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PRACTICE BASED COMPETENCY DEVELOPMENT

-A STUDY OF RESOURCE GEOLOGISTS AND THE JORC CODE SYSTEM

By

Jacqueline Coombes

MSc (Statistics)

A thesis submitted for the degree of
Doctor of Philosophy
in the Faculty of Business and Law

Edith Cowan University

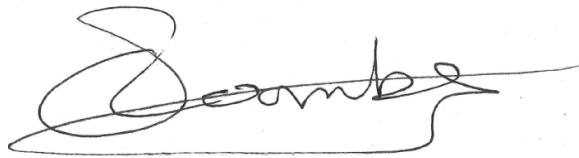
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Preface

This research was born of a desire to improve the competency criteria and competency development processes within the mining industry that can lead to effective competency in resource geologists and thereby contribute to improved mineral reporting standards. Personal experience suggested resource geologists operating as ‘Competent Persons’, who provide estimates of mineral endowment within the Australasian JORC¹ system, represent a wide range of capabilities. Most concerning, the confidence of some of these professionals in their capability does not necessarily reflect their technical competence. Since the JORC system requires geologists and mining engineers to self-evaluate their competencies to act as Competent Persons (thereby allowing them to provide critical estimates of mineral endowment within the public arena), there is a risk that inflated competency could ultimately discredit the profession, the organisations that rely on these estimates, and the reliability of investments in mining industry shares.

This research confirms that the current qualifying criteria are insufficient for identifying the style of reasoning expected of Competent Persons. Encouragingly, alternative criteria, based on exposure and context reasoning, emerged to differentiate reasoning capability in resource geologists. Moreover, this research establishes a competency development model to underscore these alternative criteria. This mixed methods research study therefore provides constructive and practical contribution to the mining industry that can lead to mitigating the risks raised in the original concerns.

In the process, this research contributes to the theory by presenting a revised model of competency and the creation of competency development model. Moreover, theories such as Learning Network Theory and Communities of Practice have been challenged and extended in a model of enduring, transient and egocentric learning-network that is better suited to the style of learning network used by transient professional scientists. The JORC system is successfully described as a social construct using a Structuration Theory framework.

By way of developing appropriate conversation within the mining industry, the researcher has published the following papers regarding the research concerns and processes:

- “*Developing Mineral Reporting Competency*” (Coombes, 2011),

¹ Joint Ore Reserves Committee

- “*Structuring Meaningful Mentoring*” (Coombes, 2012a),
- “*Developing Competence and Capability: Mineral Reporting in the Mining Industry*”²(Coombes & Barratt-Pugh, 2013),
- “*Developing Competency through Informal Learning Networks*” (Coombes, 2013)³

This research has also led to an invitation to present a keynote address at the “Resource Evaluation” Seminar in Perth (titled "Who is Competent?", Coombes, 2012b) and an invitation to address the CSGS⁴ meeting in Perth. Furthermore, the researcher was invited to join the committee for the AusIMM Society for Mining Engineers and to join the steering committee of an update of the AusIMM’s “Monograph 23”⁵.

In addition, the researcher was invited to fulfil the chapter editor role for the “Resource and Reserve Classification” chapter for the update to Monograph 23 and contribute a lead paper for the publication that describes the roles and responsibilities of Competent Persons and an additional paper describing the future of competency development in the mining industry:

- “*A Comparison of Competency Requirements for Mineral Reporting Codes*” (Abstract accepted for Chapter 1, Monograph 23 update 2013, AusIMM), and
- “*Competent Persons – Beyond JORC*” (Abstract accepted for Chapter 9 – Classification and Reporting, Monograph 23 update 2013, AusIMM)

Additional contributions emerging from this research are reflected in the following abstracts submitted for publication and presentation in 2013:

- “*Tertiary Science, Mathematics and Statistics Education and Professional Competency*” (accepted for “*The 59th World Statistical Congress*”, Hong Kong, 25-30 August 2013), and
- “*Redefining Competent Persons Criteria for Resource Geologists*” (submitted for “Exploration, Resource and Mining Geology Conference, Cardiff 21-22 October 2013).

The researcher has been invited to share research findings from this study with JORC, the AusIMM and AIG⁶ committees and within several mining and consulting companies.

² Nominated as one of four for the best paper award

³ To be presented at “The 8th International Conference on Researching Work and Learning”, University of Stirling UK, 19-22 June 2013)

⁴ City Square Geostatistical Society

⁵ The Monograph 23 provides a compendium of guidance to Competent Persons within the JORC system.

⁶ Australian Institute of Mining and Metallurgy (AusIMM) and Australian Institute of Geoscientists(AIG)

Acknowledgements

This research is dedicated to the past and present members of the Joint Ore Reserves Committee. The JORC Code's value in the mining industry is undoubtedly the result of the commitment and contribution of these volunteers. Their efforts have set a standard for professionals and their belief in Competent Persons' abilities to live up to the expectations is without compromise.

Competent Persons are the focus of this work and many shared their ideas, experiences and concerns. I am grateful to you for the time and efforts this would have taken, and value your contributions and your honesty. My hope is this work gives you a voice and, in the process, the shared results provide guidance for further competency development.

This body of work has benefitted enormously from the guidance of two great supervisors: Llandis Barratt-Pugh and Peter Lilly. After searching widely for over three years and interviewing numerous potential supervisors, I chose Llandis Barratt-Pugh because he engaged me in the potential of my ideas; he saw a kernel of an idea and helped me shape it well before committing to be part of this research. He provided care, guidance and challenge in the true spirit of a PhD supervisor. Llandis had also won a student-nominated award for best supervisor – in my experience he certainly lived up to the award with vigour, understanding and perception. I have benefited from Llandis' thrilling engagement with social science theory and workplace learning concepts I had never heard of before. He inspired me to explore so many theoretical avenues and helped me realise how little in the scheme of things I will ever really know. In the process, Llandis stretched my understanding and helped me think more rigorously about social science, about adult learners and the challenges from the scale of the individual through to the larger organisational and industry scale. He challenged me to find the truth in the data, to substantiate it with analyses and, when the time was right, he reigned me in and challenged me to pull it all together. Llandis you are a truly delightful and engaging supervisor. Thank you for your interest and unwavering support.

My gratitude to Peter Lilly extends back almost two decades. In the 1990s, Peter was a company director at Snowden where I was employed. Peter encouraged me when I first proposed formalising technical mentoring in the 1990s. He listened and saw potential in the idea. His feedback and ideas were invaluable to me. Years later when I mooted the idea of a PhD, Peter immediately offered to co-supervise. Peter's experience in high-level positions in mining industry companies, mining industry institutes, research bodies and academia meant

he was exceptionally well placed to help me connect between academia and the mining industry and to help me keep my lofty ideals grounded in the real world. I am constantly flattered by Peter's belief in me and the wonderful opportunity to have his insights and wise counsel. Given the levels of responsibility Peter has, I feel privileged he made time for me. Peter helped ensure the research focus retained a connection between the academic theory and the reality of the mining industry context. Our discussions over the years have inevitably centred on professional development. Thus, beyond recognising the implications of this study for the mining industry, Peter understood why this research was so important to me. As such, Peter insisted that the research was thoroughly validated and corroborated with evidence, and that my instruments and interpretations were verified by other experts. It has been an honour to have Peter's wise guidance for nearly two decades. Thank you Peter for your constancy, your delightful enthusiasm, and for your precious time.

It is inevitable to reflect on one's own life whilst researching competency development of others. Often I found myself reflecting on my undergraduate and early postgraduate education. One constant image is of an unwavering Prof G.P.Y. (Peter) Clarke casting his eye over me and, with a mischievous smile, persistently asking, "Yes, but why?" I was daunted by his presence, his impeccable work ethic and his apparent ability to read my mind – and not let it rest there! Peter Clarke instilled within me a passion for spatial statistics – not specifically because it was more interesting than anything else, but because he found it more interesting at the time. As his vacation student, I found the bits of work interesting and these ultimately inspired me to immediately pursue a masters' degree under him. This work in spatial statistics was to be the key that opened a door to the petroleum and then, four years later, the mining industry. Throughout my career, I have been conscious of Peter Clarke as a role model of excellence and professional dedication.

Inevitably "doing a PhD" takes the space otherwise occupied by friends and family. The price relationships pay is high. I would therefore like to thank my friends who have patiently waited on the side for my return. Thank you to Michelle, Sue, Ann-Marie, Mark and Deborah for your patience and encouragement. Thank you so much for listening to me when I went on excitedly about my research.

Most importantly, I would like to acknowledge my dear, dear family. Thank you for believing in me and for giving me the time to focus. Always interested, supportive and encouraging, Florian Coombes is a gem of a mother-in-law and deserves special mention for cheering me on from the start. Brett, my husband and best friend, you have been my constant, my rock. You asked meaningful questions that challenged my ideas, and you helped me believe in what I was doing. A special thank you to my lovely children who made space for me to pursue my

dream. Lauryn, your patience and kindness helped still me when things seemed confusing. You are an exceptional listener! Hayden, your energy and enthusiasm spurred me on – especially with your message that every word was a step closer! I hope this work can be a beacon to you both: to know that much comes from effort, including the sheer joy of being in the moment of discovery, and that curiosity and learning are the true gifts of this world.

Abstract

The mining industry is a major contributor to the Australian economy. The value of mining and exploration shares traded on the Australian Stock Exchange are contingent on the estimates of mineral deposits, which are disclosed publically in accordance with a reporting code maintained by the Australasian Joint Ore Reserves Committee (the JORC Code). Expert resource geologists, known as Competent Persons, provide classified estimates of mineral endowment that underpin these public statements. The JORC Code requirements for qualifying as Competent Persons are membership of an approved professional association and a minimum of five years' relevant experience.

This research set out to address a primarily practical issue: How do the mining industry, mining companies and individuals cooperate to develop resource geologists with sufficient competency to provide expert recommendations for public reporting of mineral resources? A corollary to this is 'Are the current standards sufficient to identify the competency expectations placed on Competent Persons?'

It is challenging to place the subsequent research in any one discipline as the study draws on multiple theories across multiple domains to facilitate a relevant description of the practice-based competency development. To properly understand the the practice of resource geologists operating in a sub-sector within the JORC Code system, the research needed to explore and consolidate diverse theories such as theories on social structures, workplace learning theories and statistical reasoning education theories. In addition, as a mixed methods study, the research draws on a wide range of tools from qualitative iterative coding and theming techniques to the more rigorous statistical tools of t-tests, paired t-tests, ANOVA and the philosophically different Rasch Analysis method.

This study reflects a broad curiosity in diverse concepts and theories that is combined with the researcher's desire to provide a meaningful practical contribution to the mining industry. The practical outcome of this research is a revised set of criteria to meet Competent Persons status under the JORC Code that is supported by a competency development model. These models are generalised to reflect a revised competency model, based on the dual expectations of practice exposure and reasoning ability, and an associated competency development model, which synthesises contributions of workplace learning experiences.

The contributions to the theory include a revised theory of workplace learning networks emerging from the practice context of transient professional workers. These networks are enduring, transient and egocentric and operate beyond organisational confines.

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1 Introduction

The mining industry is a major contributor to the Australian economy with mineral resource companies accounting for 44% of the number of companies listed on the Australian Securities Exchange (ASX), approximately a third of total market capitalisation, and 35% of the value of all ASX trades (ASX, 2012; Gallery & Nelson, 2008). The valuation of mineral companies relies directly on publically reported Exploration Results⁷ and Mineral Resource⁸ and Ore Reserve⁹ estimates supplied by technical experts (Dodd, 2012), referred to as Competent Persons.

In Australia, technical experts currently self-nominate as Competent Persons based on two qualifying criteria:

1. membership of a recognised professional association, and
2. at least five years 'relevant' experience.

These criteria and the definitions for reporting mineral assets in the public arena are articulated in a reporting code maintained by the Australasian Joint Ore Reserves Committee (JORC). The JORC Code (Appendix 1) is incorporated into the ASX listing rules, thereby directly requiring all listed mineral companies to abide by the JORC Code and to ensure the mineral assets and mining intentions that they report to the ASX are based on the work of Competent Persons.

The motivations for this research were personal observations of over-confidence in some resource geologists electing to stand as Competent Persons, as well as the observation of an apparent decline in basic analytical skills that are assumed to underpin scientific reasoning necessary for practice-based risk assessment. These trends are occurring within a climate of a tightening of standards. For example, the equivalent Canadian system now requires Competent Persons to demonstrate continued professional development. Moves such as this appear justified, but lack research support. This research seeks to bridge that gap by

⁷ "Exploration Results include data and information generated by mineral exploration programmes that might be of use to investors but which do not form part of a declaration of Mineral Resources or Ore Reserves." (JORC, 2012a, p. 10)

⁸ "A 'Mineral Resource' is a concentration or occurrence of solid material of economic interest in or on the Earth's crust in such form, grade (or quality), and quantity that there are reasonable prospects for eventual economic extraction." (JORC, 2012a, p. 11)

⁹ "An 'Ore Reserve' is the economically mineable part of a Measured and/or Indicated Mineral Resource. It includes diluting materials and allowances for losses, which may occur when the material is mined or extracted and is defined by studies at Pre-Feasibility or Feasibility level as appropriate that include application of Modifying Factors. Such studies demonstrate that, at the time of reporting, extraction could reasonably be justified." (JORC, 2012a, p. 16)

challenging the current criteria for qualifying as a Competent Person as being too lenient and open-ended and instead offering alternative, more defensible criteria. Furthermore, this thesis also provides a practice-based model for developing competency that enables resource geologists to become suitably qualified Competent Persons within the JORC system.

This research contributes on a theoretical level by providing a competency development model that is underscored by a revised competency definition model and supported by a model of enduring, transient, egocentric learning networks. The competency definition model extends Dall'Alba & Sandberg's (2006) two-dimensional model of competency by replacing the skills acquisition dimension with a set of exposure criteria and the embodied understanding dimension with a context reasoning continuum. The competency development model encompasses the factors that work together to influence competency attainment. The learning network model provides a fresh perspective on the style of learning network transient professionals create and nurture to provide access to experts. These egocentric networks are transient and are enduring despite individual and network relocation between organisations. These models provide a framework for future research in transient professions.

1.1 Purpose of This Research

There has been much discussion and debate on the competencies of resource geologists, particularly at the stage of integration of Western Bloc and the Brazil-Russia-India-China (BRIC) style codes (Gribble, Weatherstone, & Sides, 2007; Weatherstone, 2008). Whilst the BRIC codes are more prescriptive, the western style reporting codes place significant responsibility on the Competent Persons for the judicious application of the principles and guidelines of the reporting codes (Coombes, 2012b). The increasing gravity of the responsibility is evidenced by the first legal class action against a Canadian resource geologist (Seker, 2011) and moves by British Columbia Securities Commission to challenge the technical processes and techniques adopted by the Canadian equivalent of a Competent Person. This marks increasing accountability standards and the need to clarify the definitions and development processes to enable competency in line with a general “increased tendency to challenge expert opinion ...(that has) ... resulted in tighter quality monitoring procedures and a raising of minimum standards in the professions” (Cheetham & Chivers, 2005, p. 40). The JORC system is also vulnerable to these challenges. There is a perceived “basic misunderstanding of the process of estimation” (Sinclair & Blackwell, 2006, p. 317) where the most important cause of failure in technical resource estimates can be attributed to “the inexperience of those conducting the evaluation” (Sinclair & Blackwell, 2006, p. 317). Furthermore, Sinclair & Blackwell (2006) provide evidence that the expected 10% variability in resource and reserve estimates is not corroborated by actual data and is more typically between 70% lower and 70% higher than predicted¹⁰.

The purpose of this research was to investigate the mining industry practices and the expectations placed on Competent Persons within the JORC Code system, to establish an evaluation mechanism, and then to provide a framework for developing competencies required by resource geologists to meet those expectations. This aspiration required:

1. a review of current qualifying criteria for Competent Persons, including establishing an instrument to assess competency;
2. an investigation into alternative qualifying criteria; and
3. an investigation into and modelling of the experiences that lead to competency development.

¹⁰ Based on the data presented on page 318 in Sinclair & Blackwell (2006)

1.2 Problem Statement

Inadequate qualifying criteria and competency development programs can result in ill-prepared Competent Persons whose actions and recommendations could undermine their own reputation and that of the organisations that employ them, the integrity of the profession and the JORC system, as well as the stability of the Australian stock market. This research investigates the suitability of the current qualifying criteria, evaluates alternative criteria and provides a framework within which competency development can support the emerging sub-discipline of resource geology.

1.3 Research Questions

In this study the unit of analysis is the resource geologist who provides estimates of Mineral Resources to company directors. These estimates form the basis for subsequent public reports of mineral endowment in accordance with the JORC Code. According to the JORC Code, these resource geologists are Competent Persons when they are members of a recognised professional organisation and they have a minimum of five years relevant experience in the style of mineralisation and the activity in which they are electing to base their competency (JORC, 2012a).

The overarching research question is:

What does it take to develop Competent Persons for the JORC Code?

Four subsidiary research questions that are more specific emerge:

- 1. What formative qualifications enable professionals to qualify as Competent Persons according to the JORC Code community?*
- 2. What workplace experiences facilitate development of Competent Persons' competency?*
- 3. How do professional networks stimulate the development of Competent Persons' competency?*
- 4. What organisational factors influence Competent Persons' competency development?*

1.4 Summary of Practical Findings

Ahead of presenting the research process and analysis, the direct practical findings for the four research questions are summarised below.

1. What formative qualifications enable professionals to qualify as Competent Persons according to the JORC Code community?

In general, resource geologists who want to operate as Competent Persons are better equipped for diverse and complex projects if their undergraduate degree in geology has provided them with an appreciation for scientific thinking in problem solving. Furthermore, they should be equipped with at least one semester of mathematics or statistical tertiary education.

2. What workplace experiences facilitate development of Competent Persons' competency?

Critical workplace experiences include mine operational experience under the guidance of suitably qualified mentors. As well as developing depth in geological understanding by experiencing a variety of geological contexts, resource geologists should develop breadth by gaining a full understanding of the mine value chain from the early stage practices of sampling and analytical procedures through to mining and processing issues. More than simple awareness, resource geologists should build their understanding through reconciliation¹¹ studies that expose them to the full mine value chain¹² of the business.

Recommended learning experiences include formal training through industry courses augmented with situational learning under the guidance of suitably qualified and experienced mentors. Resource geologists should have at least 10 years' mining industry experience, including at least five years' resource estimation experience. In general, this study finds that resource geologists are better able to reason across the mine value chain when they have completed at least 15 resource estimates across at least two commodities and at least five reconciliation studies that allow them to examine their own resource estimates.

3. How do professional networks stimulate the development of Competent Persons' competency?

Professional networks are critical to resource geologists' competency development. These networks provide access to experts, a means to evaluate or validate technical process options and an avenue for practice-based learning. Whilst Learning Network Theory (Poell, 1998) provides a framework for organising these relationships, this research uncovers the

¹¹ A reconciliation study involves a comprehensive evaluation of estimates at various stages of a project's mining production process with a view to improving estimations and predictions based on updated estimates.

¹² The mine value chain describes the full mining process from discovery through to mine closure.

impermanence of the structure of the learning network surrounding each resource geologist since resource geologists, including network connections, are transient within the mining industry. Instead, resource geologists' professional networks are egocentric, enduring and extend well beyond the organisational frame. The professional networks therefore are "fuzzy" and evolve as the network members themselves relocate in and out of overlapping, global organisations.

4. What organisational factors influence Competent Persons' competency development?

There is abundant literature on managing and developing organisational knowledge. However, the egocentric and enduring professional learning networks indicate that discipline loyalty supersedes organisational loyalty, suggesting a refocussing of competency development at an industry-wide, co-ordinated level to help resource geologists and the organisations that employ them. The ideal organisations for developing competency provide funding for competency development, raise and maintain high standards and expectations, maintain appropriately allocated roles and responsibilities that support competency development, encourage multi-disciplinary interaction, and offer diverse projects and opportunities to develop both breadth and depth in resource geologists.

Professional bodies, whilst espousing a peer-review system to moderate the ethics of Competent Persons, have limited processes and powers to moderate the technical competence of their members. This undermines the sanctioning process within the JORC system.

1.4.1 Revising the definition of JORC Competent Persons

In light of the research findings, a JORC Code Competent Person can be described as follows:

A JORC Code Competent Person is a mining industry professional who has a mature ability to reason across the JORC Code (including all respective items in Table 1), who can provide reasoned analysis of the risks in a project, and who is able to communicate the material risks (without exclusion) to their peers, management, the board of directors and investors.

In the case of a JORC Code Competent Person reporting Mineral Resources, a mature reasoning ability is not likely to be achieved without the mining professional conducting at least 15 resource models, over at least two commodities and at least five reconciliation studies (the "15-2-5" criteria). Furthermore, these Competent Persons should have a minimum of 10 years mining industry experience, including at least five years' experience in resource estimation. Beyond these criteria, there is a heightened level of JORC Code reasoning in mining industry professionals who:

- Have greater scientific depth in their undergraduate degree;
- Place greater value in their tertiary experiences in mathematics and/or statistics;
- Seek out practical industry courses and augment them with situational learning under formal guidance of a technical mentor; and
- Have a heightened appreciation for the full mine-value-chain developed through long service and opportunities to learn through correcting their own mistakes.

