering problems | -0.622 | |
| Identify, formulate and solve complex engineering problems | -0.655 | |
| Technical and environmental interaction and impacts | -0.455 | |
| Design and conduct experiments, as well as analyse and interpret data | -0.583 | |
| Identify research needs and necessary resources | -0.482 | |
| **Construct 3: Engineering methods** | | **20%** |
| Leverage engineering techniques, skills and tools | 0.424 | |
| Specialist engineering knowledge application | 0.478 | |
| Understand engineering project and construction management | 0.756 | |
| Understanding complex engineering project and construction management | 0.548 | |

‘Domain knowledge’ (42%) is visibly the most important specific attribute provided by formal learning. It includes grounding in engineering subject knowledge to identify, design, and apply this knowledge to engineering solutions. Its negative factor loadings may represent the ongoing challenge of maintaining field-specific knowledge currency against advances in engineering tools, methodologies and research. If domain knowledge is the empirical foundation for engineering, ‘Engineering values’ (38%) encapsulates the philosophical underpinnings of an explicitly engineering set of personal standards. This is the tacit knowledge of the discipline. ‘Engineering methods’ (20%) relates to how outcomes are delivered, and how engineering methods are applied to practice.

### 4.6.5 Specific skills required for work

The eigenvalues in Table 4.2 show that for specific skills required for work, the first factor explains 40% of the variance, the second factor 10%, and the third factor 6%. The fourth factor eigenvalue of just under one explained 5%. Three and four factor solutions were examined, using a Varimax rotation of the factor loading matrix. The selected three factor solution explains 57% of the variance, with fifteen residuals (42%). One variable was cross-loaded (‘Identify, formulate and solve complex engineering problems’). It was assigned to factor 1, where it demonstrated the highest factor loading. The factor components and contributing variables for this three-factor extraction are shown in Table 4.6, where the percentages are based on averaged absolute values of the loadings for each factor construct.

**Table 4.6 Factor components and variables (specific skills—work)**

| **Component Loadings** | | |
|---|---|---|
| **Construct 1: Knowledge application** | | **46%** |
| Design a system or a component to needs | 0.493 | |
| Identify, formulate and solve complex engineering problems | 0.581 | |
| Technical and environmental interaction and impacts | 0.532 | |
| Design and conduct experiments, as well as analyse and interpret data | 0.451 | |
| Identify research needs and necessary resources | 0.461 | |
| Leverage engineering techniques, skills and tools | 0.485 | |
| Specialist engineering knowledge application | 0.656 | |
| Understand engineering project and construction management | 0.681 | |
| Understanding complex engineering project and construction management | 0.597 | |
| **Construct 2: World view** | | **36%** |
| Understand engineering professional and ethical responsibility | 0.54 | |
| Understanding social and global impacts of engineering | 0.526 | |
| Effective communication | 0.657 | |
| Leadership role, principles, and attitudes | 0.734 | |
| Recognition of the need for, and the ability to engage in, life-long learning | 0.625 | |
| Ability to function in multi-disciplinary teams | 0.756 | |

| **Component Loadings** | | |
|---|---|---|
| **Construct 3: Engineering in practice** | | **18%** |
| Apply knowledge of mathematics and other basic subjects | -0.645 | |
| Use knowledge of core engineering subjects | -0.589 | |
| Identify, formulate and solve common engineering problems | -0.665 | |

‘Knowledge application’ (46%) addresses the interrelationship between diverse knowledge areas to deliver engineering outcomes. ‘World view’ (36%) combines constructive qualities of awareness, empathy, and growth. ‘Engineering in practice’ (18%) summarises the basic knowledge and skills required by engineering professionals. Negative loadings here indicate the need for ongoing enhancements to practice.

## 4.7 Interpreting factor analysis of questionnaire responses

Analysis of the Likert responses provides two key findings: (1) negative factor loadings suggest opportunities for collaboration between educational institutions and workplaces, and (2) the relationship between skills acquisition and performance provides an interpretive framework for transition to work. Research confirms the importance of balancing these skills:

> The majority of employers continue to say that possessing *both* field-specific knowledge and a broad range of knowledge *and* skills is important for recent college graduates to achieve long-term career success. Very few indicate that acquiring knowledge and skills mainly for a specific field or position is the best path for long-term success. Notably, college students recognise the importance of having both breadth and depth of skills and knowledge for their workplace success (Hart Research Associates, 2015, p. 1).

Findings from this study also underline that broad and deep skills, and adaptive capacity are pivotal to career success.

### 4.7.1 Axial opportunities

Views differ on how to best interpret negative factor loadings. Schmitt and Stults (1985) propose that negative loadings often define a single factor, with negative weighting explained by participant interpretation of question semantics. For this dataset however, negative loadings seem closely affiliated with the notion of transitional or transformative capacity. Following Meyer and Land’s (2003) theory of learning thresholds, negatively loaded capabilities may signify ‘threshold’ or boundary crossing competences. These are difficult concepts, which open new avenues of understanding when they are grasped. Baxter Magolda's (1998, 2004) *self-authorship* model of identity development is consistent with this view. Nadelson et al. (2015) use self-authorship as a lens to understand the process of professional identity development:

> Baxter Magolda (1998) contends that competencies of the skills and abilities influenced by higher education are fundamental to progression toward self-authorship. Students can progress in their self-authorship development through interactions with people who validate them as learners, require them to develop and defend perspectives, immerse them in student-centred experiences, involve them in critical thinking, and expose them to situations of ambiguity (Nadelson et al., 2015, p. 3).

Transferring knowledge from an education setting to the workplace is "particularly difficult, because of the considerable differences in context, culture and modes of learning" (Eraut, 2009). Hays and Clements (2012) regard the move from university to the workplace as an opportunity for colleges and employing organisations to work together to more directly influence learning during transition, including providing learning programs specifically about the transition process. Negative loadings on skills required for work identify those which are participatory and experience based—engineering project delivery, managing client relationships, and collaborating with internationally based colleagues. These skills lend themselves to co-operatively created and delivered 'bridging' curriculum models. In this way, learning programs could specifically target issues involved in acclimatising new engineers to workplace social systems, and to the complexities of moving from theory to practice. Questionnaire analysis highlights the value of engineering firms and universities establishing continuing and mutually beneficial relationships (Hays & Clements, 2012), whether this takes the form of collaboratively innovating 'backpack to briefcase' programs, or guiding the pipeline of next generation talent. Valerie Todd, Talent and Resources Director for Crossrail, articulates this need: "If we want young people who are ready for the workplace, we need to be ready to help build their employability skills" (Investors in People, 2013, p. 3).

Figure 4.10 below illustrates this thinking. Questionnaire analysis counters theory-practice and novice-expert divides. Results highlight the complementary roles of academia and employment. In Figure 4.10, factor constructs with negative factor loadings are greyed out to signify knowledge areas where educational institutions and places of work could productively collaborate on learning and experience design. For general skills, this opportunity represents 48% of responses; for specific skills it represents 60% of responses. Negative factor loadings suggest transformative 'pivot points' in the journey from a work-ready graduate to an engineering professional. There is a sense of deep personal change in this process. Stevens, O'Connor, Garrison, Jocuns, and Amos (2008) express this transformation as:

> Whereas a focus on "earning" typically draws attention to changes in an individual's cognitive capacities, a focus on "becoming" draws attention to additional dimensions of change over time, and in particular, to a broader set of social organisational practices in which the engineer-in-the-making is embedded and through which she or he charts a course (p. 355).

Learning is thus not a measurable end state but "a participative process where knowing is ontologically linked with action" (Dean, 2015, p. 2).

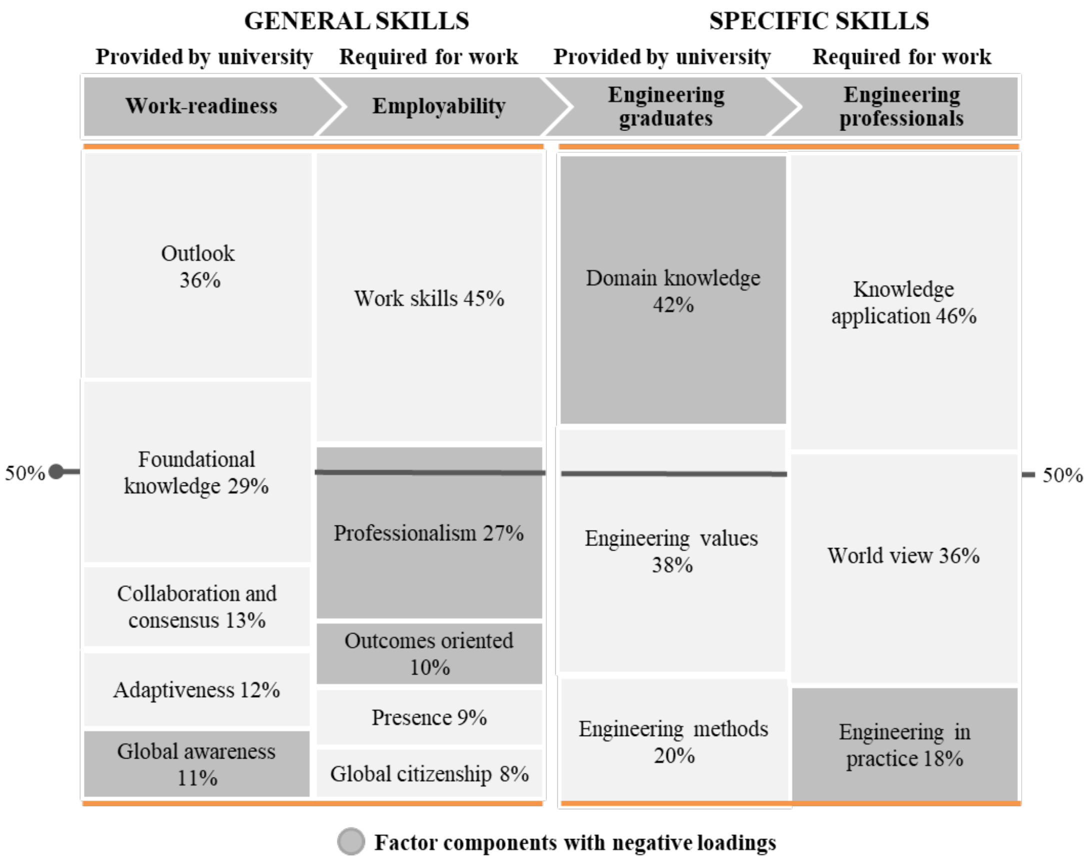



**Figure 4.10 Skills across the work lifespan**

Analysis additionally points to the value of experiential opportunities in internships and apprenticeship/paraprofessional programs. This emphasises the role of socialisation in learning. Socialisation is a means by which we acquire the knowledge, skills, and disposition that enable us to become members of a profession. Johri (2012) observes that for professions such as engineering, where technical competence is highly valued, the challenge for development programs is to identify "what newcomers do as they socialise and what this participation means to them" (p. 250). Stevens et al. (2014) refer to this as the "identity dimension". They note that despite the technical, scientific, and mathematical labour at the core of engineering, personal, social, and disciplinary identities intersect in complex ways amongst professional engineers, whose professional identities are forged in tandem with prevailing social, technological, and political forces.

### 4.7.2 Compounding capabilities and skills transformation

The transition from formal education to work "concerns significant change in an individual learner's world view, sense of self, and being" (Hays & Clements, 2012, p. 3). Stevens et al. (2014) point out that:

> Too little is known about how the practices of undergraduate education are applied and adapted in the workplace and equally little is known about what knowledge practices from one's engineering education experience have little or no clear use at work. Lines of research that look directly at these transitions from school to work are much needed (p. 126).

Study results present a transformational process extending beyond entry to the workplace. Figure 4.11 charts significant changes in this work lifespan. There is an additive quality to this process, with work-oriented constructs suggesting forms of "enrichment" through experience and practical knowledge application.

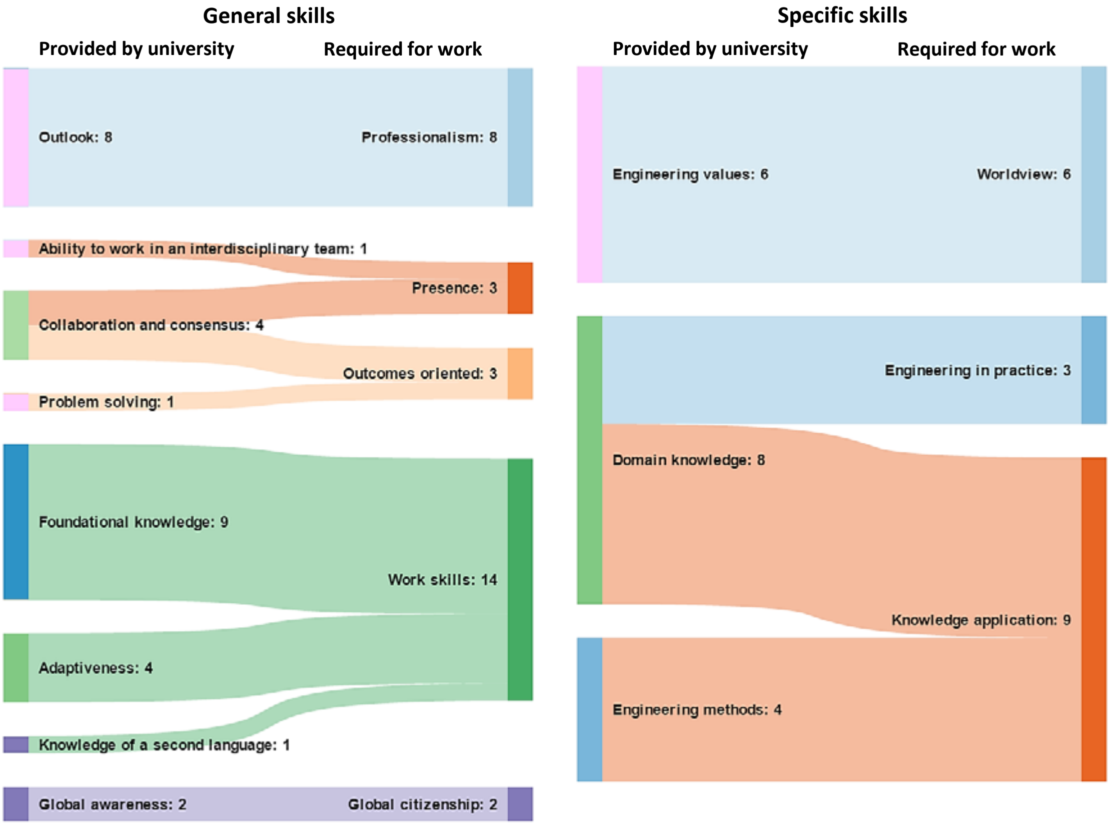



**Figure 4.11 Skills transformation in becoming an engineer**

The university-provided capabilities in ‘Outlook’ (Ability to communicate with non-experts (in the field), Appreciation of diversity and multiculturality, Concern for quality, Will to succeed) become absorbed into the negatively loaded workplace construct ‘Professionalism’. This identifies workplace opportunities for skills development. Likewise, items in the negatively loaded ‘Global awareness’ (Ability to work in an international context, Knowledge of a second language, Understanding of cultures and customs of other countries) contribute to ‘Work skills’ and ‘Global citizenship’. The work-related competencies of ‘Presence’ and ‘Outcomes oriented’ combine the cognitive dimension of ‘Problem-solving’ from the tertiary provided ‘Collaboration and consensus’ with the ‘Outcomes oriented’ workplace requirement. Similarly, ‘Interpersonal skills’ are part of the nuanced workplace construct ‘Presence’, which acknowledges the relationship between leadership and interpersonal and team skills.

Exploratory factor analysis helps reveal aspects of this developmental change. Sfard (1998) proposes that two metaphors describe learning. “The *acquisition metaphor* sees learning as a process of knowledge acquisition, while the *participation metaphor* emphasises that learning takes place by participating in the practices of social communities” (as cited in Tynjälä, 2008, p. 131). This corresponds with Hays and

Clements (2012), who highlight that workplace learning is characterised by uncertain objectives, and that learning is achieved through task accomplishment, and shared efforts. "The relationship between academic knowledge and professional knowledge is important, because the former is transformed into the latter through learning in the workplace" (Boshuizen, Bromme, & Gruber, 2004, p. 5). There is thus a real sense that "travelling changes the traveller".

Field-specific skills illustrate the importance of disciplinary values in university study to a professional engineer's world view. This is most noticeable in the aspects of 'Domain knowledge' (Apply knowledge of mathematics and other basic subjects, Identify, formulate and solve complex engineering problems, Use knowledge of core engineering subjects) which become the activities of 'Engineering in practice'. Practical engineering knowledge (Design a system or a component to needs, Design and conduct experiments, as well as analyse and interpret data, Identify research needs and necessary resources) is applied through 'Knowledge application'.

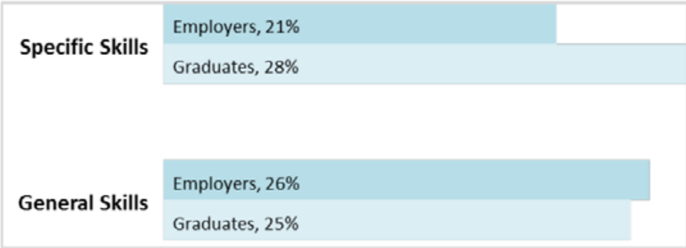
## 4.8 Participant comments

To help identify emerging themes or capabilities that are important to work, and not included in Tuning Process question items, the questionnaire was adapted to include free text responses. This is illustrated in Table 4.7.

**Table 4.7 Tuning questionnaire adapted for free text responses**

| Original Tuning Question | Adapted Question |
|---|---|
| Please rank below the five most important competences according to your opinion. Please write the number of the item within the box. Mark on the first box the most important, on the second box the second most important and so on.<br><br>1. ☐<br>2. ☐<br>3. ☐<br>4. ☐<br>5. ☐ | (III) In your opinion, what are the three to five (3-5) most important **general capabilities** required for engineering?<br><br>(IV) In your opinion, what are the three to five (3-5) most important **specific skills** required for engineering |

Respondents nominated the three to five most important general and specific capabilities they believe engineering requires. In total, 1536 (employers 722, graduates 814) comments were received. Figure 4.12 summarises these contributions.




| | Employers | Graduates | Total |
|---|---|---|---|
| General | 399 | 391 | 790 |
| Specific | 323 | 423 | 746 |
| Total | 722 | 814 | **1536** |

**Figure 4.12 Comments from employers and graduates**

## 4.8.1 Coding the responses

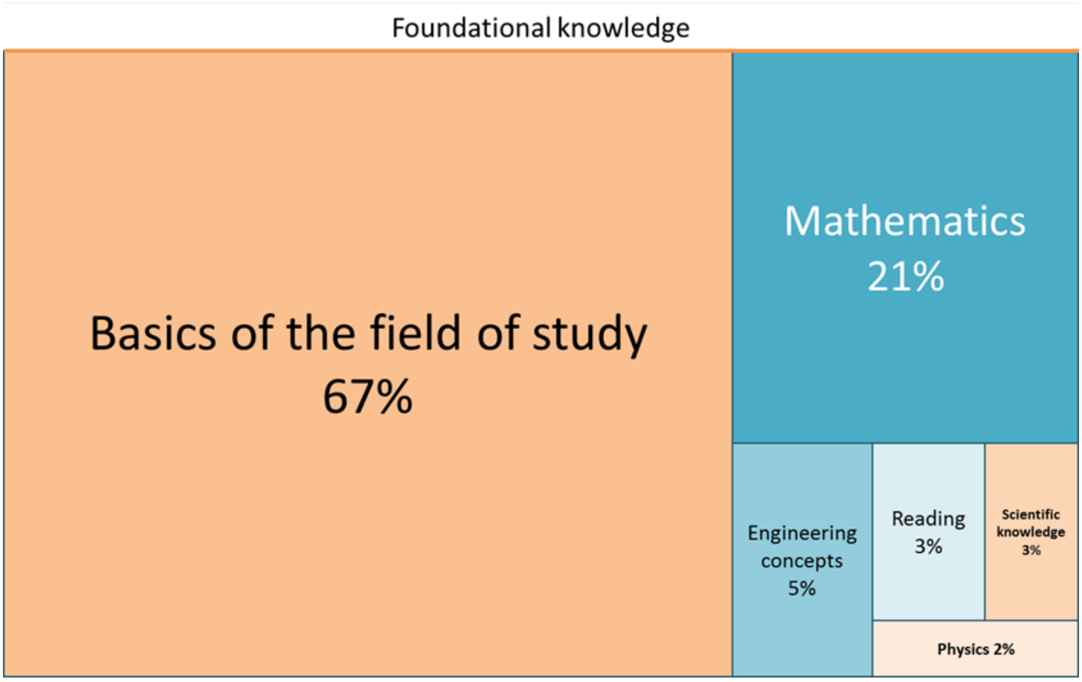
A grounded coding approach was adopted. Ryan and Bernard (2003) list a number of observational techniques to identify and classify themes, including:

- **Scrutiny techniques—**patterns and significances determined via proofreading, highlighting repeated words and phrases
- **Word repetitions—**look for commonly used words
- **Indigenous categories—** terms used by respondents with a particular meaning and significance in relation to engineering
- **Key-words-in-context—**look for the range of uses of key terms in the phrases and sentences in which they occur
- **Similarities and differences—**comparing and contrasting statements by asking ‘how does it differ from the preceding or following statements?’
- **Searching for missing information—**focused on what is mentioned that is not included in the Tuning questionnaire items.
- **Filtering and sorting—**sorting comments by general and specific observations, and comments made by graduates or employers

Concordance and word frequency analysis was conducted to discover indicative text patterns. The responses were then sorted and organised into seventeen themes, based on qualitative analysis of the different themes and thematic relationships in respondent comments. These comments are provided in Appendix 5. Following Ryan and Bernard (2003), the analysis of respondent comments involved identifying repeated words and phrases, commonly used word, terms specific to engineering, coding responses by the context in which key terms are used, and identifying possible thematic gaps in participant comments. The word cloud in Figure 4.13 is an example of the themes that emerged from this grounded coding analysis. The themes were similar for general and specific skills.


**Figure 4.13 Comment themes word cloud**

The majority of comments relate to 'Foundational knowledge', 'Problem-solving', 'Professionalism', 'Technical orientation', and 'Attitude'. 'Foundational knowledge' and 'Attitude' presented a number of sub-themes. Figure 4.14 illustrates the themes that comprise these constructs.



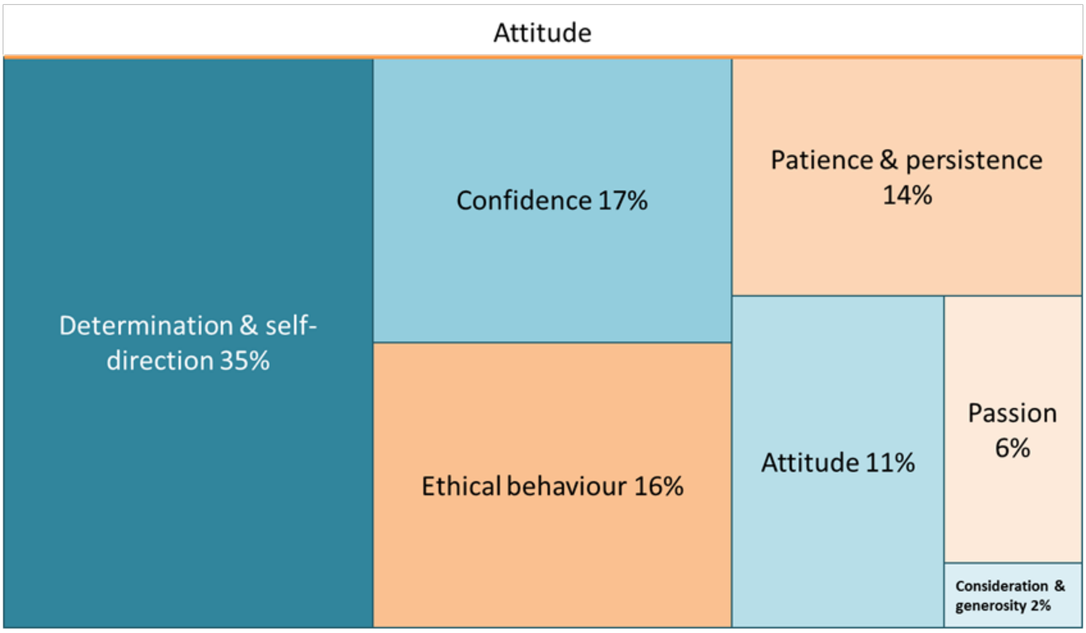



**Figure 4.14 Contributing themes for Foundational knowledge and Attitude**

'Foundational knowledge' incorporates engineering concepts, technical and mathematical skills, and core discipline knowledge. Identifying comments include: "solid engineering background", "strong fundamentals", "good knowledge of core subjects", and "strong in mathematics and science". 'Attitude' sub-themes express a compendium of: determination, self-directedness, ethical behaviour, confidence, passion, a positive attitude, consideration and generosity. Figure 4.15 shows the percentage of employer and graduate comments. Findings demonstrate similar opinions.

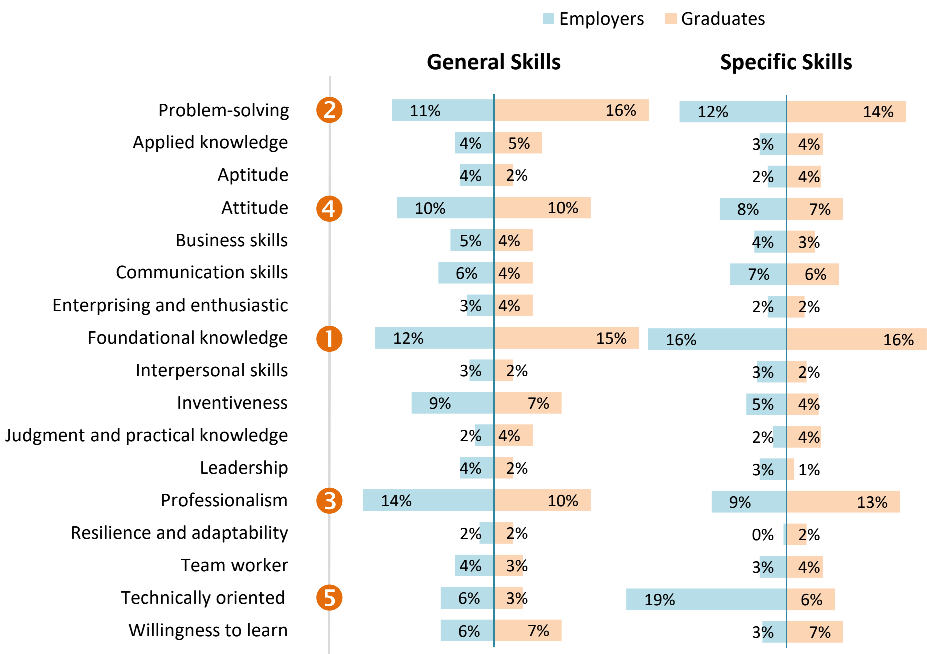



**Figure 4.15 Skills by percentage of responses**

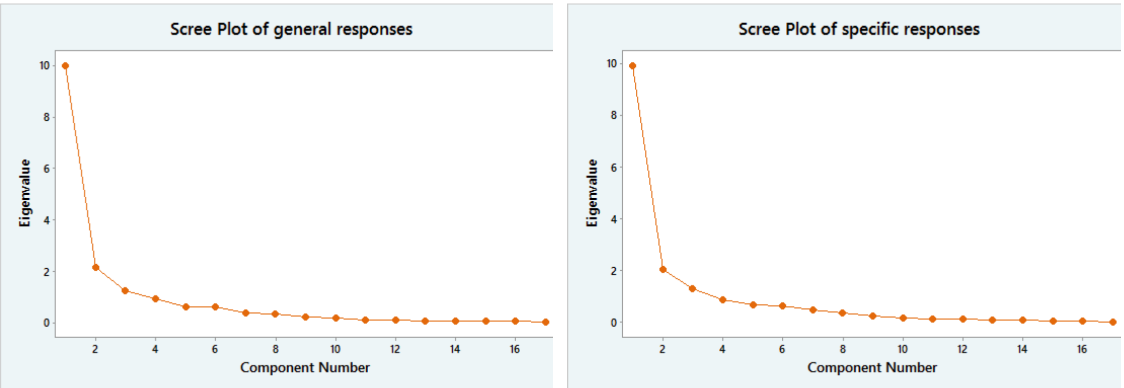
The top five skills by weighted average are: (1) Foundational knowledge, (2) Problem-solving, (3) Professionalism, (4) Attitude, (5) Technically oriented. There are a larger number of employer comments for ‘Technically oriented’, which emphasises the importance of engineering practice. A 2015 *Institution of Civil Engineers Skills Report* confirms engineering skills are responsive to current markets and the social landscape, and are underpinned by “a bedrock of core technical knowledge” (Institution of Civil Engineers, 2015, p. 4).

## 4.9 Factor analysis of participant comments

### 4.9.1 Data reduction and analysis

Analysis identified three principal components for general skills, and three principal components for specific skills. The Maximum Likelihood method was used to determine the broadest distribution of factors. Table 4.8 displays these results.

**Table 4.8 Eigenanalysis of free text responses**




| Eigenvalues (general skills) | | | | Eigenvalues (specific skills) | | | |
|---|---|---|---|---|---|---|---|
| **Component** | **Total** | **% Variance** | **% Cumulative** | **Component** | **Total** | **% Variance** | **% Cumulative** |
| 1 | 9.9746 | 59% | 59% | 1 | 9.8977 | 58% | 58% |
| 2 | 2.1299 | 13% | 71% | 2 | 2.0427 | 12% | 70% |
| 3 | 1.2379 | 7% | 79% | 3 | 1.2726 | 8% | 78% |

### 4.9.2 General skills

Principal components data reduction techniques resulted in three variables for analysis. Factor analysis was conducted with this three-factor solution using the principal components extraction method and Varimax rotation. Three items were cross loaded (‘Attitude’, ‘Communication skills’, ‘Willingness to learn’). Each was assigned to the factor where it demonstrated the highest loading. The results in Table 4.9 identify the following patterns, where the percentages are based on averaged absolute values of the loadings for each factor construct.

**Table 4.9 Factor components and contributing variables (general skills)**

| **Component Loadings** | | |
|---|---|---|
| **Construct 1: Employability** | | **65%** |
| Applied knowledge | 0.814 | |
| Aptitude | 0.907 | |
| Business skills | 0.846 | |
| Communication skills | 0.771 | |
| Enterprising and enthusiastic | 0.884 | |
| Interpersonal skills | 0.849 | |
| Judgment and practical knowledge | 0.816 | |
| Leadership | 0.883 | |
| Resilience and adaptability | 0.807 | |
| Team worker | 0.896 | |
| Technically oriented | 0.792 | |
| **Construct 2: Character** | | **23%** |
| Attitude | -0.771 | |
| Inventiveness | -0.71 | |
| Professionalism | -0.911 | |
| Willingness to learn | -0.59 | |
| **Construct 3: Engineering skills** | | **12%** |
| Problem-solving | 0.93 | |
| Foundational knowledge | 0.665 | |

'Employability' (65%) brings together a diverse range of skills and individual qualities that contribute to personal capital and facilitate employment opportunities. It combines effective communication and interpersonal skills with leadership, judgment or 'good sense', and the ability to apply knowledge. 'Technically oriented' acknowledges the sociomaterial nature of engineering implicit in participant responses. 'Character' (23%) combines important non-cognitive aspects of employability. The Confederation of British Industry (CBI) (2012) defines these qualities as "a set of behaviours and attitudes, a kind of social literacy … sometimes termed character … that plays a critical role in determining personal effectiveness" (p. 31). Negative loadings suggest this is a developmental or "growth" capability, which is fostered through work activities. 'Engineering skills' (12%) integrates an analytical and problem-solving orientation with essential mathematics, scientific knowledge, and engineering fundamentals.

### 4.9.3 Specific skills

Principal components data reduction techniques resulted in three variables for analysis. Factor analysis was conducted with this three-factor solution using the principal components extraction method and Varimax rotation. Six items were cross loaded ('Applied knowledge', 'Attitude', 'Communication skills', 'Inventiveness', 'Team worker', 'Willingness to learn'), and were assigned to the factor where each demonstrated the highest loading. The results in Table 4.10 identify the following patterns, where the percentages are based on averaged absolute values of the loadings for each factor construct.

**Table 4.10 Factor components and contributing variables (specific skills)**

| **Component Loadings** | | |
|---|---|---|
| **Construct 1: Professional practices** | | **64%** |
| Applied knowledge | 0.839 | |
| Aptitude | 0.848 | |
| Business skills | 0.849 | |
| Enterprising and enthusiastic | 0.896 | |
| Interpersonal skills | 0.889 | |
| Inventiveness | 0.756 | |
| Judgment and practical knowledge | 0.802 | |
| Leadership | 0.722 | |
| Resilience and adaptability | 0.766 | |
| Team worker | 0.839 | |
| Willingness to learn | 0.589 | |
| **Construct 2: Character** | | **18%** |
| Attitude | 0.776 | |
| Communication skills | 0.758 | |
| Technically oriented | 0.767 | |
| **Construct 3: Engineering skills** | | **19%** |
| Problem-solving | 0.845 | |
| Foundational knowledge | 0.717 | |
| Professionalism | 0.829 | |

'Professional practices' (64%) represent the values, behaviours, and outcomes focus of engineering professionals. 'Inventiveness' and 'Willingness to learn' add the dimensions of creativity and responsiveness to change and innovation. Engineering-specific 'Character' (18%) requirements are noticeably different to general skills character requirements: 'Attitude', 'Communication skills', and 'Technically oriented' here produce a 'combinatory temperament' or signature character of an engineer. 'Technically oriented' suggests that identifying as a 'technical person' is intrinsic to "becoming" or embodying an engineering persona. Stevens et al. (2008) point out that "persons are always "in-context". Forming an identity as an engineer requires that one "be identified as "engineering material," both by him or herself and by disciplinary representatives" (p. 358). 'Engineering skills' (19%) reinforces the need for field relevant knowledge, professional behaviours, and an analytical nature.

# 4.10 Interpreting factor analysis of participant comments

## 4.10.1 Mapping the engineering professional persona

Similar to the Likert responses, the free text responses indicate a building upon or additive relationship between the cognitive-developmental aspects of general skills, and the applied-performative aspects of specific skills. Analysis indicates that work practices effect this change. There is thus a sense of compounding return on experience. This transformation is evidenced by the shift in factor loading for 'Professionalism', 'Willingness to learn', and '’Technically oriented' from generic employability capabilities to components of workplace 'Professional practices'. The variable 'Attitude' does not change its central position. It is therefore unlikely to be a scaffold capability, and can instead to be taken as the 'nexus' of employability. The emerging genre of character research argues that the non-cognitive traits of attitude and character are teachable and can be included in learning and developmental programs (Duckworth, Peterson, Matthews, & Kelly, 2007; The Jubilee Centre for Character and Virtues, 2012).

Analysis indictes there are three main dimensions to engineering work: (1) a professional approach and growth mindset, (2) civic capacity and a constructive attitude, and (3) strong foundational skills and an analytical orientation, as the basis of credible and informed engineering activities. Analysis also indicates these dimensions are interlinked, and that each is a key aspect of an engineering professional persona. Figure 4.16 illustrates:

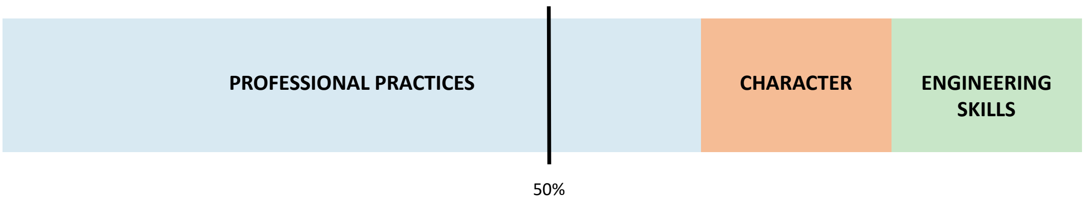



**Figure 4.16 Dimensions of an engineering professional**

While survey findings generally reinforce Tuning Process knowledge domains, they additionally suggest the dimension of 'Character'. This quality is not fully accommodated by Tuning interpersonal or social skills competences:

- **Instrumental competences:** cognitive abilities, methodological abilities, technological abilities and linguistic abilities
- **Interpersonal competences:** individual abilities including social skills such as interaction and cooperation

- **Systemic competences:** abilities and skills concerning whole systems; a combination of understanding, sensibility and knowledge; prior acquisition of instrumental and interpersonal competences required (Tuning, 2000, online)

Figure 4.17 shows these interlinkages, and where generic transferrable skills become workplace capabilities. Factor components identify this integration into workplace and engineering-specific competences.