The current criteria for qualifying as a Competent Person in the JORC Code are not sufficient to identify the level of reasoning and expertise as articulated in the revised description above.

1.5 Contribution to Theory

This study reinforces the notion that competency is contextual. The outcome of this research is a practice-based set of competency criteria, supported by a competency development model grounded in a mixed methods analysis of expectations, experiences and capabilities.

The competency model has two dimensions: (1) practice-based exposure, and (2) level of contextual reasoning. The exposure dimension is a measure of the variety and number of times a professional engages with the practice. The level of contextual reasoning describes the ability of a professional to apply their experiences to evaluate risk across the business value-chain in their practice. Critical levels of both dimensions are required to achieve competency within a scientific professional discipline. This model substitutes Dall'Alba & Sandberg's (2006) model's dimensions of (1) skill ability and (2) embodied understanding of the skills by firstly placing the competency evaluation within the practice field rather than pre-empting the competency, and secondly including the requirement for contextual reasoning.

The competency model presented in this study is underscored by a competency development model, which draws together the factors of workplace experience that influence the success of competency development. These factors include (1) entry requirements, (2) a strategic synthesis of formal and informal workplace learning, (3) workplace experiences that embody the business of the practice to develop both depth and breadth, (4) personal development of egocentric and enduring professional learning networks that supersede the confines of organisations, and (5) organisational practice opportunities.

This thesis shows that organisationally constrained learning networks, such as Poell's (1998) Learning Network Theory, are not appropriate to the mining industry, and instead presents a new model of egocentric professional networks that endure relocation of connections beyond the bounds of organisations.

1.6 Outline of this Thesis

This introductory chapter introduces the research problem, discusses the research question and summarises the key findings emerging from the study. This introductory chapter sets the scene for the research study by presenting a context as well as a summary of the research findings and outcomes.

The next chapter, Chapter 2, documents a review of the literature, with specific emphasis on theories that underpin workplace learning and the social constructs that frame the communities and organisations within which workplace learning occurs. The notion of competency, both within the mining industry context and the broader professional development context, is explored. The literature review also examines the research methodologies used in studies of workplace learning, professional learning networks and the evaluation of expertise. The chapter closes with an assessment of the relevance of these contributions to this study.

A conceptual framework, which emerges from the research questions and findings from the literature review, is presented in Chapter 3. This conceptual framework forms the basis for the subsequent research design and methodology.

The research methodology is documented in Chapter 4. This chapter begins with a summary of the strategic approach to the research, including the research paradigm, justification for the selection of a mixed methods approach, and an outline of the unit of analysis and population. The rationale behind the operationalizing of this strategy is then presented. A comprehensive description of the research instruments and their development follows, along with the data collection process and an overview of the data analysis procedures.

Chapters 5, 6 and 7 are all data analysis chapters, each emphasising different aspects of the research:

- Chapter 5 focuses on the examination of the JORC system as a social order within which competency is developed.
- Chapter 6 focuses on an exploration of the notion of competency, with particular emphasis on the definition and assessment of competency, including challenging the current criteria and presenting and testing alternative criteria.
- Chapter 7 focuses on the competency development mechanisms within the context of resource geologists' workplace experiences.

Each data analysis chapter closes with a summary of findings and implications.

The practical findings, implications and recommendations drawn from the data analysis chapters are consolidated in Chapter 8 with a discussion that re-conceptualises the notion of competency within the practice of resource estimation in the JORC system and provides practical recommendations for individuals, organisations and the mining industry.

Chapter 9 focuses on the development of models that emerge from the data analyses, including a model of competency underscored by a competency development model and a learning network model.

This thesis closes with conclusions in Chapter 10, including responses to the research questions and recommendations for future research.

2 Literature Review

2.1 Introduction

This thesis is about how mining professionals within the industry develop their competency. An exploration into what is meant by competency and how it can be measured and evaluated is therefore necessary. Furthermore, there is a need to understand how this knowledge can lead to a practice-based framing of competency development. Whilst the mining industry and some individuals within the industry appear to be able to develop and apply competency as required by the western style reporting codes, the processes that individuals, mining organisations and the mining industry adopt to do so are unexplored from both the practical and theoretical perspectives. Furthermore, the broader contextual organisational or industrial structures and their influences on development of these specialist competencies remain unexplored. In the absence of direct research and theories, the aim of this literature review is to examine potential theories and studies that may underpin a model to explain the development of reporting competency.

The literature review begins with an examination of the historical development of the notion of “competency” within the JORC Code through the various code updates, published guidelines and publications designed to guide the Competent Person in the practical interpretation of the JORC Code. This leads naturally to exploring how this contrasts with the broader understanding of competency.

Next, a review of professional development theory is presented, including informal workplace learning theories. The extension of these into the social construct of the workplace provides a link between the work people do, the places where work is conducted and the communities within which competency is developed.

The research methodologies associated with competency development, workplace learning theories and social constructs of workplaces are then examined. The variety of both qualitative and quantitative approaches, including data measurement and competency assessment mechanisms, provides meaningful context for establishing a suitable methodology for this research. The relevance of each aspect investigated in the literature review is then connected back to the research focus. In particular, the relevance and suitability of Structuration Theory and informal workplace learning theories to frame the research, and Rasch Analysis to test the validity of the competency measurement mechanism are discussed.

The review closes with a summary discussion on the gaps and relevance to this research.

2.2 The JORC Code

2.2.1 Historical context

The Joint Ore Reserves Committee (JORC) was set up in the early 1970s to standardise reporting of mineral assets in response to market instability caused by misrepresentations in public reporting. Within Australia, mineral endowments can now only be reported publicly in accordance with The Australasian Code for Reporting of Exploration Results, Mineral Resource and Ore Reserves (the JORC Code) (see Appendix 1 for the 2012 JORC Code). This document, in its various versions, and the associated reporting process has become “a blueprint for similar initiatives around the world and played a significant part in establishing Australia’s reputation as a global centre of mining excellence” (ASX, 2010). SAMREC, PERC and NI43-101 are examples of similar codes and standards for reporting within South Africa, Europe and Canada respectively. These western-style reporting codes have spawned the development of a single unifying international reporting code template, the CRIRSCO¹³ template (Weatherstone, 2008).

The JORC Code provides definitions, guidelines and considerations for public reporting of Mineral Resources and Ore Reserves and relies on an individual’s judicious application of the principle of Competence¹⁴:

“Competence requires that the Public Report be based on work that is the responsibility of suitably qualified and experienced persons who are subject to an enforceable professional code of ethics (the Competent Person).” (JORC, 2012a)

To qualify as a Competent Person¹⁵ a geologist, engineer, metallurgist or other mining industry specialist must be a member of one of the prescribed professional organisations, have a minimum of five years relevant experience, and be confident to defend their estimate in the presence of his/her peers (Vaughan & Felderhof, 2005). Although there is an assumed degree of peer review through the professional associations’ Complaints and Ethics processes, these avenues cannot mandate on technical processes adopted by the Competent Persons. There is no formal system in place to accredit or regulate the technical ability of a Competent Person to perform in accordance with industry and investor expectations.

¹³ Committee for Mineral Reserves International Reporting Standards

¹⁴ The SAMREC, NI43-101, PERC, CRISCO and other codes from Western countries have similar descriptions of the core principles.

¹⁵ Competent Person is the expression used in the JORC Code, SAMREC and PERC. NI43-101 refers to this person as the Qualified Person or QP and has more stringent registration requirements.

2.2.2 *The Evolution of the JORC Code's Definition of Competency*

The move towards a standard set of definitions for mineral inventory declaration in Australia began as early as 1909 when Herbert Hoover (future president of the United States) was working in the Kalgoorlie region of Australia (Stephenson & Miskelly, 2001). Hoovers' proposed sub-divisions of mineral estimates were based on geological continuity and sampling assumptions (Stephenson & Miskelly, 2001). However, it took eight decades, the Poseidon Nickel boom-bust and investigation into stock market practices by the Rae Commission (Rae et al., 1974, 1975) before the Australia Mining Industry crafted a universally acceptable set of definitions (Dodd, 2012). These early definitions articulated the risk levels associated with Resource and Reserve estimates and it took three committee reports (in 1972, 1980 and 1985) before general acceptance in 1989 with the release of the first formal JORC Code, which was immediately and fully incorporated into the listing rules of the Australian Stock Exchange (ASX).

Early definitions and understanding of requisite competency are evident in the Rae Commission report (Rae, et al., 1975, p. 111):

“(A) company's report on its mineralisation of ore should be based on information compiled by a member of the Australasian Institute of Mining and Metallurgy who has had at least five years' experience in his field of activity.”

From the outset, JORC emphasised estimates be produced by competent professionals. The 1972 JORC report highlights: “competence and experience are the most important factors involved in reporting of an ore or mineralisation situation.” (JORC, 1972, p. 3). At this time professionals were deemed competent if they were corporate members of the AusIMM and had “a minimum of five years' experience in the field of activity in which he is reporting.” (JORC, 1972, p. 4). In 1981 the concept of competence was formalised as a definition and expanded to “a minimum of five years' experience in the fields of activity **relevant**¹⁶ to the estimates.” (JORC, 1981, p. 5). This definition held for the committee's 1985 report (JORC, 1985).

When the JORC guidelines were elevated to the JORC Code and incorporated into the ASX listing rules the definition evolved to differentiate between the work required for Resources and Reserves: “A Competent Person is a person ... with a minimum of five years' experience in the relevant **Resource and Ore Reserve assessment field**¹⁷” (JORC, 1989, p. 3). These modifications to the definition of competency as well as the subsequent setup, inclusion and

¹⁶ Emphasis added

¹⁷ Emphasis added

development of interpretative guidelines and examples in the 1990 update hint at potential ambiguities in need of clarification.

By 1992, the Australian Institute of Geoscientists (AIG) joined JORC and alternate membership of AIG was incorporated into the definition of Competent Person. At this time the experience requirement was also elaborated: “the estimation, assessment and evaluation of Mineral Resources and Ore Reserves which is relevant **to the style of mineralisation under consideration**¹⁸.” (JORC, 1992, p. 3). Much discussion on the term “relevant”, as well as associated examples, was included in the guidelines attached to the Code to provide context and interpretive framework for the definition. As part of the guidelines (but not part of the formal definition), the onus was put back on the Competent Person to satisfy themselves “in their own minds that they could face their peers and demonstrate competence in the type of deposit under consideration.” (JORC, 1992, p. 15).

There was no change in the definition of a Competent Person in the 1996 update, however, the guidelines were expanded to include the expectation that a Competent Person’s experience include an appreciation of the whole mine value chain – from potential sampling and assaying problems through to extraction and processing techniques (JORC, 1996). The full mine value chain, from data collection through to mineral product, is complex and often times unique to specific styles of mineralisation and commodities. Rendu (2007) emphasises the range of considerations and that classification of Mineral Resources and Ore Reserves involves both experience and an ability to communicate effectively between multiple mining disciplines (Rendu, 2007). Sinclair & Blackwell (2006, p. 319) warn “Simplistic views of the complex problem of resource/reserve estimation can lead to doubt and uncertainty in the results.”

The complexities and uniqueness of the mineralisation deposits, styles of geology and processes involved mean the guidelines provided by a code cannot be prescriptive. Instead, the Competent Person takes responsibility for applying their judgement and due assessment across the mine value chain. By 1999 this spirit of judicious expertise was included in the embodied principles of Transparency, Materiality and Competence¹⁹ and for Public Reports to be based on “work which is the responsibility of a suitably qualified and experienced person who is subject to an enforceable code of ethics” (JORC, 1999, p. 2).

¹⁸ Emphasis added

¹⁹ Transparency ensures no duplicity in presentation of information; Materiality ensures all significant information is conveyed and Competence ensures appropriate skills are employed to provide technical guidance.

Throughout the code's evolution JORC has fiercely safeguarded any attempts to introduce prescriptive techniques and processes by keeping "the definitions and operational requirements relatively non-specific and non-prescriptive, thus allowing Competent Persons considerable freedom to exercise their professional judgement, but ensuring they can be held to account for their actions" (Stephenson & Miskelly, 2001, p. 625). Carmichael²⁰ (2009, p. 2) highlights that "any claim for greater prescriptiveness in regulating the content of public reports made pursuant to a code such as JORC is counter to the instincts, pragmatism and good regulation which invested competent persons and their professional bodies with authority and responsibility in defined regulatory space."

By way of emphasizing relevance, the 1999 update extended the definition of a Competent Person to clarify the differences between the work required for estimating Mineral Resources and for estimating Ore Reserves (JORC, 1999). This helped emphasise the need to consider data collection and measurement practices and encapsulate the difference between Resources and Exploration information. The 2004 revision brought in a definition of Competent Person that acknowledged the role of those professionals only reporting Exploration results (JORC, 2004). The 2004 update also included a requirement for public reports to state the Competent Person's name and attach the signed consent stating the Competent Person's consent "to the inclusion in the report of the matters based on their information in the form and context in which it appears" (JORC, 2004, p. 2). Greater transparency regarding independence or relationship to the listed company was sought by the 2004 requirement that the Competent Person's statement also acknowledge their relationship to the listed entity by stating the Competent Person's firm or employer. Overall, the 2004 JORC Code itself was more comprehensive, with each aspect, including definitions, discussions, examples and explanations, expanded and revised to reflect industry discussions.

Paralleling the evolving definition and expectations of a Competent Person is a table of guiding criteria to be considered by the Competent Person that grew from a simple half page of eleven criteria in 1985 to a total of six pages in 2004 with 32 criteria to be considered when classifying Mineral Resources (see Table 1 in JORC, 2004 (Appendix 1)). Whilst not prescriptive, this list of criteria (known as "Table 1" within the Mining Industry *lingua franca*) became a benchmark to guide Competent Persons. In 2012 the emphasis and use of Table 1 was elevated to a transparent and prescriptive checklist of items to be discussed with all maiden and materially changed resource and reserve estimates. An "If not why not?" instruction in the disclosure of all items in Table 1 puts the onus on the Competent Person to

²⁰ A barrister in Melbourne, Australia

ensure every item is considered and communicated in an unambiguous and non-misleading way (JORC, 2012a).

In 2001 the AusIMM published a monograph, Monograph 23, to provide practical examples to assist and guide Competent Persons' judicious expertise (Edwards, 2001; Stoker & Stephenson, 2001). Amongst the papers are examples of tools, interpretations and poor execution of classifications. Whilst not prescriptive, the compilation of Monograph 23 highlights an increase in expectation and responsibility for understanding the broader context of estimates. In particular, the range of potential matters the Competent Person is required to consider in assigning confidence classifications has increased: "Consideration of the whole range of available data, both raw and estimated, and the confidence in the geological interpretation need to be considered by the Competent Person in assigning a classification to the particular estimated Mineral Resource" (Stoker & Stephenson, 2001, p. 618). Stoker & Stephenson (2001) go on to stress the importance and value of familiarity with the deposit, while Snowden (2001, p. 647) emphasises "confidence in the geological framework is all-important and generally takes precedence over any mathematical indicator of confidence." By 2012, Monograph 23 was undergoing revision²¹ to accommodate changes in the JORC Code, mining industry techniques and technology.

The most recent JORC Code update in 2012 raises the expectations of the reporting entity to reflect the Competent Person's work by including the requirement that no omission be made of "material information that is known to the Competent Person"(JORC, 2012a, p. 4). Furthermore, the principle of Transparency is activated in a practical way with the requirement for the Competent Person to "provide explanatory commentary on the material assumptions underlying the declaration of Exploration Results, Mineral Resources or Ore Reserves" (JORC, 2012a, p. 4). The code's shift towards explicit articulation of Materiality provides opportunity for direct communication of a Competent Person's concerns: "The Competent Person must not remain silent on any material aspect for which the presence or absence of comment could affect the public perception or value of the mineral occurrence"(JORC, 2012a, p. 4). For the first time, direct reference is made to address all items in Table 1 of the JORC Code:

"In the context of complying with the principles of the Code, comments relating to the items in the relevant sections of Table 1 should be provided on an 'if not, why not' basis within the Competent Person's documentation. Additionally comments related to the

²¹ The researcher was invited in 2012 to join the steering committee for the Monograph 23 update, to take on the role as editor of the chapter on Resource and Reserve classification, and write a lead paper on Competent Person requirements.

relevant sections of Table 1 must be complied with on an ‘if not, why not’ basis within Public Reporting for significant projects ... when reporting Exploration Results, Mineral Resources or Ore Reserves for the first time. Table 1 also applies in instances where these items have materially changed from when they were last Publicly Reported. Reporting on an ‘if not, why not’ basis is to ensure that it is clear to an investor whether items have been considered and deemed of low consequence or are not yet addressed or resolved.”(JORC, 2012a, p. 4)

This update elevated the JORC Code’s Table 1 as a critical backbone to a Competent Person’s understanding of both their technical capability across the full range of considerations and in their ability to articulate the risk associated with these items within the JORC Code system. It is important therefore that a Competent Person can converse across the criteria listed in Table 1, to be able to appreciate, understand and articulate potential risks to a project within the JORC Code reporting system.

The understanding of competency within the JORC Code above is next contrasted against the understanding of competency in the broader literature.

2.2.3 General Competency and JORC Competency

The literature provides a variety of meanings around “competency”. Definitions of competencies with specific requirements of knowledge, skills and abilities enable organisations to pursue development programs (Clardy, 2008; Daud, Ismail, & Omar, 2010; Ranade, Tamara, Castiblanco, & Serna, 2010). At the most basic level, competency implies a dichotomous level of functional achievement where successes within Competency Frameworks are used for managing recruitment, training and promotion (Clardy, 2008; Daud, et al., 2010; Ranade, et al., 2010). In this context competency is viewed as a list or set of achievable tasks: “First we identify an activity cycle that best fits the discipline, and then we list tasks associated with each phase of that cycle” (Ranade, et al., 2010, p. 32). More broadly, competency can be viewed as achievement on a continuum or within a range of requirements (Dreyfus, 2004; Dreyfus & Dreyfus, 1980) or as a level within a hierarchy of skills acquisition (Cheetham & Chivers, 2005). Unfortunately, competency may only be fully appreciated when incompetence is experienced: “Most of the time, we take their competence for granted. But when things go wrong, they can do so catastrophically” (Cheetham & Chivers, 2005, p. xix). For this reason, professional associations of all types “recognise the need for ethical behaviour by their members” (Cheetham & Chivers, 2005, p. 31).

The notion of competency infers a confidence with the techniques, technology and practice. This is particularly evident in Dreyfus & Dreyfus’ Five Stage Model (Dreyfus, 2004; Dreyfus

& Dreyfus, 1980), a summary of which is presented in Table 1 below. This model presents a single progression from Novice to Expert. Competent reflects a stage describing learners who maintain a context and situational free understanding of the components they are learning or using, have sufficient experience to choose their own perspective and are analytical in their decision making, but still maintain a sense of detachment in terms of their understanding and a commitment to their involvement in the learning activity. Although four components of learning are addressed, the model places competence as a special case stage within a five-stage continuum from Novice to Expert. This level seems to be lower than is implied for Competent Persons within the JORC Code. The Competent Person within the JORC system would more likely equate with Dreyfus' level 5 or the Expert level of accomplishment. There is potential that a Dreyfus style model would place all emphasis on the preliminary learning and less on the competent-proficient-expert part of the continuum that this research seeks to address.

Table 1 Dreyfus and Dreyfus Five Stages of Skills Acquisition Model (after Dreyfus, 2004)

Skill Level	Components	Perspective	Decision	Commitment
1. Novice	Context free	None	Analytic	Detached
2. Advanced Beginner	Context free and Situational			Chosen
3. Competent		Involved understanding; detached deciding		
4. Proficient				
5. Expert		Experienced	Intuitive	Involved
Description:	This refers to the elements of the situation that the learner is able to perceive. These can be context free and pertaining to general aspects of the skill or situation, which only relate to the specific situation the learner is meeting	As the learner begins to be able to recognise almost innumerable components, he or she must choose which one to focus on. He or she is then taking perspective.	The learner is making a decision on how to act in the situation he or she is in. This can be based on analytical reasoning or an intuitive decision based on experience and holistic discrimination of the particular situation.	This describes the degree to which the learner is immersed in the learning situation when it comes to understanding, deciding, and the outcome of the situation-action pairing.

In addition, beyond the actual instance of achievement within a development continuum, it is worth noting the impact of technological evolutions on competency. Advancing technology

and techniques require professionals to be perpetual learners. In particular, engagement in continuous professional development is necessary to maintain high standards of competency (Dunlop, Barlow-Stewart, Butow, & Heinrich, 2011). One outcome of the deliberations of a working group at the November 2002 ‘Competencies Conference: Future Directions in Education and Credentialing in Professional Psychology’ was the consideration of how professional development could be linked to competency:

“A more sustained focus on professional development (PD) and professionalism may have implications for the credentialing and licensure of psychologists. As one example, regulatory boards might consider how PD might be approached more meaningfully and how professionalism might be assessed at initial licensing or at intervals throughout a psychologist’s career. New strategies for monitoring “continuing competence” beyond traditional continued education (CE) might be developed.”(Elman, Illfelder-Kaye, & Robiner, 2005, p. 373).

The notion of competency must therefore be considered as having an ongoing requirement to keep up to date with techniques and technological progressions.

Cheetham & Chivers (2005) go to great lengths to consolidate competency theories and to build a model of competence based on four core components: (1) Knowledge/ Cognitive competence, (2) Functional competence, (3) Personal/ Behavioural competence and (4) Values/ Ethics Competence. According to this model, the outcomes of these four components describe the differences in occupations as evidenced by these core components and are plotted as an “occupational competence mix” (see examples in Figure 1). The proportions on the competency pie charts reflect importance rankings based on interviews of 80 professionals across 20 professions (Cheetham & Chivers, 2005). Whilst there has been much deliberation, modelling and testing of the model as a reflection of professional focus, this model offers very little in the way of pursuing or targeting the technical aspects of competencies. Furthermore, beyond the model of competency distributions, Cheetham & Chivers (2005) provide limited connection of their definition of competency to the processes of competency development.

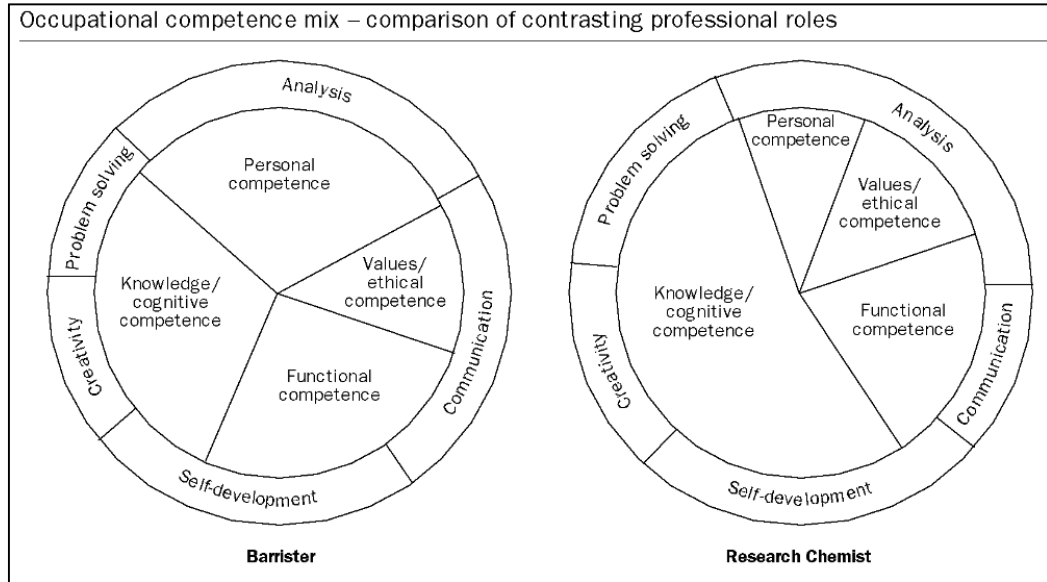


Figure 1 Examples of Occupational Competency Mixes (after Cheetham & Chivers, 2005, p. 96)

Dall’Alba & Sandberg (2006) offer an interesting model of competency which separates the single dimensional skills or accomplishment progression into a dimension describing an ability to perform a task and a depth of understanding associated with the task (Figure 2). Although arguably similar to the Dreyfus Five Stage Model, the Dall’Alba & Sandberg Model effectively extends the notion of competency away from a checkbox style progression of achievements to include the concept of embodied understanding of the tasks or skills. On the horizontal axis, Dall’Alba & Sandberg (2006) describe skills progression such as the time served (experience) or the development of an ability to perform a task. The vertical axis describes the depth of understanding associated with the task. Three examples of people’s competency development are presented in Figure 2 to highlight the different trajectories individuals make as they progress in the development of their competency. In contrast to the traditional single dimensional model describing occupational achievement as a five stage continuum from novice to expert model ‘Dreyfus’ model (Dreyfus, 2004; Dreyfus & Dreyfus, 1980), the Dall’Alba & Sandberg (2006) model provides a mechanism to explore the connection between experience and embodied understanding of that experience, as well as the progression or development of these over time. Moreover, their model respects the diversity of individuals.

This model is the basis from which Dall’Alba & Sandberg challenge recent attempts to amalgamate professional development theory across a range of occupations since the generalisations fail to “incorporate embodied understanding of the practice” (Dall’Alba & Sandberg, 2006, p. 405). Questions they pose indicate a move towards individuality and a respect for variety. Unfortunately, their model is not substantiated by data analysis. Their concepts, however, do contribute to the conceptual notion or potential requirement that a competent person within the JORC system should develop both capability to perform the tasks and an embodied understanding of those tasks.

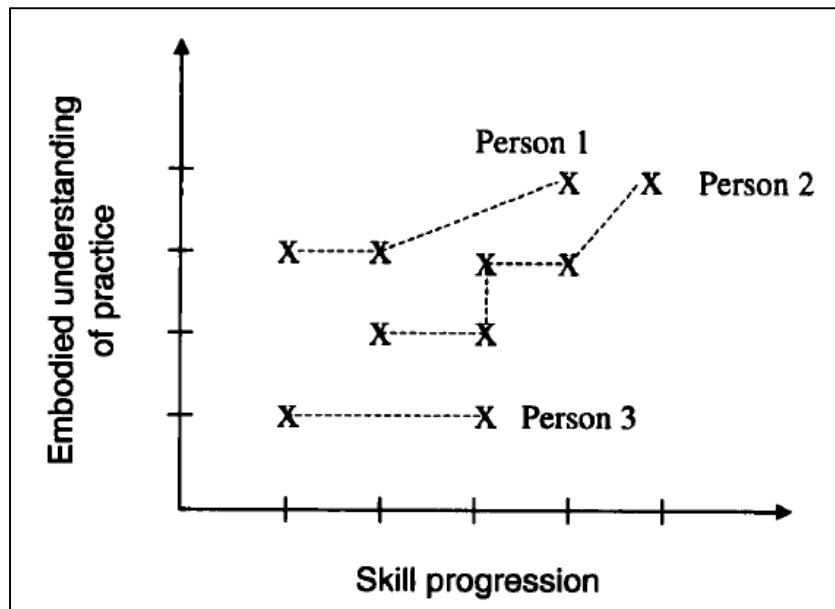


Figure 2 Model for Development of Professional Skill with Hypothetical Development Trajectories (after Dall’Alba & Sandberg, 2006, p. 400)

In contrast to these generic definitions and models of competency, the current model for competency under the JORC Code is essentially based on entrance criteria (Figure 3):

1. a minimum of five years’ experience,
2. membership of a suitable professional organisation, and
3. confidence to defend an estimate before one’s peers.

Beyond this definition and the general guidelines offered within the JORC Code, there is no underlying model of competency development. The JORC Code does express “legally well recognised and enforceable norms of competence, elsewhere expressed as conditions of an expert’s private and public utterances of opinion” (Carmichael, 2009, p. 4). In describing the legal liabilities of a Competent Person operating under the JORC Code, Livesley (2008) reinforces the legal interpretation of a Competent Person as an “expert” while Carmichael (2009, p. 3) emphasizes that “JORC’s order of things compliments legally recognised notions

of professional and expert obligation and responsibility”. A notion of Competent Person as an expert is corroborated in ASX’s 2012 listing rules that direct Competent Persons to have regard for the Australian Securities and Investments Commission’s (ASIC) Regulatory Guides detailing expectations of the content of experts’ reports (JORC, 2012a). “Competent Person” therefore implies a high level of expertise and professionalism than merely an ability to complete a set of tasks.

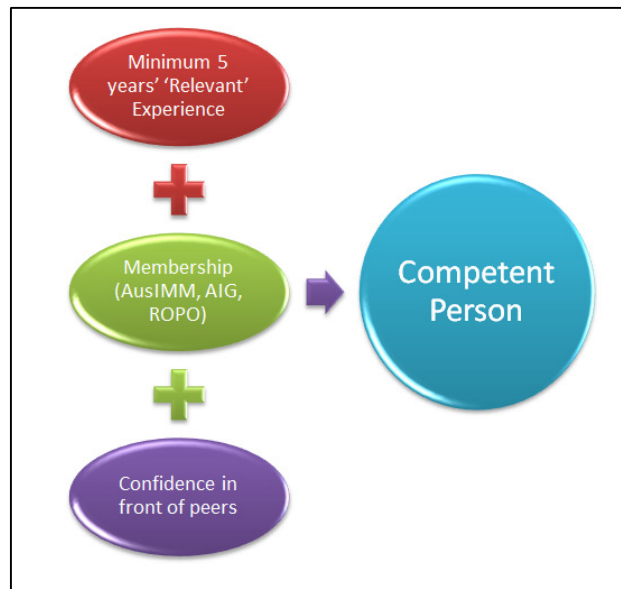


Figure 3 JORC Code Model of Competency²²

The importance of maintaining a high level of professionalism is reflected in the AusIMM’s introduction of the Chartered Professional status, which is designed to encourage professionals in the mining industry to demonstrate their commitment to ongoing professional development. A person’s Chartered Professional status is contingent on a demonstrated mix of professional development activities that are recorded and audited. A Chartered Professional status is an additional pre-requisite for AusIMM members operating within the Canadian reporting system. Collins et al. (2004) reflect the value of Chartered Professional status by setting out a list the different avenues engineers have to gather their professional development hours, but without recourse to the quality of those hours. However, attendance on a course or at a conference does not equate to an effective achievement in competency and Webster-Wrights (2009) emphasises that “despite changes in response to research findings about how professionals learn, many professional development practices still focus on delivering content rather than enhancing learning.” Therefore, rigid practice based

²² ROPO is a Recognised Overseas Professional Organisation as listed as international organisations that are considered equivalent to the AusIMM and AIG by JORC

competency models need to ensure demonstrated competency over attendance or time-served competency.

There is an apparent disconnect between the theoretical models of competency and the competency requirements implied in the JORC Code. Further exploration of competency within the practice context is necessary before a model of competency development can be established.

In the absence of a competency development model that appropriately reflects the style of competency required by the JORC Code, theories relating to competency development such as professional development theories, informal workplace learning theories and theories framing the social network, community or structure surrounding the competency development are explored below.

2.3 Theoretical Context

2.3.1 Professionals and Competency

Cheetham and Chivers (2005) provide a fascinating and comprehensive synopsis of the historical development of the notion of professionals and the advent of formal education as well as functional and social experiences to support development of their professionalism. Their descriptions echo Lave and Wenger's (1991) Communities of Practice as they go on to describe how, central to the development of a profession, is the establishment of a social system of developing expertise through a fundamental basis of education and training that is supported by an industry internship and professional associations that govern standards and ethics, as well as a community within which acceptable behaviours are role modelled by more experienced practitioners. However, they raise concerns that, through the formalisation of professions since the mid-nineteenth century, an emphasis on theory over practical skills has displaced informal learning which historically was "the prime method of development within professions" (Cheetham & Chivers, 2005, p. 32). This change in emphasis in development "may have caused earlier insights about the importance of informal learning, through for example close contact with experienced practitioners and other features relating to apprenticeships, to be lost" (Cheetham & Chivers, 2005, p. 32).

In contrast to the concerns of lost opportunities for informal workplace learning, Billett (1994, p. 1) notes a growing trend to reposition vocational learning in the workplace because "it provides access to expertise and infrastructure that is often unavailable through the public training system." In the workplace novices are "able to observe, participate and be guided by experts within an authentic culture of practice" (Billett, 1994, p. 1). This marks a "growing interest in making workplaces effective learning environments" (Billett, 2000, p. 272).

Billett (2000) pays particular attention to the interaction between mentors and their protégés, and highlights the value that this interaction brings to the capability of the protégé. He concludes that this interaction differs across organisations and that factors (such as organisational readiness, degree of formalisation and focus of the interaction and the individual human readiness of both mentor and protégé) influence the contribution of the engagement between mentor and protégé. Earlier Billett explored the importance of protégés' or novices' direct access to experts which "allowed them to take responsibility ... and respond to problems" (Billett, 1995, p. 1) and highlights that "evolving technologies and work practices require deeper understanding, yet the conceptual knowledge required for this understanding is often impenetrable for the novice" (Billett, 1995, p. 1) since "particular guidance is ... required to develop deep understanding about knowledge that is opaque and hidden from the novices" (Billett, 1995, p. 1). Central to learning is "individuals' engagement and construction of knowledge" (Billett, 2010). The process to develop competency or expertise requires deliberate practice and experience: "Expertise is developed and nurtured from years of experience, increased knowledge, and deliberate attempts to improve one's performance" (Schempp & Johnson, 2006, p. 29). This provides opportunity to learn through mistakes, thereby enabling promotion of "the quality and depth of reflection on action" (Gartmeier, Bauer, Gruber, & Heid, 2008, p. 87). There is a sense of indirect learning through observation, guidance and reflection akin to exposure through apprenticeships or mentoring programs.

The three circumstances Billett (1994) discusses that are less than ideal for apprentice style learning include:

1. Working in physical isolation from experts,
2. Technological advances which hide complex concepts in 'black boxes' and limit access to problem solving, and
3. Lack of experts to provide guidance.

These negative circumstances resonate when one considers the physical isolation, the complexity of resource estimation and classification coupled with the apparent lack of access to expertise within organisations that is experienced by resource geologists in the mining industry. Although Billett (1994) offers suggestions to counteract these circumstances, these are an addendum to the main thrust of his paper. Suggestions include formalising opportunities for greater interaction between experts and novices, ensuring experts make knowledge sufficiently explicit and accessing experts external to the organisation.

Beyond Billett's work, the literature tends to focus on urban professions with little regard to the potential isolation faced by resource geologists - either physically or through limited

access to experts from which to learn. Moreover, whilst the mining industry and some individuals within the industry appear to be able to develop and apply competency as required by the western style reporting codes, the processes that individuals, mining organisations and the mining industry adopt to do so are unexplored from both the practical and theoretical perspectives. Furthermore, the broader contextual organisational or industrial structures and their influences on development of these specialist competencies remain unexplored.

In addition, resource geologists, particularly in the Australian setting, are transient. No longer do mining professionals align themselves with a single company, instead these professionals move between organisations and so limit the ability of a single organisation to fulfil their professional development needs. Literature on professional development, however, tends to concern itself with the social construct that is the organisation rather than at a broader more encompassing industry level.

The concept of transience emerges from Wenger's recent contributions regarding Communities of Practice (Webster-Wright, 2009; Wenger, 1998; Wenger, 2000, 2013; Wenger, McDermott, & Snyder, 2002) where the emphasis in learning evolves from community governance towards individually negotiated ownership of learning along experiential trajectories of encounters within membership of communities. In short, this means that instead of communities dictating what, how and when individuals learn, individuals take personal responsibility for these decisions. In particular, Wenger describes the learning process as a trajectory through a landscape of Communities of Practice and hence the increased importance of negotiated identity in the learning process. This repositioning of individuals within the fabric of several Communities of Practice highlights the importance of professional networks for the development of competency.

In the absence of direct research and theories, the aim of the remainder of this literature review is to examine a range of theories and studies that have the potential to underpin development of a model to explain the development of mineral reporting competency. These include workplace learning and social theories that offer lenses to understand the contexts in which the learning takes place.

2.3.2 *Workplace Learning*

Workplace learning is understood to be critical for an organisation's survival as well as the advancement of an individual's career (Coetzer, 2007; Hicks, Bagg, Doyle, & Young, 2007; Poell, 1998; Wang & Ellinger, 2011). Of particular relevance are the strategic opportunities afforded by developing an organisation's skills from competitive as well as financial performance perspectives (Ellinger, Ellinger, Yang, & Howton, 2002; Karkoulian, Halawi, & McCarthy, 2008).

The importance of learning in the workplace is echoed by Ala-Härkönen & Rutenberg (1993). Unfortunately, whilst they provide an example of learning within the mining industry, their model reflects learning within merging organisations rather than provide a useful framework for understanding the competency development of resource geologists. More useful is the recognition of interpretative and high order reasoning required by geoscientists to process, assess and interpret information and data (Lisitsin, 2010; Polson & Curtis, 2010). These studies offer some insight into the style of work and associated challenges in articulating reasoning and competency requirements. Disappointingly, beyond Billett's (1994) general contribution to workplace learning, no research has been uncovered to describe or help understand how resource geologists or, more broadly, geoscientists learn when their workplaces are remote or when they operate in isolation of their professional community, which may be problematic given the need for learning through observing in an intern or apprentice style model.

Within the literature, the traditional focus of workplace learning has been on more formal and structured professional development programs. Formal workplace learning describes learning of knowledge and skills through predictable structured methods, typically within classroom style lecture formats instead of a learner's workplace. Within this more formal setting, the responsibility for learning goals, strategies and outcomes is assumed by the trainer while the learner adopts a more passive role (Doornbos, Bolhuis, & Simons, 2004). Formal structures and systems offer clear learning targets and potential consistency in expectation, delivery and outcomes.

Outcomes based development and training frameworks have been adopted by several countries as part of substantial educational reform movements. These vocational education and training (VET) systems are mostly designed to link learning and work. These competency frameworks typically include the development of competency frameworks to guide the transfer of skills and capability. For example, in the maritime industry, where standards of competence are articulated by the international body, competency development is said to be "outcome based; it requires that candidates for licenses demonstrate their ability to

perform the task for which they are going to be certified. It means applicants for competency certificate are expected to show that they are able to “do” what they are trained to do” (Emad & Roth, 2008, p. 262). However, Emad & Roth (2008) go on to challenge the effectiveness of competency based training and highlight the importance of situational learning and skills development. They conclude that “mariners obtaining certification without actual competency assessment contributes to the belief that mariners are competent when no (little) evidence has been gathered as to whether this belief is justified and therefore constitutes factual knowledge” (Emad & Roth, 2008, p. 269). Boud & Walker (1998) reinforce the connection between workplace learning and an appreciation for the specialist domain by emphasising the context as the “total cultural, social and political environment”(Boud & Walker, 1998, p. 196). Of particular relevance to the research at hand, is the development of this domain-specific competency within informal workplace learning frameworks. Indeed, Gonczi (1999, p. 187) warns: “Any programme designed to facilitate the development of expertise in a particular domain should take into account the way in which experts in that domain use their experiences for learning.”

Chipchase et al. (2012) recently challenged the notion of training courses as a sole avenue for professional development of physiotherapists. Their challenge however, is without any data collection or analysis. The research imperative of this study lends support to their arguments – professional development as a dry classroom based activity is insufficient for the effective development of competency and should be constructed longitudinally to allow participants “opportunity to practice new skills in the clinical setting and return for further training and feedback” (Chipchase, et al., 2012, p. 90). They also raise concerns that these systems may be “pragmatically impossible for rural and remote practices.” (Chipchase, et al., 2012).

The JORC Code environment with its vague notion of competency could be considered an area where domain specific knowledge is paramount. The competency notion within the various Western-style codes for reporting of mineral assets is defined by entrance criteria: membership of one of the prescribed professional institutes and a minimum of five years relevant experience. A confidence to defend a Mineral Resource or Ore Reserve before one’s peers is implied (Vaughan & Felderhof, 2005). This vague definition of competency ensures that it is the estimator, not the technical process of estimation that is regulated (Stoker, 2009b; Weatherstone, 2008). The estimator is thus able to apply their expertise and interpretation to the analyses and be flexible to the variety of circumstances that arise. For this approach to work, the Competent Person is required to maintain both a mechanistic skill to employ standard industry techniques, and domain-specific reasoning to enable them to adapt and infer from limited data and information (Weatherstone, 2008). However, the accumulated

knowledge is tacit and there is currently no mechanism for ensuring or testing whether the tacit knowledge is in fact accumulated and relevant as assumed. No evidence has been uncovered to support that the JORC Code requirements for competency are necessary and sufficient to support industry expectations. Similarly, no research has been uncovered that specifically addresses the minimum learning processes and experiences required for developing the requisite competence. Instead there is an assumption that tacit informal accumulation through workplace experiences can be measured by years employed.

There is growing interest and research into the value and recognition of informal learning (Marsick, 2009). While informal learning is not new (most craftsmen historically developed their talents through workplace exposure and experience), developing a theoretical framework to understand and explore this process is gaining momentum (Marsick, 2009). Informal learning is understood to be a “implicit and spontaneous” (Doornbos, et al., 2004), “unplanned and implicit” (Kyndt, Dochy, & Nijs, 2009), or “experience, incidental learning, self-directed learning, reflective learning and tacit knowledge” (Gola, 2009, p. 335). Ellinger (2005) defines informal learning as “learning resulting from the natural opportunities that occur in a person’s working life when the person controls his or her own learning”. This style of learning describes on-the-job learning through “problem-solving situations, in the accumulation of competencies, in learning through mistakes and in interactive negotiations with colleagues” (Collin, 2006). Although theories differ regarding the degree of structure in informal learning, or the structure of the learning group, common to these is the concept that informal learning encompasses non-classroom based learning (Berg & Chyung, 2008).

Informal learning is tacit and the challenge for many organisations is to convert this knowledge into explicit and transferable knowledge (Poell, van der Krogt, Vermulst, Harris, & Simons, 2006). Kyndt et al. (2009, p. 370) note “workplace learning is more efficient than formal training when it comes to learning job-related skills and obtaining knowledge, because these specific skills and knowledge are less appreciated in formal education and learners frequently lack the necessary insight to put theory into practice.”