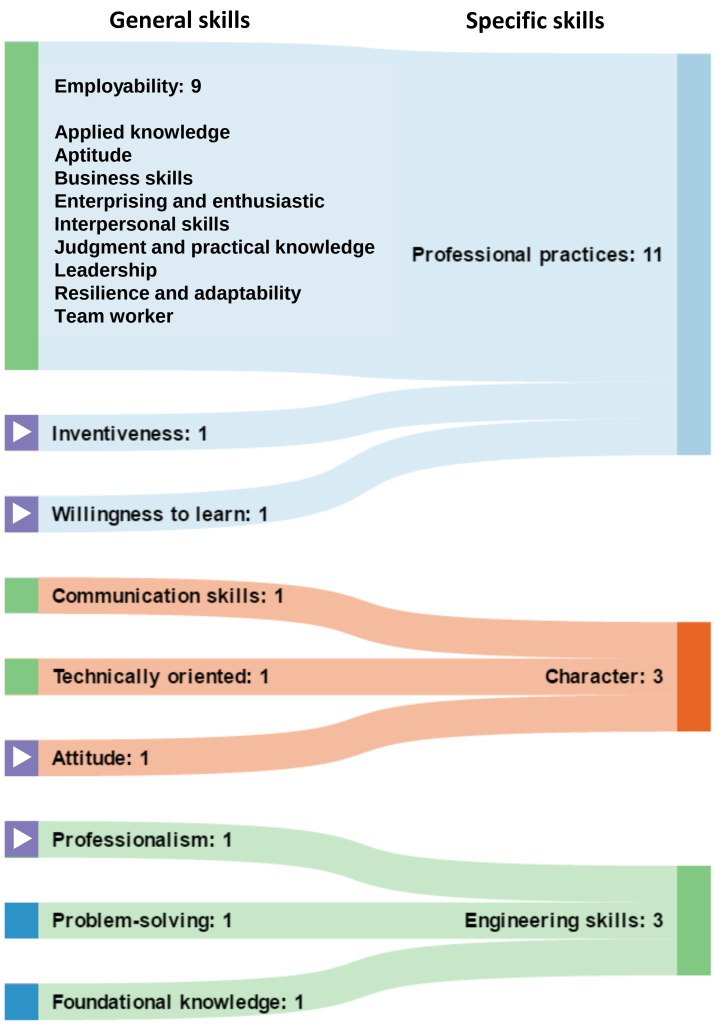



**Figure 4.17 Capabilities for the workplace**

Applied knowledge ('Business skills', 'Judgment and practical knowledge', 'Resilience and adaptability', and 'Team worker') corresponds with professional behaviours. Dweck's (2006) concept of a "growth mindset" describes the underlying beliefs people have about their abilities. To view challenges and setbacks as growth opportunities exerts a powerful effect on resilience, approach to tasks, and many other life and career dimensions (Dweck, 2006). 'Inventiveness' and 'Willingness to learn' are facets of this growth mindset. Similarly, effective communication, a technical inclination, and a constructive attitude help define the core values of an engineer. ‘Engineering skills’ brings together field-specific knowledge and habits of practice.

## 4.11 Conclusion

Becoming an engineer is equally about behaviours and values as it is about knowledge and technical skills. Leveraging the Tuning Process methodology for workplace induction and development for new career engineers extends Tuning relevance beyond application to tertiary curricula. Factor analysis of survey responses identifies important transformations in the journey from engineering student to novice engineer, and the complementary roles of universities and organisations. Results reveal patterns of interaction, or touchpoints, between places of learning and places of work. Curricular implications are beyond the scope of this analysis. However, findings highlight opportunities for partnership and learning program collaboration between academia and industry in transition to work programs. Results also demonstrate consistencies of opinion between graduates and professional engineers. This affirms the success of engineering education reform and inclusion of collaborative activities in learning programs. Adapting the Tuning instrument to include free text responses indicates that ‘attitude’ and ‘disciplinary identity’ play a significant role in the transformation from student to engineer. Study results consistently emphasise that higher education and workplaces are partners in facilitating the transition to work.

# References


Aron, A., & Aron, E. N. (2003). *Statistics for psychology* (3rd ed.). Upper Saddle River, NJ, US: Prentice Hall/Pearson Education.

ASCE. (2008). *Civil engineering body of knowledge for the 21st century: Preparing the civil engineer for the future*. Retrieved from http://www.asce.org/uploadedFiles/Education_and_Careers/Body_of_Knowledge/Content_Pieces/body-of-knowledge.pdf

Baytiyeh, H., & Naja, M. (2012). Identifying the challenging factors in the transition from colleges of engineering to employment. *European Journal of Engineering Education, 37*(1), 3-14.

Boshuizen, H., Bromme, R., & Gruber, H. (2004). On the long way from novice to expert and how travelling changes the traveller. In H. Boshuizen, R. Bromme, & H. Gruber (Eds.), *Professional Learning: Gaps and Transitions on the Way from Novice to Expert* (Vol. 2, pp. 3-8). Dordrecht, The Netherlands: Kluwer Academic Publishers.

Carvalho, J. (2008). *International aspects of Bologna: The Tuning Project*. Paper presented at the BALANCE – Bologna: A long-term approach to new certification in Europe, University of Turku, Finland. http://www.coimbra-group.eu/balance/Docs/turku/International%20Aspect%20of%20Bologna%20Process%20-Tuning.ppt.

CASEL. (2017). What is SEL? Retrieved from http://www.casel.org/what-is-sel/

Confederation of British Industry (CBI). (2012). *First Steps: A new approach for our schools*. Confederation of British Industry (CBI). London. Retrieved from http://www.cbi.org.uk/insight-and-analysis/first-steps/

Crawley, E. F., Malmqvist, J., Östlund, S., Brodeur, D. R., & Edström, K. (2014). *Rethinking engineering education: The CDIO approach* (2nd ed.). Heidelberg, Germany: Springer.

Dean, B. A. (2015). *Learning on placement: A sociomaterial, practice-based approach to work-integrated learning.* (PhD), University of Wollongong, Wollongong. Retrieved from http://ro.uow.edu.au/theses/4361/

Duckworth, A. L., Peterson, C., Matthews, M. D., & Kelly, D. R. (2007). Grit: Perseverance and passion for long-term goals. *Journal of Personality and Social Psychology, 92*(6), 1087.

Dweck, C. S. (2006). *Mindset: The new psychology of success* (1st ed.). New York: Random House.

Edvardsson Stiwne, E., & Jungert, T. (2007). *Engineering students experiences of the transition from study to work*. Paper presented at the 3rd International CDIO Conference in Massachusetts Institute of Technology, Cambridge, Massachusetts.

Eraut, M. (2009). Transfer of knowledge between education and workplace settings. In H. Daniels, H. Lauder, & J. Porter (Eds.), *Knowledge, values and educational policy: A critical perspective* (pp. 65-84). Abingdon, Oxon, UK: Routledge.

Faulkner, W. (2007). `Nuts and bolts and people'. *Social Studies of Science, 37*(3), 331-356. doi:10.1177/0306312706072175

Fricker Jr, R. D., Appleget, J. A., & Kulzy, W. W. (2012). From data to information: Using factor analysis with survey data. *Phalanx, 29*(4), 30-34.

Goldberg, D. E. (2010). The missing basics and other philosophical reflections for the transformation of engineering education. In D. Grasso & M. Burkins (Eds.), *Holistic engineering education* (pp. 145-158). New York, NY: Springer New York.

Gonzélez, J., & Wagenaar, R. (2003). *Tuning educational structures in Europe. Final report. Phase one*. Universidad de Deusto: Deusto. Retrieved from http://www.bolognakg.net/doc/Tuning_phase1_full_document.pdf

Hart Research Associates. (2015). *Falling short? College learning and career success*. Selected Findings from Online Surveys of Employers and College Students Conducted on Behalf of the Association of American Colleges & Universities. Washington DC. Retrieved from http://www.aacu.org/sites/default/files/files/LEAP/2015employerstudentsurvey.pdf

Hays, J., & Clements, M. (2012, 20-22 June, 2102). *Transition-bridging the gap between study and work.* Paper presented at the Proceedings of the 9th International Conference on Cooperative & Work-Integrated Education, Where East meets West and Theory meets Practice, Istanbul, Turkey.

Hoffmann, B., Jørgensen, U., & Christensen, H. P. (2011). *Culture in engineering education: CDIO framing intercultural competences.* Paper presented at the 7th International CDIO Conference 20-22 June, Technical University of Denmark, Copenhagen.

Institution of Civil Engineers. (2015). *Institution of Civil Engineers Skills Report 2015. Perspectives on capability and capacity: key risks and opportunities*. Institution of Civil Engineers (ICE). London. Retrieved from http://www.ice-conferences.com/ice_events/media/general/ice-skills-report-2015-.pdf

Investors in People. (2013). Grow your own: Young people, talent development and improved performance. Retrieved from https://www.investorsinpeople.com/sites/default/files/Grow%20Your%20Own%20Talent%202016_1.pdf

Johri, A. (2012). Learning to demo: The sociomateriality of newcomer participation in engineering research practices. *Engineering Studies, 4*(3), 249-269.

Magolda Baxter, M. B. (1998). Developing self-authorship in young adult life. *Journal of College Student Development, 39*(2), 143.

Magolda Baxter, M. B. (2004). Self-authorship as the common goal of 21st century education. In M. Magolda Baxter & P. M. King (Eds.), *Learning partnerships: Theory and models of practice to educate for self-authorship* (pp. 1-35). Sterling, Virginia: Stylus.

Manoliu, I. (2005). *First results of the Tuning Project with the participation of EUCEET and ECCE*. Paper presented at the 42nd ECCE meeting, Istanbul, Turkey. http://www.unideusto.org/tuningeu/images/stories/Summary_of_outcomes_TN/First_results_Civil_Engineering_PPT.ppt.

Mansilla, V. B., & Jackson, A. (2011). *Educating for global competence: Preparing our youth to engage the world*. New York, NY: Asia Society.

Mertler, C. A., & Vannatta, R. A. (2002). Advanced and multivariate statistical methods. *Los Angeles, CA: Pyrczak*.

Meyer, J. H. F., & Land, R. (2003). Threshold concepts and troublesome knowledge: Linkages to ways of thinking and practising within the disciplines. In C. Rust (Ed.), *Improving student learning: Theory and practice - Ten years on* (pp. 412-424). Oxford, UK: Centre for Staff and Learning Development.

Nadelson, L. S., McGuire, S. P., Davis, K. A., Farid, A., & Hardy, K. K. (2015). Am I a STEM professional? Documenting STEM student professional identity development. *Studies in Higher Education*, 1-20. doi:10.1080/03075079.2015.1070819

Osborne, J. W., & Costello, A. B. (2005). Best practices in exploratory factor analysis: Four recommendations for getting the most from your analysis. *Practical Assessment Research & Evaluation, 10*(7). Retrieved from http://pareonline.net/getvn.asp?v=10&n=7

Reid, A., Abrandt Dahlgren, M., Dahlgren, L. O., & Petocz, P. (2011). *From expert student to novice professional* (Vol. 99). The Netherlands: Springer.

Ryan, G. W., & Bernard, H. R. (2003). Techniques to identify themes. *Field Methods*, *15*(1), 85-109.

Sauro, J. (2010). Top-box scoring of rating scale data. Retrieved from http://www.measuringu.com/blog/top-box.php

Sauro, J. (2011). How to interpret survey responses: 5 techniques. Retrieved from http://www.measuringu.com/blog/interpret-responses.php

Schmitt, N., & Stults, D. M. (1985). Factors defined by negatively keyed items: The result of careless respondents? *Applied Psychological Measurement*, *9*(4), 367-373.

Sfard, A. (1998). On two metaphors for learning and the dangers of choosing just one. *Educational Researcher*, *27*(2), 4-13.

Stevens, R., Johri, A., & O'Connor, K. (2014). Professional engineering work. In A. Johri & B. M. Olds (Eds.), *Cambridge Handbook of Engineering Education Research:* (pp. 119-138). Cambridge, UK: Cambridge University Press.

Stevens, R., O'Connor, K., Garrison, L., Jocuns, A., & Amos, D. M. (2008). Becoming an engineer: Toward a three dimensional view of engineering learning. *Journal of Engineering Education, 97*(3), 355.

The Jubilee Centre for Character and Virtues. (2012). *School of Education, University of Birmingham.* Retrieved from http://www.jubileecentre.ac.uk/

Trevelyan, J. P. (2009). *Engineering education requires a better model of engineering practice.* Paper presented at the Research in Engineering Education Symposium 2009, Palm Cove, QLD, Australia.

Trevelyan, J. P. (2010). Reconstructing engineering from practice. *Engineering Studies, 2*(3), 175-195.

Tuning. (2000). *Tuning educational structures in Europe*. Retrieved from http://www.unideusto.org/tuningeu/

Tynjälä, P. (2008). Perspectives into learning at the workplace. *Educational Research Review, 3*(2), 130-154. doi:http://dx.doi.org/10.1016/j.edurev.2007.12.001

Vest, C. M. (2007). *Educating engineers for 2020 and beyond*. National Academy of Engineering, Grand Challenges Blog. Retrieved from http://www.engineeringchallenges.org/14373/GrandChallengesBlog/7639.aspx

# 5 Transitioning to Professional Work

*Transitioning to professional work: A view from the field*

## Overview

This chapter is published in Hawse, S. (2017). Transitioning to professional work: A view from the field. In L. N. Wood & Y. A. Breyer (Eds.), *Success in higher education: Transitions to, within and from university* (pp. 229-253). Singapore: Springer Singapore. It discusses survey responses from experienced professionals, or employers who responded to the Tuning Process questionnaire as new graduates, rather than as employer representatives. These responses are coded as Experienced Professionals, and have been analysed and included as chapter five because these outlier responses provide further explanatory insights to the study. Experienced professionals are outside the scope of the study, which surveys new graduates and employers for their assessment of the general and engineering-specific skills provided by university and required for work. As the experienced professionals cohort is outside the scope of the study, data for the this group is not included in the appendices, which focus on responses provided by graduates and employers. Instead, the responses from these 'experienced graduates' have been included in chapter five as an 'addendum;' to the chapter four analysis of the survey data. Chapter five thus interprets work-readiness from the viewpoint of 'experienced' graduates. It discusses similarities and differences of opinion between these experienced engineers and new graduates. This analysis provides 'cross-generational' views and contributes explanatory insights from experienced professionals adopting the position of engineering graduates. While graduation signifies successful completion of a higher education program of learning, philosophies of the work lifespan and career transitions present a broader view of the journey from student to professional. Questionnaire responses to the preparation for work provided by university study contribute to knowledge about the transition process, and how higher education and organisations can facilitate transition to work. This chapter starts with a brief literature review and moves on to discuss transitions and workplace expectations. It then looks at new graduate and experienced professional views relating to the work-readiness provided by formal engineering programs of study. The chapter concludes with recommendations for what academia and organisations can do to support transition to work.

## INTRODUCTION

Changes across industry and the economy, shifting social values, increased demand for higher education, and globalisation are impacts which Edgerton (2001) identifies as significantly reshaping contemporary educational programs. He contends that program completion, participant understanding, and acquisition of the literacies required for effective work, citizenship, and personal fulfilment are the quality standards against which educational programs should be evaluated. Edgerton's (2001) viewpoint is particularly resonant for contemporary STEM (Science, Technology, Engineering, and Mathematics) curricula. In the context of dwindling enrolments and increased industry need, these disciplines have received policy focus and attention directed towards encouraging students to pursue careers in science and technology. Program responses incorporate teamwork activities, communication and professional skills, and the environmental and social implications of scientific solutions. Recent US data shows that these efforts have been successful, with STEM enrolments increasing, notably in engineering and biology (Arizona State University, 2014; Jaschik, 2014; The City University of New York (CUNY), 2015; UW ‑ Madison, 2014).

Research into how knowledge is produced in digital- and science-oriented economies, and the increasing diversification of higher education indicates that the role of academia now ranges "from the most specialised research to the most utilitarian kind of training" (Gibbons et al., 1994, p. 71). Eraut (2009) hypothesises that vocational and professional education courses such as engineering degree programs claim to provide five main types of knowledge: (1) theoretical knowledge, (2) methodological knowledge, (3) practical skills and techniques, (4) generic skills, and (5) general knowledge about the occupation. These knowledge types cover foundational concepts and theories relating to the profession, as well as the ability to critique these concepts in the context of the role of the profession and its proposed new forms of practice. They also encompass the manner in which knowledge is created, analysed, and interpreted and the practical capabilities of applying the domain knowledge in practice. This also includes: indirect or generic skills of numeracy, literacy, communication, critical thinking, and self-directedness; and knowledge of the values, modes of working, and career opportunities within the profession. This indicates higher education programs are sufficiently diverse to warrant blended higher education-industry learning models that specifically address the transition between higher education and the workplace.

That is, as the focus of many university engineering programs remains largely theory-based, these programs may not always meet the professional needs of early-career engineers, for whom significant challenges include the specific skills and knowledge required for working in project-based environments with multi-disciplinary teams and cultures (Baytiyeh & Naja, 2012; Finkel & King, 2013). Baytiyeh and Naja (2012) observe that while engineering curricula provide the foundational and technical knowledge required to begin a career, the transition from student to the workplace is not well understood, and that "engineering students complete a highly structured curriculum, but a professional engineer works in a highly unstructured environment and performs multi-dimensional tasks" (p. 4).

There is a compelling need for new professionals to apply, review, and extend their knowledge in practice, and for academic and organisational development programs to provide activities that support this need. Katz (1993) interviewed professional engineers in supervisory roles across industry, consulting, and government. These representatives, who commonly employ engineering graduates, summarise challenges graduates face transitioning to the workplace:

- **Industry**—The person coming out of school [university]—unless he's had either a co-op program or fairly extensive internships in the summer—doesn't know what industry is all about.
- **Consulting**—The undergraduates are not well prepared for a job market. … They may understand some of the general principles in engineering, but they have difficulty in applying them from a practical standpoint.

- **Government**—My problem has always been…that public health and the engineering curriculum don't really match in the first place. … Most of them [new engineers] would interview for a public health job…without really knowing what it is (Katz, 1993, p. 171).

Difficulties in transitioning to the workplace persist despite activities to support this transition. University curricula and workplace professional-development responses encompass: capstone courses, work placements, training and professional development, inductions to organisational culture and modes of working, and early-career mentoring programs. Workplace induction and awareness programs provide opportunities to tailor learning and professional development to solutions that assist new engineers to acclimatise to workplace social systems and to the complexities of moving from theory to practice. Nonetheless, as Eraut (2009) observes, transferring knowledge and concepts from an education setting to the workplace is "particularly difficult, because of the considerable differences in context, culture and modes of learning" (p. 77). Wong, Chen, and Chen (2016) propose that the interaction of several complicated factors, such as the knowledge transfer gained from participation in work tasks and the design and composition of work teams, contribute to the transformation of a novice to an expert in the workplace. Working in teams, workgroup composition, supervision and coaching, and group processes influence this transformation, with implications for research into academic to workplace transitions.

## Academic and Workplace Transitions

Wood and Solomonides (2008) consider the changes that students experience as they embark on a course of study and then go on to professional life. They suggest that "one of the roles of the transition from school to university is also to foreshadow the future transition to professional work" (p. 119). The activities and programs that contribute to university induction include: first year seminars and experiences, learning and study groups, writing workshops, and tutorials. These types of activities can also inform workplace onboarding programs, workgroup integration, mentoring, and task assignment for new career starters. In Figure 5.1, Taylor, Millwater, and Nash (2007) adapt Bridges' (2003) transition model to a student's journey from pre-enrolment to graduation, and changes in focus and priority in their acquiring a professional identity.

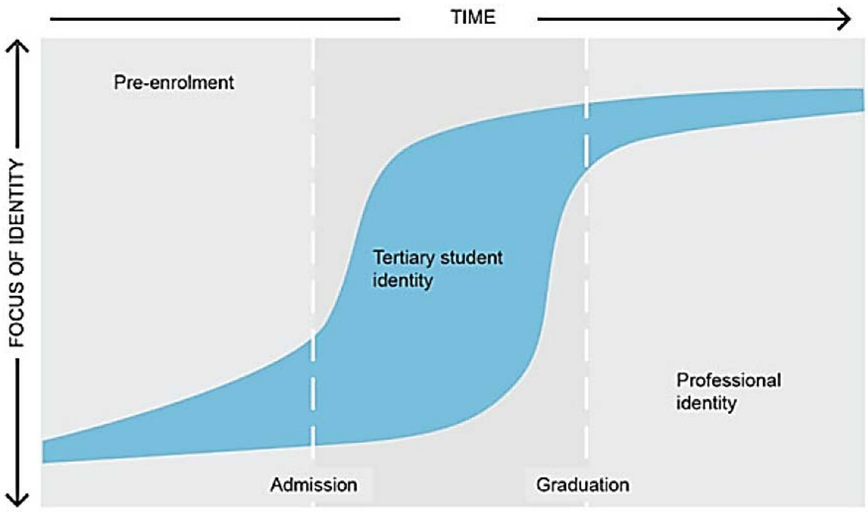



**Figure 5.1 A student's learning journey (Taylor et al., 2007, p. 2)**

Bridges (2003) identifies that disorientation, frustration, and uncertainty often accompany change, and that the process of transition incorporates separation, transition, and re-alignment phases. This is similar to Lewin's (1947) theory of change, which incorporates "unfreezing" or breaking down the existing status quo, implementing change activities, and then "refreezing" or anchoring the changes into behaviour and culture as norms. Wong et al. (2016) interpret these transitions from a workplace perspective as re-learning and re-education processes undertaken while novice practitioners acquire professional identities of the workplace and become more experienced workers. They argue that a range of factors is implicated in this change and knowledge-transfer process, including gender, workplace culture, and team member proximity. Hays and Clements (2012) note that transition can be part of a transformative learning process. They suggest that support for the move from university to the workplace can include learning tasks specifically about the transition process. This presents opportunities for universities and employing organisations to work together to more directly influence learning during transition. Hays and Clements (2012) frame this opportunity as "a flexible period extending deeply into the curriculum and well forward into at least a graduate's first professional employment" (p. 13).

Sfard (1998) proposes that two metaphors describe learning. "The *acquisition metaphor* sees learning as a process of knowledge acquisition, while the *participation metaphor* emphasises that learning takes place by participating in the practices of social communities" (as cited in Tynjälä, 2008, p. 131). Wood and Solomonides (2008) take a journey or lifespan development approach analagous to Sfard (1998) to the changes in discourses, identities, learning styles, and approaches to knowledge and capability transition points across school, university, and workplace. These are shown in Figure 5.2, adapted from Wood and Solomonides (2008, p. 122).

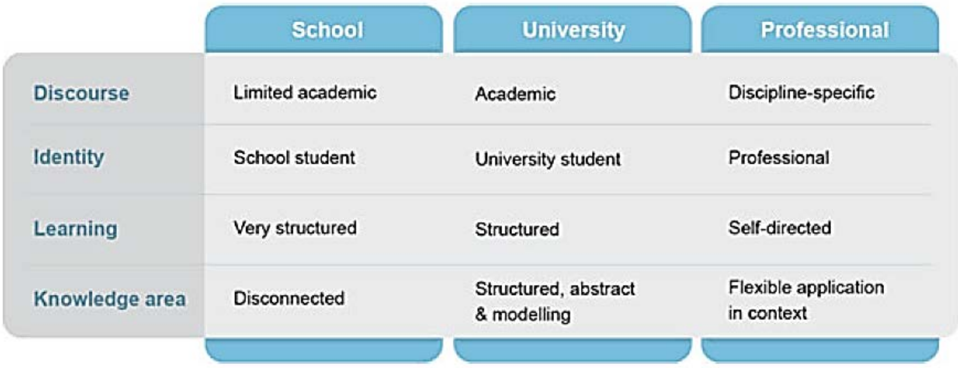



**Figure 5.2 Transitions and contexts (Wood and Solomonides, 2008)**

Wood and Solomonides (2008) acknowledge the planned or structured learning of university and the symbolic or abstract modelling of university knowledge areas do not directly correspond to the more unstructured, activity and outcome focus, and the more event-and object-oriented learning and knowledge, required in the workplace. Comparable views are provided in Eraut (2009), Hager (1998), Hays and Clements (2012), and Resnick (1987), all of whom agree the transition from university to the workplace involves changes in approaches to learning, and to the context in which knowledge is developed and applied. Hays and Clements (2012, pp. 8-9) outline key differences between academic and workplace learning. Their list in Table 5.1 highlights that workplace learning is characterised by uncertain objectives, and that learning is achieved through task accomplishment, and shared efforts. These contribute to developing both individual experience and to producing organisational outcomes.

**Table 5.1 Academic and workplace learning (Hays & Clements, 2012)**

| Academic Learning | Workplace Learning |
|---|---|
| Student learning key terminal objective. | Learning instrumental or incidental. Organisational outcomes as primary goal. |
| Learning about, of, and for, usually in the classroom or on campus, though increasingly virtual. | Learning *with*, *through*, and *in*, usually onsite/part of work; sometimes sent to offsite training. |
| Broad career-based or lifelong learning; acontextual. Theoretical and abstract. | Specific task-oriented learning; context specific. Practical and applied. |
| Learning usually one-dimensional, involving a given mode. Use of specific formula, process, theory, etc., required. | Learning involving the whole person/multimodal. Whatever works to get the job done. |

| Academic Learning | Workplace Learning |
|---|---|
| Learning generally by oneself; sometimes with others (peers). | Learning generally from others (colleagues), gradually moving toward shared learning and mentoring. |
| Low risk; accountable to self (or group members). | High risk; accountable to clients, colleagues, patients, etc. |
| Learners compete with other individuals for grade in prolonged or defined time parameters (e.g. one semester). | Transient/indefinite learning as a team or organisation; competition amongst teams or with external competitors. |
| Simple: generally passive, planned, and predictable. Simulated, artificial, controlled, detached. | Complex: generally active, purposeful, unpredictable, and spontaneous. Authentic and embedded. |
| Transmission of knowledge from expert; student as "empty vessel" (learner as recipient). | Generation of knowledge through experience; all expected to have and contribute knowledge and skill. |
| Prescribed learning outcomes and objectives; learner dependent on external authority for instruction and assessment. Learning task distinct from work or may be impractical and not usually applied. Teacher-directed. | Learning tasks and situations vague and poorly defined; learners relatively autonomous. Learning tasks and requirements are embedded and virtually inseparable from work. Worker-directed. |
| Periodic/frequent feedback provided by teacher, tightly linked to learning tasks. | Infrequent or generalised feedback provided by manager; work, itself, source of most feedback. |
| Producing while paying to learn. | Being paid to produce while learning. |
| Students can "master" the study game. They can learn to win the game without learning much that is meaningful or transferable. Often surface learning. | Learners must learn to learn. Harder to learn superficially and win as the game continually changes. Often deeper learning with greater transfer. |

Learning with and through colleagues and workplace activities, poorly defined tasks and objectives, self-directed learning, lack of feedback, and multiple stakeholders and accountabilities are important differences between academic and workplace learning. Following the work lifespan approach of Wood and Solomonides (2008), these differences can provide managers and organisational professional development with a starting point for structured programs that support the transition to work.

Finkel and King (2013) note that, "industry is ever more demanding of graduates' employability and value" (p. 1). For Edvardsson Stiwne and Jungert (2007), employability "indicates that an employable person holds knowledge, skills and characteristics that make that person useful and valuable in a specific context" (p. 1). This raises the question of what parts of the curriculum contribute the most to employability, and "if these skills are best learned within the educational context or within the context of work life, or work-based learning situations" (Edvardsson Stiwne & Jungert, 2007, p. 8). This distinction underscores that university and the workplace each play distinct and complementary roles in education and learning. It emphasises the need for new engineers to make judgments, create solutions, and communicate results. It also highlights the importance of fostering these capabilities in workplace-designed development programs.

As Katz (1993) identifies, each company has its own processes and culture for which no formal education program can prepare entrants.

## CREATING PROFESSIONAL IDENTITIES

Solving complex workplace problems with conflicting goals, employing diverse ways to achieve successful solutions, and managing non-engineering success measures and constraints that can be leveraged to support the transition of early-career engineers to professional practice (Jonassen, Strobel, & Lee, 2006). There are high levels of ambiguity in real-world engineering, and what new engineers perceive and learn about engineering work often depends on the quality of their interactions with co-workers and work groups (Korte, Sheppard, & Jordan, 2008). Socialisation is thus an important part of how novice engineers acquire the "habits of mind" or signature beliefs of their profession (Lucas & Spencer, 2015). For Sfard (1998), this is also about seeing learning through the lens of "participation". She contrasts "learner-centric" or acquisition oriented learning with "community-centric" or participatory-oriented learning practices. Aligned to the practices and values of the workgroup or organisational community, workplace learning is about participating in, contributing to, and potentially reshaping community practices and beliefs.

Developing a professional identity is therefore about being a part of a professional community and participating in the activities, ongoing development, and renewal of its practices and modes of communication. Winters, Matusovich, and Carrico (2012) note that novice engineers face authentic knowledge application for which they may not have been prepared. This includes navigating a diverse range of unfamiliar workplace systems and barriers to access the resources they need. At the same time, these early-career engineers may still be figuring out their identities, and goals for their careers (Lichtenstein et al., 2009; Matusovich, Streveler, Miller, & Olds, 2009; Polach, 2004).

Like Sfard (1998), who proposes that learning a subject is also about becoming a member of a particular community, Melrose, Miller, Gordon, and Janzen (2012) define professional socialisation as "the process of learning a professional role and emerging as a member of an occupational culture". It is a process which links the world view unique to disciplines with a professional sense of self. Socialisation is also a means by which we acquire the knowledge, skills, and disposition that enable us to become members of a profession. It thus manifests as "the way we do things"—"a subconscious process whereby persons internalise behavioural norms and standards and form a sense of identity and commitment to a professional field" (Melrose et al., 2012, p. 2). Van Maanen and Schein (1979) highlight the ongoing importance of the work group, and that since socialisation involves the transmission of information and values, it is fundamentally about culture. As we progress through a career, we adopt various identities, some of which may include: intern, colleague, manager, technical expert, or senior engineer. Better knowledge of these identities and how they are shaped and adapted to new selves can benefit new starter integration, the workplace-talent pipeline, retention, and engagement efforts.

## VIEWS FROM THE FIELD

The research question explored in this study was: "what is a successful transition to professional work for an engineering graduate"? The research was interested in hearing the views of recent graduates and more experienced engineering professionals about what they believe enables a successful transition to the workplace. The study captured views relating to the work-readiness provided by higher education curricula and graduates' assessment of the capabilities required of engineers in the workplace. The study methods adopted the Tuning methodology. The Tuning questionnaire employed was adapted for engineering by Manoliu (2005). A summary of the Tuning Process and how the questions were developed is provided in Gonzélez and Wagenaar (2003).

The Tuning Process is a higher education initiative aimed at creating diversity, cooperation, and academic exchange for European and international students and staff. Tuning focuses on establishing and "tuning" student, academic, and employer reference points, and encouraging common understanding across a range of disciplines and key stakeholder groups. It distinguishes three generic competences:

- **Instrumental competences**: cognitive abilities, methodological abilities, technological abilities, and linguistic abilities
- **Interpersonal competences**: individual abilities including social skills such as interaction and cooperation
- **Systemic competences:** abilities and skills concerning whole systems; a combination of understanding, sensibility and knowledge; prior acquisition of instrumental and interpersonal competences required (Tuning, 2000, online).

Tuning seeks to establish reference points and to encourage convergence and common understanding across a range of university subject curricula. To accommodate subject specialism and broader societal and employability needs, it includes generic and subject-specific competencies. While the Tuning Process incorporates employer and professional body input, and acknowledges that industry is a key stakeholder and client, the outcomes are directed at university curricula. Applying Tuning methodology to inform workplace professional development helps to bring the process full cycle and to close the knowledge gap between higher education and workplace expectations and needs. Reid, Abrandt Dahlgren, Dahlgren, and Petocz (2011) point out that there is little information “regarding the relationships between graduates’ expectations of working life and their employers’ explicit expectations of them” (p. 54). They also recognise that a problem for both institutions and individual students is the “lack of real knowledge about the expectations and requirements of particular professions”. Some of the challenges faced by these novice professionals relate to the nature of knowledge and the ways in which discipline-specific knowledge is enacted in professional practice (Reid et al., 2011, pp. 55-57). How experienced engineers view their profession from the perspective of a graduate can contribute to better articulating these expectations, and supporting the transition to professional practice. The Tuning Process sampling methodology is shown in Table 5.2.

**Table 5.2 Tuning process graduate sampling (Gonzélez & Wagenaar, 2003)**

| Participant Group | Sampling Methodology |
|---|---|
| Graduates | A minimum of 150 graduates.<br>The graduates selected are to have graduated within the last 3 to 5 years.<br>The criterion of selection of the 150 graduates was at random. |

An online questionnaire using the Tuning methodology was provided to participants. The Tuning sampling methodology for participant selection follows Gonzélez and Wagenaar (2003). Responses were received from civil engineering graduates in the United States, Canada, India, and Australia. A total of 188 participants completed the questionnaire, with 74% of participants male, and 26% of participants female. Although a screening question to identify only those respondents who had graduated from 2010 to 2015–2016 was provided, the further data provided by graduate questionnaire respondents was deemed to provide a richer analytical viewpoint, and was therefore analysed to investigate the extent to which contributions by experienced professionals were the same or differed to those of the new graduate target group. Table 5.3 summarises respondent demographic information.

**Table 5.3 Summary of graduate demographic information**

| | New Graduates | Experienced Professionals | Total |
|---|---|---|---|
| Respondents | 121 | 67 | 188 |
| Years | 2010–2016 | 1973–2009 | 43 years |
| Male | 92 (76%) | 48 (72%) | 140 |
| Female | 29 (24%) | 19 (28%) | 48 |
| Working in an engineering related field | 62 (51%) | 53 (79%) | 115 (83%) |
| Working in a non-engineering related field | 16 (13%) | 8 (12%) | 24 (17%) |

Responses were received from those who had graduated in 1973 to those graduating in 2015–2016. The results provided views spanning 43 years. Following Tuning methodology, the new graduates cohort were identified as having completed an engineering degree within the last 3 to 5 years or the period from 2010 to 2015–2016. The experienced professionals cohort includes all other years. This group identified their graduation year between 1973 and 2009. Respondent ages ranged from 22 to 64. The new graduates group comprised 121 respondents; 67 respondents comprised the experienced professionals group. 79% of the experienced professionals group indicated they are currently working in a position related to their degree, while at 51%, a much lower proportion of new graduates indicated they are working in an engineering-related capacity. This substantiates the Palmer, Tolson, Young, and Campbell (2015) proposal that engineering graduates are increasingly working in cognate industries. While the data obtained from new graduates presented a shortfall against Tuning sampling, comparing responses from new and experienced engineers provides a richness of information not otherwise available. Figure 5.3illustrates how both groups assess the suitability of their engineering qualification.

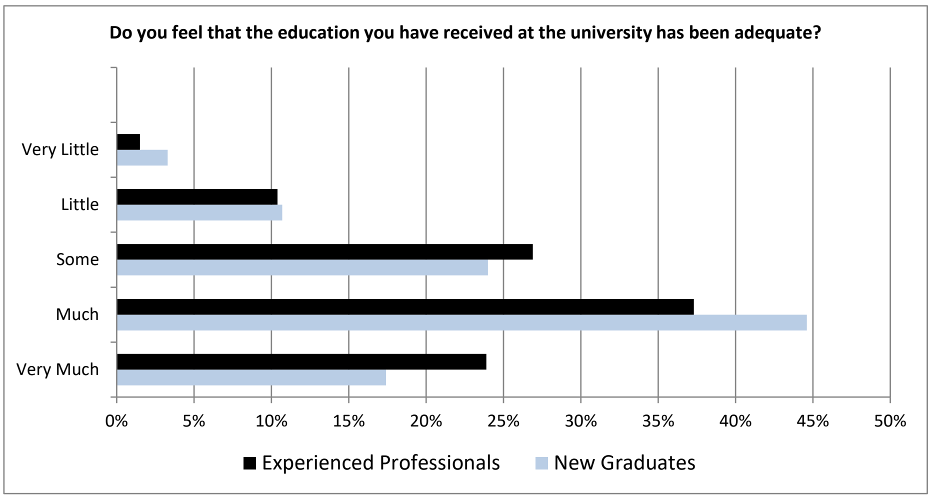
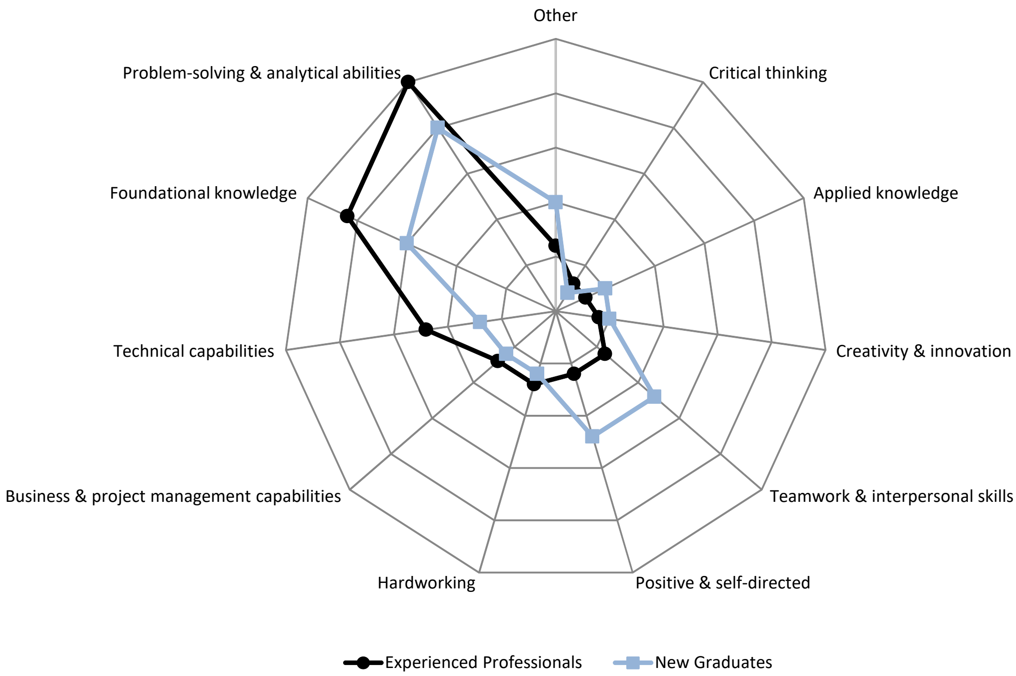



**Figure 5.3 Views of degree programs**

Results show consensus that university provides an adequate foundation for an engineering career. Participant responses indicate little significant difference in the value new and more experienced civil engineering graduates place on their university education. The “very much” results of experienced professionals may reflect that more experienced respondents are socialised into the engineering profession through seniority or career tenure and have become contributors to its knowledge base. The “much” and “very much” difference in appraisal between experienced professionals and new graduates suggests that university leavers have high expectations for a return on their degree. Matching this high expectation to those of the workplace can help mitigate different expectations.

The Tuning graduate questionnaire requests respondents to evaluate a selection of capabilities against the level to which they are developed at university and their importance for work. Respondents are then asked to nominate and rank the five most important of these items according to their opinion. The ranking section of the questionnaire was adapted for this study to encourage respondents to freely nominate the five general capabilities they believe most important to career success in engineering. These questions are shown in Appendix 1.

Results were coded against the key themes which emerged from these free text responses. The top ten general capabilities were then prioritised according to the average percentage for each of the new graduates and experienced professionals cohorts. Figure 5.4 depicts the weighted average rating of differences and similarities in their views.




| General Capabilities | Experienced Professionals | Graduates |
|---|---|---|
| Other | 6% | 10% |
| Critical thinking | 3% | 2% |
| Applied knowledge | 3% | 5% |
| Creativity & innovation | 4% | 5% |
| Teamwork & interpersonal skills | 6% | 12% |
| Positive & self-directed | 6% | 12% |
| Hardworking | 7% | 6% |
| Business & project management capabilities | 7% | 6% |
| Technical capabilities | 12% | 7% |
| Foundational knowledge | 21% | 15% |
| Problem-solving & analytical abilities | 25% | 20% |

**Figure 5.4 Views of general capabilities**

The picture that emerges is a discipline with a strong technical and analytical nature. What also emerges is a cross section of generational change and endorsement of STEM reforms to embed lifelong learning and transferable skills into the curriculum. Experienced professionals focus on balancing tool use and mental activities (Tynjälä, 2008). The view from this group orients towards problem solving and analysis, foundational knowledge, and technical skills. While both groups show these are core capabilities, this importance is more pronounced in experienced professionals, and is complemented by a focus on business skills, such as time management, attention to quality and detail, and project management. For engineering professionals, the applied or 'hard skills' required for engineering outcomes are the 'signature' of an engineer. For experienced respondents, self-direction, teamwork and interpersonal skills, and knowledge application have likely become internalised through professional experience, and thus are not distinct from engineering practice because they are seen as basic professionalism. This suggests that implicit and tacit knowledge contribute to situation specific competencies, and places greater emphasis on experienced-based judgments or ‘know-how’ and practical wisdom. As (Tynjälä, 2008) points out, in workplace learning, competencies are treated holistically, with no distinction between knowledge and skills.

Formal learning concentrates on mental activities. It separates knowledge and skills and produces explicit knowledge and generalised skills rather than the tacit or contextualised knowledge and situation-specific competencies of the workplace (Tynjälä, 2008). New graduate responses agree with this view. They balance the technical skills with more personal and development-oriented capabilities. This distribution may reflect lack of experience in knowledge application, and that without this practical exposure, graduates concentrate on the academic and developmental aspects of their formal training. Table 5.4 lists the ‘soft skills’ nominated by graduates which have been coded as “positive and self-directed” (12%) and “teamwork and interpersonal skills” (12%), and which together comprise almost a quarter of the overall capabilities they put forward.

**Table 5.4 Soft skills nominated by graduates**

| Positive and Self-directed | Teamwork and Interpersonal Skills |
|---|---|
| Fast learner | Communication and interpersonal skills |
| Clear objective and perception | Multidisciplinary team work |
| Strength | Ability to convince and influence |
| Aptitude | Express ideas/thoughts clearly |
| Confidence | Teamwork |
| Learning the needs and demands | Ability to convey understanding to others |
| Focus | Good communication skills |
| Will | Presentation |
| Effective learning | |
| Quick learner | |
| Positive attitude | |
| Self-motivated | |
| Positive mindset | |

At 20%, “problem solving and analytical abilities” was the capability most highly rated by graduates. This agrees with Edvardsson Stiwne and Jungert (2007), who note that problem solving was considered to be significant by more than 90% of students who responded to a capability-related questionnaire distributed to three successive cohorts of graduates from 1998, 1999, and 2000. The values articulated by new graduates also confirms Trevelyan’s (2009a, 2009b) assertion that engineering is both a technical and a social discipline. He notes that “engineers typically spend 60% of their time on communication with other people, mainly close associates” (Trevelyan, 2009a, p. 1). Faulkner (2007, p. 332) provides some insights. She observes that “there is a deep technical/social dualism at the heart of engineers' identities as engineers", and that, in varying degrees engineers typically oscillate between *technicist* and more *heterogenous* or socially-oriented engineering identities. Faulkner further comments that "social studies of engineering have long grasped the paradox between the heterogeneous nature of engineering practice and the technicist orientation of engineering education" (p. 332). Arguably, it is this duality that manifests in the balance of technical and interpersonal skills nominated by graduates.

While new graduate views may reflect an emerging transformative focus of engineering higher education programs (Grasso & Burkins, 2010), the values emphasised by experienced engineers relate to the outcomes and deliverables focus of engineering practice. When asked to nominate the most important technical or specific skills required for success in an engineering career, the five main areas provided by experienced professionals outline workplace expectations:

- Personal qualities
- Foundational skills
- Practical skills
- Professional skills
- Interpersonal capabilities.

Similarly, Eraut (2009) outlines the five types of knowledge provided by vocational and higher education programs: (1) theoretical knowledge, (2) methodological knowledge, (3) practical skills and techniques, (4) generic skills, and (5) general knowledge about the occupation. The distribution of these capabilities is illustrated in Figure 5.5. This snapshot from engineering alumni suggests that 'specific' has been interpreted broadly against aptitude, technical grounding, and professionalism. Problem solving and analysis thus present as capabilities specifically required by an engineering professional. The weighted average rating of individual capabilities that constitute each of the competency areas is shown below.

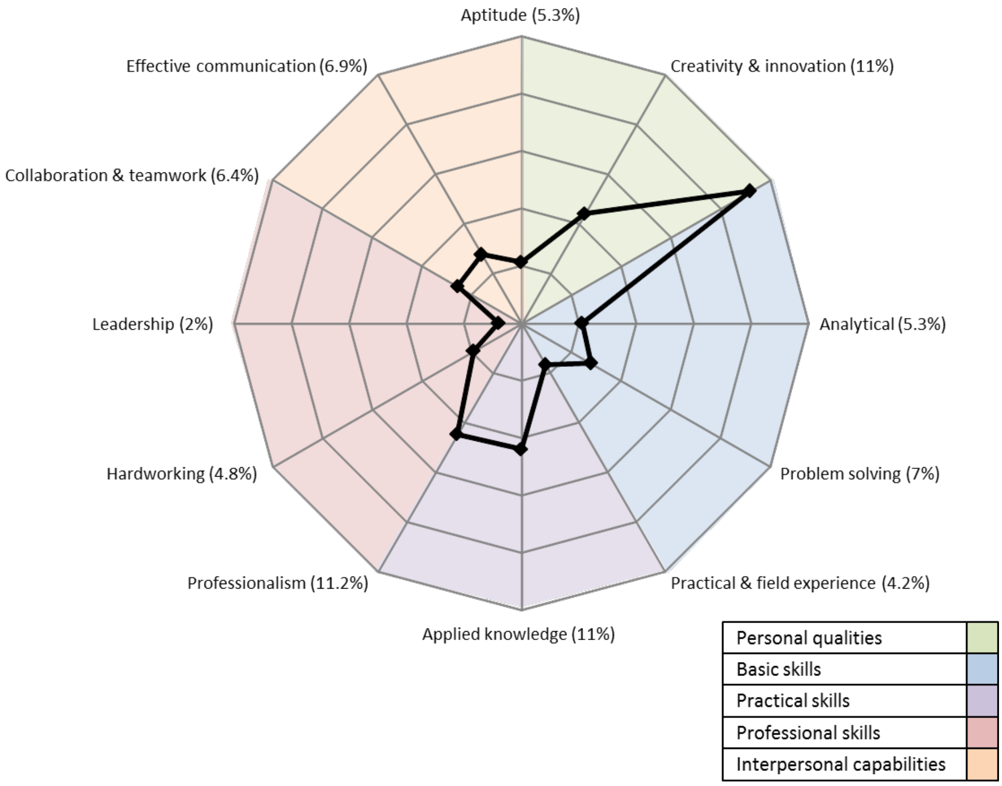



**Figure 5.5 Engineering capabilities nominated by experienced professionals**

| Competence Area | Individual Capability | Percentage | Total |
|---|---|---|---|
| Personal qualities | Aptitude | 5.3% | 16.3% |
| | Creativity and innovation | 11% | |
| Foundational skills | Foundational and technical knowledge | 23% | 35% |
| | Analytical and investigative | 5.3% | |
| | Problem solving | 7% | |
| Practical skills | Practical and field experience | 4.2% | 15.2% |
| | Applied knowledge | 11% | |
| Professional skills | Professionalism | 11.2% | 18% |
| | Hardworking | 4.8% | |
| | Leadership | 2% | |
| Interpersonal skills | Collaboration and teamwork | 6.4% | 13.3% |
| | Effective communication | 6.9% | |

While the notion of ‘aptitude’ may be contentious, Hettich (2010) observes that mastery of a work environment is heavily influenced by the values, beliefs, and experiences a graduate brings to the workplace. The closer the match of the graduate’s “attitudes, expectations, and breaking-in-skills (e.g., work ethic, willingness to learn, flexibility)” (p. 99) the greater the overall chance of success in the domain. New graduates also include aptitude in their highly ranked positive and self-directed skills set.

Professional engineers demonstrably value the core engineering skills professionalism, and aptitude in their new employees. The traditional engineering capabilities of problem solving, an analytical and investigative mindset, and strong technical skills represent 35% of required skills. At 18%, professionalism (hard work, quality outcomes, punctuality, and the ability to lead a project or team) is the next most important competence they seek. The emphasis on practical and applied knowledge indicates that preparation for the workplace in the form of experiential learning and work placements is credited by industry.

## IMPLICATIONS

“Schools are supposed to be stopovers in life, not ends in themselves. The information, skills, and understandings they offer are knowledge-to-go. Not just to use on site” Perkins and Salomon (2012, p. 248). Holton and Naquin (2001) highlight that successful higher education and workplace practices are fundamentally different. Hettich (2007) refers to this as the “paradox of preparation”, meaning that while the foundational knowledge or skills acquired in college or university are important to professional success, the workplace processes that utilise this knowledge do not directly align with university success activities. Skills for workplace success include professional skills such as interfacing with clients, working well with project teams, and pitching ideas to senior management. Hays and Clements (2012) observe that, “the period between study and career is understood as a hiatus and appears to be treated by both university and organisations as a no man’s land, with neither necessarily having the responsibility, resources, or mechanisms to work in the transition space” (p. 4). According to Wood and Solomonides (2008), transitions between study and work are “risk management points”. These transitions offer opportunities for education and the workplace to embed risk mitigation techniques and activities in learning and workplace development program design. When combined with the transition model of Bridges (2003) and Taylor et al. (2007), these risk points highlight opportunities for greater curricular and learning design reciprocity between higher education and the workplace. Leveraging these opportunities may help counter theory-practice divides and encourage learning models that better accommodate learning across the work lifespan.

### Implications for higher education

Project/Problem Based Learning (PBL) and the CIDO (Conceive, Design, Implement, Operate) Initiative (2004) align with the skills identified by experienced engineering survey respondents. CDIO has emerged from industry-diagnosed gaps in graduate capability, and Accreditation Board of Engineering and Technology (ABET) expectations. The CDIO syllabus consists of four key areas: (1) disciplinary knowledge and reasoning; (2) personal and professional skills and attributes; (3) interpersonal skills: teamwork and communication; and (4) conceiving, designing, implementing, and operating (CDIO) systems in the enterprise, societal and environmental context—the innovation process (Crawley, Malmqvist, Östlund, Brodeur, & Edström, 2014, p. 18). Ability to work on a team, awareness of workplace expectations, and the ability to communicate are three key employer challenges that Katz (1993) identifies from engineering supervisors. Many of her recommendations are implemented in university group and team activities that focus on problem identification and solutions, internships, work experience and capstone programs, and on presentation and communication skills. Hettich (2007) recommends a selection of strategies to guide student preparedness for entering the workforce. These include: examining their attitudes towards work and peers, critically examining activities and tasks for transferrable skills, reflective practice, and seeking mentorship or job shadowing opportunities.

In noting the increasing diversity of higher education curricula, Gibbons et al. (1994) signal a need for greater emphasis on industry partnerships and co-creation of curricula. This can be accomplished through work placements, capstone courses, and encouraging industry specialists to present, lecture, or co-teach university curricula. These efforts strengthen the notion of a “managed transition” from formal education, and integrate with work lifespan thinking and lifelong learning.

## Implications for the workplace

Candy and Crebert (1991) emphasise that “formal education occupies only a small proportion of the learning continuum, that most people complete their formal education early in their lives in a relatively short period, and that most learning experiences actually take place outside the educational institution” (p. 571). With cost and time to competency organisational drivers, implications for the workplace relate to how new starters are onboarded, integrated into teams, and developed through work activities. The 70:20:10 (70:20:10 Forum, 2011) is a well-recognised organisational development delivery model. It recommends balancing workplace development activities according to a delivery methodology of allocating a 70% development through experiential learning—work activities and ‘stretch’ tasks; 20% social learning—coaching or mentoring; and 10% formal classroom, eLearning, or training activities. Tynjälä (2008) reminds us of the contextual nature of workplace learning. She notes that “in order to be a true expert in working life one has to develop situation specific forms of competence, and this is possible only in authentic situations. On the other hand, situation-specific learning by itself may be very limiting. Something learnt in one situation is not easily transferred to another type of situation” (Tynjälä, 2008, p. 133). Hettich (2010) asks: “What particular academic and non-academic activities contribute most to a successful transition and in what types of work environments?” (p. 107) Eraut (2007) offers in response a taxonomy of workplace learning processes: (1) work processes with learning as a by-product, such as working in teams, tackling stretch tasks, and solving problems; (2) learning located with the workplace through asking questions, observing, reflecting, or learning from errors; and (3) learning experiences at the workplace, for example being supervised or coached. Table 5.5 shows these workplace learning activities.

**Table 5.5 Workplace learning processes (Eraut, 2007)**

| Work processes with learning as a by-product | Learning actions located within work or learning processes | Learning experiences at or near the workplace |
|---|---|---|
| Participating in group processes<br>Working alongside others<br>Consultation<br>Tackling challenging tasks and roles<br>Solving problems<br>Trying things out<br>Consolidating, extending, and refining skill | Asking questions<br>Listening<br>Observing<br>Getting information<br>Learning from mistakes<br>Reflecting<br>Locating resource people<br>Giving and receiving feedback | Being supervised<br>Being coached<br>Being mentored<br>Shadowing<br>Visiting other sites<br>Studying based on individual needs/planning<br>Going to conferences<br>Taking courses |

These activities encourage transition learning models that accommodate the needs of students and the workplace. An example of such a model is presented in Figure 5.6. This representation acknowledges the different forms of knowledge used in educational settings and in workplace settings, and suggests a number of work-readiness and early-career activities to improve successful beginning and ending transition points from higher education to work.

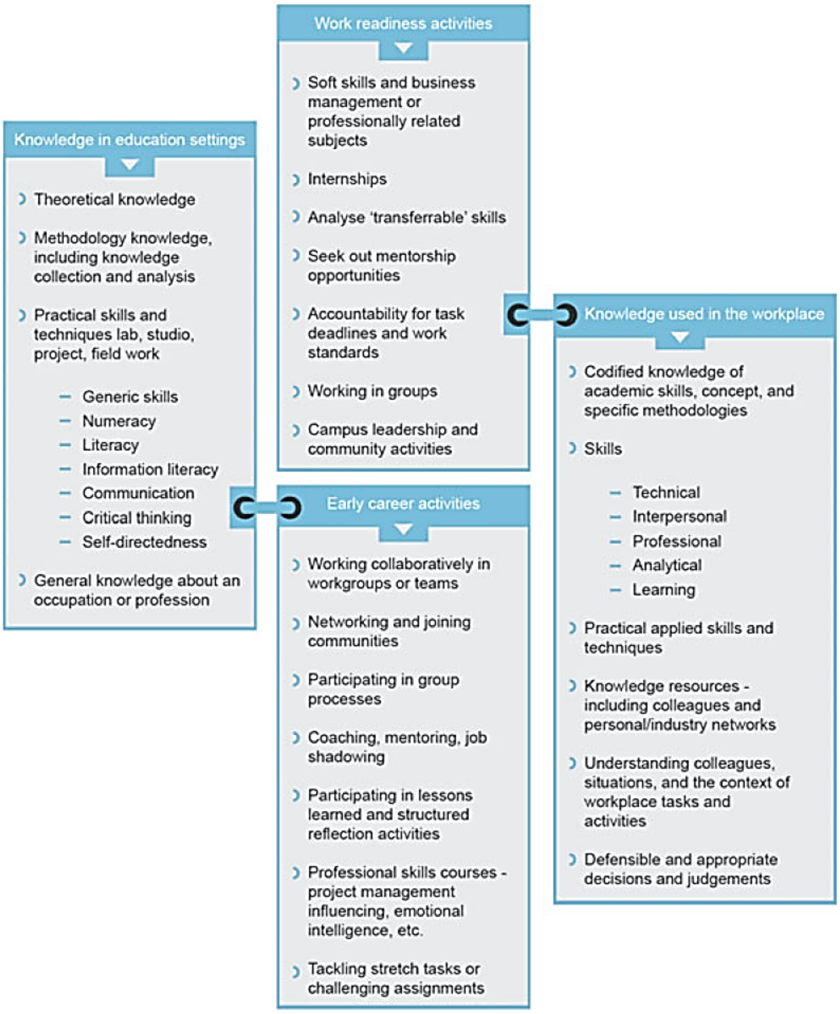



**Figure 5.6 Knowledge used in academia and the workplace**

The model in Figure 5.6 recognises the important role of formal education in developing the theoretical and methodological foundation for students' chosen career paths, and in providing general knowledge about these professions. Formal education also plays a significant foundational role in preparing students for their chosen professions through providing basic practical skills and techniques such as laboratory, project, and field work, and through activities that develop individual and interpersonal dimensions. Work-readiness activities specifically designed to support the transition to the workplace might combine internships and work-based learning undertaken in partnership with organisations; courses co-created and delivered with industry; and subjects delivered using workplace paradigms of project management, reports, and presentations. These techniques are already being implemented in higher education through guest speakers, work placements, and work-oriented forms of assessment. For the workplace, participating in internship programs and engagement with educational settings creates industry presence and supports talent pipelines.

Bariletti (2015) notes how the technology giant Google's onboarding processes include "practice-based learning and cognitive apprenticeships, to foster long-term connections between employees". This highlights Professional Year (PY) programs and workplace equivalents of the university First Year Experience (FYE) programs. These provide orientation to working life the first professional year. For the workplace, extended onboarding and professional year programs support transition into the workplace and encourage successful integration.

## CONCLUSION

Models of transition across the work lifespan illustrate different identities and forms of knowledge. They highlight there are both risks and opportunities in these transitions. A variety of educational and workplace programs contribute to this research base. That these efforts remain largely independent of each other suggests there are further opportunities to develop transition to work learning models that better align student and workplace expectations. Ideally, "increasing co-operation between education and work, and new forms of work-based learning (WBL) will change the nature of learning in both contexts and may create entirely new kinds of learning opportunities" (Tynjälä, 2008, p. 133).

# REFERENCES

70:20:10 Forum. (2011). The 70:20:10 framework. Retrieved from https://www.702010forum.com/about-702010-framework

Arizona State University. (2014). Enrollment trends in stem disciplines—metropolitan campuses. *ASU Facts.* Retrieved from https://facts.asu.edu/Pages/Enrollments/STEM-Enrollment-Trends-by-Discipline.aspx

Bariletti, M. (2015). *What's the new employee onboarding at Google like?* Retrieved from https://www.quora.com/What%E2%80%99s-the-new-employee-onboarding-at-Google-like

Baytiyeh, H., & Naja, M. (2012). Identifying the challenging factors in the transition from colleges of engineering to employment. *European Journal of Engineering Education, 37*(1), 3-14.

Bridges, W. (2003). *Managing transitions: Making the most of change* (2nd ed.). Cambridge, MA: Da Capo Press.

Candy, P. C., & Crebert, R. G. (1991). Ivory tower to concrete jungle: The difficult transition from the academy to the workplace as learning environments. *The Journal of Higher Education, 62*(5), 570-592. doi:10.2307/1982209

CDIO. (2004). CDIO (Conceive, Design, Implement, Operate) Initiative. Retrieved from http://www.cdio.org/

Crawley, E. F., Malmqvist, J., Östlund, S., Brodeur, D. R., & Edström, K. (2014). *Rethinking engineering education: The CDIO approach* (2nd ed.). Heidelberg, Germany: Springer.

Edgerton, R. (2001). *Education white paper*. Report prepared for the Pew Charitable Trusts, Pew Forum on Undergraduate Learning. Washington, DC.

Edvardsson Stiwne, E., & Jungert, T. (2007). *Engineering students experiences of the transition from study to work*. Paper presented at the 3rd International CDIO Conference in Massachusetts Institute of Technology, Cambridge, Massachusetts.

Eraut, M. (2007). Learning from other people in the workplace. *Oxford Review of Education, 33*(4), 403-422.

Eraut, M. (2009). Transfer of knowledge between education and workplace settings. In H. Daniels, H. Lauder, & J. Porter (Eds.), *Knowledge, values and educational policy: A critical perspective* (pp. 65-84). Abingdon, Oxon, UK: Routledge.

Faulkner, W. (2007). `Nuts and bolts and people'. *Social Studies of Science, 37*(3), 331-356. doi:10.1177/0306312706072175

Finkel, A., & King, R. (2013). *Innovative approaches to engineering education*. Paper presented at the CAETS, International Council of Academies of Engineering and Technological Sciences, Budapest, Hungary.

Gibbons, M., Limoges, C., Nowotny, H., Schwartzman, S., Scott, P., & Trow, M. (1994). *The new production of knowledge: The dynamics of science and research in contemporary societies*. London, UK: Sage Publications Limited.

Gonzélez, J., & Wagenaar, R. (2003). *Tuning educational structures in Europe. Final report. Phase one*. Universidad de Deusto: Deusto. Retrieved from http://www.bolognakg.net/doc/Tuning_phase1_full_document.pdf

Grasso, D., & Burkins, M. B. (Eds.). (2010). *Holistic engineering education: Beyond technology*. New York, NY: Springer.

Hager, P. (1998). Understanding workplace learning: General perspectives. In D. Boud (Ed.), *Current issues and new agendas in workplace learning* (pp. 31-46). Springfield, VA: NCVER.

Hays, J., & Clements, M. (2012, 20-22 June, 2102). *Transition-bridging the gap between study and work.* Paper presented at the Proceedings of the 9th International Conference on Cooperative & Work-Integrated Education, Where East meets West and Theory meets Practice, Istanbul, Turkey.

Hettich, P. (2007). *College to workplace issues and strategies: A primer*. Paper presented at the 14th National Conference on Students in Transition, Cincinnati, OH.

Hettich, P. (2010). College-to-workplace transitions: Becoming a freshman again. In W. T. Miller (Ed.), *Handbook of stressful transitions across the lifespan* (pp. 87-109). New York, NY: Springer New York.

Holton, E. F., & Naquin, S. S. (2001). *How to succeed in your first job: Tips for new college graduates*. San Francisco, CA: Berrett-Koehler Publishers.

Jaschik, S. (2014). Study finds increased STEM enrollments since the recession. *Inside Higher Ed.* Retrieved from https://www.insidehighered.com/news/2014/04/07/study-finds-increased-stem-enrollment-recession

Jonassen, D. H., Strobel, J., & Lee, C. B. (2006). Everyday problem solving in engineering: Lessons for engineering educators. *Journal of Engineering Education, 95*(2), 139-151. doi:10.1002/j.2168-9830.2006.tb00885.x

Katz, S. M. (1993). The entry-level engineer: Problems in transition from student to professional. *Journal of Engineering Education, 82*(3), 171-174.

Korte, R., Sheppard, S., & Jordan, W. (2008). *A qualitative study of the early work experiences of recent graduates in engineering*. Paper presented at the American Society for Engineering Education, June 22-26 2008, Pittsburgh, PA.

Lewin, K. (1947). Frontiers in group dynamics II. Channels of group life; social planning and action research. *Human relations, 1*(2), 143-153.

Lichtenstein, G., Loshbaugh, H. G., Claar, B., Chen, H. L., Jackson, K., & Sheppard, S. D. (2009). An engineering major does not (necessarily) an engineer make: Career decision making among undergraduate engineering majors. *Journal of Engineering Education, 98*(3), 227-234. doi:10.1002/j.2168-9830.2009.tb01021.x

Lucas, B., & Spencer, E. (2015). *Remaking apprenticeships: Powerful learning for work and life*. University of Winchester. Centre for Real-World Learning. Retrieved from http://www.winchester.ac.uk/aboutus/lifelonglearning/CentreforRealWorldLearning/Publications/Documents/Lucas%20and%20Spencer%20(2015)%20Remaking%20Apprenticeships.pdf

Manoliu, I. (2005). *First results of the Tuning Project with the participation of EUCEET and ECCE*. Paper presented at the 42nd ECCE meeting, Istanbul, Turkey. http://www.unideusto.org/tuningeu/images/stories/Summary_of_outcomes_TN/First_results_Civil_Engineering_PPT.ppt.

Matusovich, H., Streveler, R., Miller, R., & Olds, B. (2009). *I'm graduating this year! 'So what IS an engineer anyway?* Paper presented at the Proceedings - American Society of Engineering Education Annual Conference and Exposition, Austin, TX.

Melrose, S., Miller, J., Gordon, K., & Janzen, K. J. (2012). Becoming socialized into a new professional role: LPN to BN student nurses' experiences with legitimation. *Nursing Research and Practice, 2012*.

Palmer, S., Tolson, M., Young, K., & Campbell, M. (2015). The relationship between engineering bachelor qualifications and occupational status in Australia. *Australasian Journal of Engineering Education, 20*(2), 103-112. doi:10.1080/22054952.2015.1092666

Perkins, D. N., & Salomon, G. (2012). Knowledge to go: A motivational and dispositional view of transfer. *Educational Psychologist, 47*(3), 248-258. doi:10.1080/00461520.2012.693354

Polach, J. L. (2004). Understanding the experience of college graduates during their first year of employment. *Human Resource Development Quarterly, 15*(1), 5-23. doi:10.1002/hrdq.1084

Reid, A., Abrandt Dahlgren, M., Dahlgren, L. O., & Petocz, P. (2011). *From expert student to novice professional* (Vol. 99). The Netherlands: Springer.

Resnick, L. B. (1987). The 1987 Presidential Address: Learning in school and out. *Educational Researcher, 16*(9), 13-54.

Sfard, A. (1998). On two metaphors for learning and the dangers of choosing just one. *Educational Researcher, 27*(2), 4-13.

Taylor, P., Millwater, J., & Nash, R. (2007). *Talking about transitions: The value of a conceptual approach.* Paper presented at the Proceedings of the 30 Annual HERDSA Conference, Enhancing Higher Education, Theory and Scholarship, Adelaide, Australia.

The City University of New York (CUNY). (2015). *Ten-year trend in enrolment in science, technology, engineering, and math (STEM) disciplines*. Retrieved from http://www.cuny.edu/about/administration/offices/ira/ir/data-book/current/stem-enrollment-degrees/STEM_enr_10yr_trends.pdf

Trevelyan, J. P. (2009a). *Engineering education requires a better model of engineering practice.* Paper presented at the Research in Engineering Education Symposium 2009, Palm Cove, QLD, Australia.

Trevelyan, J. P. (2009b). *Steps toward a better model of engineering practice.* Paper presented at the Research in Engineering Education Symposium, 2009, Palm Cove, QLD, Australia.

Tuning. (2000). *Tuning educational structures in Europe*. Retrieved from http://www.unideusto.org/tuningeu/

Tynjälä, P. (2008). Perspectives into learning at the workplace. *Educational Research Review, 3*(2), 130-154. doi:http://dx.doi.org/10.1016/j.edurev.2007.12.001

UW‐Madison. (2014). *Trends in instructional activity in STEM disciplines at the University of Wisconsin‐Madison*. Retrieved from https://apir.wisc.edu/accountability/UWMadison_STEM_June202014.pdf

Van Maanen, J., & Schein, E. H. (1979). Toward a theory of organizational socialization. *Research in Organizational Behavior, 1*, 209-264.

Winters, K., Matusovich, H., & Carrico, C. (2012). *So how did that go for you? Early career engineers' success in meeting goals set as undergraduate seniors*. Paper presented at the Proceedings – American Society of Engineering Education, Southeast Section, Starkville, MS.

Wong, J.-J., Chen, P.-Y., & Chen, C.-D. (2016). The metamorphosis of industrial designers from novices to experts. *International Journal of Art & Design Education, 35*(1), 140-153.

Wood, L., & Solomonides, I. (2008). Different disciplines, different transitions. *Mathematics Education Research Journal, 20*(2), 117-134.

# 6 Co-creating Knowledge Experiences

*Co-creating Knowledge Experiences: Education and organisational partnerships in transition to work programs for new engineers*

## Overview

Chapter six comprises part of the chapters four to seven data analysis for this study of organisational development programs to facilitate entry of new graduates to the engineering workplace. This chapter discusses study results in terms of opportunities for academia and the workplace to collaborate on the design of transition to work learning programs. The study adopts the Tuning Process methodology, which asks employers, academics, and students to rate the skills the general and engineering-specific capabilities provided by university and required for engineering work. Analysis of participant responses helps plot a developmental journey from work-readiness to employability, acquiring engineering skills, to skills deployment in the field. Findings reinforce the need for collaboration and co-production of learning programs to support successful transition to work. The findings are discussed in the context of distributed knowledge, organisational knowledge forms, and experiential processes that contribute to common knowledge. Analysis upholds that educational institutions and employing organisations are knowledge and learning partners, with complementary roles in co-creating successful transition to work experiences for new career engineers.

# Knowledge Requirements in the Transition to Work

Reflecting on a knowledge transfer and transition to work program for the Indonesian mining industry, Harrison (1995) concludes that the program challenged participants to recast their views of work, and in so doing, potentially reshape the work itself:

> The job is intended as a learning and developmental experience, not 'just work'. Their concept of work needs to be reformulated from doing routine tasks, to questioning how best to do it, learning methods and adapting them to work, understanding the links between various tasks, developing a basis for making sound judgments and so on (Harrison, 1995, p. 122).

Harrison (1995) cites Bendesa's (1992) observation that there is a "certification versus capability" disparity between graduate expectations of the workplace and their tertiary preparation. He summarises this as, "given the highly theoretical, even philosophical nature of tertiary courses … the new graduates began with virtually no practical work skills" (p. 121).

Tertiary program interventions and organisational support for transition to work addresses theory-practice gaps and helps socialise novice professionals into the workplace, their team, or their discipline. These include capstone courses, work placements, training and professional development, inductions to organisational culture and work methods, and early-career mentoring programs. Specifically, workplace induction and awareness programs tailor learning and professional development to acclimatise new engineers to workplace social systems and to the complexities of moving from theory to practice. There is however, general agreement that the transition from university to the workplace involves changes in approaches to learning, and to the context in which knowledge is developed and applied, and that this process is not well understood (Baytiyeh & Naja, 2012; Eraut, 2009; Hays & Clements, 2012; Resnick, 1987; Wood & Kaczynski, 2007).

Hays and Clements (2012) outline key differences in formal and workplace learning, including: (1) work related learning is *with*, *through*, and *in* work activities, (2) learning is generally from colleagues and peers and gradually moves towards shared learning experiences and mentoring, (3) knowledge is generated through experience and all workgroup members are expected to have and contribute knowledge and skill, and (4) that in the workplace it is "harder to learn superficially and win as the game continually changes. [There is] often deeper learning with greater transfer" (p. 9). The *in situ* and solution-focused nature of workplace learning emphasises that new engineers face unstructured, real-world knowledge application for which they may not have been prepared through tertiary study. Transitioning from university to the workplace involves fundamental changes in the context of knowledge acquisition and production, with newcomers also navigating a diverse range of unfamiliar workplace systems and barriers to access the resources they need (Lichtenstein et al., 2009; Matusovich, Streveler, Miller, & Olds, 2009; Polach, 2004). H. Johnson, Watson, Delahunty, McSwiggen, and Smith (2011) observe that to be conversant in a field is the mark of understanding what it is those who work in the field *do*. This emphasises 'situational' literacies of practice (Fenwick, 2012b; Wenger, 1998). A range of 'know-what, know-why, know-how, know-who' knowledge forms thus impact the transition process (Hermans & Castiaux, 2017; B. Johnson, Lorenz, & Lundvall, 2002). This adopts Gherardi's (2001) notion of knowing-in-practice, and Fenwick et al.'s (2012a); Fenwick, Nerland, and Jensen (2012) view that disciplinary competencies are constituted in a participatory network of knowing.

This chapter summarises results of a research study that asks: "What capabilities enable successful transition to professional work for an engineering graduate?" Study results outline a developmental pattern across the career lifespan from work-readiness to the outcomes-focused knowledge of engineering professionals. Findings further reveal a 'division of labour' between university and the workplace in developing work-ready graduates. Hays and Clements (2012) assert that the transition gap between university study and a professional career results from "the fact that (a) universities…prepare students for transition but withdraw support once the student has graduated and (b) organisations essentially take over the transition process through induction once a graduate has been hired" (p. 4). This boundary or liminal space presents opportunities for education and industry to work together on programs that directly influence the transition from university to the workplace. Study results correspond with the emerging practice of co-production and foreground opportunities to further develop collaborative knowledge experiences. The findings reinforce that education and industry are partners in knowledge and capability development, and have complementary roles in co-creating successful transition-to-work experiences for new career engineers.