The four most prominent theoretical frameworks for explaining informal workplace learning include:

1. Action Learning
2. Social Networks
3. Situated Learning or Communities of Practice, and
4. Learning Network Theory

These theories are compared in Appendix 4. Action Learning broadly describes the reflective learning processes a learner-actor invokes through their actions on the situational work-related

problems and challenges they encounter (Marsick & O'Neil, 1999). O'Neil (1999) describes four different schools of thought for interpreting Action Learning: Tacit, Scientific, Experiential and Critical Reflective.

The Tacit school of thought describes learning through incidental encounters with workplace problems (Marsick & O'Neil, 1999) so that information, skills and knowledge are accumulated through a haphazard unstructured manner. This tacit action learning underpins several researchers' empirical explorations through narrative and interview techniques (Marsick & O'Neil, 1999).

The remaining three schools of thought use more deliberative techniques to shape workplace learning:

- The Scientific-based Action Learning school of thought relies on scientific deductive reasoning when faced with workplace problems (Marsick & O'Neil, 1999).
- The Experiential-based Action Learning incorporates an element of deliberate reflection, but this idea is rejected by proponents of the Scientific school of thought (Marsick & O'Neil, 1999).
- The Critical Reflective school of thought extends the Experiential approach to include reflection on assumptions and beliefs that shape the actions (Marsick & O'Neil, 1999).

On the basis of Action Learning, Marsick and Watkins (1999) formulated an informal and incidental learning model that defines how learning can cycle through a trigger before being interpreted and examined for alternatives. The process continues with examining how a learning strategy is selected and applied and how the learning occurs through reflection. This theoretical framework is centred on informal, on-the-job challenges and operates within the organisational context (Ellinger, 2005).

The theoretical framework presented by Clardy (2000) to describe informal workplace learning appears similar to the Action Learning theory as described above. The premise in both is that an event triggers the learner-actor to take action (in this case learning). Clardy (2000) does, however, differentiate between induced, synergistic and voluntaristic triggering events. An induced event occurs when the learning event is presented to the learner as an optional path. A voluntaristic event occurs when the learner opts to create a learning opportunity and a synergistic event occurs when the learner and the organisation shape the learning opportunity together. This work adds definition to the pure Action Learning approaches.

Extensions of Action Learning include framing the organisational contexts (Berg & Chyung, 2008; Marsick & O'Neil, 1999) and social networks (Ellinger, 2005; Gola, 2009; Paloniemi, 2006).

A sociocultural perspective enables informal learning to be examined as a social interchange where the workplace is “conceptualised as a complex social system in which co-workers, who constitute that social system, are assumed to co-regulate each other’s learning opportunities.” (Le Clus, 2008, p. ii). Workplace learning emerges “from peoples’ relations and interactions with the social and material elements of particular contexts” (van Woerkom & Poell, 2011, p. 216). Considering the workplace as social networks provides a meaningful description of how people connect with peers, supervisors and others external to their working context (Cho, Gay, Davidson, & Ingraffea, 2005; Del Campo, Gomez, Dimovski, & Skerlavaj, 2008; Ellinger, 2005; Gola, 2009; Paloniemi, 2006). Social Network analysis explores the connectivity, strengths and longevity of connections between individual actors in a work environment. The connections analysed tend to be disparate and individualistic.

Lave and Wengers’ (1991) highly acclaimed treatise set the groundwork for understanding learners as apprentices within a Community of Practice. In particular, they note that “mastery of knowledge and skill requires newcomers to move towards full participation in the sociocultural practices of a community” (Lave & Wenger, 1991, p. 29) and that “learning is an integral and inseparable aspect of social practice” (Lave & Wenger, 1991, p. 31). Developing mastery in one’s craft requires “(a)n extended period of legitimate (situated learning and) ... provides learners with opportunities to make the culture of practice theirs” (Lave & Wenger, 1991, p. 95). Learning a craft requires the learner or apprentice to situate themselves alongside experienced masters, to practice both the physical craft and participate in the social fabric of the community, thereby assimilating the business of the community well beyond the products of the community’s labour.

Developing a community of practice within an organisation requires scaffolding of learning through attention to the practice, the professional network and the cultural norms (Hara & Schwen, 2006). Whilst communities of practice provide “opportunity to leverage talent and strengthen team building through their unique composition of individuals with collective knowledge, specialised skills and passion for the work” (Kerno & Mace, 2010, p. 89) the inherent nebulous and informal format creates challenges at the “structural, ecological and cultural levels of organisational analysis” (Kerno & Mace, 2010, p. 84). In particular, communities of practice are constrained by the relationships and hierarchies (functional and implicit) within organisations as well as the sociocultural norms, especially for Western societies where “recent pursuit of neoliberalism, and the emphasis it places on the individual,

serve to further erode a sense of community” (Kerno & Mace, 2010, p. 87). The effectiveness of communities of practice to develop mastery “can be impaired by the inappropriate interference of management” (Kerno, 2008, p. 23) In a sense, the communities of practice appear highly informal with the only tangible structure being the relationship between master and apprentice. Kerno (2008) distinguishes between “Communities of Practice” and “Communities of Interest”. Both are fuzzy in the clarity of their boundaries and structure, but members of communities of practice self-select based on a pursuit to develop their expertise, while members of communities of interest elect to join based on interest in the community’s focus. Communities of practice rely on participants’ mutual egalitarian attitudes where “knowledge sharing is a fundamental activity” (Klein, Connell, & Meyer, 2005, p. 111). Whilst communities of practice lacks formal definition of structure between participants, recent work using a communities of practice framework by Edmonds-Cady & Sosulski (2012) emphasises the need for formal models of individual and system change.

In contrast to social networks and communities of practice, connections between actors in workplace learning are given form in Learning Network Theory (Poell, 1998, 2003; Poell, Chivers, van der Krogt, & A., 2000; Poell, Plujimen, & van der Krogt, 2003; Poell & van der Krogt, 1997; Poell & Van der Krogt, 2003; Poell, Van Der Krogt, & Warmerdam, 1998; Poell, van der Krogt, & Wildemeersch, 1999; F. J. van der Krogt, Poell, Chives, & Wildemeersch, 1998). The Learning Network Theory framework explains the system of learning relationships that interrelate to create employee learning Figure 4. Within the Learning Network Theory framework, learning and work are presented as mirror constructs, both with actors, processes and structures that influence the success or otherwise of work, learning and their integration (Poell & van der Krogt, 1997; Poell, et al., 1999; F. J. van der Krogt, et al., 1998). Further to this framework, Learning Network Theory describes four theoretical learning networks: liberal, vertical, horizontal and external. These networks flourish within different organisational climates, including the processes for learning (policy, programs and execution), the content structures, the structure of an organisation’s relations, and the climate the organisation fosters (Poell, Chivers, van der Krogt, & A., 2000).

<i>Four theoretical types of learning networks</i>				
	Liberal learning network	Vertical learning network	Horizontal learning network	External learning network
Dominant actor	individual learners	managers and trainers	learners as a group	professional associations outside
Organization of learning processes	isolated activities	linear planning	organic	externally coordinated
Content structure (profile)	unstructured	task or function oriented	problem or organization oriented	profession oriented
Organizational structure	loosely coupled	centralized	integrated	externally inspired

Figure 4 Learning Networks from Learning Network Theory (after Poell, et al., 1998)

Marsick (2009, p. 267) leads a call to unify the theoretical frameworks into an integrated model:

“A unifying framework for understanding informal learning would enable theorists to compare across smaller-sample studies in different settings; and these would provide validation of key variables and relationships that could guide more effective practice.”

However, there remain under-exploited theories and frameworks that are not incorporated into the mainline theories presented in the literature. For example, Styhre (2006) explores the influence of a temporal dimension on learning where the learning event is conditional to the histories, present experiences and expected futures of the learning participants: “In workplace learning ... the past, present, and future are always already aligned and brought together when different groups of professionals ... learn from one another. Joint learning between individuals is located on a temporal horizon bridging virtual and actual time, i.e. the past, present, and future.”(Styhre, 2006, p. 95)

Although workplace learning theories appear insufficiently mature for unification, Barratt-Pugh (2004) organises the learning tensions in a comparative framework along two axes (Figure 5): a vertical axis describing the liberation of talent versus functionalist reinforcement continuum compared with a secondary horizontal axis that describes a continuum of focus from individual to corporate competency. This model recognises the context and the impetus for organisational learning and lends credibility to Marsick’s call for

unification and the establishment of an encompassing framework to structure research into workplace learning. Moreover, Barratt-Pugh (2004, 2007) opens the way to connect workplace learning theories to the social constructs within which they occur. Of particular relevance is Structuration Theory (and its various derivatives), which are explored in more detail in the next section.

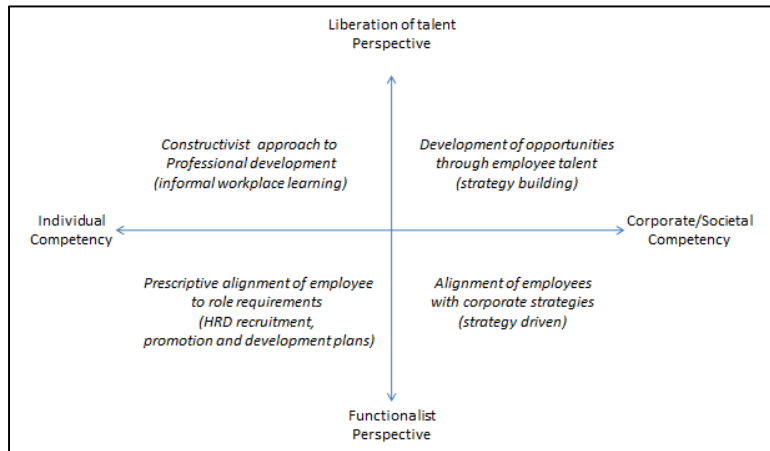


Figure 5 Workplace Learning Strategies (after Barratt-Pugh, 2004)

2.3.3 Structuration Theory

Workplace learning is influenced by the social interactions and structures that govern the organisation within which the learning takes place (Barratt-Pugh, 2007; Kissack & Callahan, 2009; Peters, Gassenheimer, & Johnston, 2009; Scheeres, Solomon, Boud, & Rooney, 2010; Yuthas, Dillard, & Rogers, 2004) as it is “actively created from the interaction and circumstance” of organisations and individuals involved (Peters, et al., 2009, p. 347). Understanding the organisational learning context provides insight into the factors which influence professional development: “Organisational culture shapes, influences and redefines training programs which, in turn, shape, influence, and redefine organisational culture” (Kissack & Callahan, 2009, p. 365). However, a broader social context that encompasses organisations within the mining industry is needed for this research since resource geologists move readily between organisations. Whilst the inter-relationship between workplace learning and the organisational structure is examined using Giddens’s Structuration Theory (Barratt-Pugh, 2004; Giddens, 1984; Stubbs, Martine, & Endlar, 2006), it can also be applied at a wider social context such as at the mining industry level that encompasses organisations involved with resource estimation.

In examining workplace learning research, van Woerkom & Poell (2011) emphasise that researchers need to recognise that individuals are “not only shaped by the environment, but also change the environment themselves as a result of individual agency, subjectivity, and intentionality” (van Woerkom & Poell, 2011, p. 216). Structuration Theory contends that all

action is performed within a pre-existing structure and that the actions of agents within the structure influence the recursive evolution of the structure (Giddens, 1984). Since each structure evolves in accordance with the actions within the structure, unique structures develop – each with their own systems of knowing or meaning, systems of ordering resources and power and systems of rules and norms (Barratt-Pugh, 2004).

Rather than operate within a pre-determined and static structure, Giddens developed Structuration Theory as a social theory to frame the recursive relationship between structure and social interaction. Theories rejected by Giddens in his search for a more fluid and dynamic framework include the Freudian focus on social-cultural agency without structural context as well as the Foucauldian notion of static structure that exerts total power over social interaction (Barratt-Pugh, 2004).

Giddens sought to provide a more dualistic theory that honours or balances the influences of both structural frameworks on social interaction and the role of social interaction on the evolution of these structures through mediating culture, communication and rules. Essentially, organisations create structure within which individuals operate. However, the way individuals conduct themselves influences the very structure within which they operate. This recursive relationship and inter-influence between organisational/societal structure and interactions between individuals within the structure is moderated through organisational mechanisms such as tangibles (e.g. policies and procedures) and accepted norms (e.g. unarticulated cultural rules). These mechanisms are identified as Modalities which connect the organisation's structural patterns to the human interactions (Barratt-Pugh, 2004). These three core aspects (structural pattern of the organisation, human interaction and associated modalities) are expanded into systems of knowing and meaning, ordering of resources and power, and rules of doing (Figure 6).

Structuration Theory	Systems of Knowing and Meaning	Systems of Ordering Resources and Power	Systems of Rules of Doing
Structural Patterns	Structures of Signification and codes	Structures of Control	Structures of Legitimation
Modalities	Interpretive Schemes	Authority and Rules distribution	Traditions and Norms Embedded in Context
Human Interaction	Through Communication	Through Power	Through Sanctions

Figure 6 Dynamic Components of Structuration Theory (after Barratt-Pugh, 2004)

Structuration Theory provides a framework for understanding how institutions or organisations simultaneously exert influence over and evolve in response to human interaction over time (Figure 7). Four critical forces exist within the Structuration Theory dualism (Englund & Gerdin, 2008):

- a. **Encoding:** the institution provides a reference structure that scaffolds the society/organisation,
- b. **Enacting:** the humans interact within this reference structure,
- c. **Reproduction:** as humans interact, they re-enforce some norms and moderate others, which in turn tempers the reference structure,
- d. **Institutionalisation:** the experience of change reforms the structure at the institutional level.

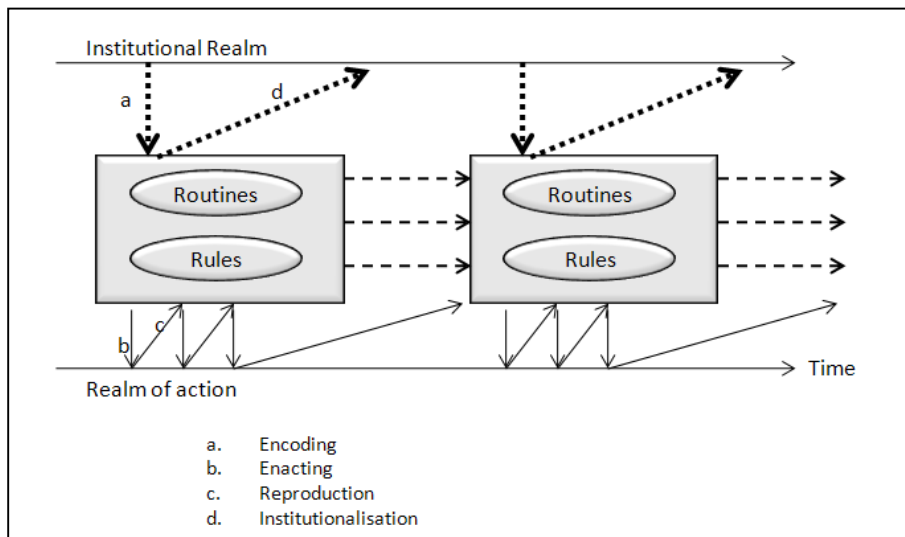


Figure 7 Structuration Theory over Time (after Englund & Gerdin (2008))

However, Structuration Theory is not without its critics (Greenhalgh & Stones, 2010; Niederman, Briggs, de Vreede, & Kolfshoten, 2008; Pozzebon & Pinsonneault, 2005). Jack & Kholeif (2007) highlight that the complexity of Structuration Theory can lead to biased application. Of particular concern are firstly the lack of “concrete constructs that give epistemological and methodological guidance to researchers” (Coad & Herbert, 2009, p. 177) and, secondly, the lack of empirical guidance (Englund & Gerdin, 2008). For example, Englund & Gerdin (2008) warn that unless scripts, rules and routines are clearly articulated, research risks conflation resulting in erroneous conclusions. Moreover, the dualism within Structuration Theory, where “both situated doings of individuals and the non-situated principles underlying those actions” (Englund & Gerdin, 2008, p. 1131) adapt over time and space, leads them to recommend research methods that hold either structure or agent static whilst the corresponding dual aspect is investigated (Englund & Gerdin, 2008). This limits an investigation into the entirety of the duality of the system. More significantly, however are the claims that there are “fundamental areas of underdevelopment in Giddens’ work ... [including] ... the relationship between agents, structures and external pressures” (Jack & Kholeif, 2007, p. 209).

In tackling the practical and empirical constraints of pure Structuration Theory, Brooks et al. (2008) present a hybrid framework based on Structuration Theory and Actor Network Theory (ANT) in response to their concerns regarding Structuration Theory’s inability to “account for technologies and non-human actors as anything other than resources whose role is to support human agency” (Brooks, et al., 2008, p. 455). Furthermore, they note that Structuration Theory does not allow for an aggressive change or “deconstruction and replacement” of a network (Archer, 1982; Brooks, et al., 2008, p. 455). StructurANTion Theory, as Brooks et al. (2008) present it, is used to explore the social aspects and inter-influences of information technology by specifically examining the influences of replicative reflexivity on Structuration Theory. ANT provides theory that similarly examines the inter-relationships of structure and agency, however, it “relies on the disruption of dichotomy between structure and agency altogether” (Jack & Kholeif, 2007, p. 210) and is viewed within a static rather than recursively evolving structure. This highlights a disadvantage of taking a societal theory into an organisation.

Archer (1982) vehemently denies Structuration Theory as a sufficient mechanism for describing society by drawing attention to the inability of Structuration Theory to accommodate step changes in structure or in the realm of action due to Structuration Theory’s assumption of fluid evolution. Instead Archer (1982) proposes a theory of Morphogenesis, which parallels Structuration Theory and provides, in her opinion, a stronger format for empirical investigation.

Adaptive Structuration Theory (AST) is another example of amalgamation of Structuration Theory with ANT (DeSanctis & Poole, 1994; Hill, Bartol, Tesluk, & Langa, 2009; Niederman, et al., 2008). Core to this merging of theories is the ability of ANT to provide a set of constructs to examine agent collaboration more comprehensively: specifically “the forces of intentional action and forces of social constraint” (Niederman, et al., 2008, p. 636). Hill et al. (2009) chose Adaptive Structuration Theory because of the inclusion of the relationship between technology and context: “AST argues that, in the absence of any other intervention, individuals will tend to appropriate or use the technology in a manner that reinforces the rules and practices for interaction in their context” (Hill, et al., 2009, p. 188). In addition, Niederman et al. (2008) outline how AST enables deeper empirical analysis by segmenting the theory according to:

1. Independent variables (e.g. the structure, context and external and internal systems),
2. Moderating variables of social interaction (appropriation and decision processes), and
3. Dependent variables (outcomes and new social structures).

An alternative extension of Structuration Theory is offered in Structuration Model of Technology (SMT) where the duality focuses on the inter-relationship between technology and agents in a parallel with traditional Structuration Theory. SMT specifically integrates the influence of software and information technology design and implementation on structures and agents, and the agents’ subsequent influences on technology (Leiden, Loeh, & Katzy, 2010; Loureiro-Koechlin, 2008). The social aspects explored by researchers include the impact of technological systems on collaboration routines (Leiden, et al., 2010) and the influence on human and social issues on the development and design of software (Loureiro-Koechlin, 2008). Orlikowski (2007) beckons us to look more broadly when considering structure such as alternative controls on structure and associated modalities. She includes the notions of Materiality (Orlikowski, 2009) and how structure and action respond to and establish temporal structures (Orlikowski & Yates, 2002), and she examines the constraining and liberating influences of technology (Orlikowski, 2000, 2009).

Strong Structuration Theory, on the other hand, aims to bolster Structuration Theory through deliberate and systematic analysis of the core aspects of the theory (Broady-Preston, 2009; Greenhalgh & Stones, 2010; Jack & Kholeif, 2007). Whilst maintaining the core of Structuration Theory, Strong Structuration Theory offers the following four tenets that require empirical exploration (Figure 8):

1. **External Structures** within which action is contemplated,
2. **Internal Structures** or the embodied knowledge and capability of individuals as well as the technological materiality and functionality
3. **Action/Active Agency** or the specific components of internal structures that agents draw from and use – the how and why they do
4. **Outcomes**, where both intended and unintended consequences on structures are examined.