# RESEARCH METHOD AND RESULTS

## Research method

Representatives from engineering organisations and recent graduates participated in a skills evaluation questionnaire of the general and specific capabilities required for engineering. Their responses represent cross-disciplinary (aerospace, biomedical, chemical, civil, electrical, mechanical, software), organisational (management, engineers, technical specialists), and geographical (Australia, Canada, India, United States) views. The study leverages an established methodology—the Tuning Process questionnaire. Tuning is about designing, developing, implementing, and evaluating higher education programs to incorporate views from industry, graduates, and academia. It is an initiative affiliated with the Bologna Process, which supports the continuous adaptation of higher degree programs towards greater consistency, with the aim of expanding employment opportunities for graduates (Carvalho, 2008; EHEA, 2016; Gonzélez & Wagenaar, 2003). While Tuning incorporates employer and professional body input, and acknowledges that industry is a key stakeholder and client, its outcomes are directed at university curricula. This study aims to help bring the Tuning Process full cycle by leveraging the Tuning methodology for transition to work development programs. The questionnaire uses a Likert-type scale of 1=‘None’, 2=‘Weak’, 3=‘Some’, 4=‘Strong’ to evaluate survey items in terms of (1) the degree to which they are developed at university, and (2) those required for work. The thirty general skills items for this study are supplied in Gonzélez and Wagenaar (2003). The eighteen engineering-specific capabilities are outlined in Manoliu (2005). A total of 215 respondents (121 graduates and 94 employers) completed the questionnaire. Following Tuning Process sampling methodology, the selection criteria were that employers should represent organisations known to employ engineering graduates, and that graduates should have completed an engineering degree in the last three to five years.

## Findings and analysis

Participant responses were analysed using principal components analysis (PCA) and exploratory factor analysis (EFA). This process identified that five factors for general skills (provided by university and required for work), and three factors for specific skills (provided by university and required for work) contributed meaningfully to the explanation. Factor loadings are presented in Appendix 4 Results show that professional learning is embedded in the practice of work. This is demonstrated through convergence and realignment of the skills provided by university and those required for work. These findings reveal a cartography of the transition from education to the workplace, and patterns of interaction between universities and employers during this process. Negative loadings are interpreted to represent transformative capabilities that are developed through experience and reflective application. Figure 6.1 shows these results.

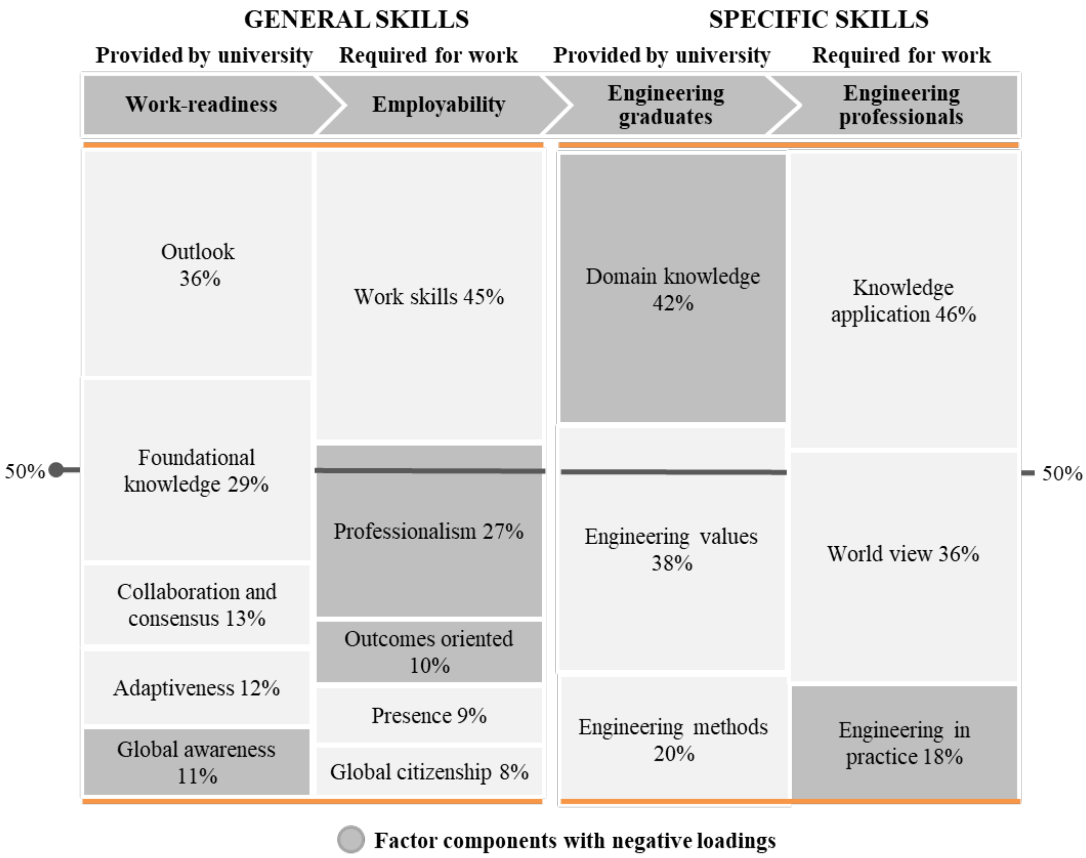



**Figure 6.1 Skills across the work lifespan**

## Work-readiness

University preparation provides both discipline-specific knowledge and skills, and generic or transferrable capabilities relevant to any discipline:

> Firstly, higher education can be a preparation for a specific profession, thus the aim is to prepare students working in that profession. Secondly, university prepares students for any job by developing generic achievements, which then becomes the focus of education (Wood & Kaczynski, 2007, p. 92).

Study results confirm this view. They indicate that tertiary study delivers preparatory skills that contribute to a constructive approach to work (‘Outlook’), learning how to learn

(‘Foundational knowledge’), contemporary skills in information and time management, tolerance of ambiguity (‘Adaptiveness’), and collective effort to achieve outcomes (‘Collaboration and consensus’). However, all items in ‘Global awareness’ are negatively loaded, which suggests a gap in tertiary provision of foundational skills required for effective participation in an increasingly globalised workplace. This includes second language skills and cultural awareness. Deep understanding of issues of global significance—economic, technical, and social—empowers engagement related to this “global competency” (Mansilla & Jackson, 2011). For Hoffmann, Jørgensen, and Christensen (2011), engineering intercultural literacy involves “the ability to communicate across differences and foster mutual learning processes and approaches to problem-solving” (Hoffmann et al., 2011, p. 651).

## Employability

‘Employability’ addresses the ability to perform work tasks and to contribute to organisational outcomes. Analysis suggests that disciplinary grounding, and the information, social, and personal development capabilities required for work (‘Work skills’) have a ‘transpositional’ relationship with the generic skills developed through university study. That is, the negatively loaded ‘Knowledge of a second language’ from the ‘Global awareness’ skills provided by university is here absorbed into ‘Work skills’. Other work-readiness items relating to skills provided by university (‘Ability to work in an international context’, ‘Understanding of cultures and customs of other countries’) comprise the workplace ‘Global citizenship’ construct. Including these attributes in a positive work-related construct may reflect increased opportunities to benefit from international and intercultural experiences made available by workplaces. Attributes that constitute professional behaviours (‘Professionalism’) and organisational outcomes (‘Outcomes oriented’) are interpreted as adaptive capabilities enabled through organisational environments and work activities. While awareness of these skills may be fostered at the tertiary level, negative loading indicates that appreciation of diversity and multiculturality, effective communication, teamwork, decision-making, and project design and delivery skills are developed through practice. ‘Presence’ acknowledges the relationship between leadership and interpersonal and team skills (Fairhurst & Cooren, 2009; Su & Wilkins, 2013). This quality is understood as the intersection of demonstrable personal values and uniqueness, with connecting and aligning with stakeholders (Su & Wilkins, 2013).

## Engineering graduates

‘Engineering values’ and ‘Engineering methods’ capture the philosophical and methodological underpinnings of engineering. ‘Domain knowledge’ is the habits of practice or how discipline values and methods are operationalised in the production of work. Negative factor loadings for ‘Domain knowledge’ highlight that there is an ongoing challenge for tertiary institutions to maintain currency with developments in field-specific knowledge. Advances in the engineering research base and methodologies, and broad social and economic stakeholder groups contribute to this challenge. At 42%, the weighting and diversity of the knowledge and skills that comprise domain knowledge amplifies the need for internships, and professional year style programs in engineering education.

## Engineering professionals

‘Knowledge application’ and engineering ‘Worldview’ encapsulate the professionally oriented variables of ‘Engineering values’ and ‘Engineering methods’. These leverage the engineering techniques, skills, and tools of diverse teams to identify, design, and deliver outcomes of social and economic value. The items in the ‘Engineering in practice’ construct (Apply knowledge of mathematics and other basic subjects, Identify, formulate and solve common engineering problems, Use knowledge of core engineering subjects) are negatively loaded. This emphasises the importance of reviewing and extending knowledge in practice, and the role of lifelong learning in bringing new knowledge forms into existing skill sets.

# DISCUSSION

Study findings highlight the interrelated and complementary roles of educating institutions and employing organisations in knowledge and skills transformation across the career lifespan. These findings underscore the need for collaborative or partnership curriculum models that balance knowledge acquisition and application. Bennett, Dunne, and Carré (2000, cited in Barnett & Coate, 2005, p. 55) propose a curricular schema of five overlapping blocks that interconnect the domains of disciplinary knowledge, work, and generic skills. Figure 6.2 shows this relationship.

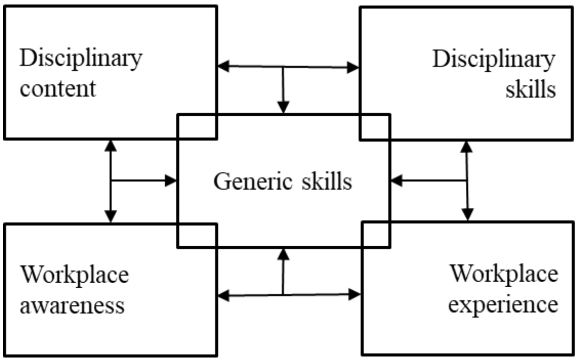



**Figure 6.2 Curricula schema (Bennett, Dunne, and Carré (2000)**

There are synergies between the Tuning questionnaire results and Bennett et al.'s (2000) schema. Both acknowledge the pivotal role of generic skills and their relationship to work-readiness and employability (workplace awareness) and both distinguish between disciplinary content and enabling skills. The Bennett et al. (2000) schema implicitly accommodates 'know-how' and 'know-why' experiential dimensions of discipline socialisation and the process of identifying with or 'becoming' an engineer (Barnett & Coate, 2005; Bereiter, 2014).

## The changing landscape of knowledge

Bell's (1976) 'knowledge age' has produced far-reaching change, and requires skills, attitudes, and approaches that continue to adapt (Edgerton, 2001; Gibbons et al., 1994; Vest, 2014). Shortened tenure of subject knowledge expertise, the less certain landscape of risk identification, interdependencies, and new modes of knowledge creation and application underpin an emerging re-distribution of capability. At the organisational level, individual experts are being supplanted by group contributors. McCauley (2016), from the world of certainty where "if a problem was encountered, an expert was called in to 'solve' it" (p. 28), the current landscape is one of greater uncertainty that requires joint leadership and collective enterprise. The mainstream skill set that now needs to be cultivated is a people development "paradigm that embraces the discomforts of ambiguity, uncertainty, and complexity" (p. 27). Increased complexity in work contexts and in operating environments has shifted focus away from individuals and certainty and consensus between knowledge holders, towards distributed knowledge and participational metaphors for knowing (Fenwick, 2012a; McCauley, 2016). Enablers focus on understanding the context of problems and resolutions, and working collaboratively towards outcomes. "Inter-professional work has emerged as a way of handling complex problems and needs in society which require contributions from several areas of expertise" (Fenwick et al., 2012, p. 3). This knowledge ecosystem requires collaborative and experiential skills, including 'know-what, know-why, know-how, know-who' knowledge forms. Figure 6.3 summarises these forms at individual and social or collective levels.

| | KNOW-WHAT | KNOW-WHY | KNOW-HOW | KNOW-WHO |
|---|---|---|---|---|
| **Individual level** | Fact, ingredients, state-of-the-art | Causality, principles, scientific explanation | Practical competences, intuition, based on experience | Information about who to reach and how to reach them |
| **Collaborative level** | Shared data | Cognitive dimension: shared interpretive schemes (script and role) | Rational dimension: routines, shared behavioural norms | Structural dimension: links and configuration of the relevant network |

**Figure 6.3 Four types of knowledge Hermans and Castiaux (2017, p. 69)**

'Know-what, know-why, know-how, know-who' knowledge categories emphasise the situational and transactional aspects of workplace knowledge and knowing; they function as knowledge structures for the development of capabilities based in collaboration, relational capability, and reflective practice. Trede and McEwen (2013) interpret this as: "the core aspect of being a DP [deliberate professional] is questioning of professional practice around the why, with whom and for what purpose rather than only around the what and how of practice" (Trede & McEwen, 2013, p. 2). Wenger-Trayner, Fenton-O'Creevy, Hutchinson, Kubiak, and Wenger-Trayner (2014) argue that professional occupations exist in a complex landscape of different communities of practice. Professional learning thus connects a 'body of knowledge' or curriculum with 'knowledgeability' or social and experience-based discipline knowledge. This landscape consists of different types of professional knowledge and expertise across the 'know-what, know-why, know-how, know-who' spectrum (Hermans & Castiaux, 2017; B. Johnson et al., 2002).

Fenwick et al. (2012) observe that "it is generally recognised that the knowledge of a profession is not stable but rather contested and subjected to transformations in a continual manner" (p. 3). Vest (2007) reviews changes in engineering education from its focus on engineering scholarship and science to its turn towards establishing stronger links with the humanities and social sciences. He aligns holistic views of engineering systems with their role in social and material systems: "Engineers of today and tomorrow must be prepared to conceive and direct projects of enormous complexity that require a highly integrative view of engineering systems" Vest (2007, online). Felder and Hadgraft (2013) affirm the contested space that prepares students for careers in engineering:

> The engineering education research community has begun to split into two divergent and sometimes antagonistic groups: the *theoreticians*, who seek to understand the learning process at a fundamental level; and the *practitioners*, who continue to focus their research on improving teaching structures and methods (Felder & Hadgraft, 2013, p. 339).

Vest (2007) reminds us that at the centre of engineering education are individuals driven by passion, curiosity, engagement, and dreams. He acknowledges that in a rapidly changing and globalised economy, neither educational institutions nor industry can adequately predict the platform or channel to best leverage and develop these capabilities: "Although we cannot know exactly what they should be taught, we can focus on the environment in which they learn and the forces, ideas, inspirations, and empowering situations to which they are exposed" (Vest, 2007, online). He sets his aspiration to a deeper understanding of how people learn and to further developments in the science of experiential learning.

## Approaches to knowledge and learning

Hermans and Castiaux note that "types of knowledge are usually examined through dichotomies" (p. 69), for example: tacit and explicit knowledge (Nonaka & Takeuchi, 1995; Polanyi, 1967); individual and social/organisational knowledge (Ghoshal, 1997; Kogut & Zander, 1996); personal and common knowledge (Dixon, 2000). Similarly, Biggs and Tang (2011) distinguish *declarative* or content knowledge (knowing about) and *functioning* knowledge (knowing how; knowing why). Declarative knowledge is cast as public knowledge, subject to rules of evidence and consistency, whereas functioning knowledge informs action:

> Functioning knowledge is…where the performance is underpinned by understanding. …Functioning knowledge is what professionals are concerned with…be it solving problems, designing buildings, planning teaching or performing surgery (Biggs & Tang, 2011, pp. 81-82).

Sfard (1998) also proposes that two metaphors describe learning. "The *acquisition metaphor* sees learning as a process of knowledge acquisition, while the *participation* *metaphor* emphasises that learning takes place by participating in the practices of social communities" (as cited in Tynjälä, 2008, p. 131). However, transferring knowledge and concepts from an education setting to the workplace is "particularly difficult, because of the considerable differences in context, culture and modes of learning" Eraut (2009, p. 77). Wood and Solomonides (2008) identify four areas of "perspective transformation" (Mezirow, 1981, p. 6) in the transition from university to the workplace. Figure 6.4, adapted from (Wood & Solomonides, 2008, p. 122), illustrates that these changes impact discourse, identity, learning approaches, and knowledge areas.

| | UNIVERSITY | WORKPLACE |
|---|---|---|
| **DISCOURSE** | Academic | Discipline-specific |
| **IDENTITY** | University student | Professional |
| **LEARNING** | Structured | Self-directed |
| **KNOWLEDGE AREA** | Structured, abstract, and modelling | Flexible application in context |

**Figure 6.4 Transitions and knowledge domains (Wood and Solomonides, 2008)**

There are implicit gaps in these domains in the transition from university to the workplace. Wood and Solomonides (2008) note that these transitions present both risk and opportunity in the pathway to employment. Risks can be mitigated by targeted transition and awareness activities at the tertiary level, and in organisational onboarding and induction programs. Following Vest (2007), there is an opportunity for universities and organisations to co-produce curricula directed specifically at transition to the engineering workplace, and which accommodates aspects of scholarship and practice.

## Co-producing the curriculum

Successful higher education and workplace practices are fundamentally different (Eraut, 2009; Hays & Clements, 2012; Holton & Naquin, 2001). Hettich (2007) refers to this as the 'paradox of preparation'; this means that, while the foundational knowledge or skills acquired in college or university are important to professional success, workplace activities that leverage this knowledge do not align with university success activities. Reid, Abrandt Dahlgren, Dahlgren, and Petocz (2011) observe that we have yet to find transition to work models that sit comfortably between academia and practice, and which bring together the theoretical and practical aspects of discipline knowledge. Wood and Kaczynski (2007) point out that "university administrators and academics are confronted with several questions about the goals of higher education when considering the broader implications of education and work" (p. 91). The two main questions are: "Are we inducting students into a particular discipline, or preparing them for the general workforce" (p. 91)? The answer is 'both', which highlights the nexus between education and the workplace. Felder and Hadgraft (2013) additionally pose a question central to both tertiary curricula and organisational development programs:

> What is the nature of current and future engineering practice and what cognitive and professional skills are required to succeed in it? (Felder & Hadgraft, 2013, p. 341)

Filliettaz (2011) discusses the predominant 'dual system' form of education used in the Swiss vocational education system. This coordinating framework is called 'dual' because it is based on close and long-standing cooperation between companies and professional associations (industry stakeholders) and government bodies. The system comprises a combination of training sites and partners, including colleges, professional associations, and employing organisations. Participants are trained in productive conditions through working part-time in companies, which is balanced with college teaching. Programs include sessions hosted by professional associations "with the aim of learning complementary knowledge that is difficult to secure in the productive conditions of everyday work" (Filliettaz, 2011, p. 486). He notes the collaborative co-creation of the dual system curricula requires professional associations to "define the relevant content of the programs, contribute to the preparation of pedagogical resources, and support the provision of practical training in cross-company courses as well as in ordinary workplaces" (Filliettaz, 2011, p. 486).

Likewise, Felder and Hadgraft (2013) make a case for forging learning alliances that balance knowledge and skills acquisition with industry need and expectation. The essence of this process is sense-making in practice:

> Most innovations in science and engineering (and every other discipline) have begun with observations and experimental data. Theories arose later in an effort to make sense of the observations and data (Felder & Hadgraft, 2013, p. 341).

Dixon (2000) refers to an equivalent grounded approach of creating 'common knowledge', or the practice underpinnings of collective 'know-what, know-why, know-how'. Translating experience into knowledge is a co-produced and iterative activity anchored in experience and deliberative reflection. This is illustrated in Figure 6.5.

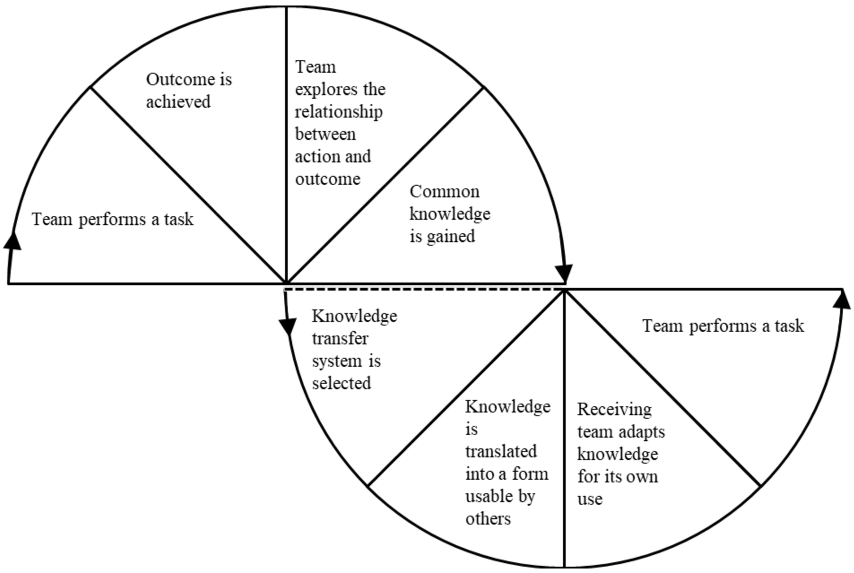



**Figure 6.5 Creating common knowledge (Adapted from Dixon, 2000, p. 20)**

The reflective process of creating and leveraging experience to create common or community/discipline knowledge is enacted through a Kolbian experiential *plan, do, reflect, review* learning cycle (Kolb, 1984; Kolb & Yeganeh, 2012). At the individual level, this process helps develop personal expertise. At the group level, it generates shared knowledge and extends knowledge to new areas of practice and contexts of use.

## CONCLUSION

Successful transition from university to the engineering workplace requires the input and shared efforts of tertiary institutions and workplaces. Representatives from engineering organisations and recent graduates participated in a questionnaire to rate the skills provided by university and those required for the workplace. Analysis of questionnaire results charts the developmental and transformative journey from work-readiness to employability, acquiring engineering skills, to skills deployment in the field. Findings suggest a ‘division of labour’ pattern that highlights the complementary roles of universities and organisations in successful transition to work experiences for new career engineers. Increased complexity in work environments has created focus on networks of knowledge holders, and situational and transactional aspects of workplace knowledge and knowing. This offers opportunities for co-creating transition to work models of learning.

# References


Barnett, R., & Coate, K. (2005). *Engaging the curriculum in higher education*. London, UK: McGraw-Hill.

Baytiyeh, H., & Naja, M. (2012). Identifying the challenging factors in the transition from colleges of engineering to employment. *European Journal of Engineering Education, 37*(1), 3-14.

Bell, D. (1976). The coming of the post-industrial society. *The Educational Forum, 40*(4), 574-579.

Bendesa, I. (1992). Komang Gde. 1992, The structural change of employment, and education in Indonesia. *Indonesian Quarterly, 20*(4), 447-460.

Bennett, N., Dunne, E., & Carré, C. (2000). *Skills development in higher education and employment*. Buckingham, UK: Society for Research into Higher Education & Open University Press.

Bereiter, C. (2014). Principled practical knowledge: Not a bridge but a ladder. *Journal of the Learning Sciences, 23*(1), 4-17. doi:10.1080/10508406.2013.812533

Biggs, J. B., & Tang, C. (2011). *Teaching for quality learning at university* (4th ed.). Maidenhead, Berkshire, UK: Open University Press, McGraw-Hill Education.

Carvalho, J. (2008). *International aspects of Bologna: The Tuning Project*. Paper presented at the BALANCE – Bologna: A long-term approach to new certification in Europe, University of Turku, Finland. http://www.coimbra-group.eu/balance/Docs/turku/International%20Aspect%20of%20Bologna%20Process%20-Tuning.ppt.

Dixon, N. M. (2000). *Common knowledge: How companies thrive by sharing what they know*: Harvard Business School Press.

Edgerton, R. (2001). *Education white paper*. Report prepared for the Pew Charitable Trusts, Pew Forum on Undergraduate Learning. Washington, DC.

EHEA. (2016). European Higher Education Area and Bologna Process. Retrieved from http://www.ehea.info/

Eraut, M. (2009). Transfer of knowledge between education and workplace settings. In H. Daniels, H. Lauder, & J. Porter (Eds.), *Knowledge, values and educational policy: A critical perspective* (pp. 65-84). Abingdon, Oxon, UK: Routledge.

Fairhurst, G. T., & Cooren, F. (2009). Leadership as the hybrid production of presence (s). *Leadership, 5*(4), 469-490.

Felder, R. M., & Hadgraft, R. G. (2013). Educational practice and educational research in engineering: Partners, antagonists, or ships passing in the night? *Journal of Engineering Education, 102*(3), 339-345.

Fenwick, T. (2012a). Co-production in professional practice: a sociomaterial analysis. *Professions and Professionalism, 2*(2), 1-16.

Fenwick, T. (2012b). Matterings of knowing and doing: Sociomaterial approaches to understanding practice. In P. Hager, A. Lee, & A. Reich (Eds.), *Practice, learning and change: Practice-theory perspectives on professional learning* (pp. 67-83). Dordrecht: Springer Netherlands.

Fenwick, T., Nerland, M., & Jensen, K. (2012). Sociomaterial approaches to conceptualising professional learning and practice. *Journal of Education and Work, 25*(1), 1-13. doi:10.1080/13639080.2012.644901

Filliettaz, L. (2011). Collective guidance at work: A resource for apprentices? *Journal of Vocational Education & Training, 63*(3), 485-504. doi:10.1080/13636820.2011.580359

Gherardi, S. (2001). From organizational learning to practice-based knowing. *Human relations, 54*(1), 131-139.

Ghoshal, S. (1997). The individualized corporation: An interview with Sumantra Ghoshal. *European Management Journal, 15*(6), 625-632. doi:http://dx.doi.org/10.1016/S0263-2373(97)00046-7

Gibbons, M., Limoges, C., Nowotny, H., Schwartzman, S., Scott, P., & Trow, M. (1994). *The new production of knowledge: The dynamics of science and research in contemporary societies*. London, UK: Sage Publications Limited.

Gonzélez, J., & Wagenaar, R. (2003). *Tuning educational structures in Europe. Final report. Phase one*. Universidad de Deusto: Deusto. Retrieved from http://www.bolognakg.net/doc/Tuning_phase1_full_document.pdf

Harrison, A. (1995). The selection and development of Indonesian graduates in an industry training program. *Asia Pacific Journal of Human Resources, 32*(3), 114-123. doi:10.1177/103841119503200309

Hays, J., & Clements, M. (2012, 20-22 June, 2102). *Transition-bridging the gap between study and work.* Paper presented at the Proceedings of the 9th International Conference on Cooperative & Work-Integrated Education, Where East meets West and Theory meets Practice, Istanbul, Turkey.

Hermans, J., & Castiaux, A. (2017). Contingent knowledge transfers in university–industry R&D projects. *Knowledge Management Research & Practice*, 1-10.

Hettich, P. (2007). *College to workplace issues and strategies: A primer*. Paper presented at the 14th National Conference on Students in Transition, Cincinnati, OH.

Hoffmann, B., Jørgensen, U., & Christensen, H. P. (2011). *Culture in engineering education: CDIO framing intercultural competences.* Paper presented at the 7th International CDIO Conference 20-22 June, Technical University of Denmark, Copenhagen.

Holton, E. F., & Naquin, S. S. (2001). *How to succeed in your first job: Tips for new college graduates*. San Francisco, CA: Berrett-Koehler Publishers.

Johnson, B., Lorenz, E., & Lundvall, B. (2002). Why all this fuss about codified and tacit knowledge? *Industrial and Corporate Change, 11*(2), 245-262.

Johnson, H., Watson, P. A., Delahunty, T., McSwiggen, P., & Smith, T. (2011). What it is they do? Differentiating knowledge and literacy practices across content disciplines. *Journal of Adolescent & Adult Literacy, 55*(2), 100-109.

Kogut, B., & Zander, U. (1996). What firms do? Coordination, identity, and learning. *Organization Science, 7*(5), 502-518.

Kolb, D. A. (1984). *Experiential learning: Experience as the source of learning and development* (Vol. 1). Englewood Cliffs, New Jersey, NJ: Prentice-Hall

Kolb, D. A., & Yeganeh, B. (2012). Deliberate experiential learning. *Contemporary Organizational Behavior in Action*.

Lichtenstein, G., Loshbaugh, H. G., Claar, B., Chen, H. L., Jackson, K., & Sheppard, S. D. (2009). An engineering major does not (necessarily) an engineer make: Career decision making among undergraduate engineering majors. *Journal of Engineering Education, 98*(3), 227-234. doi:10.1002/j.2168-9830.2009.tb01021.x

Manoliu, I. (2005). *First results of the Tuning Project with the participation of EUCEET and ECCE*. Paper presented at the 42nd ECCE meeting, Istanbul, Turkey. http://www.unideusto.org/tuningeu/images/stories/Summary_of_outcomes_TN/First_results_Civil_Engineering_PPT.ppt.

Mansilla, V. B., & Jackson, A. (2011). *Educating for global competence: Preparing our youth to engage the world*. New York, NY: Asia Society.

Matusovich, H., Streveler, R., Miller, R., & Olds, B. (2009). *I'm graduating this year! 'So what IS an engineer anyway?* Paper presented at the Proceedings - American Society of Engineering Education Annual Conference and Exposition, Austin, TX.

McCauley, D. H. (2016). Rediscovering the art of strategic thinking. *National Defense University Press, Joint Force Quarterly 81 (JFQ)*(2nd Quarter, April 2016).

Mezirow, J. (1981). A critical theory of adult learning and education. *Adult education, 32*(1), 3-24.

Nonaka, I., & Takeuchi, H. (1995). *The knowledge-creating company : How Japanese companies create the dynamics of innovation*. New York: Oxford University Press.

Polach, J. L. (2004). Understanding the experience of college graduates during their first year of employment. *Human Resource Development Quarterly, 15*(1), 5-23. doi:10.1002/hrdq.1084

Polanyi, M. (1967). *The tacit dimension*. Garden City, N.Y.: Anchor Books.

Reid, A., Abrandt Dahlgren, M., Dahlgren, L. O., & Petocz, P. (2011). *From expert student to novice professional* (Vol. 99). The Netherlands: Springer.

Resnick, L. B. (1987). The 1987 Presidential Address: Learning in school and out. *Educational Researcher, 16*(9), 13-54.

Sfard, A. (1998). On two metaphors for learning and the dangers of choosing just one. *Educational Researcher, 27*(2), 4-13.

Su, A. J., & Wilkins, M. M. (2013). *Own the room: Discover your signature voice to master your leadership presence*. Boston, MA: Harvard Business Review Press.

Trede, F., & McEwen, C. (2013). *Educating the deliberate professional* Occasional Paper 9. The Education For Practice Institute, Charles Sturt University. Sydney. Retrieved from https://www.csu.edu.au/__data/assets/pdf_file/0009/742482/EFPI_OP9_EducatingDP.pdf

Tynjälä, P. (2008). Perspectives into learning at the workplace. *Educational Research Review, 3*(2), 130-154. doi:http://dx.doi.org/10.1016/j.edurev.2007.12.001

Vest, C. M. (2007). *Educating engineers for 2020 and beyond*. National Academy of Engineering, Grand Challenges Blog. Retrieved from http://www.engineeringchallenges.org/14373/GrandChallengesBlog/7639.aspx

Vest, C. M. (2014). Forward: Educating engineers for 2020 and beyond. In E. F. Crawley, J. Malmqvist, S. Östlund, D. R. Brodeur, & K. Edström (Eds.), *Rethinking engineering education: The CDIO approach* (2nd ed.). Heidelberg, Germany: Springer.

Wenger-Trayner, E., Fenton-O'Creevy, M., Hutchinson, S., Kubiak, C., & Wenger-Trayner, B. (Eds.). (2014). *Learning in landscapes of practice: Boundaries, identity, and knowledgeability in practice-based learning*. Oxford: Routledge.

Wenger, E. (1998). *Communities of practice: Learning, meaning and identity*. Cambridge, UK: Cambridge University Press.

Wood, L., & Kaczynski, D. (2007). University students in USA and Australia: Anticipation and reflection on the transition to work. *International Journal of Employment Studies, 15*(2), 91.

Wood, L., & Solomonides, I. (2008). Different disciplines, different transitions. *Mathematics Education Research Journal, 20*(2), 117-134.

# 7 COMPONENTS OF THE ENGINEERING PROFESSIONAL PERSONA

Components of the engineering professional persona: The transformative role of experience

## OVERVIEW

Chapter seven completes the discussion of the data analysis for this study of how to design organisational development programs that facilitate entry of new graduates to the engineering workplace. This analysis is based on exploratory factor analysis of qualitative and quantitative responses to a Tuning Process survey, which asks which asks employers, academics, and students to rate the skills the general and engineering-specific capabilities provided by university and required for engineering work. This chapter summarises survey findings of graduate and employer views of the skills required for the engineering workplace. Results summarise the key components, or ‘building blocks’ of the engineering professional persona. These components align with Bloom’s cognitive, affective, and psychomotor domains, and broadly with ‘knowledge, skills, attitude’ (KSA) development typologies. Analysis provides an evidence-based corollary to these models, and highlights the transformative role of experience. Study results are interpreted from potential benefit to workplace development programs for new career engineers. Theories of knowledge and capability serve as conceptual and interpretative lenses.

# INTRODUCTION

Shepherd (2017) writes: "Skills define us. They are what make us useful and productive. They are the foundation of our achievements". He further observes that, "'what we are' is constantly changing as we continue to develop our existing skills and take on new challenges to respond to a changing world around us" (online). Engineering graduates and employers shared their views of the key general and specific skills required for engineering work. Findings agree with Shepherd. Study results are assessed from the viewpoint of designing organisational development programs to facilitate the transition of novice engineers to the workplace. Results show broad alignment with Bloom's cognitive, affective, and psychomotor domains, with Habermas' technical, practical and emancipatory domains (Mezirow, 1981), and with a range of 'knowledge, skills, attitude' typologies. Exploratory factor analysis of results suggests a framework for development activities that synergise with these capability models. Findings provide an evidence-based corollary, and highlight the transformative role of experience.

# METHODOLOGY

Participants from engineering organisations and recent graduates contributed their opinions of the three to five most important general and specific capabilities required for engineering. Responses represent cross-disciplinary (aerospace, biomedical, chemical, civil, electrical, mechanical, software), organisational (management, engineers, technical specialists), and geographical (Australia, Canada, India, United States) views. Participants completed an online Tuning Process questionnaire adapted to include free text answers. Tuning is about designing, developing, implementing, and evaluating higher education programmes to incorporate views from industry, graduates, and academia. It is an initiative affiliated with the Bologna Process, which supports the continuous adaptation of higher degree programs towards greater consistency, with the aim of expanding employment opportunities for graduates. The developing global knowledge society and related changes in modes of knowledge production and transfer provide the context for the systematic and institutional changes in higher education that underpin the Bologna and Tuning Processes (Carvalho, 2008; Department of Education and Training, 2010; EHEA, 2016). While Tuning incorporates employer and professional body input, and acknowledges that industry is a key stakeholder and client, its outcomes are largely directed at university curricula. This study aims to help bring the Tuning Process full cycle by leveraging the Tuning methodology for transition to work development programs. Theories of knowledge and capability development are conceptual and interpretative lenses.

To help identify emerging industry themes or capabilities not directly accommodated by Tuning Process question items, the questionnaire was adapted to include free text responses. Table 7.1 shows this adaptation.

**Table 7.1 Tuning questionnaire adapted for free text responses**

| Original Tuning Question | Adapted Question |
|---|---|
| Please rank below the five most important competences according to your opinion. Please write the number of the item within the box. Mark on the first box the most important, on the second box the second most important and so on.<br><br>1. [ ]<br>2. [ ]<br>3. [ ]<br>4. [ ]<br>5. [ ] | (III) In your opinion, what are the three to five (3-5) most important **general capabilities** required for engineering?<br><br>(IV) In your opinion, what are the three to five (3-5) most important **specific skills** required for engineering |

Responses were received from 215 (94 employers and 121 graduates) participants. Following Tuning Process sampling methodology, selection criteria was that employers should represent organisations known to employ engineering graduates and that graduates should have completed an engineering degree in the last three to five years. There is comparable representation in employer and graduate comments, and for general and specific skills. Table 7.2 summarises these contributions.

**Table 7.2 Comments from employers and graduates**

| | Employers | Graduates | Total |
|---|---|---|---|
| **General skills** | 399 (26%) | 391 (25%) | 790 (51%) |
| **Specific skills** | 323 (21%) | 423 (28%) | 746 (49%) |
| **Total** | 722 | 814 | 1536 |

A grounded coding analysis of responses generated seventeen themes, with the same themes relevant to both general and specific skills comments. These themes are shown in Table 7.3. Appendix 5 lists participant comments and classification into the themes that comprise this analysis.

**Table 7.3 Themes—skills required for work**

| Coded Free Text Themes | | |
|---|---|---|
| Applied knowledge<br>Aptitude<br>Attitude<br>Business skills<br>Communication skills<br>Enterprising and enthusiastic | Foundational knowledge<br>Interpersonal skills<br>Inventiveness<br>Judgment and practical knowledge<br>Leadership<br>Problem-solving | Professionalism<br>Resilience and adaptability<br>Team worker<br>Technical orientation<br>Willingness to learn |

# ANALYSIS

The statistical methods of principal components analysis (PCA) and exploratory factor analysis (EFA) were utilised to help determine the meaningful commonalities in this set of thematic variables. Using Kaiser rule and Scree plot techniques, PCA identified that three principal components for general skills, and three principal components for specific skills contributed explanatory power to the analysis. The goal of EFA is "to discover likely factors that will account for at least 50% of the common variation in the observed factors" (Fricker Jr, Appleget, & Kulzy, 2012, p. 30). EFA with the maximum likelihood method was used to determine the greatest distribution of factors identified through the PCA analysis. A three-factor solution was examined, using a Varimax rotation of the factor loading matrix. Factor loadings, communality, and factor score coefficients were examined. Factor communalities were for the most part above 0.7, confirming that each item shared common variance with other items. All factor loadings were included for analysis. Cross loaded variables were assigned to the factor where they demonstrated the highest loading. Appendix 4 shows the factor loadings, communalities, and coefficients. The results in Table 7.4 identify the following patterns, where the percentages are based on averaged absolute values of the loadings for each factor construct. Negative loadings are seen as constituting transformative capabilities that are developed through experience and reflective application.

**Table 7.4 Factor components and contributing variables**

| General Skills | | Specific Skills | |
|---|---|---|---|
| **Component Loadings** | | **Component Loadings** | |
| **Construct 1: Employability** | **65%** | **Construct 1: Professional practices** | **64%** |
| Applied knowledge | 0.814 | Applied knowledge | 0.839 |
| Aptitude | 0.907 | Aptitude | 0.848 |
| Business skills | 0.846 | Business skills | 0.849 |
| Communication skills | 0.771 | Enterprising and enthusiastic | 0.896 |
| Enterprising and enthusiastic | 0.884 | Interpersonal skills | 0.889 |

| General Skills | | |
|---|---|---|
| **Component Loadings** | | |
| Interpersonal skills | 0.849 | |
| Judgment and practical knowledge | 0.816 | |
| Leadership | 0.883 | |
| Resilience and adaptability | 0.807 | |
| Team worker | 0.896 | |
| Technically oriented | 0.792 | |
| **Construct 2: Character** | | **23%** |
| Attitude | -0.771 | |
| Inventiveness | -0.71 | |
| Professionalism | -0.911 | |
| Willingness to learn | -0.59 | |
| **Construct 3: Engineering skills** | | **12%** |
| Problem-solving | 0.93 | |
| Foundational knowledge | 0.665 | |

| Specific Skills | | |
|---|---|---|
| **Component Loadings** | | |
| Inventiveness | 0.756 | |
| Judgment and practical knowledge | 0.802 | |
| Leadership | 0.722 | |
| Resilience and adaptability | 0.766 | |
| Team worker | 0.839 | |
| Willingness to learn | 0.589 | |
| **Construct 2: Character** | | **18%** |
| Attitude | 0.776 | |
| Communication skills | 0.758 | |
| Technically oriented | 0.767 | |
| **Construct 3: Engineering skills** | | **19%** |
| Problem-solving | 0.845 | |
| Foundational knowledge | 0.717 | |
| Professionalism | 0.829 | |

## General skills

‘Employability’ (65%) brings together a diverse range of skills and individual qualities that contribute to personal capital and facilitate employment opportunities. It combines effective communication and interpersonal skills with leadership, judgment or ‘good sense’, and the ability to apply knowledge. Following Orlikowski and Scott (2008) who argue that sociomateriality “advances the view that there is an inherent inseparability between the technical and the social” (p. 434), ‘Technically oriented’ goes beyond technical literacy and acknowledges the sociomaterial aspects of engineering implicit in participant responses. ‘Character’ (23%) is seen as a required civic, performance, and intellectual aspect of employability. The Confederation of British Industry (CBI) (2012) defines it as “a set of behaviours and attitudes, a kind of social literacy … sometimes termed character … that plays a critical role in determining personal effectiveness” (p. 31). Negative loadings signify this is a developmental or “growth” construct, which is fostered through work activities, and which is central to professional and career success. ‘Engineering skills’ (12%) integrates an analytical and problem-solving orientation with mathematics, science, and engineering fundamentals.

## Specific skills

‘Professional practices’ (64%) represent the important values, behaviours, and outcomes focus of engineering professionals. ‘Inventiveness’ and ‘Willingness to learn’ add the dimensions of creativity and responsiveness to change, or to new approaches. The 'Character' (18%) requirements for engineering are noticeably different to general skills character requirements: 'Attitude', 'Communication skills', and 'Technically oriented' produce a "combinatory temperament" or signature character of an engineer. 'Technically oriented' infers that identifying with discipline-specific knowledge is intrinsic to "becoming" or embodying this engineering persona. Stevens, O'Connor, Garrison, Jocuns, and Amos (2008) point out that "persons are always "in-context". Forming an identity as an engineer requires that one "be identified as "engineering material," both by him or herself and by disciplinary representatives" (p. 358). 'Engineering skills' (19%) reinforces the need for field relevant knowledge, professional behaviours, and an analytical nature.

## KNOWLEDGE, SKILLS, AND ATTITUDE

Survey responses suggest that professional practices, character, and engineering skills constitute the 'engineering professional persona'. Figure 7.1 illustrates, with approximate 60:20:20 dimensions.

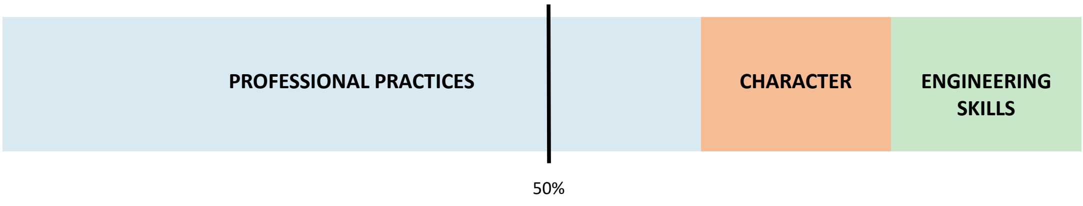



**Figure 7.1 Dimensions of an engineering professional**

This aligns with Gordon (1984), who asks "What is an engineer"? His response foregrounds engineering education reform from knowledge acquisition to distributed and transactional knowledge—leading teams of resources: "financial, personal, and material, at all levels of engineering activity" (p. 12). Gordon (1984) encompasses the knowledge, skills, and attitudes of individuals in a network of knowing and practice. Echoing a systems or complexity science mindset (Benham-Hutchins & Clancy, 2010; Best & Holmes, 2010; Von Bertalanffy). Gordon (1984) outlines the engineering persona as:

> One who has attained and continuously enhances technical, communications, and human relations knowledge, skills, and attitudes, and who contributes effectively to society by theorizing, conceiving, developing, and producing reliable structures and machines of practical and economic value (Gordon, 1984, p. 4).

He thus frames individual capability that is dynamic, relational, and reflective, within a discipline construct with touchpoints across multiple social, technical, practical, and economic dimensions. This complex landscape is increasingly confederate and widespread (Fenwick, Nerland, & Jensen, 2012; Suchman, 2000; Trevelyan, 2013).

The 'head, heart, habit' pattern that emerges in participant comments aligns with the Bloom, Engelhart, Furst, Hill, and Krathwohl (1956) domains of 'knowledge, skills, attitude' (p. 7). Whether framed through 'head, heart, habit' metaphors, leveraged for evaluation as in Bloom et al. (1956), or seen through the lenses of transformative learning experiences, KSA remains an enduring heuristic. Its origins are in Aristotle's three types of knowledge: *episteme* (to know), *techné* (craftsmanship, practice), *phronesis* (practical wisdom, values). Table 7.5 correlates views of learning and capability development which focus on the domains of knowledge, skills, and attitude.

**Table 7.5 Skills, character, practice domains**

| | **Bloom et al. (1956)** | **Habermas, (Mezirow, 1981)** | **Gordon (1984)** | **Barnett and Coate (2005)** | **Institution of Civil Engineers (2011)** | **Study Free Text Analysis** |
|---|---|---|---|---|---|---|
| **Head** | Cognitive (Knowledge) | Technical | Knowledge | Knowing | Contextual | Engineering skills |
| **Heart** | Affective (Attitude) | Emancipatory | Attitude | Being | Behavioural | Character |
| **Habit** | Psychomotor (Skills) | Practical | Skills | Acting | Practice | Professional practices |
| | Capability evaluation | Critical social philosophy | Disciplinary persona | Discipline epistemology | Professional competences | Discipline persona |

For Mezirow (1981), Habermas' three generic and interrelated "knowledge constitutive" domains of the technical, the practical, and the emancipatory are seminal to understanding adult learning and education. These categories provide a framework for knowledge discovery and warrant knowledge grounded in "different aspects of social existence: work, interaction and power" (p. 4). Similarly, Gordon (1984) refers to the sense-making and transformational aspects at the core of engineering practice as "relational knowledge". He notes that a signature skill is having: "a relational *understanding* of the data and [an engineer] will have learned how to recall and correlatively process *relevant* data in order to synthesise *new information* to solve problems" (p. 11). In this, Gordon (1984) differentiates between knowledge acquisition and informed application. Barnett and Coate (2005) explore how different disciplines quantify the domains of knowing, being, and acting. They suggest that professional, and scientific and technical disciplines prioritise these domains as in Figure 7.2.

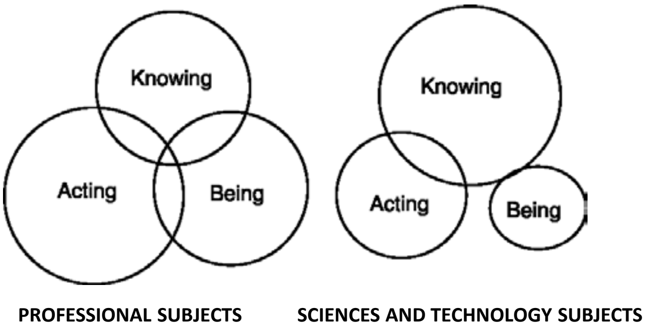



**Figure 7.2 Domain knowledge (Adapted from Barnett & Coate, 2005, pp. 75,77)**

Although it is a technical discipline, survey results indicate that engineering aligns towards Barnett and Coate's (2005) *professional subjects* and prioritises practical usage, enabled by behavioural and character qualities, and scientific and technical skills. The Institution of Civil Engineers (2011, 2015) supports these findings. It sets out for members the knowledge, skills, and attitudes that are recognised and valued by the institution. These include the broad lenses of self, citizenship, and the context of practice to "help engender those competencies attributed to a well-rounded practitioner at the heart of society" (2011, p. 3).

## TRANSFORMATIVE CAPABILITIES

"Character" negative loadings are viewed as transformative capabilities central to the engineering professional. Analysis suggests that these adaptive qualities are developed through experience, relational understanding, and reflective application. Figure 7.3 illustrates the influence of experience on each of the four 'Character' variables: 'Attitude', 'Inventiveness', 'Professionalism', 'Willingness to learn' in the transition from generic skills to engineering-specific capabilities.

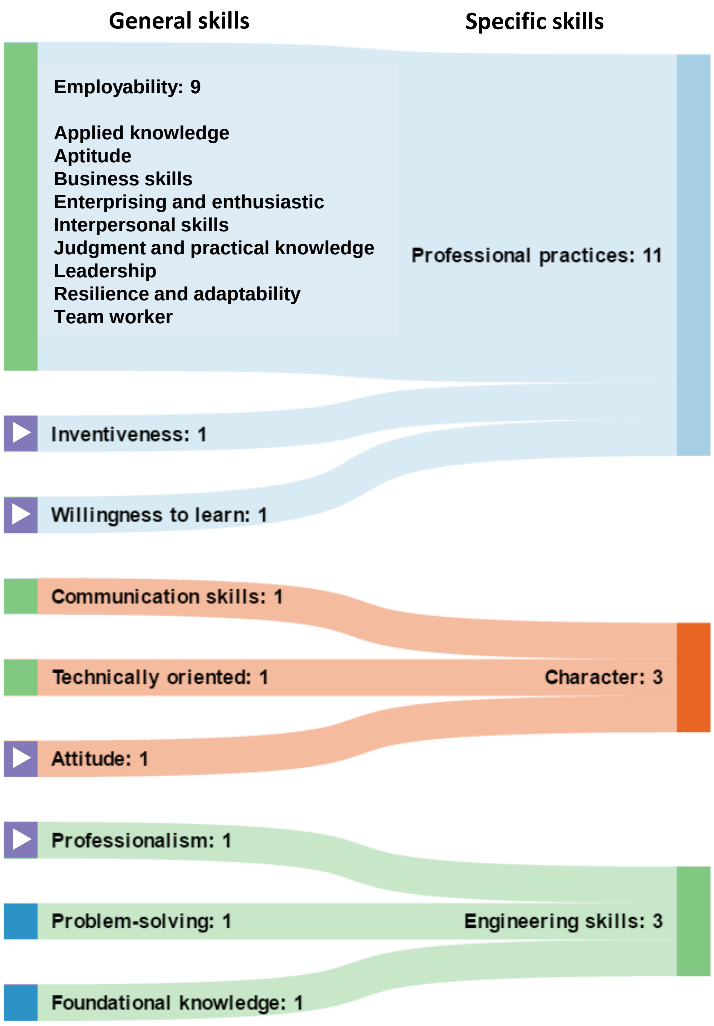



**Figure 7.3 Capability transformation**

General professionalism, including ‘Applied knowledge, ‘Business skills’, ‘Judgment and practical knowledge’, ‘Resilience and adaptability’, and ‘Team worker’ correlates with professional practices expectations of engineers. ‘Inventiveness’ and ‘Willingness to learn’ transition from the general skills ‘Character’ construct to become components of workplace ‘Professional practices’. This suggests these qualities are essential to the personality of technical teams. According to O'Dell and Trees (2014), characteristics of technical teams include valuing face-to-face interaction and problem solving, and a preference for innovation over reuse. At its most rudimentary, a “growth mindset” describes the underlying beliefs people have about their abilities. To view challenges and setbacks as growth opportunities exerts a powerful effect on resilience, approach to tasks, and many other life and career dimensions (Dweck, 2006). From this perspective, ‘Inventiveness’ and ‘Willingness to learn’ are also facets of a growth mindset, which survey analysis indicates are integral to engineering professional practices. Likewise, effective communication, a technical inclination, and a constructive attitude are qualities that combine to help define the 'Character' attributes or intrinsic identity of an engineer. Significantly, while the variable 'Attitude' has a negative factor loading, it is the only negatively loaded variable that does not move from the general 'Character' construct, but retains its pivotal position for both the general skills and specific skills. It is therefore unlikely to be a scaffold capability, and may instead be taken as a pivotal aspect of the engineering professional persona. 'Engineering skills' brings together engineering knowledge and habits of practice.

Dweck (2006) underscores the importance of engagement and of cultivating curiosity, and their role in knowledge transformation. She distinguishes between fixed and growth mindsets. A *fixed mindset* assumes intelligence, capability, and moral character are established, while growth mindsets see opportunity for continuous improvement:

> There's another mindset. …In this mindset, the hand you're dealt is just the starting point for development. This *growth mindset* is based on the belief that your basic qualities are things you can cultivate through your efforts…everyone can change and grow through application and experience (Dweck, 2006, p. 8).

Kilpi (2016) takes a 'new economics of knowledge' approach to knowledge, skills, and how knowledge work is enacted. He interprets a growth mindset as: "Recently, researchers have claimed that "there is a decisive, third, concept. It is the practice of lifelong curiosity. …Researchers claim that cognition materialises in an interpersonal space" (Kilpi, 2016, p. 34). He further notes that intelligence is relational and social. It manifests in communities and communication, and defines practice:

> Both learning and non-learning reside in communication. …All intelligence emerges from the coordinated efforts of a community. Work starts from problems and learning starts from questions. Work is about creating value and learning is about creating knowledge. Both work and learning require the same things: interaction and engagement (Kilpi, 2016, p. 34).

Perhaps Kilpi's observation is what Vest (2007) intends in his call for forming a "deeper understanding of the nature of experiential learning—a real science of learning. Then we might see a quantum leap, a true transformation in education" (online). To this end, Ambrose, Bridges, DiPietro, Lovett, and Norman (2010) define learning as: "a *process* that leads to *change*, which occurs as a result of *experience* and increases the potential for improved performance and future learning" (p. 3). Learning is thus ongoing, transformative, and compounding. Fink (2003) refers to the activities that enable this process as "significant learning experiences". Table 7.6 illustrates his typology of significant learning.

**Table 7.6 Taxonomy of significant learning (Adapted from Fink, 2003, p. 30)**

| Foundational knowledge | Understanding and remembering information and ideas |
|---|---|
| **Knowledge application** | Skills<br>Thinking (critical, creative, practical)<br>Delivering outcomes |
| **Relating and integrating** | Connecting ideas, people, other aspects |
| **Human dimension** | Learning about oneself and others |
| **Caring** | Developing new feelings, interests, values |
| **Learning how to learn** | Becoming a better student/engineer<br>Developing capacity for broad and deep inquiry<br>Becoming a self-directed learner |

Reflecting on a transition to work program for the Indonesian mining industry, Harrison (1995) observes that a measure of program success is the ability to create transformative learning experiences:

> The job is intended as a learning and developmental experience, not 'just work'. Their concept of work needs to be reformulated from doing routine tasks, to questioning how best to do it, learning methods and adapting them to work, understanding the links between various tasks, developing a basis for making sound judgments and so on (Harrison, 1995, p. 122).

Harrison (1995) outlines the organisational need for learning frameworks that encourage the conceptual and capability development of new career starters beyond onboarding. Fink's taxonomy is a potential vehicle to support this development. It acknowledges that key aspects in this change process include (1) a knowledge foundation to build upon, (2) skills to apply knowledge and deliver outcomes, (3) the capacity to relate and integrate ideas, people, and tools, (4) that learning facilitates deeper knowledge of oneself and others, (5) that engagement creates a virtuous cycle of knowledge enrichment and more diverse interests, and (6) transformative learning processes build on themselves, and continue to develop and extend ability. Fink provides a framework that also gives voice to Vest's experiential pedagogy. It aids workplace development programs to engender the capabilities required of a professional whose discipline is at the nexus of a network of society, knowing and practice.

# Conclusion

Graduate and employer contributions to a study that asked them to share their views of the capabilities required for engineering work help define the engineering professional persona. The knowledge, attitudes, and skills that embody this persona align with a range of ‘head, heart, habit’ development typologies. While learning models of experience is a formative knowledge area, study results highlight the transformative role of experience in the transition to professional practice. Findings suggest that capabilities broadly related to the engineering disciplinary ‘character’ are pivotal in this transformation, and that these qualities underpin the innovative, distributed and relational nature of engineering practice.

# REFERENCES

Ambrose, S. A., Bridges, M. W., DiPietro, M., Lovett, M. C., & Norman, M. K. (2010). *How learning works: Seven research-based principles for smart teaching*. San Francisco, CA: John Wiley & Sons.

Barnett, R., & Coate, K. (2005). *Engaging the curriculum in higher education*. London, UK: McGraw-Hill.

Benham-Hutchins, M., & Clancy, T. R. (2010). Social networks as embedded complex adaptive systems. *Journal of Nursing Administration, 40*(9), 352-356.

Best, A., & Holmes, B. (2010). Systems thinking, knowledge and action: Towards better models and methods. *Evidence & Policy: A Journal of Research, Debate and Practice, 6*(2), 145-159.

Bloom, B. S., Engelhart, M. D., Furst, E. J., Hill, W. H., & Krathwohl, D. R. (1956). *Taxonomy of educational objectives*. N.Y.: Longmans, Green.

Carvalho, J. (2008). *International aspects of Bologna: The Tuning Project*. Paper presented at the BALANCE – Bologna: A long-term approach to new certification in Europe, University of Turku, Finland. http://www.coimbra-group.eu/balance/Docs/turku/International%20Aspect%20of%20Bologna%20Process%20-Tuning.ppt.

Confederation of British Industry (CBI). (2012). *First Steps: A new approach for our schools*. Confederation of British Industry (CBI). London. Retrieved from http://www.cbi.org.uk/insight-and-analysis/first-steps/

Department of Education and Training. (2010). *The Bologna Process*. DET. Retrieved from https://internationaleducation.gov.au/About-AEI/Government-Relations/Pages/TheBolognaProcess.aspx

Dweck, C. S. (2006). *Mindset: The new psychology of success* (1st ed.). New York: Random House.

EHEA. (2016). European Higher Education Area and Bologna Process. Retrieved from http://www.ehea.info/

Fenwick, T., Nerland, M., & Jensen, K. (2012). Sociomaterial approaches to conceptualising professional learning and practice. *Journal of Education and Work, 25*(1), 1-13. doi:10.1080/13639080.2012.644901

Fink, L. D. (2003). *Creating significant learning experiences: An integrated approach to designing college courses*. San Francisco: Jossey-Bass.

Fricker Jr, R. D., Appleget, J. A., & Kulzy, W. W. (2012). From data to information: Using factor analysis with survey data. *Phalanx, 29*(4), 30-34.

Gordon, B. M. (1984). *What is an engineer? Invited keynote presentation.* Paper presented at the European Society for Engineering Education (SEFI) Annual Conference, Nürnberg, Germany.

Harrison, A. (1995). The selection and development of Indonesian graduates in an industry training program. *Asia Pacific Journal of Human Resources, 32*(3), 114-123. doi:10.1177/103841119503200309

Institution of Civil Engineers. (2011). *Competency framework for professional development*. Institution of Civil Engineers (ICE). Westminster, London. Retrieved from http://www.gedcouncil.org/sites/default/files/ICE-Competency-Framework.pdf

Institution of Civil Engineers. (2015). *Institution of Civil Engineers Skills Report 2015. Perspectives on capability and capacity: key risks and opportunities*. Institution of Civil

Engineers (ICE). London. Retrieved from http://www.ice-conferences.com/ice_events/media/general/ice-skills-report-2015-.pdf

Kilpi, E. (2016). Perspectives on new work: Exploring emerging conceptualizations. *Sitra Studies 114.* Retrieved from http://www.sitra.fi/en/julkaisu/2016/perspectives-new-work

Mezirow, J. (1981). A critical theory of adult learning and education. *Adult education, 32*(1), 3-24.

O'Dell, C. S., & Trees, L. (2014). *How smart leaders leverage their experts*. Best Practices Report. American Productivity & Quality Center (APQC). Retrieved from https://www.apqc.org/knowledge-base/download/309016/K04979_How_Smart_Leaders_Leverage_Their_Experts.pdf

Orlikowski, W. J., & Scott, S. V. (2008). Sociomateriality: Challenging the separation of technology, work and organization. *The Academy of Management Annals, 2*(1), 433-474. doi:10.1080/19416520802211644

Shepherd, C. (2017). The changing skill set of the learning professional. Retrieved from http://clive-shepherd.blogspot.com.au/2017/02/the-changing-skill-set-of-learning.html

Stevens, R., O'Connor, K., Garrison, L., Jocuns, A., & Amos, D. M. (2008). Becoming an engineer: Toward a three dimensional view of engineering learning. *Journal of Engineering Education*, *97*(3), 355.

Suchman, L. (2000). Embodied practices of engineering work. *Mind, Culture, and activity, 7*(1-2), 4-18.

Trevelyan, J. P. (2013). Towards a theoretical framework for engineering practice. *Engineering Practice in a Global Context: Understanding the Technical and the Social*, 33.

Vest, C. M. (2007). *Educating engineers for 2020 and beyond*. National Academy of Engineering, Grand Challenges Blog. Retrieved from http://www.engineeringchallenges.org/14373/GrandChallengesBlog/7639.aspx

Von Bertalanffy, L. (1968). *General system theory: Foundations, development, applications*. New York: George Brazillier.

# 8 CONCLUSIONS

This chapter presents the overall conclusions for this study. Major findings are summarised through answers to the research question, and implications of the research are examined, with recommendations suggested for subsequent investigation.

## RESEARCH QUESTION

There is general agreement that there is a lack of knowledge about how university education is applied and adapted in the workplace, and that further research needs to be done to bridge education and work and to bring together the theoretical and practical aspects of discipline knowledge (Reid, Abrandt Dahlgren, Dahlgren, & Petocz, 2011; Stevens, Johri, & O'Connor, 2014). While there is a growing body of inquiry on transition to work, there is a gap in the literature on the role of the workplace in facilitating this transition. This study contributes to addressing this gap. It investigates issues relating to the transition of novice engineers to the workplace from an organisational perspective, for the purpose of designing induction and development programs for new career engineers. The study focuses on (1) identifying areas where workplace programs can constructively impact the transition to work for new engineers, and (2) further understanding the knowledge, skills, and attitude which relate to the engineering workplace. To achieve these aims, it asks: "What capabilities enable successful transition to professional work for an engineering graduate?" Three components—capabilities, the nature of professional work, and what it means to be an engineer—comprise the investigative question. To answer this question, engineering representatives and recent engineering graduates rated a selection of generic and discipline-specific skills for the degree to which they are provided by university and required for work. Study findings and their significance are discussed below.

# FINDINGS

## Capabilities

Overall, participant responses indicate similar views of the skills provided by university and required for engineering work. This parity contrasts with studies that find sizeable differences in employer and graduate expectations of work life (Baytiyeh & Naja, 2012; Nadelson, McGuire, Davis, Farid, & Hardy, 2015; Reid et al., 2011; Stevens et al., 2014). For general skills, employers emphasise foundational knowledge, the ability to apply knowledge in practice, problem-solving, and working as part of a team. Graduates also emphasise the generic capabilities of problem-solving and teamwork. For specific skills, employers prioritise discipline-related knowledge, and skills in collaboration, information analysis and synthesis, technical capability, and knowledge of engineering practice, while graduates highlight navigating the workplace, and the development of a professional identity. Their top rated 'Planning and time management', 'Decision making', 'Teamwork', and 'Capacity to learn' underline the need to translate these abstract skills to the environment of work.

Graduate responses reflect a focus on knowledge acquisition. This suggests they have not yet adopted the discourse of the workplace and their profession (Wood & Solomonides, 2008). Sfard (1998) proposes that two metaphors describe learning: "The *acquisition metaphor* sees learning as a process of knowledge acquisition, while the *participation metaphor* emphasises that learning takes place by participating in the practices of social communities". Study results substantiate this viewpoint. Where questionnaire items are semantically comparable, engineering professionals emphasise knowledge application, and the skills that underpin interdisciplinary work, while graduates point to socialisation and professional integration. For example, 'Planning and time management' (graduates, 93%) and 'Capacity for analysis and synthesis' (employers, 88%) indicate different expectations of similar skills. Likewise, from discussion with professional engineers in supervisory roles across industry, consulting, and government, Katz (1993) observes that challenges graduate engineers face transitioning to the workplace include lack of industry knowledge, difficulty in practical application of engineering knowledge, and lack of general knowledge of how engineering as a discipline operates in practice.

The similar views of employers and graduates, and the ‘proximal differences’ in how comparable skills are interpreted and rated, indicates there may be latent factors that contribute to these views. Exploratory factor analysis was selected as the analytical methodology best suited to surfacing this possibility. Factor analysis confirms the contextual or situational nature of capability. Findings from this analysis indicate that: (1) negative factor loading signify mismatch in capacity in relation to its need at various stages in the work lifespan, (2) there is mutuality and ‘division of labour’ between higher education and workplaces in provision and application of skills. Figure 4.10 illustrates this relationship.

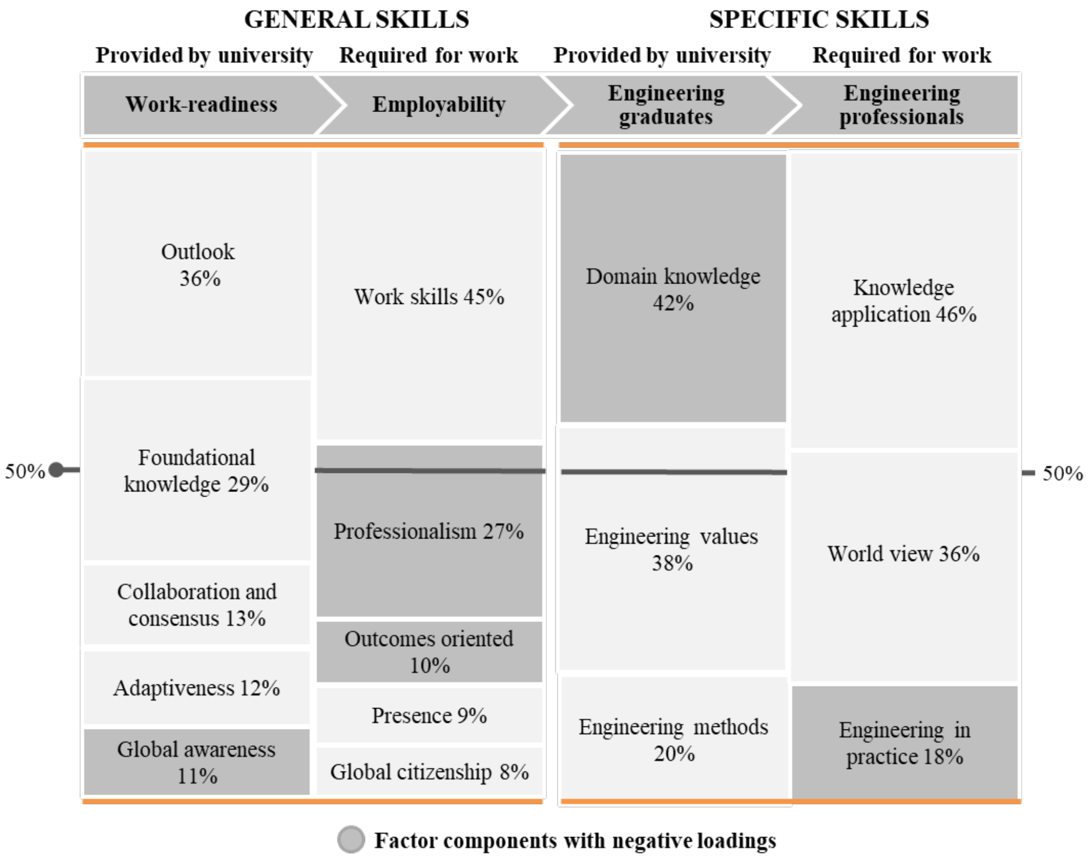



**Figure 8.1 Skills across the work lifespan**

Significantly, these findings demonstrate the interrelation of acquisition and participation across the stages of work-readiness, employability, the skills of engineering graduates, and the skills required for engineering practice. Analysis thus reinforces that educational institutions and employing organisations are knowledge and learning partners, with complementary roles, and who co-create successful transition to work experiences for new career engineers.

Analysis also illustrates a transformational process extending beyond entry to the workplace, and across the work lifespan. There is an additive quality to how skills are applied and transformed in the context of work. Work-oriented constructs suggest “enrichment” through experience and practical knowledge application. The transferrable skills which contribute to this transformation include working in interdisciplinary teams, collaboration and consensus, problem-solving, and the intercultural capabilities of second languages and global awareness. The discipline-specific skills which contribute to this transformation relate to application of domain knowledge and extending this knowledge in practice through innovation and knowledge renewal. These results affirm the social and situated nature of knowing and that peers, colleagues, and interdisciplinary influences contribute to knowledge creation. Collaborative work and reflective activities are catalysts for this change.

## Professional work

Study findings indicate there are three key aspects of an engineering professional. These dimensions encompass a range of skills, behaviours, and knowledge areas. They align to established ‘head, heart, habit’ metaphors or ‘knowledge, skills, attitude’ (KSA) domains such as in Bloom’s taxonomy (1956). These knowledge domains originate in Aristotle’s three types of knowledge: *episteme* (to know), *techné* (craftsmanship, practice), *phronesis* (practical wisdom, values). Professional practices, character, and engineering skills constitute the ‘engineering professional persona’. Figure 7.1 illustrates, with approximate 60:20:20 weightings.

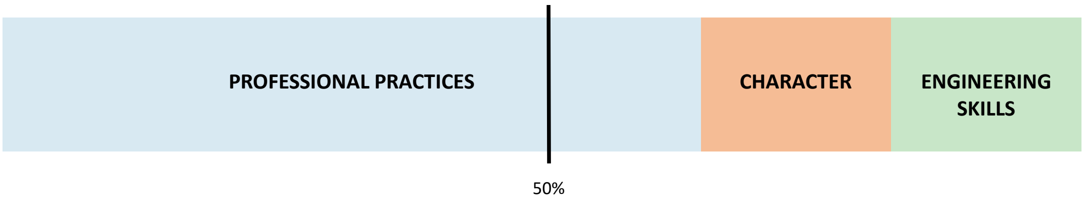



**Figure 8.2 Dimensions of an engineering professional**

This emphasises that engineering prioritises practical knowledge application and equally weights an engineering ethos or disciplinary set of values with technical and scientific skills. By way of corroboration, Jonassen, Strobel, and Lee (2006) and Crawley, Malmqvist, Östlund, Brodeur, and Edström (2014) point out that professional engineers rarely recommend more engineering subjects as preparation for engineering practice.

Instead they highlight the importance of developing practical and interpersonal skills, leadership and decision-making, and skills in applied creativity or innovation.

### Engineering graduates

The question: "What capabilities enable successful transition to professional work for an engineering graduate?" anchors inquiry in the skills and knowledge forms required by engineering graduates in transition to professional work. Analysis of survey results confirms that tertiary study adequately prepares students to commence a career in engineering. Findings also confirm Wood and Kaczynski (2007), who observe that higher education fulfils the dual role of developing generic, transferrable capabilities that enhance employment opportunities and of providing preparation for specific disciplines, including their intellectual, philosophical, and methodological foundations. To provide this grounding, engineering education increasingly adopts practice-related influences and learning methods. These include Problem/Project Based Learning (PBL) and CDIO (Conceive, Design, Implement, Operate). Problem-based learning presents students with authentic, loosely structured problems to solve, and guides them through the problem-solving process. Project-based learning engages activities that investigate and respond to an authentic and complex question, problem, or challenge. CDIO uses the engineering project delivery lifecycle as the context for learning activities and as a delivery framework. Study findings affirm the transformational nature of these experiential approaches and their role in facilitating transition to work. Findings further identify the significant role of socialisation and the work group in this transformational process from engineering graduate to novice engineer.

## Opportunities for Further Research

### Texts of engineering practice

Problem/Project Based Learning (PBL) and the Conceive, Design, Implement, Operate (CDIO) initiative are examples of delivering engineering curricular content in a practice environment, including activities and modes of inquiry that relate to engineering work. Other 'texts' relate to how decisions are made, and the more transactional processes of operating across discipline boundaries. These texts consist of know-what, know-why, know-how, know-who knowledge forms. Findings from this investigation suggest that professional learning connects a 'body of knowledge' or curriculum with 'knowledgeability' or social and experience-based discipline knowledge, and that these knowledge forms could play a more central role in the design of transition to work learning experiences.

## Relationship between problem-solving and decision making

Chapter three asks: “How can workplace programs assist novice engineers to develop their capacity to exercise professional judgment?” Increasing attention towards aligning risk, professional judgment and the decision-making process in infrastructure projects (Flyvbjerg, Landman, & Schram, 2012; Flyvbjerg, Skamris Holm, & Buhl, 2004) Judgment is the ability to make sound decisions and to recognise the consequences of decisions taken or actions performed. Problem-solving is the process of defining or selecting an appropriate course of action where alternative strategies are available (ROTC, 2009). While this study adopts a scaffolding approach to developing the professional capability of problem-solving and judgments through deliberative reflective, or critical reconstruction of practice, its investigation into judgment does not accommodate the emerging research genre of decision science. This includes developments in fast and frugal heuristics, and naturalistic decision-making. Fast and frugal are task-specific decision-making strategies that support judgments and decision tasks Gigerenzer and Todd (1999); naturalistic decision-making explores how people make decision in ambiguous, real-world situations (Klein, 2008). These areas of inquiry derive from reflection grounded in practice and represent authentic means to foster the ‘wise judgments’ required at all stages of an engineering career.

## Approaches that promote co-production of transition to work learning experiences.

Wood and Solomonides (2008) note that a range of factors, including: academic and discipline-specific discourse, identifying as a student or engineer, the structured learning of formal education versus the self-directed and incidental learning of work, and theoretical versus context-based, knowledge application differentiate university and work knowledge areas. These present both risk and opportunity in the pathway to employment. Risks can be mitigated at tertiary level by activities specific to transition, and at the organisational level by onboarding and induction programs. The further opportunity is for universities and employing organisations to evolve learning design models which accommodate lifewide learning and aspects of both scholarship and practice.