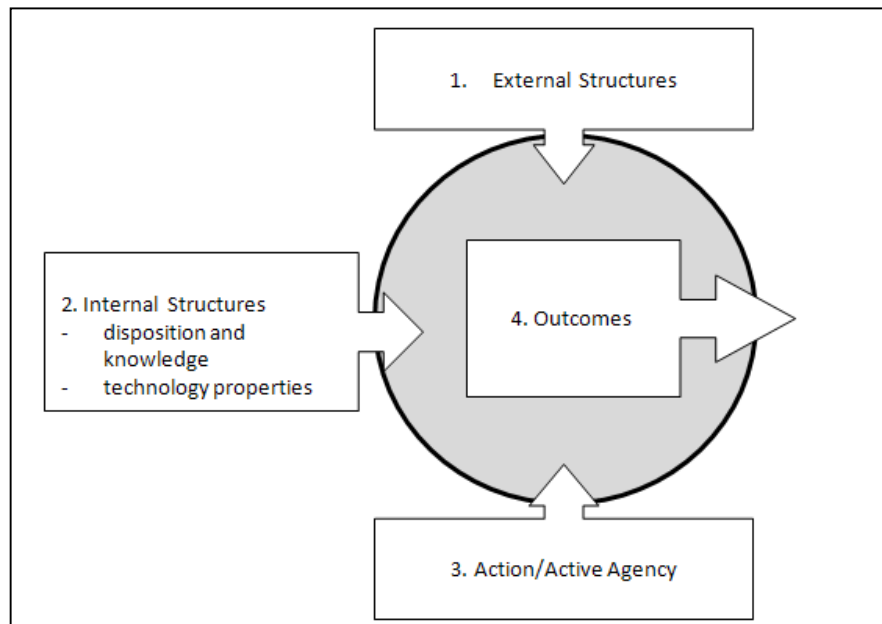


Figure 8 Empirical Tenets of Strong Structuration Theory

The evolution of the JORC Code since its inception in the 1970's shows numerous structural responses to human application of the JORC Code (Stephenson, 2000). Stephenson (2000) describes the recursive development of the JORC Code in the context of the Mining Industry and its relationship with the market. Revisions to the JORC Codes and guidelines are ongoing (JORC, 2010; Stoker, 2009a). Structuration Theory and its various forms offers an opportunity to explore how reporting professionals operate within the mining industry where the JORC Code and guidelines provide just one technological mediating implement for developing competencies to support public reported estimates. This in turn iteratively influences the structure and behaviour of the mining industry as a social entity or community.

2.3.4 *Relevance of Theories to this Research*

Structuration Theory and its various derivatives seek to understand both the institutional realm and the realm of action within the institution. Whilst Giddens's (1984) original concepts apply more generally as a social theory, Barley & Tolbert (1997) provide a more applicable definition of an institution:

"...we define institutions as shared rules and typifications that identify categories of social actors and their appropriate activities or relationships" (Barley & Tolbert, 1997, p. 96).

This definition allows institutes or structures, to be described at numerous scales. Three examples of structure in the mining industry are:

1. The entire mining industry in Australia
2. Mining companies and
3. Departments within mining companies responsible for provision of mineral inventory estimation and classification.

Alternatively, Structuration Theory can be used to describe the community who participate in the JORC Code. This includes the Competent Persons, the corporate executives, the ASX, ASIC and the investment community. The human interactions under focus are those that pertain to the modalities that are JORC Code and guidelines.

Structuration Theory and its various derivatives consider learning as an action. There is limited definition within the current theories to accommodate the network of relationships that contribute to learning. Of all the network learning theories presented, the continuum between Lave and Wenger's (1991) fuzzy descriptions of Communities of Practice and Poell's (1998) more structured Learning Network Theory provide platforms for exploring the learning relationships and requirements for resource geologists' development towards the JORC Code style of competency. While Communities of Practice offer the potential flexibility required for the *ad hoc* style of learning of resource geologists, Learning Network Theory's structured framework identifies the differences in social relationships and the power influences these can have on the learning event. For example, learning from one's supervisor through a vertical network will instil a different set of learning expectations from the individual than the learning from a peer within a horizontal relationship. Due to its more structured framework, Learning Network Theory was selected for this research to scaffold the concepts and research to ensure recognition of both the social as well as the power relationships during learning events. However, the core concepts of Communities of Practice were explored during data analysis and modelling of the emerging learning process.

In summary, four theories are particularly relevant to this research:

1. **Structuration Theory** (Giddens, 1984): Structuration Theory provides a basis for exploring the symbiotic relationship between the Competent Persons as actors and the social framework as constituted by the reporting system, governed by the rules, regulations and norms established within the JORC system.
2. **Learning Network Theory** (Poell, 1998). Workplace learning is core to the development of competency. Learning Network Theory provides a theory that links workplace learning and the members of the professional community, whilst simultaneously recognising and ordering the diverse power relationships underpinning these network interactions.
3. **Communities of Practice** (Lave & Wenger, 1991): Attainment of competency is predicated on the professional interactions of the resource geologists within their local operational communities. The theory of Communities of Practice provides scaffolding to the exploration of these professional exchanges as moments of competency development. The power of the professional resource geology community is expected to extend beyond the organisational levels. Communities of Practice theory offers opportunity for professional bodies to contribute to the dynamics of competency development of transient professionals.

and

4. **Competency Models**: Various models have been presented above. Dall’Alba & Sandberg’s (2006) bi-axial model of competency does provide promise for developing a practice-based definition that suits the JORC Code definitions and expectations.

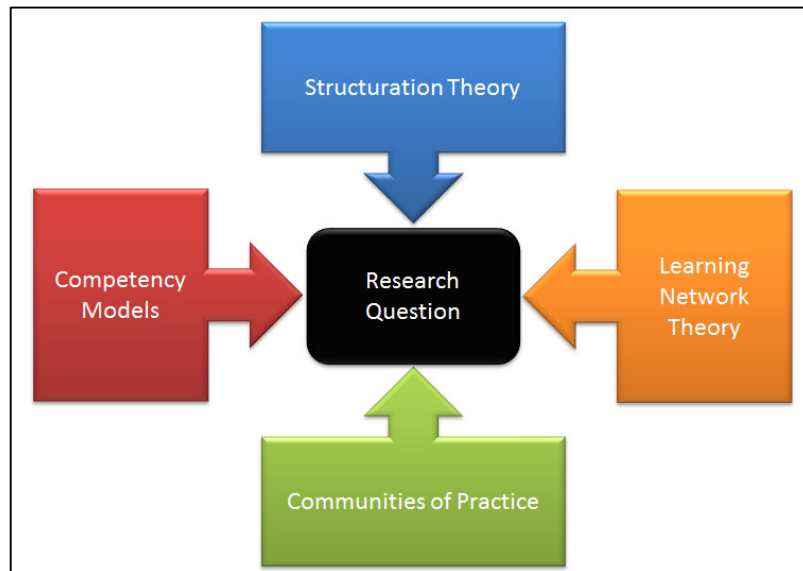


Figure 9 Theories Contribution to the Research Study

2.4 Research Methodologies

The literature review now turns to an investigation of the methods researchers have adopted to operationalize their explorations of workplace learning and the social context and frameworks for learning. Of particular relevance are the methods associated with research based on Structuration Theory and workplace learning theories. Moreover, it is worthwhile to explore the research methods associated with evaluating expertise. Each of these three aspects is explored below. This section closes with a summary highlighting the relevance of various approaches to this study.

2.4.1 Structuration Theory and Organisational Context

Although initially proposed three decades ago to unify the symbiotic evolutionary influences of human interaction and social order (Giddens, 1984), Structuration Theory has more recently underpinned research of social interaction and influence within organisational structures in a variety of organisational contexts. These include Frontline Management development (Barratt-Pugh, 2004), work patterns of general practitioners (Geneau, Lehoux, Pineault, & Lamarche, 2008), relationships between managers and users within knowledge management systems (Chen, Shang, Harris, & Chen, 2007), creation of education systems (Stubbs, et al., 2006), and the social interaction in knowledge translation (McWilliam et al., 2009).

Common to these studies is the qualitative research methodology, such as case studies, social phenomenology and interviews. These are used to explore the applicability of Structuration Theory for defining the social relationships and their inter-relationships with the social structures within which they occur. In addition, researchers have applied Structuration Theory to support retrospective analysis (Jack & Kholeif, 2007) and sub-sets of analysis through retrospective examination and analysis (Greenhalgh & Stones, 2010). Greenhalgh & Stones (2010) investigated the impact of introduced technology on human interactions, human engagement of the technology and the impact on the overall system in the case of British healthcare system. Jack & Kholeif (2007, p. 222) argue for the use of Strong Structuration Theory at the design stage of accounting, organisation and management studies to “impose a discipline on the researcher, to ask more penetrating questions of their sources and themselves that will elicit responses about internal and external agents and structures, context and perceptions of conduct.”

Much debate has surfaced regarding the conflation and erroneous conclusions in research due to the poor articulation of modalities and/or scripts (Englund & Gerdin, 2008; Greenhalgh & Stones, 2010). Poor mediating tools spawn individual solutions that are not necessarily re-integrated into the structure (Leiden, et al., 2010). Recommendations for research

methodologies include the investigation of both situated data that describes recurrent interaction as well as information that helps one understand the non-situated principles (Englund & Gerdin, 2008).

In an attempt to address ontological concerns, Stones (2005) presented Strong Structuration Theory, which includes four tenets that help move Structuration Theory “beyond the abstract philosophical concepts” (Greenhalgh & Stones, 2010). The strengthening of Structuration Theory facilitates observation of structure and action, and an examination of the meaning in an agent’s actions (Broady-Preston, 2009). Greenhalgh & Stones (2010) describe how Strong Structuration Theory allows researchers to explore and examine the critical conjuncture of both internal and external structures, the action or active agency and the outcome. **External structures** describe the position-practice power relationships that provide context for action. **Internal structures** of agents within the structure include both the general dispositions or embodied skills and the “hermeneutic understanding of external structures” (Greenhalgh & Stones, 2010, p. 1288). **Action/Active Agency** describes the active engagement of particular elements of internal structures. The **Outcomes** of the actions are evidenced by both the intended and unintended consequences on external and internal structures. Detailed questions designed to guide research from a Strong Structuration Theory perspective is presented by Greenhalgh & Stones (2010, p. 1291). These questions and the scalar framework are reproduced in Appendix 2.

Jack and Kholief (2007) also offer a detailed analytical framework based on the quadripartite nature of Strong Structuration Theory. In particular, they recommend an analytical study begin with the “the internal structures based on the agents in focus” (Jack & Kholeif, 2007, p. 13), followed by an exploration of their “interpretative schemes, norms and allocation of resources”(Jack & Kholeif, 2007, p. 13). From there the analysis should broaden to the agents’ perceptions and networks, including the inter-relationships. Next the study should examine the quality and strength of the “relevant external structures, and the authority and material resources at their disposal” (Jack & Kholeif, 2007, p. 13) as well as the ability of the agent to modify these external structures. Finally, the research turns to the effectiveness of both the agents and the structures and the extent to which modification has occurred. Their view of Strong Structuration Theory appears to be scalar: focussing first on the internal and then systematically broadening until the effect of the dualism is explored. There may, however, be a risk in this approach: what if the initial internal focus is the wrong one? It seems illogical to start with the detail before framing a study within a broader context. In contrast a more interactive approach is presented by Englund & Gerdin’s (2008) Structuration Theory forces (see details on page 34). Their presentation of Structuration Theory allows researchers to examine the forces of Encoding, Enacting, Reproduction and

Institutionalisation, with a particular emphasis on examining how these forces work together to keep the social construct alive. Examination of these forces appears to provide a more realistic opportunity to evaluate the human interactions, rules and norms, and structures that result and co-evolve and does not require any part to be held static during the research.

Interestingly, Giddens never intended for his research to provide specific guidelines for research methodology, instead intending Structuration Theory to be used “more selectively” (Stones, 2005, p. 2) and the guiding concepts to be “seen as ‘sensitising’ devices for research purposes” (Stones, 2005, p. 3). Giddens complained about research that “tended to import his concepts *en bloc* ... in a way that merely served to unnecessarily burden and clutter studies with an excess of abstract concepts” (Stones, 2005, p. 2). Therefore, whilst Strong Structuration Theory does offer more detailed framework, it would be wise to maintain an open and flexible approach to the research – one that works for the context and examines the structure, human interactions and modalities as a whole. Therefore, special attention should be given to examining Englund & Gerdin’s (2008) four forces and use to describe the structure of the JORC system ahead of investigation of the learning events and relationships contained within the structure.

2.4.2 Workplace Learning

Research into workplace learning is varied. Whether qualitative or quantitative, workplace learning studies tend to be explorative and are highly localised. They therefore offer limited opportunity for generalisations across contexts and disciplines. Within disparate and under-explored theoretical frameworks, researchers have tended to explore informal learning more often using qualitative techniques (Appendix 3).

At its heart, the very nature of workplace learning is difficult to articulate being tacit, spontaneous and often occurring without conscious recognition (see discussion on theories above). Therefore, many studies focus on developing a deeper understanding of the learning taking place through narrative studies and qualitative interviews (Appendix 3). Case studies, interviews and observations allow a deeper contextual understanding of the workplace learning processes in place. Analytical methods require coding, content analysis and analyses of themes to development an understanding of the patterns inherent in the information. These qualitative research methods seem appropriate for the subject matter, although they lack transferability due to their context, industry and geographical constraints. Quantitative methods employed in the literature are based on survey results with subsequent analyses including Factor Analysis, correlation analysis and ANOVA (Appendix 3). The quantitative analyses are based on large surveys of learner-actors. Karkoulian et al. (2008) provide a robust sample set of 499 employees within 10 Lebanese banks. A relatively extensive survey

of 1,162 employees across 31 organisations is also offered by Kyndt et al. (2009). These more extensive sampling protocols provide greater opportunity to generalise results at the expense of rich, in-depth information.

Given the unique characteristics in people, combined with the variety of organisational contexts and industries, as well as the tacit nature of informal workplace learning, it is not surprising then that the methodologies employed to understand workplace learning focus on developing a deeper sense of the informal workplace learning factors through more personalised data collection procedures. However, the research on workplace learning should adhere to the six key principles shared by Chin et al. (2011) (Table 2).

Table 2 Key Workplace Learning Research Principles (After Chin, et al., 2011)

Principle	Description
1. Broad Focus	Research on workplace learning should include a range of expertise from novice to proficient worker
2. Saliency	Research should examine how learners find their way towards competence
3. Commonplaces	Research should include inquiry methods appropriate to context (viz. learner, teacher, content and milieu) and enable thorough and informative accounts
4. Inclusion	Research should not discriminate against or deliberately exclude participants
5. Richness	Research should include diverse and rich perspectives
6. Congruence	Research should be authentic to both the learner and the workplace and needs to consider the characteristics and context of the individual learner

These principles provide comprehensive considerations when designing investigations into workplace learning for this study.

2.4.3 Evaluating Expertise

Since this study focuses on competency, there is a need to assess or evaluate the competencies of resource geologists. Competency, as intended within the JORC Code context, relates to a level of professional expertise that enables the Competent Person to complete estimates, evaluate the risks against criteria itemised in Table 1 of the JORC Code and classify their estimates in line with the risk levels defined in the JORC Code. The primary concern in this research is the development of the professional expertise that enables resource geologists to declare themselves a Competent Person in accordance with the JORC Code. However, based on the literature reviewed regarding competency, self-declared competency and duration of employment may be insufficient indicators of competency. Moreover, there is little to evaluate the degree of competency attained, especially for non-experts. Koppl (2010, p. 221) describes this concern eloquently:

“Competition among experts may not be sufficient to keep the expectations of novices aligned with the competencies of experts if the novices cannot independently judge the results of expert advice or practice.”

Inevitably competency evaluation is necessary “because, however competence is defined and articulated, it is necessary to know when people have attained the desired standard.” (Cheetham & Chivers, 2005, p. 76).

Evaluation of expertise can follow a traditional process of modelling competencies and then a large scale quantitative evaluation of the corresponding gap analyses. One example is a study of 300 executives in an Indian automobile industry sector (Anitha & Thenmozhi, 2011). Another example is a quantitative investigation into the expertise of Malaysian Occupational Safety and Health professionals using the Delphi Technique which involves “systematically soliciting and collating judgements on a particular topic through a set of carefully designed sequential questionnaires interspersed with summarised information and feedback of opinions derived from earlier responses” (Daud, et al., 2010, p. 41). Govaerts et al (2011) provide an alternative approach for examining context specific competency evaluation of raters who conduct workplace-based assessments, while Young & Chapman (2010) broaden the definition of competency by providing a consolidation of global and generic competencies for workplace success. Campion et al (2011) provide a detailed linking of competency modelling to job analysis and organisational goals. The transient nature of resource geologists, however, limits the applicability of these approaches to understand competencies. What is valuable in Campion et al.’s (2011) study, however, is the structuring of levels of competency from those requiring assistance through to those with a heightened level of self-responsibility. These levels allow competency to be envisaged as a continuum from novice to expert rather than an

evaluation against a set of requisite skills. Both Dreyfus & Dreyfus (1980) and Cheetham & Chivers' (2005) models transcend context specific competencies and provide frameworks for understanding expertise. In general, these continuum style models recognise the gradual acquisition of expertise and the stark differences between the extremes of novice and expert (Dall'Alba & Sandberg, 2006; Jones, 2008). Rather than a dichotomous novice/expert comparison, "acquiring expertise is a process" (Lehmann & Carolyn Strand, 2006). Beyond superior knowledge, experts are proficient performers within their domain of expertise (Anandarajan, Kleinman, & Palmon, 2008; Ericsson, 2008; Jones, 2008) and practitioners' performance along with their knowledge can be mapped on a continuum from novice to expert.

However, even with generic competency continuum defined, no data or research has been uncovered to connect expectations with resource geologists' expertise within the JORC system. The level and definitions of resource geologists' expertise therefore remains vague. Approaches to evaluating competency in geologists range from a highly specialised and detailed case study of only four expert geologists (Polson & Curtis, 2010), to a quantitative analysis of geologist's interpretation through focus group workshops (Lisitsin, 2010), through to a detailed mixed methods study focussed on a university mineralogy class (Ozdemir, 2009). What makes evaluating geologists' competency difficult is the lack of tangible verifiable outcomes from the application of their competencies. Moreover "geologists are often required to make judgments and interpretations in situations of uncertainty where data are inadequate to fully constrain any particular interpretation" (Polson & Curtis, 2010, p. 5) and the risks associated with relying on a single expert includes "misunderstandings and incorrect assumptions, which may remain undetected ... (while) group elicitation allows knowledge and expertise to be shared amongst the experts and can reduce bias" (Polson & Curtis, 2010, p. 9). An element of expert peer review is thus necessary for the evaluation of these indeterminate competencies.

The current competency requirements are membership of an association and a minimum of five years' experience. However, "superior performance does not automatically develop from extensive experience, general education and domain-related knowledge." (Ericsson, 2008, p. 993). Recent moves by Canadian parties to insist on AusIMM members attaining Chartered Professional status before acting as the equivalent Competent Person in the Canadian system warrant investigation into the value of certification for Competent Persons. However, "if a certification signals competence, the individual possessing the certification should *actually be competent* ... because certification is designed to separate the marginal practitioners from the superior ones" (Fertig, 2011, p. 120). AusIMM's Chartered Professional status indicates an

equivalent of 50 hours per annum non-prescribed content dedicated to professional development, but no academic support for this expectation has been uncovered.

Competent Persons are expected to self-assess their ability to apply their expertise in accordance with the JORC Code. However, there is a real risk of over-confidence across the spectrum of expertise:

“Novices, like their more experienced counterparts, also need self-knowledge with respect to where their abilities fundamentally lie. Without that understanding, the individuals are even more likely to be subject to the characteristic overconfidence that afflicts much of decision-making” (Anandarajan, et al., 2008, p. 360)

Rather than a specific set of competencies as articulated for cost estimating professionals (Hollmann & Elliott, 2006) or a visual grid for engineers (Ranade, et al., 2010), geoscientists' competencies relate more to interpretation and reasoning (Bond, Philo, & Shipton, 2010) and are more challenging to map, list and articulate. Resource geologists require ability to reason through limited data, to apply expertise to test a range of hypotheses and to recursively incorporate learning from new experiences. “Professional geoscientists can rarely be certain of the ‘right answer’ to problems posed by most geological datasets, and reasoning through this uncertainty, being intelligently flexible in interpreting data which are limited in resolution and spatial distribution” (Bond, et al., 2010). This inference is akin to the expectations placed on statistical analysis, which “involves drawing conclusions that go beyond the data” (Bakker, Kent, Derry, Noss, & Hoyles, 2008, p. 130). Bakker et al. (2008, p. 132) note that inference involves “a general sense of drawing conclusions, including the possibly tacit reasoning processes that precede and support explicit inference from a premise to a conclusion”. Furthermore, they identify three types of inference: deduction, induction and abduction. Abduction, they note, is “a method of reasoning in which a hypothesis is formed that may explain the data” (Bakker, et al., 2008, p. 132). All three modes of inference would appear relevant for resource estimation. These early assessments of statistical reasoning evolved into hierarchical levels of reasoning, initially espoused as a five-level Model of Statistical Reasoning (Garfield, 2002) and later as a six-level Statistical Literacy Construct (Watson & Callingham, 2003). The concept of a literacy construct is valuable as it pulls together the analysis, reasoning and communication of inference. The mechanism used to evaluate the validity and generalisability of the associated statistical reasoning or literacy levels is Rasch Analysis (Watson & Callingham, 2003, 2004; Wilson, 2006). The reasoning levels emerging from statistical education research range from “Idiosyncratic” to “Critical Mathematical” (Table 3).