# CONCLUSION

Gherardi's (2001) "practice turn," has prompted much research focus into professions and professionalism. It underpins innovation in university engineering education, and focuses on the discourses, situational capabilities, and experiential learning in the workplace. For Gherardi (2001), this emphasis on practice provides for new interpretations and forms of work, practice, student, and professional to emerge. Similarly, Reid et al. (2011) observe that we have yet to find transition to work models that sit comfortably between academia and practice, and which bring together the theoretical and practical aspects of discipline knowledge. This study contributes to this body of inquiry. The study focuses on (1) identifying areas where workplace programs can constructively impact the transition to work for new engineers, and (2) further understanding the knowledge, skills, and attitude which relate to the engineering workplace. This study contributes to the transition to work research field and strengthens the argument for developing models of 'learning experience co-production'. It explores issues and implications of what it means to be between student-professional and university-work, and how learning models of collaboration and co-production can assist the transition from university to professional work. Study findings affirm the interdependence of universities and workplaces to engendering the forces, ideas, inspirations, and empowering authentic situations to which new engineers are exposed.

# REFERENCES

Anderson, L. W., & Krathwohl, D. R. (Eds.). (2001). *A taxonomy for learning, teaching, and assessing: A revision of Bloom's Taxonomy of Educational Objectives*. Boston, MA: Allyn & Bacon (Pearson Education Group)

Baytiyeh, H., & Naja, M. (2012). Identifying the challenging factors in the transition from colleges of engineering to employment. *European Journal of Engineering Education, 37*(1), 3-14.

Bloom, B. S., Engelhart, M. D., Furst, E. J., Hill, W. H., & Krathwohl, D. R. (1956). *Taxonomy of educational objectives*. N.Y.: Longmans, Green.

Crawley, E. F., Malmqvist, J., Östlund, S., Brodeur, D. R., & Edström, K. (2014). *Rethinking engineering education: The CDIO approach* (2nd ed.). Heidelberg, Germany: Springer.

Flyvbjerg, B., Landman, T., & Schram, S. (2012). *Real social science: Applied phronesis*. New York, NY: Cambridge University Press.

Flyvbjerg, B., Skamris Holm, M. K., & Buhl, S. L. (2004). What causes cost overrun in transport infrastructure projects? *Transport Reviews, 24*(1), 3-18. doi:10.1080/0144164032000080494a

Gherardi, S. (2001). From organizational learning to practice-based knowing. *Human relations, 54*(1), 131-139.

Gigerenzer, G., & Todd, P. M. (1999). Fast and frugal heuristics: The adaptive toolbox. In *Simple heuristics that make us smart* (pp. 3-34). Oxford, UK: Oxford University Press.

Jonassen, D. H., Strobel, J., & Lee, C. B. (2006). Everyday problem solving in engineering: Lessons for engineering educators. *Journal of Engineering Education, 95*(2), 139-151. doi:10.1002/j.2168-9830.2006.tb00885.x

Katz, S. M. (1993). The entry-level engineer: Problems in transition from student to professional. *Journal of Engineering Education, 82*(3), 171-174.

Klein, G. (2008). Naturalistic decision making. *Human Factors: The Journal of the Human Factors and Ergonomics Society, 50*(3), 456-460. doi:10.1518/001872008x288385

Nadelson, L. S., McGuire, S. P., Davis, K. A., Farid, A., & Hardy, K. K. (2015). Am I a STEM professional? Documenting STEM student professional identity development. *Studies in Higher Education*, 1-20. doi:10.1080/03075079.2015.1070819

Reid, A., Abrandt Dahlgren, M., Dahlgren, L. O., & Petocz, P. (2011). *From expert student to novice professional* (Vol. 99). The Netherlands: Springer.

ROTC. (2009). *Lesson 3: Decision-making and problem-solving*. Reserve Officer Training Corps (ROTC). Retrieved from http://www.au.af.mil/au/awc/awcgate/army/rotc_dm_ps.pdf

Sfard, A. (1998). On two metaphors for learning and the dangers of choosing just one. *Educational Researcher*, *27*(2), 4-13.

Stevens, R., Johri, A., & O'Connor, K. (2014). Professional engineering work. In A. Johri & B. M. Olds (Eds.), *Cambridge Handbook of Engineering Education Research:* (pp. 119-138). Cambridge, UK: Cambridge University Press.

Wood, L., & Kaczynski, D. (2007). University students in USA and Australia: Anticipation and reflection on the transition to work. *International Journal of Employment Studies, 15*(2), 91.

Wood, L., & Solomonides, I. (2008). Different disciplines, different transitions. *Mathematics Education Research Journal, 20*(2), 117-134.

# 9 FULL REFERENCE LIST


70:20:10 Forum. (2011). The 70:20:10 framework. Retrieved from https://www.702010forum.com/about-702010-framework

Alberts, C. J., & McIntire, D. (2014). *A Systematic approach for assessing workforce readiness*. Technical Report. CERT Division. Carnegie Mellon University. Software Engineering Institute.

Alexander, P. A. (2003). The development of expertise: The journey from acclimation to proficiency. *Educational Researcher, 32*(8), 10-14.

Ambrose, S. A., Bridges, M. W., DiPietro, M., Lovett, M. C., & Norman, M. K. (2010). *How learning works: Seven research-based principles for smart teaching*. San Francisco, CA: John Wiley & Sons.

Anderson, L. W., & Krathwohl, D. R. (Eds.). (2001). *A taxonomy for learning, teaching, and assessing: A revision of Bloom's Taxonomy of Educational Objectives*. Boston, MA: Allyn & Bacon (Pearson Education Group)

Arizona State University. (2014). Enrollment trends in stem disciplines—metropolitan campuses. *ASU Facts.* Retrieved from https://facts.asu.edu/Pages/Enrollments/STEM-Enrollment-Trends-by-Discipline.aspx

Arlin, P. K. (1990). Wisdom: The art of problem finding. In R. J. Sternberg (Ed.), *Wisdom: Its nature, origins, and development* (pp. 230-243). Cambridge: Cambridge University Press.

Aron, A., & Aron, E. N. (2003). *Statistics for psychology* (3rd ed.). Upper Saddle River, NJ, US: Prentice Hall/Pearson Education.

Arup. (2017). Graduate program. Retrieved from https://www.arup.com/careers/graduates-and-interns/australasia/graduate-program

ASCE. (2008). *Civil engineering body of knowledge for the 21st century: Preparing the civil engineer for the future*. Retrieved from http://www.asce.org/uploadedFiles/Education_and_Careers/Body_of_Knowledge/Content_Pieces/body-of-knowledge.pdf

AusIMM. (2017). *Graduate program best practice guidelines*. Australasian Institute of Mining and Metallurgy. Carlton, Victoria Australia. Retrieved from http://www.ausimm.com.au/content/docs/ausimm_graduate_guidelines.pdf

Bariletti, M. (2015). *What's the new employee onboarding at Google like?* Retrieved from https://www.quora.com/What%E2%80%99s-the-new-employee-onboarding-at-Google-like

Barnett, R., & Coate, K. (2005). *Engaging the curriculum in higher education*. London, UK: McGraw-Hill.

Bassett, C. L. (2011). Understanding and teaching practical wisdom. *New Directions for Adult and Continuing Education, 2011*(131), 35-44. doi:10.1002/ace.419

Baytiyeh, H., & Naja, M. (2012). Identifying the challenging factors in the transition from colleges of engineering to employment. *European Journal of Engineering Education, 37*(1), 3-14.

Beckett, D. (1996). Critical judgment and professional practice. *Educational Theory, 46*(2), 135-149.

Beckett, D. (2008). Holistic competence: Putting judgements first. *Asia Pacific Education Review, 9*(1), 21-30.

Bell, D. (1976). The coming of the post-industrial society. *The Educational Forum, 40*(4), 574-579.

Bendesa, I. (1992). Komang Gde. 1992, The structural change of employment, and education in Indonesia. *Indonesian Quarterly, 20*(4), 447-460.

Benham-Hutchins, M., & Clancy, T. R. (2010). Social networks as embedded complex adaptive systems. *Journal of Nursing Administration, 40*(9), 352-356.

Bennett, N., Dunne, E., & Carré, C. (2000). *Skills development in higher education and employment*. Buckingham, UK: Society for Research into Higher Education & Open University Press.

Bereiter, C. (2014). Principled practical knowledge: Not a bridge but a ladder. *Journal of the Learning Sciences, 23*(1), 4-17. doi:10.1080/10508406.2013.812533

Bereiter, C., & Scardamalia, M. (1993). *Surpassing ourselves: An inquiry into the nature and implications of expertise*. Chicago: Open Court.

Best, A., & Holmes, B. (2010). Systems thinking, knowledge and action: Towards better models and methods. *Evidence & Policy: A Journal of Research, Debate and Practice, 6*(2), 145-159.

Biggs, J. B., & Tang, C. (2011). *Teaching for quality learning at university* (4th ed.). Maidenhead, Berkshire, UK: Open University Press, McGraw-Hill Education.

Bloom, B. S., Engelhart, M. D., Furst, E. J., Hill, W. H., & Krathwohl, D. R. (1956). *Taxonomy of educational objectives*. N.Y.: Longmans, Green.

Boshuizen, H., Bromme, R., & Gruber, H. (2004). On the long way from novice to expert and how travelling changes the traveller. In H. Boshuizen, R. Bromme, & H. Gruber (Eds.), *Professional Learning: Gaps and Transitions on the Way from Novice to Expert* (Vol. 2, pp. 3-8). Dordrecht, The Netherlands: Kluwer Academic Publishers.

Boud, D., Keogh, R., & Walker, D. (1985). *Reflection: Turning experience into learning*. Oxford, UK: Routledge.

Bransford, J. (2007). Preparing people for rapidly changing environments. *Journal of Engineering Education, 96*(1), 1-3.

Bridges, W. (2003). *Managing transitions: Making the most of change* (2nd ed.). Cambridge, MA: Da Capo Press.

Brookfield, S. (1986). *Understanding and facilitating adult learning: A comprehensive analysis of principles and effective practices*. Milton Keynes, UK: Open University Press.

Candy, P. C., & Crebert, R. G. (1991). Ivory tower to concrete jungle: The difficult transition from the academy to the workplace as learning environments. *The Journal of Higher Education, 62*(5), 570-592. doi:10.2307/1982209

Carvalho, J. (2008). *International aspects of Bologna: The Tuning Project*. Paper presented at the BALANCE – Bologna: A long-term approach to new certification in Europe, University of Turku, Finland. http://www.coimbra-group.eu/balance/Docs/turku/International%20Aspect%20of%20Bologna%20Process%20-Tuning.ppt.

CASEL. (2017). What is SEL? Retrieved from http://www.casel.org/what-is-sel/

CDIO. (2004). CDIO (Conceive, Design, Implement, Operate) Initiative. Retrieved from http://www.cdio.org/

Charan, R. (2015). *The attacker's advantage: Turning uncertainty into breakthrough opportunities*. New York: Public Affairs.

Clayton, V. P., & Birren, J. E. (1980). The development of wisdom across the life span: A re-examination of an ancient topic. *Lifespan Development and Behavior, 3,* 103-135.

Coles, C. (2002). Developing professional judgment. *Journal of Continuing Education in the Health Professions, 22*(1), 3-10. doi:10.1002/chp.1340220102

Confederation of British Industry (CBI). (2012). *First Steps: A new approach for our schools*. Confederation of British Industry (CBI). London. Retrieved from http://www.cbi.org.uk/insight-and-analysis/first-steps/

Crawley, E. F., C., J., Malmqvist, J., & Brodeur, D. R. (2008). *The context in engineering education*. Paper presented at the 4th International CDIO Conference, Hogeschool Gent, Gent, Belgium, . http://www.cdio.org/files/document/file/m1-crawley2008.pdf

Crawley, E. F., Malmqvist, J., Östlund, S., Brodeur, D. R., & Edström, K. (2014). *Rethinking engineering education: The CDIO approach* (2nd ed.). Heidelberg, Germany: Springer.

Cropp, N., Banks, A., & Elghali, L. (2011). Expert decision making in a complex engineering environment: A comparison of the lens model, explanatory coherence, and matching heuristics. *Journal of Cognitive Engineering and Decision Making, 5*(3), 255-276. doi:10.1177/1555343411415795

Day, D. V. (2010). The difficulties of learning from experience and the need for deliberate practice. *Industrial and Organizational Psychology, 3*(1), 41-44. doi:10.1111/j.1754-9434.2009.01195.x

Dean, B. A. (2015). *Learning on placement: A sociomaterial, practice-based approach to work-integrated learning.* (PhD), University of Wollongong, Wollongong. Retrieved from http://ro.uow.edu.au/theses/4361/

Deepwell, M. (2017). #CMALT 1 year on: #edtech reflection & professional practice. Retrieved from http://marendeepwell.com/cpd/cmalt-1-year-on-edtech-reflection-professional-practice/

Department of Education and Training. (2010). *The Bologna Process*. DET. Retrieved from https://internationaleducation.gov.au/About-AEI/Government-Relations/Pages/TheBolognaProcess.aspx

Dixon, N. M. (2000). *Common knowledge: How companies thrive by sharing what they know*: Harvard Business School Press.

Dreyfus, S. E., & Dreyfus, H. L. (1980). *A five-stage model of the mental activities involved in directed skill acquisition*. Monograph. Operations Research Center. California University Berkeley. Retrieved from http://www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA084551&Location=U2&doc=GetTRDoc.pdf

Duckworth, A. L., Peterson, C., Matthews, M. D., & Kelly, D. R. (2007). Grit: Perseverance and passion for long-term goals. *Journal of Personality and Social Psychology, 92*(6), 1087.

Dweck, C. S. (2006). *Mindset: The new psychology of success* (1st ed.). New York: Random House.

Dye, V. (2011). Reflection, Reflection, Reflection. I'm thinking all the time, why do I need a theory or model of reflection? In D. McGregor & L. Cartwright (Eds.), *Developing reflective practice: A guide for beginning teachers*. Maidenhead, Berkshire, UK: Open University Press, McGraw-Hill Education.

Edgerton, R. (2001). *Education white paper*. Report prepared for the Pew Charitable Trusts, Pew Forum on Undergraduate Learning. Washington, DC.

Edvardsson Stiwne, E., & Jungert, T. (2007). *Engineering students experiences of the transition from study to work*. Paper presented at the 3rd International CDIO Conference in Massachusetts Institute of Technology, Cambridge, Massachusetts.

EHEA. (2016). European Higher Education Area and Bologna Process. Retrieved from http://www.ehea.info/

Eraut, M. (2004). Informal learning in the workplace. *Studies in Continuing Education, 26*(2), 247-273. doi:10.1080/158037042000225245

Eraut, M. (2005). Expert and expertise: Meanings and perspectives. *Learning in Health and Social Care, 4*(4), 173-179. doi:10.1111/j.1473-6861.2005.00102.x

Eraut, M. (2007). Learning from other people in the workplace. *Oxford Review of Education, 33*(4), 403-422.

Eraut, M. (2009). Transfer of knowledge between education and workplace settings. In H. Daniels, H. Lauder, & J. Porter (Eds.), *Knowledge, values and educational policy: A critical perspective* (pp. 65-84). Abingdon, Oxon, UK: Routledge.

Exon. (2017). *BEng Civil Engineering Site Management*. Engineering. University of Exeter. Retrieved from http://www.exeter.ac.uk/undergraduate/degrees/engineering/civil-engineering/

Fairhurst, G. T., & Cooren, F. (2009). Leadership as the hybrid production of presence (s). *Leadership, 5*(4), 469-490.

Faulkner, W. (2007). `Nuts and bolts and people'. *Social Studies of Science, 37*(3), 331-356. doi:10.1177/0306312706072175

Felder, R. M., & Hadgraft, R. G. (2013). Educational practice and educational research in engineering: Partners, antagonists, or ships passing in the night? *Journal of Engineering Education, 102*(3), 339-345.

Feldman, M. S., & Orlikowski, W. J. (2011). Theorizing practice and practicing theory. *Organization Science, 22*(2011), 1240-1253.

Fenwick, T. (2012a). Co-production in professional practice: a sociomaterial analysis. *Professions and Professionalism, 2*(2), 1-16.

Fenwick, T. (2012b). Matterings of knowing and doing: Sociomaterial approaches to understanding practice. In P. Hager, A. Lee, & A. Reich (Eds.), *Practice, learning and change: Practice-theory perspectives on professional learning* (pp. 67-83). Dordrecht: Springer Netherlands.

Fenwick, T., Nerland, M., & Jensen, K. (2012). Sociomaterial approaches to conceptualising professional learning and practice. *Journal of Education and Work, 25*(1), 1-13. doi:10.1080/13639080.2012.644901

Filliettaz, L. (2011). Collective guidance at work: A resource for apprentices? *Journal of Vocational Education & Training, 63*(3), 485-504. doi:10.1080/13636820.2011.580359

Fink, L. D. (2003). *Creating significant learning experiences: An integrated approach to designing college courses*. San Francisco: Jossey-Bass.

Finkel, A., & King, R. (2013). *Innovative approaches to engineering education*. Paper presented at the CAETS, International Council of Academies of Engineering and Technological Sciences, Budapest, Hungary.

Fish, D., & Coles, C. (2005). *Medical education: Developing a curriculum for practice*. Maidenhead, Berkshire, UK: Open University Press, McGraw-Hill Education.

Flyvbjerg, B., Landman, T., & Schram, S. (2012). *Real social science: Applied phronesis*. New York, NY: Cambridge University Press.

Flyvbjerg, B., Skamris Holm, M. K., & Buhl, S. L. (2004). What causes cost overrun in transport infrastructure projects? *Transport Reviews*, *24*(1), 3-18. doi:10.1080/0144164032000080494a

Fricker Jr, R. D., Appleget, J. A., & Kulzy, W. W. (2012). From data to information: Using factor analysis with survey data. *Phalanx*, *29*(4), 30-34.

Fuller, A., & Unwin, L. (2004). Expansive learning environments: Integrating organisational and personal development. In A. Fuller, H. Rainbird, & A. Munro (Eds.), *Workplace learning in context* (pp. 126-144). London, UK: Routledge.

Gates, A., & Higgs, J. (2013). Realising wise practitioners. In J. Higgs, D. Sheehan, J. Currens, W. Letts, & G. Jensen (Eds.), *Realising exemplary practice-based education* (Vol. 7, pp. 43-56). Rotterdam, The Netherlands: Sense Publishers.

Gherardi, S. (2001). From organizational learning to practice-based knowing. *Human relations, 54*(1), 131-139.

Ghoshal, S. (1997). The individualized corporation: An interview with Sumantra Ghoshal. *European Management Journal*, *15*(6), 625-632. doi:http://dx.doi.org/10.1016/S0263-2373(97)00046-7

Gibbons, M., Limoges, C., Nowotny, H., Schwartzman, S., Scott, P., & Trow, M. (1994). *The new production of knowledge: The dynamics of science and research in contemporary societies*. London, UK: Sage Publications Limited.

Gibbs, G. (1998, 2013). *Learning by doing: A guide to teaching and learning methods*. Oxford Brookes University, UK: Oxford Centre for Staff and Learning Development.

Gigerenzer, G., & Todd, P. M. (1999). Fast and frugal heuristics: The adaptive toolbox. In *Simple heuristics that make us smart* (pp. 3-34). Oxford, UK: Oxford University Press.

Goldberg, D. E. (2010). The missing basics and other philosophical reflections for the transformation of engineering education. In D. Grasso & M. Burkins (Eds.), *Holistic engineering education* (pp. 145-158). New York, NY: Springer New York.

Gonzélez, J., & Wagenaar, R. (2003). *Tuning educational structures in Europe. Final report. Phase one*. Universidad de Deusto: Deusto. Retrieved from http://www.bolognakg.net/doc/Tuning_phase1_full_document.pdf

Gordon, B. M. (1984). *What is an engineer? Invited keynote presentation.* Paper presented at the European Society for Engineering Education (SEFI) Annual Conference, Nürnberg, Germany.

Grasso, D., & Burkins, M. B. (Eds.). (2010). *Holistic engineering education: Beyond technology*. New York, NY: Springer.

Greeno, J. G., Collins, A. M., & Resnick, L. B. (1996). Cognition and learning: Handbook of educational psychology. In (pp. 15-46). New York, NY: Simon & Shuster, MacMillan.

Guille, J., Abraham, N., & Patel, U. (2010). *Designing an educational experience of relevance to real world situations*. Northumbria Research Link. Northumbria University. Newcastle, UK. Retrieved from http://nrl.northumbria.ac.uk/id/eprint/9837

Hager, P. (1998). Understanding workplace learning: General perspectives. In D. Boud (Ed.), *Current issues and new agendas in workplace learning* (pp. 31-46). Springfield, VA: NCVER.

Harrison, A. (1995). The selection and development of Indonesian graduates in an industry training program. *Asia Pacific Journal of Human Resources, 32*(3), 114-123. doi:10.1177/103841119503200309

Hart Research Associates. (2015). *Falling short? College learning and career success*. Selected Findings from Online Surveys of Employers and College Students Conducted on Behalf of the Association of American Colleges & Universities. Washington DC. Retrieved from http://www.aacu.org/sites/default/files/files/LEAP/2015employerstudentsurvey.pdf

Hays, J., & Clements, M. (2012, 20-22 June, 2102). *Transition-bridging the gap between study and work.* Paper presented at the Proceedings of the 9th International Conference on Cooperative & Work-Integrated Education, Where East meets West and Theory meets Practice, Istanbul, Turkey.

Hermans, J., & Castiaux, A. (2017). Contingent knowledge transfers in university–industry R&D projects. *Knowledge Management Research & Practice,* 1-10.

Hettich, P. (2007). *College to workplace issues and strategies: A primer*. Paper presented at the 14th National Conference on Students in Transition, Cincinnati, OH.

Hettich, P. (2010). College-to-workplace transitions: Becoming a freshman again. In W. T. Miller (Ed.), *Handbook of stressful transitions across the lifespan* (pp. 87-109). New York, NY: Springer New York.

Hinett, K. (2002). *Improving learning through reflection–part one*. The Higher Education Academy. Retrieved from http://jisctechdis.ac.uk/assets/documents/resources/database/id485_improving_learning_part_one.pdf

Hoffman, R. R., Shadbolt, N. R., Burton, A. M., & Klein, G. (1995). Eliciting knowledge from experts: A methodological analysis. *Organizational Behavior and Human Decision Processes, 62*(2), 129-158.

Hoffmann, B., Jørgensen, U., & Christensen, H. P. (2011). *Culture in engineering education: CDIO framing intercultural competences.* Paper presented at the 7th International CDIO Conference 20-22 June, Technical University of Denmark, Copenhagen.

Holton, E. F., & Naquin, S. S. (2001). *How to succeed in your first job: Tips for new college graduates*. San Francisco, CA: Berrett-Koehler Publishers.

Ibarra, H. (1999). Provisional selves: Experimenting with image and identity in professional adaptation. *Administrative Science Quarterly, 44*(4), 764-791.

Institution of Civil Engineers. (2011). *Competency framework for professional development*. Institution of Civil Engineers (ICE). Westminster, London. Retrieved from http://www.gedcouncil.org/sites/default/files/ICE-Competency-Framework.pdf

Institution of Civil Engineers. (2015). *Institution of Civil Engineers Skills Report 2015. Perspectives on capability and capacity: key risks and opportunities*. Institution of Civil Engineers (ICE). London. Retrieved from http://www.ice-conferences.com/ice_events/media/general/ice-skills-report-2015-.pdf

Investors in People. (2013). Grow your own: Young people, talent development and improved performance. Retrieved from https://www.investorsinpeople.com/sites/default/files/Grow%20Your%20Own%20Talent%202016_1.pdf

Jaschik, S. (2014). Study finds increased STEM enrollments since the recession. *Inside Higher Ed.* Retrieved from https://www.insidehighered.com/news/2014/04/07/study-finds-increased-stem-enrollment-recession

Johnson, B., Lorenz, E., & Lundvall, B. (2002). Why all this fuss about codified and tacit knowledge? *Industrial and Corporate Change, 11*(2), 245-262.

Johnson, H., Watson, P. A., Delahunty, T., McSwiggen, P., & Smith, T. (2011). What it is they do? Differentiating knowledge and literacy practices across content disciplines. *Journal of Adolescent & Adult Literacy, 55*(2), 100-109.

Johri, A. (2010). Open organizing: Designing sustainable work practices for the engineering workforce. *International Journal of Engineering Education, 26*(2), 278.

Johri, A. (2012). Learning to demo: The sociomateriality of newcomer participation in engineering research practices. *Engineering Studies, 4*(3), 249-269.

Jonassen, D. H., Strobel, J., & Lee, C. B. (2006). Everyday problem solving in engineering: Lessons for engineering educators. *Journal of Engineering Education, 95*(2), 139-151. doi:10.1002/j.2168-9830.2006.tb00885.x

Kajewski, K., & Madsen, V. (2012). Demystifying 70:20:10 White Paper. Retrieved from http://deakinprime.com/media/47821/002978_dpw_70-20-10wp_v01_fa.pdf

Kamstrup, A. K. (2016). CDIO Enacted: Tracing the multiplicity of an initiative in engineering education. In U. Jørgensen & S. Brodersen (Eds.), *Engineering professionalism: Engineering practices in work and education* (pp. 105-123). Rotterdam: SensePublishers.

Katz, S. M. (1993). The entry-level engineer: Problems in transition from student to professional. *Journal of Engineering Education, 82*(3), 171-174.

Kilpi, E. (2016). Perspectives on new work: Exploring emerging conceptualizations. *Sitra Studies 114.* Retrieved from http://www.sitra.fi/en/julkaisu/2016/perspectives-new-work

Klein, G. (2008). Naturalistic decision making. *Human Factors: The Journal of the Human Factors and Ergonomics Society, 50*(3), 456-460. doi:10.1518/001872008x288385

Knorr-Cetina, K. (1999). *Epistemic cultures: How the sciences make knowledge*. Harvard: Harvard University Press.

Kogut, B., & Zander, U. (1996). What firms do? Coordination, identity, and learning. *Organization Science, 7*(5), 502-518.

Kolb, D. A. (1984). *Experiential learning: Experience as the source of learning and development* (Vol. 1). Englewood Cliffs, New Jersey, NJ: Prentice-Hall

Kolb, D. A., & Yeganeh, B. (2012). Deliberate experiential learning. *Contemporary Organizational Behavior in Action*.

Korte, R. (2013). The formulation of engineering identities: Storytelling as philosophical inquiry. In *Philosophy and Engineering: Reflections on Practice, Principles and Process* (pp. 39-50). The Netherlands: Springer.

Korte, R., Sheppard, S., & Jordan, W. (2008). *A qualitative study of the early work experiences of recent graduates in engineering*. Paper presented at the American Society for Engineering Education, June 22-26 2008, Pittsburgh, PA.

Kuhlmann, D. O., & Ardichvili, A. (2015). Becoming an Expert: Developing expertise in an applied discipline. *European Journal of Training and Development, 39*(4), 262-276. doi:doi:10.1108/EJTD-08-2014-0060

Lewin, K. (1947). Frontiers in group dynamics II. Channels of group life; social planning and action research. *Human relations, 1*(2), 143-153.

Lichtenstein, G., Loshbaugh, H. G., Claar, B., Chen, H. L., Jackson, K., & Sheppard, S. D. (2009). An engineering major does not (necessarily) an engineer make: Career decision making among undergraduate engineering majors. *Journal of Engineering Education, 98*(3), 227-234. doi:10.1002/j.2168-9830.2009.tb01021.x

Litzinger, T., Lattuca, L. R., Hadgraft, R., & Newstetter, W. (2011). Engineering education and the development of expertise. *Journal of Engineering Education*, *100*(1), 123-150.

Lucas, B., & Spencer, E. (2015). *Remaking apprenticeships: Powerful learning for work and life*. University of Winchester. Centre for Real-World Learning. Retrieved from http://www.winchester.ac.uk/aboutus/lifelonglearning/CentreforRealWorldLearning/Publications/Documents/Lucas%20and%20Spencer%20(2015)%20Remaking%20Apprenticeships.pdf

MacIntyre, A. (2007). *After virtue: A study in moral theory* (3rd ed. Vol. 99). Notre Dame, Indiana: University of Notre Dame Press.

Magolda Baxter, M. B. (1998). Developing self-authorship in young adult life. *Journal of College Student Development*, *39*(2), 143.

Magolda Baxter, M. B. (2004). Self-authorship as the common goal of 21st century education. In M. Magolda Baxter & P. M. King (Eds.), *Learning partnerships: Theory and models of practice to educate for self-authorship* (pp. 1-35). Sterling, Virginia: Stylus.

Manoliu, I. (2005). *First results of the Tuning Project with the participation of EUCEET and ECCE*. Paper presented at the 42nd ECCE meeting, Istanbul, Turkey. http://www.unideusto.org/tuningeu/images/stories/Summary_of_outcomes_TN/First_results_Civil_Engineering_PPT.ppt.

Mansilla, V. B., & Jackson, A. (2011). *Educating for global competence: Preparing our youth to engage the world*. New York, NY: Asia Society.

Matusovich, H., Streveler, R., Miller, R., & Olds, B. (2009). *I'm graduating this year! 'So what IS an engineer anyway?* Paper presented at the Proceedings - American Society of Engineering Education Annual Conference and Exposition, Austin, TX.

McCall, M. W. (2010). Recasting leadership development. *Industrial and Organizational Psychology, 3*(1), 3-19. doi:10.1111/j.1754-9434.2009.01189.x

McCauley, D. H. (2016). Rediscovering the art of strategic thinking. *National Defense University Press, Joint Force Quarterly 81 (JFQ)*(2nd Quarter, April 2016).

Meacham, J. A. (1990). The loss of wisdom. In R. J. Sternberg (Ed.), *Wisdom: Its nature, origins, and development* (pp. 181-211). Cambridge, UK: Cambridge University Press.

Melrose, S., Miller, J., Gordon, K., & Janzen, K. J. (2012). Becoming socialized into a new professional role: LPN to BN student nurses' experiences with legitimation. *Nursing Research and Practice, 2012*.

Mertler, C. A., & Vannatta, R. A. (2002). Advanced and multivariate statistical methods. *Los Angeles, CA: Pyrczak.*

Meyer, J. H. F., & Land, R. (2003). Threshold concepts and troublesome knowledge: Linkages to ways of thinking and practising within the disciplines. In C. Rust (Ed.), *Improving student learning: Theory and practice - Ten years on* (pp. 412-424). Oxford, UK: Centre for Staff and Learning Development.

Mezirow, J. (1981). A critical theory of adult learning and education. *Adult education, 32*(1), 3-24.

Miller, P. J., & Goodnow, J. J. (1995). Cultural practices: Toward an integration of culture and development. *New Directions for Child and Adolescent Development*, *1995*(67), 5-16.

Mukerji, C. (2009). *Impossible engineering: Ttechnology and territoriality on the Canal du Midi*. Princeton, NJ: Princeton University Press.

Nadelson, L. S., McGuire, S. P., Davis, K. A., Farid, A., & Hardy, K. K. (2015). Am I a STEM professional? Documenting STEM student professional identity development. *Studies in Higher Education*, 1-20. doi:10.1080/03075079.2015.1070819

Nonaka, I., & Takeuchi, H. (1995). *The knowledge-creating company : How Japanese companies create the dynamics of innovation*. New York: Oxford University Press.

O'Dell, C. S., & Trees, L. (2014). *How smart leaders leverage their experts*. Best Practices Report. American Productivity & Quality Center (APQC). Retrieved from https://www.apqc.org/knowledge-base/download/309016/K04979_How_Smart_Leaders_Leverage_Their_Experts.pdf

Orlikowski, W. J., & Scott, S. V. (2008). Sociomateriality: Challenging the separation of technology, work and organization. *The Academy of Management Annals, 2*(1), 433-474. doi:10.1080/19416520802211644

Osborne, J. W., & Costello, A. B. (2005). Best practices in exploratory factor analysis: Four recommendations for getting the most from your analysis. *Practical Assessment Research & Evaluation, 10*(7). Retrieved from http://pareonline.net/getvn.asp?v=10&n=7

Palmer, S., Tolson, M., Young, K., & Campbell, M. (2015). The relationship between engineering bachelor qualifications and occupational status in Australia. *Australasian Journal of Engineering Education, 20*(2), 103-112. doi:10.1080/22054952.2015.1092666

Passow, H. J., & Passow, C. H. (2017). What competencies should undergraduate engineering programs emphasize? A systematic review. *Journal of Engineering Education, 106*(3), 475-526. doi:10.1002/jee.20171

Perkins, D. N., & Salomon, G. (2012). Knowledge to go: A motivational and dispositional view of transfer. *Educational Psychologist, 47*(3), 248-258. doi:10.1080/00461520.2012.693354

Perry, W. G., Jr. (1970). *Forms of intellectual and ethical development in the college years: A scheme*. New York: Holt, Rinehart, and Winston.

Polach, J. L. (2004). Understanding the experience of college graduates during their first year of employment. *Human Resource Development Quarterly, 15*(1), 5-23. doi:10.1002/hrdq.1084

Polanyi, M. (1967). *The tacit dimension*. Garden City, N.Y.: Anchor Books.

Reid, A., Abrandt Dahlgren, M., Dahlgren, L. O., & Petocz, P. (2011). *From expert student to novice professional* (Vol. 99). The Netherlands: Springer.

Resnick, L. B. (1987). The 1987 Presidential Address: Learning in school and out. *Educational Researcher, 16*(9), 13-54.

RMS. (2017). *Road designer in training*. Employment Services. Roads and Maritme Services. Sydney, NSW, Australia. Retrieved from http://www.rms.nsw.gov.au/about/careers/working-with-us/employment-programs/road-designer-in-training.html

ROTC. (2009). *Lesson 3: Decision-making and problem-solving*. Reserve Officer Training Corps (ROTC). Retrieved from http://www.au.af.mil/au/awc/awcgate/army/rotc_dm_ps.pdf

Ryan, G. W., & Bernard, H. R. (2003). Techniques to identify themes. *Field Methods, 15*(1), 85-109.

Saito, A. (2007). *Educating knowledge managers: A competence-based approach.* (PhD), Japan Advanced Institute of Science and Technology (JAIST), Nomi, Japan. Retrieved from https://dspace.jaist.ac.jp/dspace/bitstream/10119/3739/2/121paper.pdf

Saito, K., Salazar, A. J., Kreafle, K. G., & Grulke, E. A. (2011). Hitozukuri and monozukuri: Centuries' old eastern philosophy to seek harmony with nature. *Interdisciplinary Information Sciences, 17*(1), 1-9.

Sauro, J. (2010). Top-box scoring of rating scale data. Retrieved from http://www.measuringu.com/blog/top-box.php

Sauro, J. (2011). How to interpret survey responses: 5 techniques. Retrieved from http://www.measuringu.com/blog/interpret-responses.php

Scanlon, L. (2011). ‘Becoming’ a professional. In L. Scanlon (Ed.), *"Becoming" a professional* (Vol. 16, pp. 13-32). The Netherlands: Springer.

Schmitt, N., & Stults, D. M. (1985). Factors defined by negatively keyed items: The result of careless respondents? *Applied Psychological Measurement, 9*(4), 367-373.

Schön, D. A. (1983). *The reflective practitioner: How professionals think in action*. New York, NY: Basic Books.

Sfard, A. (1998). On two metaphors for learning and the dangers of choosing just one. *Educational Researcher*, *27*(2), 4-13.

Shepherd, C. (2017). The changing skill set of the learning professional. Retrieved from http://clive-shepherd.blogspot.com.au/2017/02/the-changing-skill-set-of-learning.html

Sheppard, S., Macatangay, K., Colby, A., & Sullivan, W. M. (2009). *Educating engineers: Designing for the future of the field* (Vol. 9). San Francisco, CA: Jossey-Bass.

Smagorinsky, P. (2001). If meaning is constructed, what is it made from? Toward a cultural theory of reading. *Review of Educational Research, 71*(1), 133-169.

Steinaker, N., & Bell, M. (1979). *The experiential taxonomy: A new approach to teaching and learning*. New York, NY: Academic Press.

Sternberg, R. J. (1998). A balance theory of wisdom. *Review of General Psychology, 2*(4), 347.

Sternberg, R. J. (2001). Why schools should teach for wisdom: The balance theory of wisdom in educational settings. *Educational Psychologist, 36*(4), 227-245.

Stevens, R., Johri, A., & O’Connor, K. (2014). Professional engineering work. In A. Johri & B. M. Olds (Eds.), *Cambridge Handbook of Engineering Education Research:* (pp. 119-138). Cambridge, UK: Cambridge University Press.

Stevens, R., O'Connor, K., Garrison, L., Jocuns, A., & Amos, D. M. (2008). Becoming an engineer: Toward a three dimensional view of engineering learning. *Journal of Engineering Education, 97*(3), 355.