Table 3 Statistical Reasoning Levels

Level	Watson & Callingham (2003) Levels	Descriptions of Levels of Statistical Reasoning (Wilson, 2006, p. 135)
1	Idiosyncratic	"relying on Idiosyncratic engagement with context, tautological use of terminology and fundamental mathematical skills"
2	Informal	"relying on informal engagement with context, reflecting intuitive beliefs, single aspects of terminology and basic one-step calculation"
3	Inconsistent	"requiring selective engagement with context, conclusions without justification, qualitative use of statistics"
4	Consistent non-critical	"requiring non-critical engagement with context, multiple aspects of terminology, some appreciation of variation, basic quantitative statistical skills"
5	Critical	"requiring critical engagement with context, appropriate use of terminology, qualitative statistical skills but not including proportional reasoning"
6	Critical mathematical	"requiring critical and questioning engagement with context; understanding of subtle aspects of language, use of proportional reasoning"

Wilson (2006) provides a comprehensive demonstration of the development and testing of a statistical reasoning assessment at the secondary-tertiary interface. The Rasch Analysis used by Wilson (2006) enabled the assessment tool and the reasoning levels to be updated in line with the study context. There is potential to leverage off the approaches and processes in the statistical reasoning studies to develop and test a mechanism for assessing the application of the JORC Code in resource geologists' reasoning within a range of scenarios.

2.5 Relevance to the Research Problem

The literature review has provided a synopsis of theories, models and methodologies that may underpin this study. Next follows discussions clarifying the relevance of these to the research context. Firstly, the framing theory of Structuration Theory and its relevance to mining organisational context is examined. Secondly, workplace learning theories, with particular emphasis on the social context of learning, are discussed. Finally, the relevance of assessing competency is considered with an emphasis on Rasch Analysis as a means to develop a reliable and consistent assessment mechanism.

2.5.1 Structuration Theory and Organisational Context

No research has been identified that examines the social interaction within disparate workplaces, such as the mining industry where the structures mediating the relationships are dispersed between an urban head-office and typically isolated mines. The closest context is a study on the work of general medical practitioners (GPs) that examines and contrasts the factors that shape their work in different environments, including urban and rural settings (Geneau, et al., 2008). Their study concludes that a lack of peer-to-peer interaction and limited social interaction mars professional development (Geneau, et al., 2008). Moreover, the social isolation is not limited to physical isolation and can manifest as a lack of opportunity to interact (Geneau, et al., 2008).

Assessment of the implementation of a regulatory code (the Sarbanes-Oxley Code of Ethics) within a Structuration Theory framework provides an example of analysis of codes as a form of organisational discourse (Canary & Jennings, 2008). Although limited by lack of organisational contribution, the analysis (applied retrospectively) hints at a lack of ethical behaviour expected from the implementation of a code of ethics, with agents and organisations instead focussing on procedural compliance (Canary & Jennings, 2008). This intimation has implications for the proposed research pertaining to the JORC Code, which itself hinges on the ethics codes of the various professional institutes (JORC, 2004). Canary & Jennings (2008) suggest that, although organisations are in general attempting to incorporate codes of ethics into everyday practice, the discourse is not necessarily culturally ingrained. The impact of the culture is highlighted as a potential missing component in Structuration Theory that may influence the actions of the various players within the system (Chen, et al., 2007). Contradicting this position, Kissack & Callahan (2009) suggest (without empirical evidence) the reciprocal role of culture on training and development programs can be mapped using the Structuration Theory tenets.

Studies vary between using Structuration Theory as a framework for designing and managing social systems (Stubbs, et al., 2006) to studies explaining the power relationships and

subsequent successes of implementing change (Chen, et al., 2007). The power and interaction of relationships are moderated by the process tools and communications between players (Chen, et al., 2007). However, rather than assume mediating tools are constructive to relationships, a potential outcome is that the tools can form a barrier between players (Leiden, et al., 2010). A three-year case study examining the relationship between a lead team of six managers/consultants and 32 end users in a knowledge management system implementation highlights that power and influence played out by all participants in the system are critical in the success or otherwise of a business implementation (Chen, et al., 2007).

In contrast to using Structuration Theory to explain the relationships and subsequent success or otherwise of an implementation, this theory can be used to design mechanisms a priori to moderate and mediate relationships and the overarching holistic framework (Stubbs, et al., 2006). By tracking the progress and adaption of approximately 200 students, the engagement and response of tutors and the adaption of the tools and processes, Stubbs et al. (2006) presented a convincing articulation of the interplay between structure (the framework of the designed blended learning unit) and the society (the students and tutors).

2.5.2 Informal Workplace Learning

Most of the research on informal workplace learning has explored the contextual factors underpinning this topic, including organisational contexts and employee profiles (age, seniority, gender, education) (see summary provided in Appendix 3).

A small proportion of researchers have explored features of the theoretical framework. For example, van der Krogt & Vermulst (2000) examine the differences between manager and employee perceptions and then linked these back to Action Theory. The individualistic nature of learner-actors, the social networks within organisation and differences between organisations, challenge the broad application of theory (Collin, 2009; Gola, 2009).

In addition, definitions for terms such as “organisational context” are not universal and this lack of clear definition limits the ability to compare and contrast research findings. For example Ellinger (2005), Ellinger and Cseh (2007) and Doornbos et al. (2008) highlight the importance of commitment to a learning culture on the part of an organisation’s leadership, whereas Berg and Chyung’s (2008) found no link between organisational culture and informal learning engagement. A common definition of organisational context is missing from these papers, which highlights the need for explicit definitions in research.

Researchers have explored the influence of learner-actor profiles on workplace learning. Specifically, there are differences in informal workplace learning styles according to gender (Jubas & Butterwick, 2008; Kyndt, et al., 2009), age and seniority (Hicks, et al., 2007; Kyndt, et al., 2009) and levels of education (Kyndt, et al., 2009). However, the differences in

characteristics highlighted may be contextual. In addition, there is limited discussion to link these characteristic differences back to the theoretical frameworks underpinning the research.

The social network analysis provides the closest link between the research purpose and the theoretical context. Actors within a learning context are found to integrate to different degrees and with varieties of successes (Cho, et al., 2005; Del Campo, et al., 2008). Perhaps this should not be surprising given the variety of combinations of experiences, expectations and aspirations that are possible in the workplace (Collin, 2006; Gola, 2009; Styhre, 2006).

The features and constructs of the social network as a learning network, as explored by del Campo et al. (2008), help define the strength of ties with respect to expertise level and physical proximity. Intuitively one expects a construct that articulates the order and strength of relationships would be useful for clarifying and supporting theoretical concepts regarding learning networks. However, Cho et al. (2005) failed to connect their research to learning networks. Social network analysis provides an underutilised research tool for analysing informal workplace learning, but requires substantial sample sizes for meaningful insight.

During the data analysis of this research, the key features and influences as articulated by Lave & Wenger (1991) in their theory of Communities of Practice emerged, suggesting the need to broaden the theoretical model originally proposed. Specifically, the Communities of Practice Theory describes relationships that allow the learner to act as an apprentice within a specialist area community. In this apprentice role, the learner establishes three important aspects of their craft (Lave & Wenger, 1991), namely:

1. They learn the knowledge and skills which enable them to participate in the craft;
2. They learn the social interaction skills to enable them to practice within the community and as representative of the community, and
3. Through peer reviewed experience, they develop a tacit understanding for what is considered acceptable quality by their fellow artisans.

These aspects resonate as relevant to the development of competency within highly skilled and reasoning technical communities such as the relationships between resource estimators.

2.5.3 *Assessing Competency*

In the absence of a competency framework and in recognition of the interpretation and reasoning skills required by resource geologists, it is necessary to establish a competency evaluation instrument. There is opportunity to contextualise Wilson's (2006) systems and tools to enable assessment of resource geologists' engagement or reasoning in the JORC Code.

The validity of such an assessment system can be analysed using Rasch Analysis, which offers a systematic process to define these reasoning levels through data analysis instead of evaluating a pre-existing construct of reasoning levels and expertise (Long, Wendt, & Dunne, 2011; Myers, Wolfe, Maier, Feltz, & Reckase, 2006; Waugh, 2011). The Rasch Analysis technique evaluates an assessment tool for internal consistency. A successful assessment tool is one where participants with low scores do so on easier questions rather than more difficult questions. Similarly, differentiation between higher and lower scoring participants is done on the more difficult questions (Kersten & Kayes, 2011). Used primarily in evaluation of education instruments, Rasch Analysis provide measures of internal consistency by testing the assumption of invariance of the measurement instrument items as well as invariance of the measurement instrument to participants (Pollitt, 2012; Rivet & Kastens, 2012; Watson & Callingham, 2003; Wild & Pfannkuch, 1999). Moreover, when the Rasch Analysis has shown the test is internally consistent, and that the question difficulty and person ability are compatible, the individual capability score can be used to examine the characteristics and factors which may influence their capability (Andrich, 1989, 2011; Griffin, 2007; Schumacker & Smith, 2007) thereby systematically underscoring competency expectations (Dalton, Davidson, & Keating, 2011; Teo, 2011).

Furthermore, Rasch Analysis provides measures of item difficulty that can be used to establish reasoning or competency levels relevant to the context and domain. In addition, individual capability scores from the Rasch Analysis presents opportunities to compare backgrounds, experiences and workplace learning contexts between more and less capable resource geologists.

Aspects pertinent to competence that may require further investigation include the value of association membership and Chartered Professional status, whether a minimum of five years' experience is sufficient to imply competency – or is there an alternative timeframe and or combination of experiences that trigger competency?

2.6 Discussion, Gaps and Relevance

The variety of aspects, factors and contexts explored and presented in this review support a view that, should a unifying workplace learning theory exist, it would need to accommodate a wide variety of styles, contexts and needs. In calling researchers towards a unifying framework for informal workplace learning, Marsick (2009, p. 273) admits there is a strong case for “drawing on multiple theoretical perspectives to make an integrative sense of the individual, social, organisational, and broader cultural dimensions of workplace learning.” Unification of theories is only possible through the examination of their contributions and unique contributions. An analysis of a subset of theories presented in Appendix 4 underscores this challenge.

Learning is individual. People are unique and the variability between their experiences may limit the likelihood of establishing the unified theory sought by Marsick (2009). Research into workplace learning practices of design engineers in Sweden presents different factors and influences compared with social workers in Italy or accountants in Canada (Gola, 2009; Hicks, et al., 2007; Styhre, 2006). The unifying theory would need to accommodate this variety.

Overprinting this individuality are temporal factors: what a person experiences in the learning event is contingent on their experience to date, their expectations of the learning event, and their aspirations that this learning may affect (Styhre, 2006). Indeed, the learning is also influenced by the trainer’s temporal context. Attending the same learning event at some other point in a learner’s timeline will shape learning in different ways (Styhre, 2006). The current workplace learning theories do not incorporate a temporal component. Other events such as organisational change could be disruptive and could affect receptiveness to learning.

It is disappointing that, apart from a few research papers, the distinguishing features of workplace learning as articulated in the Action Theory and Learning Network Theory have not been sufficiently challenged. Research into features such as responses to or styles of triggering events, or styles of learning networks in an emerging profession is missing from the literature. The workplace learning theories assume a static workforce and place the learner within a single organisational context. This limits the applicability of these learning theories to resource geologists who are transient and whose loyalties align more closely with the industry than with specific organisations.

In addition, there is limited research to unify workplace learning within a wider recursive social theory. Although presented as a powerful empirical foundation for examining Structuration Theory, Strong Structuration Theory is undermined by its lack of empirical analyses. There is no evidence of examination of the mining industry in the context of

Structuration Theory, particularly for informal workplace development of professional competency as required by the JORC Code.

On a more practical level, there is no construct describing the continuum from novice to expert that can be used to test or reformulate qualifying criteria for Competent Persons.

In summary, the gaps identified in this literature review are:

1. Lack of a unifying framework between workplace learning theories;
2. The need to incorporate a temporal and transient component into the workplace learning theories;
3. The need for greater understanding of the connection or networks between professional resource geologists;
4. The need to create a defensible competency assessment tool; and
5. A better understanding of the relationships between the social framework and drivers on the professional learning imperatives to essentially knit workplace learning back to the broader industry context.

This research therefore needs to contribute to the greater body of knowledge by providing a practice-based definition and assessment of the competency of transient professionals – i.e. professionals who lack commitment to any single organisation within the industry (and therefore the associated development programs of those organisations). Special attention to workplace learning practices and the professional networks or communities that facilitate these is necessary. This will inevitably require an exploration into the social framework within which these professionals operate.

The conceptual framework underpinning the research needs to accommodate the social structure, the community within that structure and the individuals operating and influencing the community and the evolution of the social structure and its associated systems. Moreover, the conceptual framework needs to consider factors such as the structure and systems surrounding the JORC Code, the learning processes within these structures and the social dimension associated with the professional networks through which learning and sanction occur.

The research method should include a qualitative investigation into the workplace experiences of Competent Persons, and quantitative mechanisms to enable measurement of competency. It is imperative that the mechanism take due cognisance of the items identified in Table 1 of the JORC Code. A Rasch Analysis is also necessary to ensure internal consistency of the mechanism.

These findings, concerns and objectives are integrated with the study's research questions in the description of the conceptual framework that follows in the next chapter.

3 Conceptual Framework

The purpose of this section is to consolidate the ideas, concerns and observations emerging from the literature review, and to connect these to the research questions. The conceptual framework provides guidance for the subsequent research process.

Key theories that emerge from the literature review included Structuration Theory, Learning Network Theory and Communities of Practice. In addition, various models of competency were explored. These theories and models provide scaffolding for the research questions raised earlier (page 4). The four main aspects in competency development are:

1. The entry requirements,
2. The workplace experiences,
3. The professional networks, and
4. The organisational context.

Ultimately, the purpose of this research is to explore and model the competency development that resource geologists require to enable them to attain Competent Persons status.

3.1 The Conceptual Model

The following describes the conceptual framework that contains the potential factors and theories used to explore the development of competency (Figure 10). In Figure 10, the conceptual framework is bounded by the social construct within which competency is developed. In practice, this describes the social interaction and systems involved in estimating and reporting in accordance with the JORC Code. Structuration Theory was selected to explore the social construct around the JORC Code, herein referred to as the JORC system. Initially Learning Network Theory was selected to provide form to both the relationships that shape workplace learning and the styles of learning that occur. Additional factors that are likely to influence the effectiveness of competency development are the basis of entry requirements of the resource geologists, the formative experiences that enable them to draw learning from and the constraints or opportunities afforded them by virtue of the organisations within which they work.

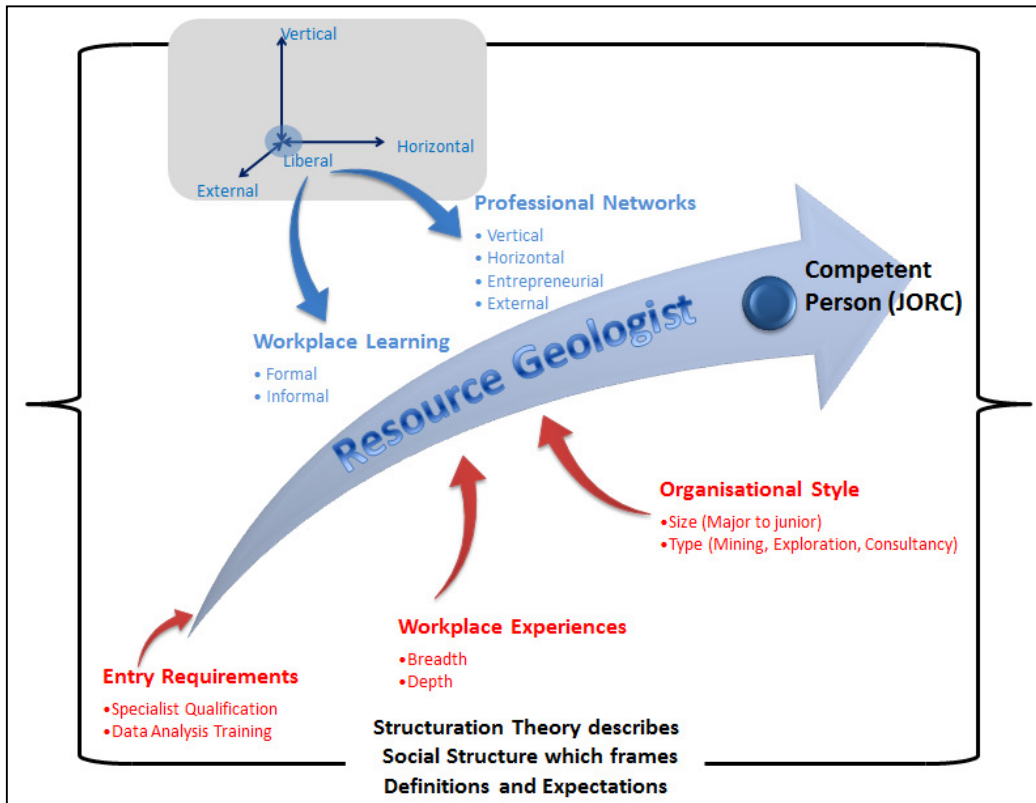


Figure 10 Conceptual Framework

Structuration Theory provides a scaffolding lens to clarify the dynamic social order, the evolution of the human interactions within that social order and the mechanisms or modalities that act as catalysts within these mutations. This research study utilises Structuration Theory to frame the social order of the mining industry that supports the development of resource geologists' competency. In particular, Structuration Theory helps to frame the interactions surrounding the JORC Code and its implementation in accordance with the ASX listing rules, the governance surrounding the directors who ultimately provide public reports based on the work of resource geologists and the sanctioning of competency in accordance with the professional organisations' codes of ethics and associated systems. This social structure is described in this research as the "JORC system".

The JORC system essentially frames the opportunities for competency development by providing purpose, process and sanction. Within this framework, there are two primary foci: firstly the target competency and, secondly, the processes and mechanisms that underscore the development of that competency. In Figure 10 the rising and widening arrow reflects the competency development process for a resource geologist. At the beginning (lower left hand corner), a resource geologist has limited competency. However, there may be specialist qualifications or training entry requirements to support subsequent competency development.

The rising and widening competency over time is underscored by workplace experiences that add both breadth and depth to the competency. These workplace experiences are augmented by both formal and informal workplace learning, within the context of a professional learning network. The organisational style, defined by company focus and size, moderates the development of competency through the opportunities and professional development provided to a resource geologist. There is a point on this development curve where the resource geologist can be considered a Competent Person within the context of the JORC Code. The research aims to ascertain the underlying qualification criteria for Competent Persons, as well as the developmental processes that most efficiently underscore achievement of Competent Persons status. This will require the development of an assessment mechanism.

The investigation into the contribution of professional networks on competency development, especially to informal workplace learning, is a significant aspect of the research since resource geologists often work in geographical and/or professional isolation. Learning Network Theory promises a sense of order to the learning relationships within the workplace. For example, Learning Network Theory classifies four styles of learning relationships, including two internal to organisations (the vertical and the horizontal), one describing the learning relationship within the individual and one learning relationship style that connects the learner to expertise external to the organisation.

The style of learning opportunity may also affect the competency development trajectory. The contribution of both formal and informal learning needs to be explored to provide context for framing future the implementation of competency development programs for resource geologists.

Whilst not initially incorporated into the research design, aspects of Communities of Practice were ultimately used to explore the intent and purpose across the learning network relationships. In particular, the emerging emphasis on informal access of professional networks beyond the confines of the resource geologist's workplace organisation indicated the value in Communities of Practice as an underlying theory.

3.2 Questions Emerging from the Conceptual Model

The questions emerging from the conceptual model include:

1. Entry requirements:
 - Does the type of **professional qualification** help resource geologists learn how to generate resource estimates?
 - Does a **background in mathematics/statistics** help resource geologists to learn about resource estimation?
2. Workplace learning:
 - How do formal **training courses** help resource geologists learn how to generate resource estimates?
 - How do the informal learning avenues contribute to competency development?
3. Workplace experiences:
 - What **work experiences** are critical to the development of resource reporting competency?
4. Learning through professional networks:
 - In what ways do **professional networks** contribute to developing resource estimation competency?
5. Organisational styles:
 - How do mining/exploration **companies** help or hinder development of reporting competency?

These questions are revisited in the instrument design (see §4.3.2.3, page 84).

4 Methodology

The focus of this chapter is to draw on the conceptual framework presented above and explain how the research study progressed from considerations at a theoretical and strategic level through to the operational level, including the plans for data collection and analysis. This chapter starts with an examination of the research strategy, including an analysis of the research paradigm and justification for a mixed methods approach. Next, the unit of analysis and the study population are described. The associated challenges and considerations for the sampling strategy are introduced.

The chapter then turns to the research instruments. After outlining the format and content of the semi-structured interviews, particular attention is given to the development of the survey questions, including the structure of the self-assessment mechanism, the creation of a JORC Code reasoning assessment mechanism and the open-ended questions seeking qualitative data on competency development experiences.

The next section focuses on the data collection, including representativity, reliability and validity, limitations and ethical considerations.

This chapter closes with an overview of the methods of data analysis processes adopted for this study.

4.1 Research Strategy

4.1.1 Research Paradigm

It would be natural for the researcher to adopt a post-positivism paradigm. With both undergraduate and postgraduate degrees in Mathematics and Statistics, the researcher is naturally drawn to a reductionist and logical paradigm. Evidence based decision making is a fundamental philosophy the researcher encourages in those she works with, trains and mentors. This includes employing strict distinctions between assumptions, opinions, facts and interpretations. Systematic, supportable and repeatable analyses are thus critical to the researcher's worldview.