Su, A. J., & Wilkins, M. M. (2013). *Own the room: Discover your signature voice to master your leadership presence*. Boston, MA: Harvard Business Review Press.

Suchman, L. (2000). Embodied practices of engineering work. *Mind, Culture, and activity, 7*(1-2), 4-18.

Taylor, P., Millwater, J., & Nash, R. (2007). *Talking about transitions: The value of a conceptual approach.* Paper presented at the Proceedings of the 30 Annual HERDSA Conference, Enhancing Higher Education, Theory and Scholarship, Adelaide, Australia.

The City University of New York (CUNY). (2015). *Ten-year trend in enrolment in science, technology, engineering, and math (STEM) disciplines*. Retrieved from http://www.cuny.edu/about/administration/offices/ira/ir/data-book/current/stem-enrollment-degrees/STEM_enr_10yr_trends.pdf

The Jubilee Centre for Character and Virtues. (2012). *School of Education, University of Birmingham.* Retrieved from http://www.jubileecentre.ac.uk/

Torii, K., & O’Connell, M. (2017). *Preparing young people for the future of work*. Mitchell Institute. Melbourne. Retrieved from http://www.mitchellinstitute.org.au/reports/preparing-young-people-for-the-future-of-work/

Tough, A. (1971). *The adult's learning projects. A fresh approach to theory and practice in adult learning*. Toronto, Ontario: Institute for Studies in Education.

Trede, F., & McEwen, C. (2013). *Educating the deliberate professional* Occasional Paper 9. The Education For Practice Institute, Charles Sturt University. Sydney. Retrieved from https://www.csu.edu.au/__data/assets/pdf_file/0009/742482/EFPI_OP9_EducatingDP.pdf

Trevelyan, J. P. (2009a). *Engineering education requires a better model of engineering practice.* Paper presented at the Research in Engineering Education Symposium 2009, Palm Cove, QLD, Australia.

Trevelyan, J. P. (2009b). *Steps toward a better model of engineering practice.* Paper presented at the Research in Engineering Education Symposium, 2009, Palm Cove, QLD, Australia.

Trevelyan, J. P. (2010). Reconstructing engineering from practice. *Engineering Studies, 2*(3), 175-195.

Trevelyan, J. P. (2013). Towards a theoretical framework for engineering practice. *Engineering Practice in a Global Context: Understanding the Technical and the Social*, 33.

Trevelyan, J. P. (2014). *The making of an expert engineer*. Leiden, The Netherlands: CRC Press.

Tripp, D. (1993). *Critical incidents in teaching: Developing professional judgement*. Oxford, UK: Routledge.

Tuning. (2000). *Tuning educational structures in Europe*. Retrieved from http://www.unideusto.org/tuningeu/

Tynjälä, P. (2008). Perspectives into learning at the workplace. *Educational Research Review, 3*(2), 130-154. doi:http://dx.doi.org/10.1016/j.edurev.2007.12.001

UW‐Madison. (2014). *Trends in instructional activity in STEM disciplines at the University of Wisconsin‐Madison*. Retrieved from https://apir.wisc.edu/accountability/UWMadison_STEM_June202014.pdf

UWA. (2017, 7 July 2017). Professional practicum. *Faculty of engineering and mathematical sciences, University of Western Australia.* Retrieved from http://www.ecm.uwa.edu.au/students/professional-practicum

Van Maanen, J., & Schein, E. H. (1979). Toward a theory of organizational socialization. *Research in Organizational Behavior, 1*, 209-264.

Vest, C. M. (2007). *Educating engineers for 2020 and beyond*. National Academy of Engineering, Grand Challenges Blog. Retrieved from http://www.engineeringchallenges.org/14373/GrandChallengesBlog/7639.aspx

Vest, C. M. (2014). Forward: Educating engineers for 2020 and beyond. In E. F. Crawley, J. Malmqvist, S. Östlund, D. R. Brodeur, & K. Edström (Eds.), *Rethinking engineering education: The CDIO approach* (2nd ed.). Heidelberg, Germany: Springer.

Villachica, S. (2013). *When performance is fuzzy: The critical incident technique*. Paper presented at the International Society for Performance Improvement (ISPI) Conference 2014, Reno, Nevada.

Von Bertalanffy, L. (1968). *General system theory: Foundations, development, applications*. New York: George Brazillier.

Vygotsky, L. S. (1927). *The historical meaning of the crisis in psychology: A methodological investigation* (R. van der Veer, Trans. 1987 ed.). New York: Plenum.

Wenger-Trayner, E., Fenton-O'Creevy, M., Hutchinson, S., Kubiak, C., & Wenger-Trayner, B. (Eds.). (2014). *Learning in landscapes of practice: Boundaries, identity, and knowledgeability in practice-based learning*. Oxford: Routledge.

Wenger, E. (1998). *Communities of practice: Learning, meaning and identity*. Cambridge, UK: Cambridge University Press.

Winters, K., Matusovich, H., & Carrico, C. (2012). *So how did that go for you? Early career engineers' success in meeting goals set as undergraduate seniors*. Paper presented at the Proceedings – American Society of Engineering Education, Southeast Section, Starkville, MS.

Wong, J.-J., Chen, P.-Y., & Chen, C.-D. (2016). The metamorphosis of industrial designers from novices to experts. *International Journal of Art & Design Education, 35*(1), 140-153.

Wood, L., & Kaczynski, D. (2007). University students in USA and Australia: Anticipation and reflection on the transition to work. *International Journal of Employment Studies*, *15*(2), 91.

Wood, L., & Solomonides, I. (2008). Different disciplines, different transitions. *Mathematics Education Research Journal*, *20*(2), 117-134.

World Economic Forum. (2016). *New vision for education: Fostering social and emotional learning through technology*. Retrieved from https://www.weforum.org/reports/new-vision-for-education-fostering-social-and-emotional-learning-through-technology

Yunxia, Z. H. U., Rooney, D., & Phillips, N. (2016). Practice-based wisdom theory for integrating institutional logics: A new model for social entrepreneurship learning and education. *Academy of Management Learning & Education*, *15*(3), 607-625. doi:10.5465/amle.2013.0263

# 10 Appendices

# APPENDIX 1: TUNING QUESTIONNAIRE

## Ia. Background information (engineering graduates)

*This questionnaire presents a series of questions related to the skills and competences that may be important for success in your career. Please answer all the questions. The answers may be very valuable in improving course planning for future students of your degree subject.*

1. Age in years:
2. Gender:
   a. Male
   b. Female
3. Year in which you graduated:
4. Title of your first degree (in the national language):
5. Present employment situation:
   a. Working in a position related to your degree
   b. Working in a position not related to your degree
   c. Further study
   d. Looking for your first job
   e. Unemployed, but have previously been employed
   f. Neither employed nor looking for employment
   g. Other (please specify):
6. Do you feel that the education you have received at university has been adequate?
   a. Very much
   b. Much
   c. Some
   d. Little
   e. Very little
7. How would you rate the employment potential of your degree?
   a. Very poor
   b. Poor
   c. Fair
   d. Good
   e. Very Good

## Ib. Background information (engineering employers)

*This questionnaire presents a series of questions related to the skills and competences that may be important for career success in engineering. Please answer all the questions. The answers will be very valuable in improving the planning of courses for future students of this subject.*

1. What is the name of your organisation?
2. What is your position in the organisation?
3. How many employees are in your organisation?
   a. 1-10
   b. 10-100
   c. 100-1000
   d. 1000-10,000
   e. 10,000 +
4. Do you consider that university has given your employees working in the area of engineering adequate preparation for working in your company?
   a. Very much
   b. Much
   c. Some
   d. Little
   e. Very little

## II. Generic skills

For each of the skills listed below, please estimate:

**Employers**
The level to which each skill or capability is developed by degree programs at university in engineering;
The importance of the skill or capability, in your opinion, for work in your organisation.
**Graduates**
The level to which each skill or capability is important to an engineering degree program at your university;
The importance of the skill or capability, in your opinion, for work in the engineering profession.

The blank spaces may be used to indicate any other skills that you consider important but which do not appear on the list.
Please use the following scale:

**1 = None; 2 = Weak; 3 = Considerable; 4 = Strong**

| Skill/capability | Level to which developed by University degree | Importance for work |
|---|---|---|
| | **1 2 3 4** | **1 2 3 4** |

1. Capacity for analysis and synthesis
2. Capacity for applying knowledge in practice
3. Planning and time management
4. Basic general knowledge in the field of study
5. Grounding in basic knowledge of the profession in practice
6. Oral and written communication in your native language
7. Knowledge of a second language
8. Elementary computing skills
9. Research skills
10. Capacity to learn
11. Information management skills (ability to retrieve and analyse information from different sources)
12. Critical and self-critical abilities
13. Capacity to adapt to new situations
14. Capacity for generating new ideas (creativity)
15. Problem-solving
16. Decision-making
17. Teamwork
18. Interpersonal skills
19. Leadership
20. Ability to work in an interdisciplinary team
21. Ability to communicate with non-experts (in the field)
22. Appreciation of diversity and multiculturality
23. Ability to work in an international context
24. Understanding of cultures and customs of other countries
25. Ability to work autonomously
26. Project design and management
27. Initiative and entrepreneurial spirit
28. Ethical commitment
29. Concern for quality
30. Will to succeed

## III. Your opinion for generic skills (the same for employers and graduates)

*In your opinion, what are the three to five (3-5) most important general capabilities required for engineering? Please enter your choices below.*

1. <free text>
2. <free text>
3. <free text>
4. <free text>
5. <free text>

## IV. Specific skills

For each of the skills listed below, please estimate:

**Employers**
The level to which each skill or capability is developed by degree programs at university in engineering;
The importance of the skill or capability, in your opinion, for work in your organisation.
**Graduates**
The level to which each skill or capability is important to an engineering degree program at your university;
The importance of the skill or capability, in your opinion, for work in the engineering profession.

The blank spaces may be used to indicate any other skills that you consider important but which do not appear on the list.
Please use the following scale:

**1 = None; 2 = Weak; 3 = Considerable; 4 = Strong**

| Skill/capability | Level to which developed by University degree | Importance for work |
|---|---|---|
| | 1 2 3 4 | 1 2 3 4 |

1. An ability to apply knowledge of mathematics and other basic subjects
2. An ability to use knowledge of mechanics, applied mechanics and of other core subjects relevant to civil engineering
3. An ability to design a system or a component to meet desired needs
4. An ability to identify, formulate and solve common civil engineering problems
5. An ability to identify, formulate and solve complex civil engineering problems
6. An understanding of the interaction between technical and environmental issues and ability to design and construct environmentally friendly civil engineering works
7. An ability to design and conduct experiments, as well as analyse and interpret data
8. An ability to identify research needs and necessary resource
9. An ability to use the techniques, skills and modern engineering tools, including IT, necessary for engineering practice
10. An ability to apply knowledge in a specialized area related to civil engineering
11. An understanding of the elements of project and construction management of common civil engineering works
12. An understanding of the elements of project and construction management of complex civil engineering works
13. An understanding of professional and ethical responsibility of civil engineers
14. An understanding of the impact of solutions for civil engineering works in a global and societal context
15. An ability to communicate effectively
16. An understanding of the role of the leader and leadership principles and attitudes
17. A recognition of the need for, and the ability to engage in, life-long learning
18. An ability to function in multi-disciplinary teams

## V. Your opinion for specific skills (the same for graduates and employers)

*In your opinion, what are the three to five (3-5) most important specific skills required for engineering? Please enter your choices below.*

1. <free text>
2. <free text>
3. <free text>
4. <free text>
5. <free text>

# APPENDIX 2: SURVEY RESULTS FOR LIKERT QUESTIONS

## 10.2.1 General skills provided by university and required for work

| | | Graduates (*n*=121) | | | | | | | | Employers (*n*=94) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | University | | | | Work | | | | University | | | | Work | | | |
| | Variable | None | Weak | Considerable | Strong | None | Weak | Considerable | Strong | None | Weak | Considerable | Strong | None | Weak | Considerable | Strong |
| 1 | Capacity for analysis and synthesis | 3 | 26 | 69 | 23 | 1 | 15 | 52 | 53 | 4 | 24 | 49 | 17 | 3 | 8 | 41 | 42 |
| 2 | Capacity for applying knowledge in practice | 2 | 34 | 59 | 26 | 1 | 12 | 52 | 56 | 6 | 20 | 48 | 20 | 5 | 11 | 35 | 43 |
| 3 | Planning and time management | 5 | 18 | 53 | 45 | 1 | 8 | 46 | 66 | 11 | 20 | 38 | 24 | 5 | 14 | 29 | 45 |
| 4 | Basic general knowledge in the field of study | 2 | 22 | 56 | 40 | 2 | 10 | 60 | 49 | 5 | 13 | 43 | 33 | 4 | 7 | 43 | 39 |
| 5 | Grounding in basic knowledge of the profession in practice | 1 | 26 | 67 | 27 | 2 | 12 | 63 | 44 | 11 | 14 | 42 | 27 | 6 | 6 | 44 | 38 |
| 6 | Oral and written communication in your native language | 13 | 19 | 48 | 41 | 7 | 18 | 51 | 44 | 8 | 18 | 31 | 37 | 9 | 12 | 40 | 33 |
| 7 | Knowledge of a second language | 21 | 29 | 44 | 27 | 18 | 23 | 53 | 27 | 14 | 18 | 39 | 23 | 9 | 13 | 42 | 30 |
| 8 | Computing skills | 2 | 19 | 58 | 42 | 3 | 8 | 50 | 60 | 9 | 11 | 29 | 45 | 6 | 5 | 36 | 47 |
| 9 | Research skills | 7 | 27 | 52 | 35 | 4 | 22 | 53 | 42 | 10 | 22 | 34 | 28 | 7 | 17 | 34 | 36 |
| 10 | Capacity to learn | 2 | 15 | 54 | 50 | 1 | 9 | 51 | 59 | 6 | 18 | 38 | 31 | 6 | 11 | 30 | 46 |
| 11 | Information management skills | 6 | 21 | 61 | 33 | 3 | 12 | 52 | 53 | 9 | 21 | 39 | 24 | 7 | 16 | 35 | 35 |
| 12 | Critical and self-critical abilities | 7 | 26 | 60 | 28 | 3 | 17 | 55 | 46 | 8 | 32 | 36 | 18 | 4 | 18 | 44 | 28 |
| 13 | Capacity to adapt to new situations | 5 | 31 | 54 | 31 | 3 | 11 | 54 | 52 | 7 | 23 | 31 | 32 | 6 | 8 | 38 | 41 |
| 14 | Capacity for generating new ideas (creativity) | 13 | 24 | 53 | 30 | 3 | 18 | 40 | 58 | 8 | 19 | 40 | 26 | 5 | 10 | 39 | 39 |
| 15 | Problem solving | 8 | 15 | 60 | 37 | 1 | 11 | 45 | 63 | 7 | 11 | 41 | 35 | 4 | 9 | 36 | 45 |
| 16 | Decision-making | 7 | 22 | 54 | 36 | 2 | 5 | 52 | 59 | 11 | 23 | 36 | 24 | 6 | 9 | 35 | 43 |
| 17 | Teamwork | 5 | 15 | 54 | 45 | 1 | 10 | 43 | 64 | 7 | 10 | 44 | 32 | 3 | 6 | 32 | 52 |
| 18 | Interpersonal skills | 6 | 18 | 59 | 34 | 4 | 16 | 49 | 49 | 8 | 18 | 40 | 25 | 5 | 12 | 35 | 38 |
| 19 | Leadership | 6 | 30 | 44 | 38 | 1 | 5 | 60 | 51 | 9 | 14 | 41 | 29 | 5 | 8 | 42 | 38 |
| 20 | Ability to work in an interdisciplinary team | 7 | 21 | 49 | 40 | 2 | 8 | 49 | 59 | 9 | 21 | 36 | 26 | 3 | 9 | 37 | 43 |
| 21 | Ability to communicate with non-experts (in the field) | 8 | 32 | 44 | 33 | 4 | 10 | 58 | 45 | 10 | 18 | 39 | 26 | 3 | 13 | 36 | 41 |
| 22 | Appreciation of diversity and multiculturality | 8 | 23 | 46 | 40 | 4 | 15 | 55 | 43 | 12 | 17 | 40 | 23 | 4 | 20 | 36 | 32 |
| 23 | Ability to work in an international context | 22 | 31 | 42 | 21 | 8 | 20 | 50 | 39 | 13 | 30 | 31 | 19 | 5 | 15 | 49 | 24 |
| 24 | Understanding of cultures and customs of other countries | 25 | 21 | 45 | 26 | 12 | 23 | 45 | 37 | 15 | 28 | 27 | 22 | 6 | 17 | 35 | 34 |
| 25 | Ability to work autonomously | 8 | 18 | 50 | 42 | 3 | 14 | 52 | 49 | 9 | 14 | 43 | 26 | 3 | 17 | 43 | 29 |
| 26 | Project design and management | 4 | 24 | 53 | 35 | 3 | 7 | 57 | 49 | 9 | 23 | 44 | 16 | 6 | 9 | 41 | 36 |
| 27 | Initiative and entrepreneurial spirit | 18 | 27 | 45 | 27 | 6 | 20 | 53 | 38 | 9 | 27 | 38 | 18 | 7 | 15 | 47 | 23 |
| 28 | Ethical commitment | 10 | 21 | 46 | 38 | 5 | 15 | 44 | 51 | 12 | 18 | 37 | 25 | 9 | 15 | 33 | 35 |
| 29 | Concern for quality | 8 | 15 | 57 | 37 | 3 | 9 | 42 | 63 | 4 | 19 | 47 | 23 | 3 | 9 | 36 | 45 |
| 30 | Will to succeed | 9 | 14 | 38 | 54 | 4 | 4 | 34 | 73 | 5 | 14 | 30 | 44 | 3 | 9 | 30 | 51 |

## 10.2.2 Specific skills for engineering provided by university and required for work

| | | Graduates (*n*=121) | | | | | | | | Employers (*n*=94) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | University | | | | Work | | | | University | | | | Work | | | |
| | **Variable** | **None** | **Weak** | **Considerable** | **Strong** | **None** | **Weak** | **Considerable** | **Strong** | **None** | **Weak** | **Considerable** | **Strong** | **None** | **Weak** | **Considerable** | **Strong** |
| 1 | Apply knowledge of mathematics and other basic subjects | 3 | 18 | 64 | 36 | 2 | 19 | 62 | 38 | 5 | 14 | 44 | 31 | 6 | 18 | 37 | 32 |
| 2 | Use knowledge of core engineering subjects | 3 | 17 | 68 | 33 | 4 | 16 | 61 | 39 | 4 | 24 | 40 | 26 | 5 | 19 | 40 | 29 |
| 3 | Design a system or a component to needs | 5 | 23 | 68 | 25 | 3 | 13 | 58 | 47 | 9 | 19 | 42 | 24 | 5 | 13 | 35 | 41 |
| 4 | Identify, formulate and solve common engineering problems | 2 | 13 | 52 | 53 | 4 | 14 | 53 | 49 | 6 | 17 | 34 | 37 | 5 | 16 | 36 | 37 |
| 5 | Identify, formulate and solve complex engineering problems | 3 | 18 | 69 | 30 | 6 | 23 | 48 | 42 | 9 | 17 | 38 | 30 | 5 | 19 | 37 | 33 |
| 6 | Technical and environmental interaction and impacts | 10 | 27 | 57 | 27 | 5 | 18 | 54 | 44 | 5 | 22 | 36 | 30 | 3 | 11 | 43 | 36 |
| 7 | Design and conduct experiments, as well as analyse and interpret data | 3 | 30 | 51 | 37 | 5 | 18 | 48 | 50 | 8 | 20 | 36 | 30 | 6 | 7 | 47 | 34 |
| 8 | Identify research needs and necessary resources | 6 | 23 | 62 | 30 | 5 | 21 | 49 | 45 | 6 | 22 | 38 | 27 | 6 | 15 | 38 | 34 |
| 9 | Leverage engineering techniques, skills and tools | 4 | 29 | 58 | 28 | 2 | 14 | 55 | 47 | 7 | 20 | 40 | 27 | 2 | 15 | 35 | 42 |
| 10 | Specialist engineering knowledge application | 8 | 28 | 42 | 42 | 7 | 14 | 47 | 52 | 9 | 23 | 31 | 30 | 2 | 16 | 41 | 34 |
| 11 | Understand engineering project and construction management | 6 | 23 | 56 | 35 | 8 | 11 | 50 | 50 | 8 | 16 | 42 | 28 | 6 | 13 | 39 | 35 |
| 12 | Understanding complex engineering project and construction management | 10 | 19 | 57 | 32 | 6 | 14 | 55 | 43 | 8 | 22 | 41 | 23 | 6 | 14 | 39 | 34 |
| 13 | Understand engineering professional and ethical responsibility | 8 | 21 | 54 | 34 | 4 | 10 | 54 | 48 | 6 | 25 | 38 | 25 | 4 | 9 | 45 | 36 |
| 14 | Understanding social and global impacts of engineering | 10 | 30 | 44 | 33 | 8 | 15 | 51 | 43 | 5 | 26 | 35 | 28 | 6 | 16 | 36 | 35 |
| 15 | Effective communication | 4 | 18 | 53 | 42 | 2 | 9 | 36 | 70 | 5 | 24 | 30 | 35 | 5 | 9 | 36 | 44 |
| 16 | Leadership role, principles, and attitudes | 9 | 25 | 51 | 31 | 3 | 8 | 49 | 56 | 8 | 18 | 42 | 25 | 5 | 15 | 38 | 35 |
| 17 | Recognition of the need for, and the ability to engage in, life-long learning | 8 | 19 | 53 | 36 | 3 | 7 | 47 | 59 | 5 | 13 | 46 | 29 | 3 | 14 | 36 | 40 |
| 18 | Ability to function in multi-disciplinary teams | 8 | 28 | 46 | 34 | 5 | 8 | 43 | 60 | 6 | 20 | 36 | 30 | 4 | 11 | 43 | 34 |

# APPENDIX 3: DESCRIPTIVE STATISTICS

## 10.3.1 General skills provided by university

| Variable | Group | Mean | SD | Variance | Skewness | Kurtosis |
|---|---|---|---|---|---|---|
| 1. Capacity for analysis and synthesis | E | 2.8404 | 0.7663 | 0.5872 | -0.3 | -0.15 |
| | G | 2.9256 | 0.7091 | 0.5028 | -0.32 | 0.08 |
| 2. Capacity for applying knowledge in practice | E | 2.8723 | 0.8196 | 0.6717 | -0.48 | -0.11 |
| | G | 2.9008 | 0.7462 | 0.5567 | -0.08 | -0.63 |
| 3. Planning and time management | E | 2.777 | 0.996 | 0.993 | -0.53 | -0.42 |
| | G | 3.1405 | 0.8196 | 0.6718 | -0.73 | 0.03 |
| 4. Basic general knowledge in the field of study | E | 3.1064 | 0.8356 | 0.6982 | -0.77 | 0.17 |
| | G | 3.0909 | 0.8062 | 0.65 | -0.75 | 0.82 |
| 5. Grounding in basic knowledge of the profession in practice | E | 2.9043 | 0.9512 | 0.9047 | -0.65 | -0.4 |
| | G | 2.9917 | 0.6892 | 0.4749 | -0.14 | -0.4 |
| 6. Oral and written communication in your native language | E | 3.0319 | 0.9667 | 0.9345 | -0.65 | -0.61 |
| | G | 2.9669 | 0.9655 | 0.9322 | -0.67 | -0.48 |
| 7. Knowledge of a second language | E | 2.755 | 0.991 | 0.982 | -0.43 | -0.79 |
| | G | 2.6364 | 1.0165 | 1.0333 | -0.23 | -1.03 |
| 8. Computing skills | E | 3.17 | 0.98 | 0.96 | -0.98 | -0.09 |
| | G | 3.157 | 0.7417 | 0.5501 | -0.51 | -0.22 |
| 9. Research skills | E | 2.851 | 0.972 | 0.945 | -0.41 | -0.82 |
| | G | 2.9504 | 0.8646 | 0.7475 | -0.45 | -0.48 |
| 10. Capacity to learn | E | 2.9787 | 0.9388 | 0.8813 | -0.75 | 0.16 |
| | G | 3.2562 | 0.7363 | 0.5421 | -0.7 | 0.04 |
| 11. Information management skills | E | 2.8085 | 0.9647 | 0.9307 | -0.56 | -0.24 |
| | G | 3 | 0.8062 | 0.65 | -0.58 | 0.03 |
| 12. Critical and self-critical abilities | E | 2.6809 | 0.8825 | 0.7788 | -0.09 | -0.72 |
| | G | 2.9008 | 0.8206 | 0.6734 | -0.46 | -0.19 |
| 13. Capacity to adapt to new situations | E | 2.915 | 0.991 | 0.982 | -0.57 | -0.4 |
| | G | 2.9174 | 0.8225 | 0.6764 | -0.3 | -0.55 |
| 14. Capacity for generating new ideas (creativity) | E | 2.8723 | 0.953 | 0.9083 | -0.65 | -0.05 |
| | G | 2.8099 | 0.9602 | 0.9219 | -0.58 | -0.27 |
| 15. Problem solving | E | 3.1064 | 0.8856 | 0.7843 | -0.88 | 0.19 |
| | G | 3.0248 | 0.88 | 0.7744 | -0.94 | 0.84 |
| 16. Decision-making | E | 2.7766 | 0.9634 | 0.928 | -0.35 | -0.81 |
| | G | 2.9504 | 0.9296 | 0.8642 | -0.85 | 0.61 |
| 17. Teamwork | E | 3.0532 | 0.9201 | 0.8466 | -1.04 | 0.89 |
| | G | 3.1157 | 0.8962 | 0.8032 | -1.15 | 1.53 |
| 18. Interpersonal skills | E | 2.809 | 1.029 | 1.06 | -0.81 | 0.27 |
| | G | 2.9339 | 0.9638 | 0.9289 | -1.12 | 1.37 |
| 19. Leadership | E | 2.936 | 0.971 | 0.942 | -0.81 | 0.11 |
| | G | 2.8926 | 0.99 | 0.98 | -0.72 | 0.24 |

| Variable | Group | Mean | SD | Variance | Skewness | Kurtosis |
|---|---|---|---|---|---|---|
| 20. Ability to work in an interdisciplinary team | E | 2.798 | 1.022 | 1.045 | -0.63 | -0.16 |
| | G | 2.9421 | 1.019 | 1.0383 | -0.99 | 0.71 |
| 21. Ability to communicate with non-experts (in the field) | E | 2.84 | 0.987 | 0.974 | -0.63 | -0.25 |
| | G | 2.7769 | 1.0287 | 1.0581 | -0.66 | 0.08 |
| 22. Appreciation of diversity and multiculturality | E | 2.745 | 1.036 | 1.074 | -0.65 | -0.24 |
| | G | 2.9091 | 1.0408 | 1.0833 | -0.9 | 0.4 |
| 23. Ability to work in an international context | E | 2.574 | 1 | 1 | -0.18 | -0.73 |
| | G | 2.43 | 1.102 | 1.214 | -0.31 | -0.7 |
| 24. Understanding of cultures and customs of other countries | E | 2.553 | 1.084 | 1.175 | -0.22 | -0.83 |
| | G | 2.529 | 1.141 | 1.301 | -0.4 | -0.87 |
| 25. Ability to work autonomously | E | 2.872 | 0.997 | 0.994 | -0.87 | 0.35 |
| | G | 2.9917 | 0.9958 | 0.9916 | -1.01 | 0.73 |
| 26. Project design and management | E | 2.6702 | 0.9434 | 0.8901 | -0.62 | 0.19 |
| | G | 2.9008 | 0.995 | 0.9901 | -1.04 | 1.15 |
| 27. Initiative and entrepreneurial spirit | E | 2.649 | 0.97 | 0.94 | -0.47 | -0.11 |
| | G | 2.6033 | 1.0915 | 1.1913 | -0.48 | -0.55 |
| 28. Ethical commitment | E | 2.755 | 1.054 | 1.112 | -0.62 | -0.36 |
| | G | 2.826 | 1.116 | 1.245 | -0.89 | 0.18 |
| 29. Concern for quality | E | 2.9255 | 0.8455 | 0.7148 | -0.73 | 0.78 |
| | G | 2.9504 | 0.9988 | 0.9975 | -1.12 | 1.11 |
| 30. Will to succeed | E | 3.1809 | 0.95 | 0.9024 | -1.06 | 0.6 |
| | G | 3.033 | 1.147 | 1.316 | -1.18 | 0.59 |

## 10.3.2 General skills required for work

| | Variable | Group | Mean | SD | Variance | Skewness | Kurtosis |
|---|---|---|---|---|---|---|---|
| 1. | Capacity for analysis and synthesis | E | 3.2979 | 0.7596 | 0.577 | -1.01 | 0.93 |
| | | G | 3.2975 | 0.7147 | 0.5107 | -0.65 | -0.27 |
| 2. | Capacity for applying knowledge in practice | E | 3.234 | 0.8604 | 0.7403 | -0.99 | 0.35 |
| | | G | 3.3471 | 0.6917 | 0.4785 | -0.74 | 0.01 |
| 3. | Planning and time management | E | 3.1915 | 0.9535 | 0.9092 | -1.08 | 0.6 |
| | | G | 3.4628 | 0.6588 | 0.434 | -1.02 | 0.69 |
| 4. | Basic general knowledge in the field of study | E | 3.2234 | 0.8444 | 0.713 | -1.32 | 2.22 |
| | | G | 3.2893 | 0.6885 | 0.474 | -0.76 | 0.65 |
| 5. | Grounding in basic knowledge of the profession in practice | E | 3.2128 | 0.8279 | 0.6854 | -1.12 | 1.09 |
| | | G | 3.2314 | 0.6923 | 0.4793 | -0.65 | 0.46 |
| 6. | Oral and written communication in your native language | E | 3.0319 | 0.9327 | 0.8699 | -0.8 | -0.13 |
| | | G | 3.0744 | 0.9052 | 0.8194 | -0.9 | 0.51 |
| 7. | Knowledge of a second language | E | 2.9894 | 0.9216 | 0.8493 | -0.74 | -0.16 |
| | | G | 2.7355 | 0.9727 | 0.9461 | -0.44 | -0.73 |
| 8. | Computing skills | E | 3.3191 | 0.8451 | 0.7143 | -1.32 | 1.38 |
| | | G | 3.3802 | 0.7218 | 0.5209 | -1.13 | 1.29 |
| 9. | Research skills | E | 3.0532 | 0.9317 | 0.8681 | -0.68 | -0.45 |
| | | G | 3.0992 | 0.8104 | 0.6567 | -0.57 | -0.28 |
| 10. | Capacity to learn | E | 3.2128 | 0.9602 | 0.922 | -1.19 | 0.84 |
| | | G | 3.3719 | 0.7318 | 0.5355 | -1.36 | 3.12 |
| 11. | Information management skills | E | 3.021 | 0.973 | 0.946 | -0.83 | 0.1 |
| | | G | 3.2645 | 0.8038 | 0.6461 | -1.2 | 1.94 |
| 12. | Critical and self-critical abilities | E | 3.0213 | 0.8162 | 0.6662 | -0.52 | -0.2 |
| | | G | 3.1901 | 0.7672 | 0.5886 | -0.68 | 0.03 |
| 13. | Capacity to adapt to new situations | E | 3.1915 | 0.9191 | 0.8447 | -1.24 | 1.34 |
| | | G | 3.2645 | 0.7934 | 0.6295 | -1.22 | 2.14 |
| 14. | Capacity for generating new ideas (creativity) | E | 3.1702 | 0.8997 | 0.8094 | -1.16 | 1.26 |
| | | G | 3.2314 | 0.9107 | 0.8293 | -1.22 | 1.43 |
| 15. | Problem solving | E | 3.2979 | 0.8143 | 0.663 | -1.09 | 0.77 |
| | | G | 3.3884 | 0.7569 | 0.5729 | -1.37 | 2.67 |
| 16. | Decision-making | E | 3.2021 | 0.9342 | 0.8727 | -1.23 | 1.16 |
| | | G | 3.3388 | 0.8422 | 0.7092 | -1.9 | 4.95 |
| 17. | Teamwork | E | 3.3936 | 0.8324 | 0.6929 | -1.65 | 3.15 |
| | | G | 3.3554 | 0.8647 | 0.7477 | -1.78 | 4.08 |
| 18. | Interpersonal skills | E | 3.043 | 1.067 | 1.138 | -1.23 | 1.12 |
| | | G | 3.1322 | 0.9393 | 0.8824 | -1.25 | 1.71 |
| 19. | Leadership | E | 3.1809 | 0.8794 | 0.7734 | -1.24 | 1.66 |
| | | G | 3.2645 | 0.8541 | 0.7295 | -1.93 | 5.3 |
| 20. | Ability to work in an interdisciplinary team | E | 3.234 | 0.909 | 0.8264 | -1.45 | 2.43 |
| | | G | 3.314 | 0.8663 | 0.7506 | -1.75 | 4.02 |
| 21. | Ability to communicate with non-experts (in the field) | E | 3.2021 | 0.8747 | 0.7652 | -1.1 | 1.2 |
| | | G | 3.124 | 0.936 | 0.8762 | -1.49 | 2.68 |
| 22. | Appreciation of diversity and multiculturality | E | 2.9787 | 0.9614 | 0.9243 | -0.85 | 0.55 |
| | | G | 3.0661 | 0.9551 | 0.9123 | -1.3 | 1.96 |
| 23. | Ability to work in an international context | E | 2.9574 | 0.854 | 0.7294 | -0.87 | 1.02 |
| | | G | 2.9256 | 1.026 | 1.0528 | -0.98 | 0.64 |

| Variable | Group | Mean | SD | Variance | Skewness | Kurtosis |
|---|---|---|---|---|---|---|
| 24. Understanding of cultures and customs of other countries | E | 2.989 | 1 | 1 | -0.9 | 0.4 |
| | G | 2.8182 | 1.0801 | 1.1667 | -0.76 | -0.08 |
| 25. Ability to work autonomously | E | 3 | 0.904 | 0.8172 | -0.98 | 1.3 |
| | G | 3.1653 | 0.9069 | 0.8225 | -1.36 | 2.32 |
| 26. Project design and management | E | 3.0957 | 0.9624 | 0.9262 | -1.23 | 1.4 |
| | G | 3.1736 | 0.9546 | 0.9113 | -1.7 | 3.36 |
| 27. Initiative and entrepreneurial spirit | E | 2.8723 | 0.9417 | 0.8868 | -0.92 | 0.81 |
| | G | 2.9504 | 0.9904 | 0.9809 | -1.05 | 1.04 |
| 28. Ethical commitment | E | 2.957 | 1.057 | 1.116 | -0.86 | 0.02 |
| | G | 3.0661 | 1.0781 | 1.1623 | -1.31 | 1.33 |
| 29. Concern for quality | E | 3.2872 | 0.8503 | 0.7231 | -1.34 | 2.07 |
| | G | 3.2975 | 0.9543 | 0.9107 | -1.74 | 3.24 |
| 30. Will to succeed | E | 3.3511 | 0.8639 | 0.7464 | -1.47 | 2.2 |
| | G | 3.3554 | 1.0477 | 1.0977 | -2 | 3.54 |