However, this in itself is insufficient for the underlying research theme. Here the issues are social and relate to much broader concepts that cannot be simply reduced and systematically tested as logical processes. Rather, here each resource geologist establishes his/her perceptions in accordance with his/her personal experiences – a sequence that is unrepeatable let alone paralleled. In addition, the world within which the resource geologists work is also

the world the researcher works in. The resource geologists are part of the network within which she earns her livelihood. The research here influences how the researcher conducts her work and, as a known personality to many of the research participants, her presence in the data collection stage will inevitably influence the way the participants contribute. Recognition of the importance of the social network on this research limits the plausibility of a post-positivist paradigm for this research. Indeed, it is the texture and variety in the responses that is of particular interest to the core themes of this research. A social constructivist paradigm is more likely to help illustrate how emerging and diverse experiences contribute to the theory. Interviews with open-ended questions enable exploration of experiences at a deeper social and experiential level. However, these broad experiences are likely to be interpreted by participants to varying degrees into a self-assessed confidence in expertise and ability to perform as Competent Persons. Furthermore, the self-declaration of competence becomes more a statement of confidence to engage in the power dynamic than of legitimate competence to deliver superior technical results and, as such, leads the researcher to consider an advocacy/participatory research paradigm where the research seeks to reflect the truth on competency.

Whilst gender advocacy within the mining industry (in particular female advocacy) has increased in recent years with deliberate focus such as the establishment of the Women in Mining forum, this research will not take on a feminist research paradigm. This is a deliberate decision shaped by the researcher's own bias that as a female she is equal to the task and has not personally encountered or been limited by gender-bias issues within the mining industry. Whilst this may not be the same experience for others, the researcher believes that taking a feminist stance will limit the scope and intent of this research. The impetus for this research was born from issues identified as a participant in the industry that in no way reflect gender issues. Indeed advocating the expectations for technical reporting is better served by focussing on broader needs than being side tracked by a gender or minority advocacy paradigm. A more meaningful platform from which to advocate is on behalf of the technical professionals seeking a more deliberate communication of their technical results. In a significant way, the research intent is to "advance an action agenda for change" (Creswell, 2007, p. 22) and to create "debate and discussion so that change will occur" (Creswell, 2007, p. 22) that relate to the power tensions and sanction of what is viewed as acceptable technically. The participants could be viewed as active collaborators with this research providing a shared voice of its participants and thereby providing a conduit for change.

Given the potential stances discussed above, a more fitting research paradigm is Pragmatism since the researcher is "not committed to any one philosophy and reality" (Creswell, 2007, p.

23) and takes the view of the research existing within a “social, historical and political” context (Creswell, 2007, p. 23). A Pragmatic paradigm enables multiple methods of data collection including qualitative and quantitative and allows the research to focus on practical implications. Moreover, this paradigm allows flexibility in the components best suited to the intention (advocacy/participatory), allows breadth in perspectives (social constructivist) and the reductionist understanding of the components of technical mastery (post-positivist) without constraint or marginalisation of participants allowing establishment of a broader and more total world view from which an action agenda can be extracted.

4.1.2 Mixed Methods Approach

The emphasis in this research is on understanding the learning relationships, attitudes and events that shape a Competent Person’s capability. The expectation is that this study describes the lived experiences that lead to sufficient competency. However, in order to achieve this there is also a need to articulate and evaluate the competency of resource geologists.

Qualitative methods, such as semi-structured interviews and open-ended questions in surveys, provide opportunity to explore the experiences and processes that support competency development. A key advantage of qualitative approaches is in the quality of insight gained through not pre-empting the research outcomes. The interviewer can prompt but not predict the thoughts, ideas and contributions from the participants. Semi-structured interviews therefore allow unexpected contributions to be explored within conversations. Similarly, open-ended survey questions allow participants to contribute their own ideas, perspectives and concerns.

In contrast, quantitative methods allow the data to be ordered and compared statistically. Of particular value is the access to a measure of the capability of resource geologists’ efficacy in applying the JORC Code – essentially their reasoning in the JORC Code. Quantitative measures of self-assessed competency are also useful since these allow for direct comparisons and statistical tests against the quantitative measures of reasoning. However, given the limited ability of quantitative methods to “capture the meaning people attached to ... social phenomena” (Collingridge & Gantt, 2008, p. 389), a qualitative or mixed method approach is identified as best suited to the purposes of this research. Combining qualitative and quantitative methods also provides a more powerful base from which to draw conclusions regarding competency and the associated experiences and processes that lead to the requisite competency.

4.1.3 Unit of Analysis

The unit of study are resource geologists within the mining industry. These geologists are specifically engaged in contributing as team members; in contributing to the technical work of generating resource estimates; and/or in supervising the development of a resource estimates for public reporting. The resource geologist, who signs off on the resource estimate as Competent Person in accordance with the JORC Code, provides the estimate and the technical report to the company directors (or a more senior person within their organisation).

4.1.4 The Study Population

The population for this research includes resource geologists across a range of ages and experiences, and across a range of mining contexts and commodities. The population boundary encompasses resource geologists operating within the JORC Code environment. However, this does not preclude geologists operating under the CRIRSCO family of codes (such as SAMREC in South Africa, NI43-101 in Canada and PERC in Europe) since the technical processes adopted by the resource geologists are equivalent to those adopted under the JORC Code. The study population excludes geologists operating within the more prescriptive BRIC (Brazil, Russia, India and China) frameworks where external, predominantly state-run, organisations govern the choice of technical processes, decisions at key technical milestones decisions, and the selection of technical parameters.

4.1.5 Sampling Strategy

Debate surrounding sample collection for qualitative data collection highlights the need for transparency in both the design and implementation of the sample selection process (Abrams, 2010; Koerber & McMichael, 2008). Although researchers decry the lack of specific guidance for sampling procedures in qualitative and mixed methods approaches (K. M. T. Collins, Onwuegbuzie, & Jiao, 2007; Koerber & McMichael, 2008), Abrams (2010) and K.M.T. Collins, Onwuegbuzie, & Jiao (2007) offer criteria for critiquing sampling strategies in qualitative and mixed methods studies (Table 4).

Table 4 Addressing Challenges of Mixed Methods Sampling

Challenge	Recommended considerations
Representation	Sampling decisions are derived from the research goal, the research objectives, the rationale of the study, the study purpose and purpose for mixing methods, the research questions, and “ensuring that the sample selected for each component of the mixed methods study is compatible with the research design” (K. M. T. Collins, et al., 2007, p. 270)
Legitimation/ validity	The sampling process should generate sufficient samples to “allow thick, rich descriptions that increases the descriptive validity and interpretative validity” (K. M. T. Collins, et al., 2007, p. 270), lead to data saturation, enable “statistical and/or analytical generalisations” (K. M. T. Collins, et al., 2007, p. 270). Legitimation is enhanced by transparency of design, process and collection (K. M. T. Collins, et al., 2007).
Integration	Issues of integration of quantitative and qualitative findings are lessened by using sample designs that “help researchers to make meta-inferences...[that allow] ... both sets of inferences [to be] combined into a coherent whole” (K. M. T. Collins, et al., 2007)
Politics	Sample design should be realistic, efficient, practical and ethical (K. M. T. Collins, et al., 2007)

The population for this research are the resource geologists operating under the JORC Code. However, there is no definitive list of resource geologists to enable representative random sampling. Whilst membership of either the AusIMM or AIG is a requisite for reporting to the ASX, both associations extend membership to professionals beyond resource geologists. Furthermore, membership of any one of 18 other internationally recognised institutes is acceptable for resource geologists to qualify as Competent Persons. These additional 18 institutes, referred to as Registered Professional Organisations or RPO (JORC, 2012a), also extend membership to other mining professionals who are not necessarily resource geologists. Listed mineral resource reports within Australia may be used to stratify the scale and complexity of resource estimates. However, this in turn introduces biases related to the number of resources generated by individual resource geologists and an inability to uncouple pooled efforts of several contributing professionals. Taub et al. (2011) note the difficulties of gathering a representative sample when no listing of professionals exists. They go on to stress that the sampling and skills identification process must ensure “that the skills and competencies identified are generic, multidimensional, and truly representative of what these professionals do in their respective practice settings” (Taub, et al., 2011, p. 12). Abrams (2010) provides more specific guidance when sampling hard to reach populations (Table 5). An alternative approach is necessary to meet these criteria, including designing a sampling strategy that is “realistic (i.e. leads to an accurate account of the phenomena), efficient (i.e. can be undertaken using the available resources), practical (i.e. compatible with the researcher’s competencies, experiences, interests and work style; within the scope of the potential sample members)” (K. M. T. Collins, et al., 2007, p. 270). It is evident that great

care is required when collecting samples when there is no register or list of the population from which a sample can be drawn.

Table 5 Qualitative Sampling Strategy Criteria (after Abrams, 2010)

Sampling Strategy Criteria 1	Sampling Strategy Criteria 2	Sampling Strategy Criteria 3
1. "The sampling strategy should be <i>relevant</i> to conceptual framework and questions addressed by research; 2. The sample should be likely to <i>generate rich information</i> on the type of phenomena which need to be studied; 3. The sample should <i>enhance the 'generalizability'</i> of the findings (meaning a study's analytical boundaries, not population representation); 4. The sample should <i>produce believable descriptions</i> and explanations; 5. The sample should be <i>ethical</i> ; and 6. The sample should be <i>feasible.</i> " (Abrams, 2010, p. 5)	1. "Starting with a set of observations that meet the particular aims of the study; 2. Seeking a full range and variation of developing categories through sampling; 3. Sampling deliberately to test, and elaborate and verify the validity of the category; 4. Developing the relationships and interrelationships between categories through further sample selection; and, 5. Knowing when saturation has occurred." (Abrams, 2010, p. 5)	1. Credibility – "the extent to which the findings represent a credible conceptual interpretation" (Abrams, 2010, p. 5) 2. Transferability – "how the findings extend beyond the bounds of the project" (Abrams, 2010, p. 5) 3. Dependability – "the quality of the integrated process of data collection, data analysis and theory generation" (Abrams, 2010, p. 5) 4. Confirmability – "how well the inquiry's findings are supported by the data that is collected" (Abrams, 2010, p. 5)

One sampling approach that, with careful implementation, can meet the sampling criteria is Purposeful Sampling, which allows the researcher to exercise "his or her judgment about who will provide the best perspective on the phenomenon of interest, and then intentionally invites those specific perspectives into the study" (Abrams, 2010, p. 3). Purposeful sampling allows the researcher to consider "the aim of the research and select samples accordingly" (Koerber & McMichael, 2008, p. 464) and is guided by opportunity to establish a representative sample that allows "maximum variation ...[and where the participants]... represent the widest variety of perspectives possible within a range specified by their purpose" (Koerber & McMichael, 2008, p. 464).

Three pitfalls of purposeful sampling include (1) a sample with insufficient variation, (2) deliberate selection of samples to achieve a designed outcome and (3) insufficient detail regarding purpose in sample selection (Koerber & McMichael, 2008). With these potential pitfalls in mind, the sampling strategy has to ensure maximum variation, a high level of detail and no preconceived outcome from the data. These criteria are validated in this study through examination of the demographic representation of the respondents, including their level of experience, the representation of commodities, and the range of responsibility levels represented as reflected by their job titles.

4.2 Data Collection

This section describes how the samples were collected and how the sample set representativity, maximum variation, reliability and validity was assessed. Limitations of the sample set, and hence the study, are also discussed. Finally, the ethical considerations pertinent to the study are presented.

4.2.1 The Sample Set

Data was collected through a two-stage mixed purposeful sampling process:

1. The first level of sampling focussed on interviews designed to canvass the opinions and perspectives of industry representatives from the key stakeholder groups (JORC, ASX, ASIC, AusIMM, AIG), known industry experts who have played significant roles in development and application of the JORC Code, as well as resource geologists with a cross-section of capability and experience. All JORC members were invited to participate in the interviews. Eleven members were interviewed. An additional nine recognised industry experts and seven emerging or newly competent resource geologists were targeted and agreed to be interviewed. A group of five of these resource geologists requested a focus group style discussion rather than individual interviews. This total of 27 participants exceeds the minimum sample size recommended by Collins' et al. (2007) in their synopsis of sampling criteria in the literature.
2. The strategy for the second level of sampling was a survey of resource geologists where maximise variability in participant representation was sought. Since the researcher has been involved as an independent trainer, auditor, reviewer and technical mentor in the mining industry since 1994, the researcher's contact list represents a wide cross section of expertise and exposure to exploration, mining and commodities as well as a range of positions within organisational hierarchies. All resource geologists on the contact list were invited to participate in an online survey (hosted by Qualtrics²³ through Edith Cowan University). These participants were in turn invited to recruit participants. Out of 108 invited geologists, 65 participated (60% response rate) with 43 providing complete contributions (40% of the invited geologists or two thirds of the participating geologists).

Whilst the sample number is small, the contributions from each participant was expansive, including a self-assessment, detailed responses to 12 JORC Code contextual questions, open-ended contributions to questions on competency development as well as

²³ Qualtrics is a provider of online survey systems.

demographic information. The expansive breadth of contribution enabled a cross section of themes to be established. Future research may target specific areas for greater clarification.

4.2.2 Representativity

Interview Representativity

The purpose of the semi-structured interviews was to establish JORC Code experts' view of the JORC system and implicit expectations of Competent Persons. It is necessary to span stakeholder representation including members of JORC, ASIC, ASX and representation across both company size and commodity. Moreover, representation by mining industry professionals focussed on providing guidance and consultation in the application of JORC Code is important to establish a view representative of the mining industry as a whole.

Purposeful sampling was adopted to ensure representativity across the spectrum of perspectives. All 16 JORC members were invited to participate in the semi-structured interviews of JORC Code experts. The majority of the members of JORC contributed (eleven participants). Representation was sought and gained from both the ASX and ASIC (one representative each). A further 15 interviews were conducted. These interviews focussed predominantly on recognised experienced mining industry professionals, deliberately selected for their high levels of experience and recognition within the industry. Three emerging and less experienced mining professionals working in applying the JORC Code were interviewed to provide contrast to the expectations and knowledge of the experts.

Roles and responsibilities represented in the interviews included managers, directors and recognised industry consultants. Participants operate across all commodities within the mining industry. Furthermore, interviewees were drawn across company sizes and types (majors, mid-tier and junior organisations and consultancies of varying sizes).

Survey Representativity

The purpose of the the survey was to collect data from geologists participating in generating and classifying mineral resources. Participant demographics confirm a cross-section of experience and commodities. The survey participants represent a range of positions in the industry with 82% of them currently working within Australian projects (Table 6). As is highlighted in the bar charts in Table 6, approximately 85% of participants cite membership of at least one of AIG, AusIMM or a RPO. Chartered Professional status is held by 23% of the participants. Participants reflect a range of qualifications and mathematics/statistics education. Two-thirds of the participants completed undergraduate studies in Australia/New Zealand. Geologists account for 92% of the sample.

Table 6 Summary of Demographics

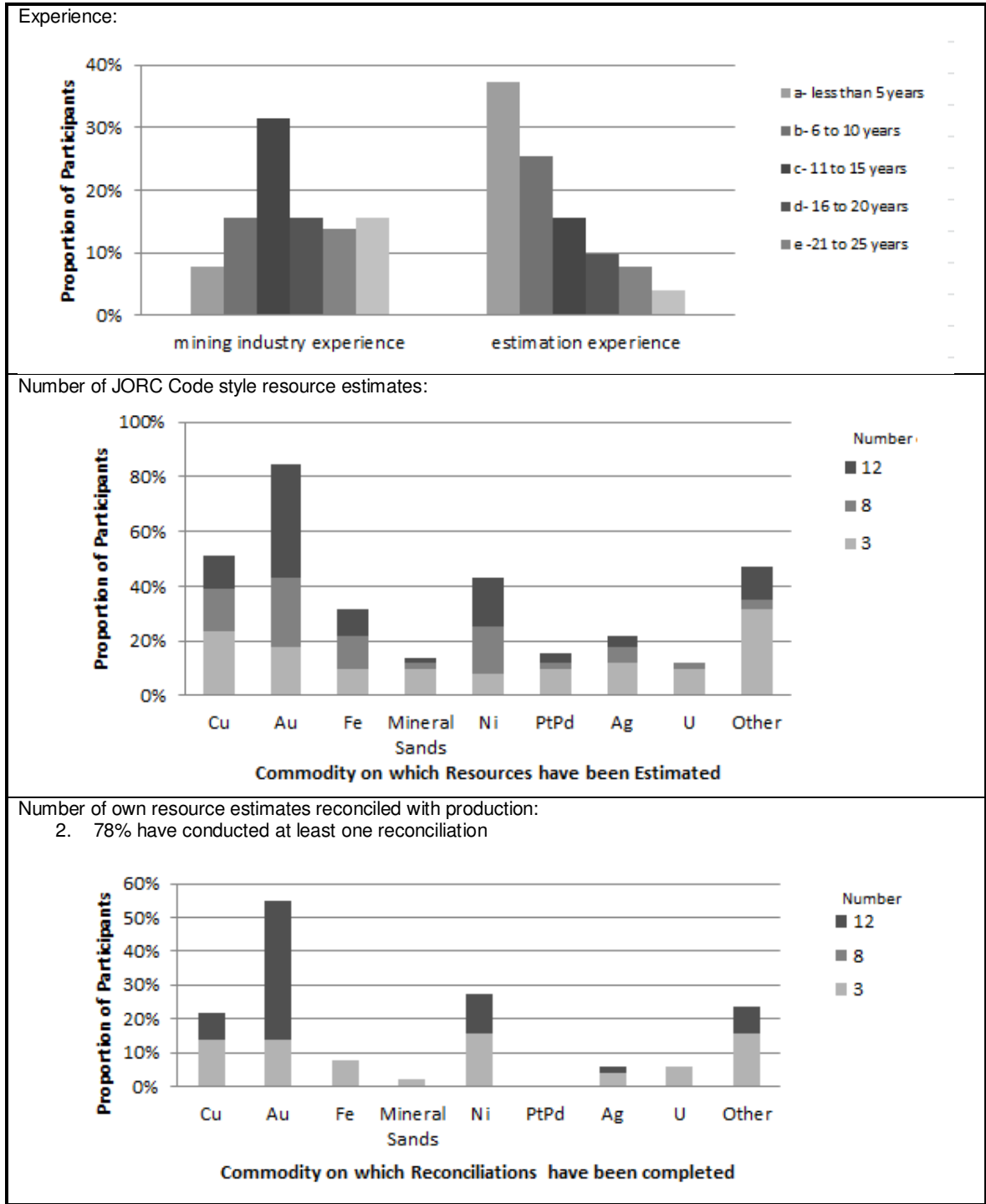
<p>Current job title</p> <table border="1"> <caption>Current job title data</caption> <thead> <tr> <th>Job Title</th> <th>Proportion of Participants</th> </tr> </thead> <tbody> <tr> <td>Director</td> <td>10%</td> </tr> <tr> <td>Chief/Manager</td> <td>21%</td> </tr> <tr> <td>Principal/Consultant</td> <td>21%</td> </tr> <tr> <td>Senior/Geologist</td> <td>40%</td> </tr> <tr> <td>Project</td> <td>8%</td> </tr> </tbody> </table>		Job Title	Proportion of Participants	Director	10%	Chief/Manager	21%	Principal/Consultant	21%	Senior/Geologist	40%	Project	8%										
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Project	8%																						
<p>Country where most of work is conducted:</p> <ul style="list-style-type: none"> 82% in Australia; 16% outside of Australia 																							
<p>Member of professional institute:</p> <ul style="list-style-type: none"> 75% are Members, 10% are Fellow and 15% are not affiliated with an institute 	<p>Chartered Status:</p> <ul style="list-style-type: none"> 23% of participants are registered as either CP, RPGeo or equivalent 																						
<p>Highest level of education:</p> <table border="1"> <caption>Highest level of education data</caption> <thead> <tr> <th>Education Level</th> <th>Proportion of Participants</th> </tr> </thead> <tbody> <tr> <td>Doctorate</td> <td>2%</td> </tr> <tr> <td>Masters Degree</td> <td>22%</td> </tr> <tr> <td>Honours Degree</td> <td>42%</td> </tr> <tr> <td>Post-graduate Diploma</td> <td>10%</td> </tr> <tr> <td>Bachelors Degree</td> <td>24%</td> </tr> </tbody> </table>	Education Level	Proportion of Participants	Doctorate	2%	Masters Degree	22%	Honours Degree	42%	Post-graduate Diploma	10%	Bachelors Degree	24%	<p>Highest level of Mathematics education:</p> <table border="1"> <caption>Highest level of Mathematics education data</caption> <thead> <tr> <th>Mathematics Education Level</th> <th>Proportion of Participants</th> </tr> </thead> <tbody> <tr> <td>more than 1 year uni</td> <td>23%</td> </tr> <tr> <td>first year</td> <td>45%</td> </tr> <tr> <td>one semester</td> <td>19%</td> </tr> <tr> <td>high school</td> <td>13%</td> </tr> </tbody> </table>	Mathematics Education Level	Proportion of Participants	more than 1 year uni	23%	first year	45%	one semester	19%	high school	13%
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The sample set also reflects a wide range of both mining industry and resource estimation experience (Table 7). Experience levels include representation from entry level geologists (less than 5 years' experience) through to experience in excess of 20 years. This is also the case for resource estimation experience. As is evident in the bar chart in Table 7, a cross-section of experience is evident in the number of estimates across the full range of commodities. Furthermore, at least 78% of participants have reconciled²⁴ their own estimate and this experience occurs across the commodities as is evident in the number of reconciliations per commodity in Table 7. Note that there is no experience in reconciliation of Platinum/Palladium. However, this is not concerning since Australia's contribution to global Platinum and Palladium resources are considered insignificant (less than 0.1% of world share (Miezitis, 2011)).