## 10.3.3 Specific skills provided by university

| Variable | Group | Mean | SD | Variance | Skewness | Kurtosis |
|---|---|---|---|---|---|---|
| 1. Apply knowledge of mathematics and other basic subjects | E | 3.0745 | 0.8327 | 0.6933 | -0.71 | 0.1 |
| | G | 3.0992 | 0.7349 | 0.5401 | -0.54 | 0.17 |
| 2. Use knowledge of core engineering subjects | E | 2.9362 | 0.84 | 0.7056 | -0.32 | -0.61 |
| | G | 3.0826 | 0.714 | 0.5098 | -0.54 | 0.4 |
| 3. Design a system or a component to needs | E | 2.8617 | 0.9111 | 0.8301 | -0.5 | -0.45 |
| | G | 2.9339 | 0.7498 | 0.5623 | -0.49 | 0.24 |
| 4. Identify, formulate and solve common engineering problems | E | 3.0851 | 0.9118 | 0.8314 | -0.69 | -0.4 |
| | G | 3.2727 | 0.7853 | 0.6167 | -1.15 | 1.93 |
| 5. Identify, formulate and solve complex engineering problems | E | 2.9468 | 0.9432 | 0.8896 | -0.6 | -0.49 |
| | G | 3.0248 | 0.7579 | 0.5744 | -0.86 | 1.73 |
| 6. Technical and environmental interaction and impacts | E | 2.9468 | 0.9317 | 0.8681 | -0.63 | -0.03 |
| | G | 2.8347 | 0.8694 | 0.7558 | -0.44 | -0.37 |
| 7. Design and conduct experiments, as well as analyse and interpret data | E | 2.9362 | 0.9368 | 0.8776 | -0.51 | -0.62 |
| | G | 3.0083 | 0.8113 | 0.6583 | -0.3 | -0.74 |
| 8. Identify research needs and necessary resources | E | 2.8936 | 0.9329 | 0.8703 | -0.6 | -0.04 |
| | G | 2.9587 | 0.8 | 0.6399 | -0.52 | -0.02 |
| 9. Leverage engineering techniques, skills and tools | E | 2.9255 | 0.8949 | 0.8008 | -0.5 | -0.47 |
| | G | 2.876 | 0.8619 | 0.7428 | -0.71 | 0.86 |
| 10. Specialist engineering knowledge application | E | 2.851 | 1.016 | 1.031 | -0.51 | -0.55 |
| | G | 2.9587 | 0.9609 | 0.9233 | -0.6 | -0.33 |
| 11. Understand engineering project and construction management | E | 2.9574 | 0.903 | 0.8154 | -0.63 | -0.27 |
| | G | 2.9752 | 0.8705 | 0.7577 | -0.72 | 0.42 |
| 12. Understanding complex engineering project and construction management | E | 2.8404 | 0.8957 | 0.8022 | -0.41 | -0.53 |
| | G | 2.8678 | 0.9827 | 0.9657 | -0.91 | 0.57 |
| 13. Understand engineering professional and ethical responsibility | E | 2.8723 | 0.8827 | 0.7792 | -0.32 | -0.67 |
| | G | 2.876 | 1.0047 | 1.0095 | -0.95 | 0.7 |
| 14. Understanding social and global impacts of engineering | E | 2.9149 | 0.8879 | 0.7884 | -0.3 | -0.81 |
| | G | 2.7603 | 1.049 | 1.1004 | -0.65 | -0.06 |
| 15. Effective communication | E | 3.0106 | 0.9216 | 0.8493 | -0.44 | -0.87 |
| | G | 3.0331 | 0.9655 | 0.9322 | -1.2 | 1.6 |
| 16. Leadership role, principles, and attitudes | E | 2.8723 | 0.9417 | 0.8868 | -0.69 | 0.07 |
| | G | 2.7769 | 1.0447 | 1.0915 | -0.83 | 0.35 |
| 17. Recognition of the need for, and the ability to engage in, life-long learning | E | 3.0319 | 0.8732 | 0.7624 | -0.95 | 1.04 |
| | G | 2.8843 | 1.0424 | 1.0865 | -1.02 | 0.74 |
| 18. Ability to function in multi-disciplinary teams | E | 2.915 | 0.991 | 0.982 | -0.77 | 0.24 |
| | G | 2.7934 | 1.0561 | 1.1153 | -0.78 | 0.24 |

## 10.3.4 Specific skills required for work

| Variable | Group | Mean | SD | Variance | Skewness | Kurtosis |
|---|---|---|---|---|---|---|
| 1. Apply knowledge of mathematics and other basic subjects | E | 2.9894 | 0.9446 | 0.8924 | -0.76 | 0.13 |
| | G | 3.124 | 0.7254 | 0.5262 | -0.46 | -0.12 |
| 2. Use knowledge of core engineering subjects | E | 2.9681 | 0.9094 | 0.8269 | -0.73 | 0.29 |
| | G | 3.0992 | 0.8104 | 0.6567 | -0.95 | 1.37 |
| 3. Design a system or a component to needs | E | 3.1915 | 0.871 | 0.7586 | -0.88 | 0.07 |
| | G | 3.2314 | 0.7389 | 0.546 | -0.78 | 0.47 |
| 4. Identify, formulate and solve common engineering problems | E | 3.117 | 0.8781 | 0.7711 | -0.72 | -0.25 |
| | G | 3.1983 | 0.8329 | 0.6937 | -1.09 | 1.43 |
| 5. Identify, formulate and solve complex engineering problems | E | 3.0426 | 0.8788 | 0.7724 | -0.57 | -0.46 |
| | G | 3.0083 | 0.9442 | 0.8916 | -0.86 | 0.51 |
| 6. Technical and environmental interaction and impacts | E | 3.1702 | 0.8378 | 0.7019 | -1.12 | 1.68 |
| | G | 3.1322 | 0.8159 | 0.6657 | -0.72 | 0.04 |
| 7. Design and conduct experiments, as well as analyse and interpret data | E | 3.1596 | 0.8205 | 0.6732 | -1.02 | 0.95 |
| | G | 3.1818 | 0.8367 | 0.7 | -0.79 | -0.02 |
| 8. Identify research needs and necessary resources | E | 3.0426 | 0.938 | 0.8799 | -0.88 | 0.4 |
| | G | 3.0909 | 0.8851 | 0.7833 | -0.84 | 0.45 |
| 9. Leverage engineering techniques, skills and tools | E | 3.2447 | 0.799 | 0.6384 | -0.73 | -0.27 |
| | G | 3.1653 | 0.8789 | 0.7725 | -1.38 | 2.71 |
| 10. Specialist engineering knowledge application | E | 3.117 | 0.8406 | 0.7066 | -0.89 | 1.04 |
| | G | 3.1736 | 0.9099 | 0.828 | -1.1 | 0.87 |
| 11. Understand engineering project and construction management | E | 3.0745 | 0.9302 | 0.8654 | -0.97 | 0.63 |
| | G | 3.1405 | 0.9514 | 0.9051 | -1.23 | 1.29 |
| 12. Understanding complex engineering project and construction management | E | 3.0532 | 0.9317 | 0.8681 | -0.92 | 0.52 |
| | G | 3.0661 | 0.9464 | 0.8956 | -1.21 | 1.57 |
| 13. Understand engineering professional and ethical responsibility | E | 3.2021 | 0.784 | 0.6146 | -0.92 | 0.77 |
| | G | 3.124 | 0.988 | 0.9762 | -1.52 | 2.46 |
| 14. Understanding social and global impacts of engineering | E | 3.0426 | 0.9494 | 0.9014 | -0.86 | 0.27 |
| | G | 3 | 1.0247 | 1.05 | -1.13 | 0.98 |
| 15. Effective communication | E | 3.266 | 0.8447 | 0.7135 | -1.09 | 0.68 |
| | G | 3.3719 | 0.941 | 0.8855 | -1.91 | 3.89 |
| 16. Leadership role, principles, and attitudes | E | 3.0745 | 0.9186 | 0.8439 | -0.92 | 0.57 |
| | G | 3.2231 | 0.9788 | 0.9581 | -1.71 | 3.14 |
| 17. Recognition of the need for, and the ability to engage in, life-long learning | E | 3.1809 | 0.8794 | 0.7734 | -1.04 | 1.03 |
| | G | 3.2562 | 0.9792 | 0.9588 | -1.78 | 3.36 |
| 18. Ability to function in multi-disciplinary teams | E | 3.0957 | 0.9166 | 0.8402 | -1.22 | 1.77 |
| | G | 3.2231 | 1.0287 | 1.0581 | -1.63 | 2.41 |

# Appendix 4: Likert Factor Loadings, Communalities and Coefficients

## 10.4.1 Factor analysis of general skills provided by university

| ID | Variable | Factor Loadings | | | | | Communality | Factor Coefficients | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Factor 1 | Factor 2 | Factor 3 | Factor 4 | Factor 5 | | Factor 1 | Factor 2 | Factor 3 | Factor 4 | Factor 5 |
| 1 | Capacity for analysis and synthesis | 0.110 | 0.577 | 0.281 | 0.212 | -0.010 | 0.469 | -0.062 | 0.160 | 0.035 | 0.022 | 0.046 |
| 2 | Capacity for applying knowledge in practice | 0.243 | 0.551 | 0.212 | 0.177 | -0.122 | 0.454 | -0.025 | 0.151 | -0.017 | -0.015 | 0.003 |
| 3 | Planning and time management | 0.089 | 0.341 | 0.364 | 0.254 | -0.062 | 0.326 | -0.054 | 0.034 | 0.097 | 0.049 | 0.023 |
| 4 | Basic general knowledge in the field of study | 0.298 | 0.430 | 0.191 | 0.005 | -0.030 | 0.311 | 0.036 | 0.092 | 0.015 | -0.085 | 0.040 |
| 5 | Grounding in basic knowledge of the profession in practice | 0.330 | 0.616 | 0.064 | 0.054 | -0.150 | 0.518 | 0.021 | 0.237 | -0.127 | -0.105 | -0.021 |
| 6 | Oral and written communication in your native language | 0.134 | 0.548 | 0.097 | 0.111 | -0.118 | 0.354 | -0.038 | 0.158 | -0.061 | -0.022 | -0.026 |
| 7 | Knowledge of a second language | 0.073 | 0.177 | 0.163 | 0.136 | -0.536 | 0.368 | -0.102 | 0.028 | -0.002 | 0.000 | -0.211 |
| 8 | Computing skills | 0.177 | 0.618 | 0.060 | 0.308 | -0.220 | 0.561 | -0.100 | 0.249 | -0.177 | 0.100 | -0.083 |
| 9 | Research skills | 0.196 | 0.549 | 0.393 | 0.033 | -0.223 | 0.545 | -0.059 | 0.165 | 0.126 | -0.150 | -0.061 |
| 10 | Capacity to learn | 0.206 | 0.458 | 0.313 | 0.185 | 0.037 | 0.386 | -0.006 | 0.084 | 0.069 | 0.003 | 0.081 |
| 11 | Information management skills | 0.167 | 0.339 | 0.599 | 0.151 | -0.195 | 0.563 | -0.080 | 0.006 | 0.322 | -0.063 | -0.014 |
| 12 | Critical and self-critical abilities | 0.146 | 0.437 | 0.433 | 0.146 | -0.171 | 0.450 | -0.065 | 0.076 | 0.142 | -0.038 | -0.020 |
| 13 | Capacity to adapt to new situations | 0.241 | 0.277 | 0.483 | 0.230 | -0.222 | 0.470 | -0.045 | -0.014 | 0.188 | 0.007 | -0.017 |
| 14 | Capacity for generating new ideas (creativity) | 0.362 | 0.183 | 0.592 | 0.226 | -0.187 | 0.602 | 0.008 | -0.113 | 0.361 | -0.019 | 0.049 |
| 15 | Problem solving | 0.393 | 0.388 | 0.212 | 0.328 | -0.007 | 0.457 | 0.039 | 0.054 | -0.003 | 0.082 | 0.104 |
| 16 | Decision-making | 0.321 | 0.295 | 0.314 | 0.478 | -0.181 | 0.550 | -0.043 | -0.011 | 0.055 | 0.206 | 0.025 |
| 17 | Teamwork | 0.240 | 0.270 | 0.201 | 0.483 | -0.095 | 0.413 | -0.037 | 0.006 | -0.006 | 0.191 | 0.038 |
| 18 | Interpersonal skills | 0.332 | 0.148 | 0.186 | 0.673 | -0.227 | 0.672 | -0.079 | -0.109 | -0.058 | 0.523 | 0.004 |
| 19 | Leadership | 0.334 | 0.174 | 0.258 | 0.438 | -0.268 | 0.472 | -0.029 | -0.045 | 0.030 | 0.162 | -0.029 |
| 20 | Ability to work in an interdisciplinary team | 0.552 | 0.234 | 0.214 | 0.319 | -0.119 | 0.522 | 0.098 | -0.023 | 0.008 | 0.070 | 0.087 |
| 21 | Ability to communicate with non-experts (in the field) | 0.502 | 0.343 | 0.009 | 0.273 | -0.396 | 0.601 | 0.037 | 0.103 | -0.212 | 0.049 | -0.138 |
| 22 | Appreciation of diversity and multiculturality | 0.513 | 0.269 | 0.126 | 0.298 | -0.294 | 0.527 | 0.053 | 0.021 | -0.074 | 0.057 | -0.037 |
| 23 | Ability to work in an international context | 0.565 | 0.037 | 0.217 | 0.180 | -0.623 | 0.788 | 0.087 | -0.205 | 0.036 | -0.102 | -0.486 |
| 24 | Understanding of cultures and customs of other countries | 0.544 | 0.115 | 0.203 | 0.154 | -0.614 | 0.751 | 0.057 | -0.090 | -0.008 | -0.128 | -0.424 |
| 25 | Ability to work autonomously | 0.580 | 0.282 | 0.210 | 0.104 | -0.147 | 0.492 | 0.125 | 0.021 | 0.019 | -0.086 | 0.055 |
| 26 | Project design and management | 0.705 | 0.122 | 0.269 | 0.206 | -0.030 | 0.628 | 0.258 | -0.116 | 0.109 | -0.027 | 0.221 |
| 27 | Initiative and entrepreneurial spirit | 0.664 | 0.222 | 0.169 | 0.085 | -0.238 | 0.583 | 0.181 | -0.001 | -0.010 | -0.130 | 0.021 |
| 28 | Ethical commitment | 0.699 | 0.226 | 0.133 | 0.224 | -0.170 | 0.637 | 0.217 | -0.016 | -0.064 | -0.015 | 0.095 |
| 29 | Concern for quality | 0.666 | 0.333 | 0.091 | 0.104 | -0.036 | 0.575 | 0.216 | 0.068 | -0.075 | -0.098 | 0.145 |
| 30 | Will to succeed | 0.622 | 0.188 | 0.089 | 0.336 | -0.181 | 0.576 | 0.137 | -0.030 | -0.094 | 0.101 | 0.061 |
| | **Variance** | 5.2158 | 3.9225 | 2.3339 | 2.2228 | 1.9242 | 15.6192 | | | | | |
| | **% Var** | 0.174 | 0.131 | 0.078 | 0.074 | 0.064 | 0.521 | | | | | |

## 10.4.2 Factor analysis of general skills required for work

| ID | Variable | Factor Loadings | | | | | Communality | Factor Coefficients | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Factor 1 | Factor 2 | Factor 3 | Factor 4 | Factor 5 | | Factor 1 | Factor 2 | Factor 3 | Factor 4 | Factor 5 |
| 1 | Capacity for analysis and synthesis | 0.436 | -0.187 | 0.168 | -0.303 | -0.033 | 0.346 | 0.056 | 0.002 | 0 | -0.047 | -0.058 |
| 2 | Capacity for applying knowledge in practice | 0.551 | -0.185 | 0.313 | -0.224 | -0.152 | 0.51 | 0.119 | 0.007 | 0.107 | 0.024 | -0.154 |
| 3 | Planning and time management | 0.509 | -0.3 | 0.202 | -0.421 | -0.053 | 0.57 | 0.075 | -0.036 | -0.02 | -0.12 | -0.132 |
| 4 | Basic general knowledge in the field of study | 0.664 | -0.043 | 0.159 | -0.155 | 0.076 | 0.498 | 0.2 | 0.095 | 0.002 | 0.058 | 0.013 |
| 5 | Grounding in basic knowledge of the profession in practice | 0.56 | -0.136 | 0.289 | -0.097 | 0.182 | 0.458 | 0.14 | 0.074 | 0.071 | 0.092 | 0.034 |
| 6 | Oral and written communication in your native language | 0.448 | -0.189 | 0.058 | -0.076 | 0.096 | 0.254 | 0.089 | -0.008 | -0.04 | 0.045 | 0.005 |
| 7 | Knowledge of a second language | 0.462 | -0.022 | 0.037 | -0.044 | 0.277 | 0.294 | 0.114 | 0.067 | -0.044 | 0.052 | 0.096 |
| 8 | Computing skills | 0.583 | -0.164 | 0.26 | -0.165 | 0.092 | 0.47 | 0.139 | 0.05 | 0.049 | 0.057 | -0.013 |
| 9 | Research skills | 0.594 | -0.122 | 0.187 | -0.029 | 0.173 | 0.434 | 0.167 | 0.056 | 0.016 | 0.118 | 0.041 |
| 10 | Capacity to learn | 0.577 | -0.285 | 0.08 | -0.279 | 0.111 | 0.511 | 0.135 | -0.021 | -0.103 | -0.019 | -0.011 |
| 11 | Information management skills | 0.546 | -0.331 | 0.1 | -0.213 | 0.08 | 0.47 | 0.119 | -0.05 | -0.077 | 0.02 | -0.034 |
| 12 | Critical and self-critical abilities | 0.596 | -0.218 | 0 | -0.151 | 0.015 | 0.425 | 0.154 | -0.028 | -0.103 | 0.038 | -0.031 |
| 13 | Capacity to adapt to new situations | 0.47 | -0.337 | 0.078 | -0.352 | 0.198 | 0.504 | 0.074 | -0.03 | -0.119 | -0.078 | 0.023 |
| 14 | Capacity for generating new ideas (creativity) | 0.484 | -0.175 | 0.077 | -0.342 | 0.331 | 0.497 | 0.095 | 0.071 | -0.105 | -0.081 | 0.123 |
| 15 | Problem solving | 0.384 | -0.26 | 0.346 | -0.437 | 0.059 | 0.529 | 0.004 | 0.026 | 0.088 | -0.129 | -0.068 |
| 16 | Decision-making | 0.353 | -0.149 | 0.327 | -0.6 | 0.172 | 0.644 | -0.038 | 0.152 | 0.085 | -0.333 | 0.021 |
| 17 | Teamwork | 0.288 | -0.253 | 0.162 | -0.704 | 0.202 | 0.71 | -0.109 | 0.071 | -0.128 | -0.549 | 0.043 |
| 18 | Interpersonal skills | 0.228 | -0.306 | 0.468 | -0.25 | 0.187 | 0.462 | -0.033 | 0.016 | 0.166 | -0.015 | -0.016 |
| 19 | Leadership | 0.207 | -0.254 | 0.674 | -0.168 | 0.213 | 0.635 | -0.06 | 0.099 | 0.453 | 0.067 | -0.02 |
| 20 | Ability to work in an interdisciplinary team | 0.335 | -0.367 | 0.428 | -0.205 | 0.316 | 0.572 | 0.015 | 0.015 | 0.144 | 0.039 | 0.05 |
| 21 | Ability to communicate with non-experts (in the field) | 0.242 | -0.402 | 0.391 | -0.223 | 0.386 | 0.572 | -0.029 | -0.003 | 0.109 | 0.006 | 0.088 |
| 22 | Appreciation of diversity and multiculturality | 0.269 | -0.443 | 0.326 | -0.125 | 0.423 | 0.57 | 0.008 | -0.037 | 0.057 | 0.077 | 0.111 |
| 23 | Ability to work in an international context | 0.167 | -0.351 | 0.31 | -0.063 | 0.667 | 0.696 | -0.015 | 0.068 | 0.076 | 0.128 | 0.399 |
| 24 | Understanding of cultures and customs of other countries | 0.059 | -0.378 | 0.11 | -0.162 | 0.715 | 0.697 | -0.082 | 0.006 | -0.156 | -0.037 | 0.46 |
| 25 | Ability to work autonomously | 0.284 | -0.622 | 0.225 | -0.073 | 0.194 | 0.561 | 0.018 | -0.207 | -0.02 | 0.114 | -0.052 |
| 26 | Project design and management | 0.164 | -0.673 | 0.296 | -0.217 | 0.237 | 0.671 | -0.103 | -0.276 | 0.015 | 0.008 | -0.069 |
| 27 | Initiative and entrepreneurial spirit | 0.267 | -0.697 | 0.056 | -0.098 | 0.239 | 0.627 | 0.021 | -0.316 | -0.197 | 0.093 | -0.027 |
| 28 | Ethical commitment | 0.203 | -0.633 | 0.132 | -0.303 | 0.22 | 0.599 | -0.061 | -0.228 | -0.128 | -0.079 | -0.037 |
| 29 | Concern for quality | 0.254 | -0.61 | 0.392 | -0.176 | 0.081 | 0.628 | -0.042 | -0.22 | 0.129 | 0.068 | -0.166 |
| 30 | Will to succeed | 0.165 | -0.484 | 0.445 | -0.307 | 0.214 | 0.599 | -0.104 | -0.08 | 0.162 | -0.061 | -0.047 |
| | **Variance** | 5.0925 | 4.0429 | 2.399 | 2.3297 | 2.1481 | 16.0122 | | | | | |
| | **% Var** | 0.17 | 0.135 | 0.08 | 0.078 | 0.072 | 0.534 | | | | | |

### 10.4.3 Factor analysis of specific skills provided by university

| | | Factor Loadings | | | | Factor Coefficients | | |
|---|---|---|---|---|---|---|---|---|
| **ID** | **Variable** | **Factor 1** | **Factor 2** | **Factor 3** | **Communality** | **Factor 1** | **Factor 2** | **Factor 3** |
| 1 | Apply knowledge of mathematics and other basic subjects | 0.082 | -0.596 | 0.075 | 0.368 | -0.049 | -0.196 | -0.081 |
| 2 | Use knowledge of core engineering subjects | 0.222 | -0.641 | 0.164 | 0.487 | -0.035 | -0.225 | -0.079 |
| 3 | Design a system or a component to needs | 0.231 | -0.586 | 0.314 | 0.495 | -0.049 | -0.169 | 0.018 |
| 4 | Identify, formulate and solve common engineering problems | 0.098 | -0.622 | 0.158 | 0.422 | -0.063 | -0.207 | -0.053 |
| 5 | Identify, formulate and solve complex engineering problems | 0.228 | -0.655 | 0.22 | 0.53 | -0.048 | -0.239 | -0.056 |
| 6 | Technical and environmental interaction and impacts | 0.408 | -0.455 | 0.336 | 0.487 | 0.019 | -0.081 | 0.032 |
| 7 | Design and conduct experiments, as well as analyse and interpret data | 0.307 | -0.583 | 0.232 | 0.488 | -0.012 | -0.174 | -0.041 |
| 8 | Identify research needs and necessary resources | 0.416 | -0.482 | 0.236 | 0.461 | 0.032 | -0.108 | -0.031 |
| 9 | Leverage engineering techniques, skills and tools | 0.23 | -0.397 | 0.424 | 0.39 | -0.036 | -0.049 | 0.102 |
| 10 | Specialist engineering knowledge application | 0.425 | -0.409 | 0.478 | 0.576 | 0.011 | -0.033 | 0.147 |
| 11 | Understand engineering project and construction management | 0.198 | -0.311 | 0.756 | 0.707 | -0.161 | 0.086 | 0.587 |
| 12 | Understanding complex engineering project and construction management | 0.438 | -0.284 | 0.548 | 0.573 | 0.021 | 0.055 | 0.223 |
| 13 | Understand engineering professional and ethical responsibility | 0.612 | -0.263 | 0.346 | 0.563 | 0.123 | 0.039 | 0.057 |
| 14 | Understanding social and global impacts of engineering | 0.665 | -0.161 | 0.366 | 0.601 | 0.169 | 0.116 | 0.095 |
| 15 | Effective communication | 0.643 | -0.258 | 0.088 | 0.488 | 0.155 | -0.017 | -0.104 |
| 16 | Leadership role, principles, and attitudes | 0.711 | -0.168 | 0.297 | 0.622 | 0.211 | 0.105 | 0.035 |
| 17 | Recognition of the need for, and the ability to engage in, life-long learning | 0.697 | -0.162 | 0.283 | 0.593 | 0.194 | 0.095 | 0.026 |
| 18 | Ability to function in multi-disciplinary teams | 0.81 | -0.218 | -0.009 | 0.703 | 0.391 | 0.001 | -0.304 |
| | **Variance** | 3.9462 | 3.4714 | 2.1366 | 9.5543 | | | |
| | **% Var** | 0.219 | 0.193 | 0.119 | 0.531 | | | |

## 10.4.4 Factor analysis of specific skills required for work

| ID | Variable | Factor Loadings | | | Communality | Factor Coefficients | | |
|---|---|---|---|---|---|---|---|---|
| | | Factor 1 | Factor 2 | Factor 3 | | Factor 1 | Factor 2 | Factor 3 |
| 1 | Apply knowledge of mathematics and other basic subjects | 0.194 | 0.107 | -0.645 | 0.466 | -0.104 | -0.038 | -0.319 |
| 2 | Use knowledge of core engineering subjects | 0.351 | 0.148 | -0.589 | 0.492 | -0.02 | -0.047 | -0.251 |
| 3 | Design a system or a component to needs | 0.493 | 0.235 | -0.376 | 0.439 | 0.091 | -0.02 | -0.064 |
| 4 | Identify, formulate and solve common engineering problems | 0.225 | 0.174 | -0.665 | 0.523 | -0.118 | -0.023 | -0.355 |
| 5 | Identify, formulate and solve complex engineering problems | 0.581 | 0.115 | -0.484 | 0.585 | 0.163 | -0.11 | -0.148 |
| 6 | Technical and environmental interaction and impacts | 0.532 | 0.275 | -0.383 | 0.505 | 0.114 | -0.015 | -0.062 |
| 7 | Design and conduct experiments, as well as analyse and interpret data | 0.451 | 0.3 | -0.285 | 0.374 | 0.077 | 0.013 | -0.018 |
| 8 | Identify research needs and necessary resources | 0.461 | 0.373 | -0.317 | 0.453 | 0.073 | 0.036 | -0.031 |
| 9 | Leverage engineering techniques, skills and tools | 0.485 | 0.143 | -0.14 | 0.275 | 0.127 | -0.027 | 0.047 |
| 10 | Specialist engineering knowledge application | 0.656 | 0.226 | -0.247 | 0.543 | 0.247 | -0.049 | 0.063 |
| 11 | Understand engineering project and construction management | 0.681 | 0.207 | -0.254 | 0.572 | 0.281 | -0.066 | 0.069 |
| 12 | Understanding complex engineering project and construction management | 0.597 | 0.32 | -0.132 | 0.476 | 0.205 | 0.01 | 0.114 |
| 13 | Understand engineering professional and ethical responsibility | 0.306 | 0.54 | -0.084 | 0.392 | 0.034 | 0.121 | 0.065 |
| 14 | Understanding social and global impacts of engineering | 0.349 | 0.526 | -0.11 | 0.411 | 0.049 | 0.112 | 0.063 |
| 15 | Effective communication | 0.095 | 0.657 | -0.284 | 0.522 | -0.154 | 0.222 | -0.106 |
| 16 | Leadership role, principles, and attitudes | 0.291 | 0.734 | -0.071 | 0.628 | 0.005 | 0.301 | 0.131 |
| 17 | Recognition of the need for, and the ability to engage in, life-long learning | 0.195 | 0.625 | -0.071 | 0.434 | -0.024 | 0.176 | 0.053 |
| 18 | Ability to function in multi-disciplinary teams | 0.116 | 0.756 | -0.206 | 0.627 | -0.174 | 0.337 | -0.051 |
| | **Variance** | 3.3373 | 3.1532 | 2.2254 | 8.7158 | | | |
| | **% Var** | 0.185 | 0.175 | 0.124 | 0.484 | | | |

# APPENDIX 5: CODED FREE TEXT THEMES

| Capability and Number of Comments | Comments from Respondents | |
|---|---|---|
| **Foundational knowledge (227)** | Basics of the field of study<br>Engineering concepts/basic fundamental concepts that can relate theory and practical<br>Maths/should be mathematically inclined | Physics<br>Reading<br>Scientific knowledge |
| **Problem-solving (203)** | Ability to identify, formulate, and solve common engineering problems<br>Analytical skills<br>Logical reasoning/critical as well as logical thinking | Practical problem-solving<br>Problem-solving ability<br>Strong analytical aptitude |
| **Professionalism (177)** | Ability to be professional and know your role<br>Able to keep a cool head in tense situations<br>Accuracy<br>Attentive<br>Calm and steady mind<br>Customer focus<br>Dedication<br>Dignity<br>Follow-up<br>Getting it right<br>Good behaviour | Hard working capacity<br>High level of commitment<br>Performance<br>Punctuality<br>Quality work<br>Reliable<br>Respect<br>Shows attention to detail<br>Stress management<br>To have concern and a strong work ethic<br>To take ownership |
| **Attitude (132)** | Attitude<br>Ethical behaviour and business practices<br>Integrity/sincere<br>Confidence<br>Consideration and generosity | Patience and persistence/ability to try until you succeed<br>Passion<br>Determination and self-direction/willingness to give effort 24/7 |
| **Technical orientation (119)** | Ability to design using current drafting technology Engineering/technical mastery<br>Technical competency | Technical knowledge<br>Technical skills<br>The ability to understand and analyse data. |
| **Inventiveness (94)** | Ability to think out of the box<br>Capacity for generating new ideas (creativity)<br>Creative and innovative ideas<br>Creator/understanding engineering by imagination which helps to increase the basics<br>Curiosity<br>Deep creativity | Enjoy building or improving the way things work<br>Experiment<br>Exploration<br>Inquisitiveness<br>Try out new things<br>Visualization |
| **Willingness to learn (87)** | Ability and willingness to learn/personality development<br>Ability to learn on ongoing basis<br>Continual improvement<br>Keen to learn from every aspect of life | Lifelong learning<br>Recognition of the need for, and the ability to engage in, life-long learning<br>Takes part in continuing education |
| **Communication skills (85)** | Ability to communicate with non-experts (in the field)<br>Effective communication<br>Express ideas and thoughts clearly | Explanation<br>Presentation skills<br>Verbal and written communication skills |
| **Applied knowledge (63)** | Applying new skills and knowledge in the field.<br>Experience in the field/how to apply the knowledge gained<br>Knowledge of field and be able to carry a discussion about it.<br>Practical working knowledge | The ability to apply learned knowledge with working knowledge in the field.<br>Translation of learning into practical applications<br>Understanding how things work |

| Capability and Number of Comments | Comments from Respondents | |
|---|---|---|
| **Business skills (60)** | Create harmony between cost and quality<br>Plan the work<br>Prioritizing tasks | Project design and execution<br>Project management<br>Time management |
| **Team worker (57)** | Ability to function in multi-disciplinary teams<br>Team player<br>Team spirit | Team work<br>Working as a team |
| **Aptitude (47)** | Ability<br>Aptitude<br>Capacity<br>Intelligence | Interest in technical domain<br>Scientific temper<br>Talent |
| **Judgment and practical knowledge (46)** | Ability to express and interpret environment<br>Ability to observe and analyse given situation<br>Common sense<br>Credibility<br>Domain-specific knowledge<br>Exposure to the faults made by previous students<br>Pattern recognition | Practical knowledge/practicality<br>Understanding needs of an engineer<br>Understanding the how<br>Understanding the what if<br>Understanding the when<br>Understanding the why<br>Wisdom |
| **Enterprising and enthusiastic (42)** | Energy<br>Enthusiastic<br>Entrepreneurship<br>Focus | Initiative<br>Interest<br>Potential and enthusiasm |
| **Interpersonal skills (37)** | Ability to interact with all<br>Good interpersonal skills<br>Handling co worker<br>Inter-personal communication<br>Networking | Non-technical knowledge<br>People skills<br>Persuading people to take your case (whether it's your boss or your client)<br>Tact |
| **Leadership (35)** | Leadership<br>Leadership quality | Leadership skills<br>Team leader |
| **Resilience and adaptability (25)** | Ability to adapt to challenges<br>Ability to mould to situation<br>Ability to think on the job and adapt | Adaptability<br>Flexibility<br>Willingness to step out of comfort level |

# Appendix 6: Factor Analysis of Free Text Responses

## 10.6.1 Factor analysis of general skills

| ID | Variable | Factor Loadings | | | Communality | Factor Coefficients | | |
|---|---|---|---|---|---|---|---|---|
| | | **Factor 1** | **Factor 2** | **Factor 3** | | **Factor 1** | **Factor 2** | **Factor 3** |
| 1 | Problem-solving | 0.124 | 0.046 | 0.93 | 0.882 | -0.018 | 0.221 | 0.627 |
| 2 | Applied knowledge | 0.814 | -0.353 | 0.151 | 0.809 | 0.086 | -0.038 | -0.007 |
| 3 | Aptitude | 0.907 | -0.128 | 0.07 | 0.844 | 0.139 | 0.079 | -0.023 |
| 4 | Attitude | 0.185 | -0.771 | 0.473 | 0.852 | -0.104 | -0.289 | 0.161 |
| 5 | Business skills | 0.846 | -0.347 | 0.141 | 0.856 | 0.093 | -0.032 | -0.014 |
| 6 | Communication skills | 0.771 | -0.417 | 0.174 | 0.799 | 0.068 | -0.073 | -0.001 |
| 7 | Enterprising and enthusiastic | 0.884 | -0.203 | 0.089 | 0.83 | 0.123 | 0.04 | -0.023 |
| 8 | Foundational knowledge | 0.038 | -0.266 | 0.665 | 0.514 | -0.065 | -0.007 | 0.394 |
| 9 | Interpersonal skills | 0.849 | -0.022 | 0.038 | 0.722 | 0.146 | 0.12 | -0.021 |
| 10 | Inventiveness | 0.379 | -0.71 | 0.373 | 0.787 | -0.055 | -0.248 | 0.095 |
| 11 | Judgment and practical knowledge | 0.816 | -0.196 | 0.088 | 0.711 | 0.112 | 0.033 | -0.019 |
| 12 | Leadership | 0.883 | -0.101 | 0.062 | 0.793 | 0.139 | 0.088 | -0.022 |
| 13 | Professionalism | 0.099 | -0.911 | -0.161 | 0.866 | -0.108 | -0.497 | -0.288 |
| 14 | Resilience and adaptability | 0.807 | -0.007 | 0.032 | 0.652 | 0.141 | 0.121 | -0.02 |
| 15 | Team worker | 0.896 | -0.256 | 0.105 | 0.879 | 0.117 | 0.016 | -0.023 |
| 16 | Technical orientation | 0.792 | -0.375 | 0.156 | 0.792 | 0.078 | -0.052 | -0.007 |
| 17 | Willingness to learn | 0.572 | -0.59 | 0.275 | 0.751 | 0.002 | -0.175 | 0.043 |
| | **Variance** | 8.3541 | 3.0817 | 1.9066 | 13.3424 | | | |
| | **% Var** | 0.491 | 0.181 | 0.112 | 0.785 | | | |

## 10.6.2 Factor analysis of specific skills

| | | Factor Loadings | | | | Factor Coefficients | | |
|---|---|---|---|---|---|---|---|---|
| **ID** | **Variable** | **Factor 1** | **Factor 2** | **Factor 3** | **Communality** | **Factor 1** | **Factor 2** | **Factor 3** |
| 1 | Problem-solving | 0.106 | 0.182 | 0.845 | 0.758 | -0.072 | -0.003 | 0.375 |
| 2 | Applied knowledge | 0.839 | 0.409 | 0.162 | 0.897 | 0.209 | 0.052 | -0.038 |
| 3 | Aptitude | 0.848 | 0.335 | 0.135 | 0.849 | 0.128 | -0.021 | -0.025 |
| 4 | Attitude | 0.346 | 0.776 | 0.414 | 0.893 | -0.135 | 0.36 | 0.091 |
| 5 | Business skills | 0.849 | 0.33 | 0.147 | 0.852 | 0.129 | -0.025 | -0.019 |
| 6 | Communication skills | 0.428 | 0.758 | 0.355 | 0.885 | -0.106 | 0.334 | 0.06 |
| 7 | Enterprising and enthusiastic | 0.896 | 0.086 | 0.077 | 0.816 | 0.209 | -0.186 | -0.028 |
| 8 | Foundational knowledge | 0.087 | -0.157 | 0.717 | 0.546 | 0.019 | -0.2 | 0.353 |
| 9 | Interpersonal skills | 0.889 | 0.182 | 0.111 | 0.835 | 0.18 | -0.126 | -0.022 |
| 10 | Inventiveness | 0.756 | 0.455 | 0.188 | 0.814 | 0.069 | 0.074 | -0.007 |
| 11 | Judgment and practical knowledge | 0.802 | 0.323 | 0.128 | 0.764 | 0.119 | -0.016 | -0.024 |
| 12 | Leadership | 0.722 | 0.145 | 0.086 | 0.549 | 0.147 | -0.103 | -0.019 |
| 13 | Professionalism | 0.186 | 0.266 | 0.829 | 0.791 | -0.071 | 0.031 | 0.354 |
| 14 | Resilience and adaptability | 0.766 | 0.032 | 0.057 | 0.591 | 0.19 | -0.184 | -0.024 |
| 15 | Team worker | 0.839 | 0.409 | 0.162 | 0.897 | 0 | 0 | 0 |
| 16 | Technical orientation | 0.197 | 0.767 | -0.342 | 0.744 | -0.125 | 0.475 | -0.258 |
| 17 | Willingness to learn | 0.589 | 0.545 | 0.298 | 0.733 | -0.005 | 0.163 | 0.046 |
| | **Variance** | 7.5044 | 3.119 | 2.5897 | 13.2131 | | | |
| | **% Var** | 0.441 | 0.183 | 0.152 | 0.777 | | | |

Appendix 7 of this thesis has been removed as it may contain sensitive/confidential content