²⁴ Reconciling an estimate requires a resource geologist to compare actual mineral production against estimates from various stages in the process. This comparison includes detailed investigation of the mining processes – both planned and actual. A reconciliation study therefore enables a comprehensive analysis of the requisite adjustments to estimates within the process.

In the researcher’s opinion, the sample set represents a high degree of variation in experience and work context since the sample set includes participants across commodities, roles and experience levels.

Table 7 Summary of Experience



4.2.3 *Reliability and Validity*

The maturing of qualitative methods has seen resolution on much of the debate on quantitative and qualitative methodologies (Patton, 2002), especially with the development of expectations in terms of rigour and transparency (Collingridge & Gantt, 2008; Koerber & McMichael, 2008; Patton, 2002). Collingridge & Gantt (2008, p. 389) emphasise the fundamental issues required in rigorous qualitative research are “reliability, validity, sampling and generalizability” while Patton (2002) argues the challenge is “appropriately matching methods to questions rather than adhering to some narrow methodological orthodoxy” (Patton, 2002, p. 264). Patton (2002) contrasts views held towards mixed methods research, highlighting concerns that the “internal consistency and logic of each approach, or paradigm, militates against methodological mixing of different inquiry modes and data collection strategies (quantitative and qualitative)” (Patton, 2002, p. 273), but goes on to support the practicality of combining approaches emphasising the complexity and sophistication of human reasoning. Abrams’ (2010, p. 2) emphasis of the difference in assumptions, however, raises concerns regarding “major differences in sampling goals and strategies.”

Further to the understanding of meaning attached to experiences and the interconnected powers and influences between the mining industry and professionals, this study extends the vague notion of competency to a quantitative mechanism to measure participants’ ability to reason through the JORC Code requirements. The assessment tool provides an indication of a resource geologist’s capacity to reason through the items listed in JORC Code Table 1 and to form a view on risk in accordance with the definitions of the JORC Code as intended by the JORC Code. Whilst the score does not measure resource geologists’ accuracy in estimation, nor does it measure their ability to apply their geological training, the score does provide a measure of their ability to reason through the factors deemed important in the JORC Code.

The reliability and validity of the assessment tool was confirmed through a Rasch Analysis. A Rasch Analysis tests the invariance of the instrument. Essentially, a Rasch Analysis confirms whether there is internal consistency (persons with higher scores must have a high probability of answering easy questions correctly and, conversely, persons with lower scores should have a low probability of scoring difficult questions correctly). “Validated competencies reflect the responsibilities and roles of a profession and guide professional preparation, credentialing, and professional development” (Taub, et al., 2011, p. 11) so it is imperative that the instrument accurately reflect the intent. Therefore, in addition to the Rasch Analysis, the JORC Code reasoning assessment instrument was reviewed by three independent industry experts. These three expert reviewers represented a cross section of responsibilities, including one expert with global responsibility for the quality of Mineral Resource estimates and

classifications for a major resources company, a second expert who is a corporate executive, and a third expert who is an internationally renowned consultant in the area. Two expert reviewers represented the AusIMM and AIG on JORC²⁵.

When a Rasch Analysis confirms internal consistency of an assessment instrument, the corresponding scores of item difficulty can be used to assess reasoning levels expected in questions. In addition, the Rasch Analysis person ability scores can be used to assess individual competency. This means the data sets can be grouped and analysed according to Rasch Scores for further analysis. Although many texts recommend sample numbers in the order of several hundred for Rasch Analysis, both time and resource constraints limited the possibility of samples in the order of most studies using Rasch Analysis. There are, however, indications that smaller samples sizes could produce meaningful results. Linacre (1994, p. 398) indicates “30 items administered to 30 persons (with reasonable targeting and fit) should produce statistically stable measures”. However, there is a risk of small sample numbers due to the sample design. High numbers of samples are required for low errors in measurement systems, and sample sizes in the order of 100 are required to mitigate the influence of “guessing” in the sampling instruments (de Gruijter, 1986). The competency assessment tool was thus deliberately designed to eliminate opportunity for guessing by excluding multiple-choice style responses. Instead questions were designed to be open-ended, which required participants to provide textual responses (Any guessing would require information of the item criteria thereby indicating the participant’s knowledge of the topic). Suitability of the Rasch results based on a relatively small number of respondents was analysed and, with consistently low standard errors, was not considered an issue.

“If the purpose of the research is to describe what individuals do in practice, then asking practicing professionals what they do is the most direct and valid source of information. Seeking feedback directly from a representative sample of currently practicing professionals contributes to the development of a more comprehensive description of practice, rather than relying solely on the insights and experiences of a limited number of representatives. Further, this engages the profession in the process of the research, and assists in attaining ‘buy in’ for the results” (Taub, et al., 2011). The views of the JORC members were therefore tested using the survey data.

²⁵ Whilst the reviewers are members of these organisations, the views and comments they expressed were personal.

Taub et al. (2011, p. 12) warn:

*“When the study sample for role delineation research consists of individuals who volunteer to participate or are samples of convenience, random selection is affected, thereby **limiting the generalizability of the study findings to an entire profession.** Researchers are encouraged to examine the various factors that affect external validity. The use of representative random samples from the population of interest, and taking steps to secure the highest possible response rate, are important considerations.”*

Limitations of the study are therefore made explicit to ensure the generalisability is meaningful and reflects the population as represented by the participants in the surveys and interviews. In addition, participant demographic and contextual information was collected to provide context to the limitations.

4.2.4 Limitations

The JORC Code requires Competent Persons for the reporting of Exploration Results, Mineral Resources and Ore Reserves. These three activities are distinct and are supported by different occupational professionals: exploration geologists, resource geologists and mining engineers respectively. Whilst many competent geologists may be able to provide the more factual information required in reporting Exploration Results, a different set of competencies are required to estimate and classify Mineral Resources. Again, a different set of expertise, experiences and competencies more are required to estimate, classify and report Ore Reserves and this is typically the domain of mining engineers. This research focuses on the resource geologists' domain of Mineral Resource estimation and classification. Whilst there is no real difference between the technical work of resource geologists in generating and classifying resource estimates for mineral deposits located globally, this study focuses on the Australian reporting environment. It is possible that under different statutory and regulatory frameworks, resource geologists will experience different pressures, imperatives, professional networks and working environments. This then limits the generalizability of the research to systems in line with the JORC system. The research is also limited to resource geologists operating in so called hard-rock commodities. Excluded from the study are the processes required for estimation, classification and reporting of coal and diamonds.

In keeping with the principles-based theme of the JORC Code, this research does not seek to measure or evaluate the detailed practice competencies required for geological interpretation and modelling that underpins resource geology. The accuracies of the resource estimate are also not tested. Instead, this research focuses on the ability of the resource geologist to adequately interpret and deliver on the JORC Code expectations. Therefore, resource geologists qualifying as competent according to this study is able to interpret and reason

through the principles and guidelines provided by the JORC Code, and does not necessarily endorse their geological interpretations or the accuracy of their resource estimates.

The survey portion of the study is potentially limited by specific links to the researcher. The researcher's contacts were used to seed the purposeful sampling. However, additional participants were included through snowball sampling within the survey. Whilst all members of JORC were invited to participate in the interviews, and invited to recommend further study participants, there is potential that the study is limited by links to the researcher.

In addition, there is potential that only higher end or engaged resource geologists sought to participate. Alternatively, the higher end/engaged participant may be too time constrained to participate.

4.2.5 Ethical Considerations

Ethics in research refers to the conduct of the researcher as well as the respect shown towards participants and their organisations in the research. The researcher is responsible for maintaining confidentiality and privacy of the individuals and the participating organisations, as well as the information they share as part of the research. Edith Cowan University provided ethics clearance to proceed with the study on 28 May 2010.

Respect for interviewees is also manifest through maintenance of confidentiality. Whilst "confidentiality norms are also being challenged by new directions in qualitative inquiry" (Patton, 2002, p. 278), unless express permission is given by the individual participants, participants' names should not be captured in any database. A temporary reference and retrieval system that links actual names to the database was held only during the data collection phase to track and facilitate analyses. This retrieval system was held in a private computer and deleted on completion of analyses.

At no time is the researcher to compromise or harm the participants and their organisations through physical harm, embarrassment, pain or loss of privacy. This was achieved by abiding by the ethical codes of conduct set up by Edith Cowan University. In addition, the researcher has abided the ethical codes of conduct required by memberships of both the AusIMM and AIG.

Ahead of the interviews and surveys, participants were notified of the research purpose and the anticipated benefits. Participants were advised of their rights and protection and asked for their informed consent.

A concern in qualitative research is the effect the research process has on participants:

“A good interview lays open thoughts, feelings, knowledge, and experience, not only to the interviewer, but also to the interviewee. The process of being taken through a directed, reflective process affects the persons being interviewed and leaves them knowing things about themselves that they did not know – or at least were not fully aware of – before the interview” (Patton, 2002, p. 277).

It is imperative therefore that all engagements with participants be conducted in a manner constructive to the research to ensure accurate reflection of the context without compromising the integrity of the individual, their professional networks and their organisations.

Challenging an individual’s competency is to challenge the very foundation of their place in the professional world. It is imperative therefore that the intervention and engagement opportunities in this research remain constructive and confidential.

4.3 Research Instruments

Two research instruments were developed, namely: (1) the Expert Interview Questions and (2) the Competency Survey.

The focus of the first instrument was to elicit an understanding of the social order within which resource geologists apply the JORC Code, as well as the personal expectations, beyond the JORC Code definition, experts place on Competent Persons.

The purpose of the second instrument was to gather data and information from resource geologists to help form a perspective on the experiences, expectations and JORC Code reasoning competency levels.

Both instruments are described in more detail below.

4.3.1 Expert Interviews

All JORC members (between 1 January 2010 and 30 June 2012) were invited to participate in interviews regarding the JORC system and their personal interpretation and evaluations of competency criteria beyond the standard definition within the JORC Code. Other recognised industry experts, Competent Persons and members of both ASX and ASIC were also interviewed to provide an understanding outside of the committee directing JORC Code developments.

The core questions posed during the semi-structured face-to-face or telephonic interviews were:

1. *In your experience, what have been the most significant influences on the JORC Code?*
2. *How has the JORC Code influenced geoscientists' behaviour over time?*
3. *Conversely, how have the behaviours and actions of practitioners influenced the development of the JORC Code?*
4. *Beyond the JORC Code requirements, what signals indicate to you that a person is "ready" to be a Competent Person?*

Interviewees' responses were documented, transcribed and sent to each participant for them to verify or edit their contributions. Prior to coding, the interview transcripts were read through and notes written. The interviews were then coded using NVivo10 in three phases: (1) open coding, (2) thematic coding and (3) conceptual coding. The final coding was used to analyse the JORC system within a Structuration Theory framework. In addition, expert views on competency expectations were extracted and used to inform the development of the competency survey.

4.3.2 Competency Survey Development

The JORC Code does not prescribe how resource estimates are to be generated, nor does it prescribe the process by which they should be classified. There are thus no prescriptive approaches or tools to address JORC Code's Table 1 criteria. The JORC Code specifically "does not regulate the procedures used by Competent Persons to estimate and classify Mineral Resources" (Stoker & Stephenson, 2001, p. 617). Rather the Competent Person is required to apply their expert knowledge to reason through the information, data and the gaps:

"Mineral Resource and Ore Reserve estimation is a challenging and demanding field, requiring application of professional knowledge, skill and experience of the highest order" (Stephenson & Vann, 2001, p. 13).

Snowden (2001) offers some practical guidance on using statistical tools to address some, but not all, the criteria, while MacKenzie & Wilson (2001, p. 111) emphasise that "the choice of techniques used by the interpreting geoscientist is usually governed by the type and geometry of the deposit under examination." MacKenzie & Wilson (2001, p. 111) go on to express the need for engaging with and learning through experiences: "Only experience can bring the skill necessary for choosing the right ones (techniques) and often trial and error is needed to recognise the important components of a deposit and with what techniques they should be

treated.” Competent Persons should also understand the full context of their estimates and subsequent reporting classification within the realm of the mining industry, the full range of technical components as well as the intended consequences (Mackenzie & Wilson, 2001; Snowden, 2001; Stephenson & Vann, 2001).

One of the difficulties in testing competency is the inability within the mining system to cross-check the accuracy of a resource estimate. Numerous factors contribute to differences between predicted and actual realised mineral content. Some of these are physical, such a mining dilution where unplanned waste rock is inadvertently extracted and processed as having mineral content. Since grade is measured as mineral units per rock mass, this results in a lower grade in production. Similarly, production content may be lower due to the sterilisation of volumes of rock due to inappropriate mining methods or instabilities in the rock structures rendering the areas unsafe to pursue. A mining reconciliation study provides opportunity to explore, understand and quantify adjustments to estimates. Proper reconciliation studies track estimates and the physical engagement with the operations. These adjusted estimates are compared with the produced metal. Reconciliation studies then inform updated estimates to ensure realistic planning and decision making. However, if processing facilities access material from a variety of sources, the production figures that are used to anchor reconciliation studies are compromised. Moreover, the approaches, techniques and considerations in generating resource estimates are not universal across commodities, geological styles or even organisations. It is difficult thus to establish a right or wrong approach in resource estimation. Nonetheless, the JORC Code provides Table 1 as a comprehensive checklist and description of 68 criteria (as listed in Table 1 of JORC, 2004)²⁶ that may affect the reliability and risk associated with exploration results and resource estimates. These criteria apply universally across commodities and geological settings. The JORC Code recommends Competent Persons consider all items listed and described in a comprehensive Table of Criteria that spans “the normal systematic approach to exploration and evaluation” (JORC, 2012a, p. 26). These items serve as a guideline or checklist for Competent Persons as the basis for analysis of risk, and to ensure full disclosure, in the Competent Person’s opinion, of aspects that could materially affect the estimate. Competent Persons are required to address these criteria when generating mineral resource estimates and to use the stated principle of Transparency when addressing the criteria. In other words, the Competent Person is expected to evaluate the Materiality of all criteria and to communicate the associated risks in accordance with the JORC Code principles of Transparency and

²⁶ The survey was developed before the 2012 version of the JORC Code was released and so relies on the 68 criteria of the JORC 2004 code. In the researcher’s opinion the survey questions developed are still relevant to the 2012 JORC Code.

Materiality in their technical report to mining executives. Table 1 therefore offers a critical cornerstone in the evaluation of resource geologists' ability to apply the listed criteria.

The set of survey questions was therefore designed around Table 1 in an attempt to collect information that could assist with the evaluation of resource geologists' reasoning in the JORC Code. The survey comprises four parts:

1. A self-assessment of competency to operate across the 11 stages of resource estimation as articulated by Table 1 of the JORC Code;
2. A set of 12 typical scenarios and questions designed to span the criteria in Table 1 of the JORC Code;
3. A set of open-ended questions regarding influences on competency development experiences; and
4. Demographic questions to test range in representation of levels of experience, commodities and responsibility levels.

The development of each of these sections is described in more detail below.

4.3.2.1 Development of Self-Assessment Questions

Resource geologists are required to self-evaluate their competency: "Competent Persons should be clearly satisfied in their own minds that they could face their peers and demonstrate competence" (JORC, 2004, p. 5). This call for self-assessment combined with a requirement for "application of professional knowledge, skill and experience of the highest order" (Stephenson & Vann, 2001, p. 13) places the responsibility for determining competency in the hands of the resource geologists themselves. A self-assessment evaluation was thus designed to provide a measure of self-assessed competency based on resource geologists' self-perception of knowledge, skills and experience across the eleven core stages of estimation (see Table 8 for the eleven stages). A Likert-scale for each of knowledge, skills and experience provides an indication of an individual's confidence in their ability to evaluate each stage (see scale description in Table 9).

The scores for self-assessed knowledge, skills and experience were averaged to provide a measure of self-assessed competency in each stage identified in the JORC Code's Table 1. An overall average of these measures summarises the individual's self-perception of their competency.

Reflecting on the scales set up for the self-assessments, a Competent Person is expected, as a minimum: to understand and explain their work (knowledge level 3), work independently with some degree of review (a skills level of 3), and have reasonable experience (an experience level of 3). Thus, an overall minimum of level of '3' reflects an indication of a self-perceived level of 'Competent Person'.

Table 8 JORC Components for Self-Assessment

Stage	JORC Component	Knowledge	Skill	Experience
		0 1 2 3 4 5*	0 1 2 3 4 5*	0 1 2 3 4 5*
1	Drilling and logging			
2	Sampling design and preparation			
3	Data spacing, orientation and intercept length and angle			
4	Geology (regional, local and relationship to mineralisation)			
5	Data QAQC and database integrity			
6	Estimation and modelling techniques			
7	Mining and metallurgical factors or assumptions			
8	Bulk density determination and inclusion in estimation			
9	Cost and revenue factors			
10	Classifying Resources/Reserves			
11	Reporting Resources/Reserves Publically			

* See Table 9 for descriptions of Likert Scale

Table 9 Self-Assessment Likert Scale

Scale value	Knowledge	Skill	Experience
	This refers to your knowledge of the subject	This refers to your toolbox of skills for the subject	This refers to your level of exposure/ use of knowledge and skills for the subject
0	Know nothing	Can do nothing	Never done this
1	Have heard about this	Enough to be dangerous	Been with someone who has done this
2	Have done a bit of self-study	Need supervision	Done small project in this
3	Understand and can explain this (based on formal training)	Can help myself, need review	Have done bigger projects in this
4	Can describe in detail	Comfortable and efficient to do this	Company expert
5	Can teach others	Can coach others	National expert

4.3.2.2 *Development of JORC Code Reasoning Instrument*

Interviews with industry experts highlighted the potential for over-confidence in self-assessments (§6.3, page 117). An instrument to evaluate this assertion as well as articulate the degree of competency in the sample data to explore the requirements for developing competency is thus necessary. Such an instrument should assess individuals’ technical competency in line with the JORC Code’s Table 1 criteria in a way that is objective and valid. Using a combination of Chin et al.’s (2011) key research principles (Table 2 on page 43) and the Rasch Analysis assumptions of objectivity and reliability as described by Wright & Stone (Wright & Stone, 1999), design features were created to guide development of a JORC Code reasoning assessment instrument (Table 10).

Table 10 Competency Assessment Design Specifications

Design Feature	Description	Design Implication
Completeness	<ul style="list-style-type: none"> Spans the full range of criteria outlined in JORC Code Table 1 and so enable comment on the full JORC Code rather than a subset 	<ul style="list-style-type: none"> Questions must test full range of criteria, not a subset
Universal and Inclusive	<ul style="list-style-type: none"> Applicable across commodities and mineralisation styles so as not to inadvertently exclude or bias participant contribution 	<ul style="list-style-type: none"> Questions must not include aspects or technical processes relating to single or specific contexts
Openness and Richness	<ul style="list-style-type: none"> Enable Competent Persons to use their own language to describe their interpretations and so enable greater richness and depth in contribution 	<ul style="list-style-type: none"> Cannot be multiple choice or Likert-scaled
Contained	<ul style="list-style-type: none"> Limited number of questions to ensure engaged participation and quality responses and achieve the highest level of contribution for the least inconvenience to the participant 	<ul style="list-style-type: none"> Minimise number of questions – no more than is necessary
Consistent	<ul style="list-style-type: none"> Difficult questions should be independent of persons answering them Questions should be independent of the sample of participants Ability score should be independent of the sample participants 	<ul style="list-style-type: none"> Rasch Analysis is required to test validity of instrument and validity of sample assessments
Objective	<ul style="list-style-type: none"> Instrument should apply to people beyond the sample set 	<ul style="list-style-type: none"> Rasch Analysis is required to assess objectivity of instrument
Differentiate	<ul style="list-style-type: none"> The instrument should be able to distinguish persons with higher order thinking and application of the JORC Code from those with lower capability The instrument should have sufficient coverage of question difficulty to span participants and provide sufficient detail to fairly distinguish between reasoning levels 	<ul style="list-style-type: none"> Rasch Analysis is needed to test item difficulty followed by item assessments in terms of consideration themes

Figure 11 describes the process used to develop the JORC Code reasoning assessment instrument.

The process begins by leveraging off the comprehensive outline and reasoning questionnaire presented by Wilson (2006). Wilson's questionnaire was designed to test statistical reasoning at the secondary-tertiary interface. The questions essentially seek responses to a range of statistical contexts. Multiple choice answers are provided for each question. In Wilson's design, erroneous responses within the multiple choice options reflect typical misconceptions in statistical reasoning.

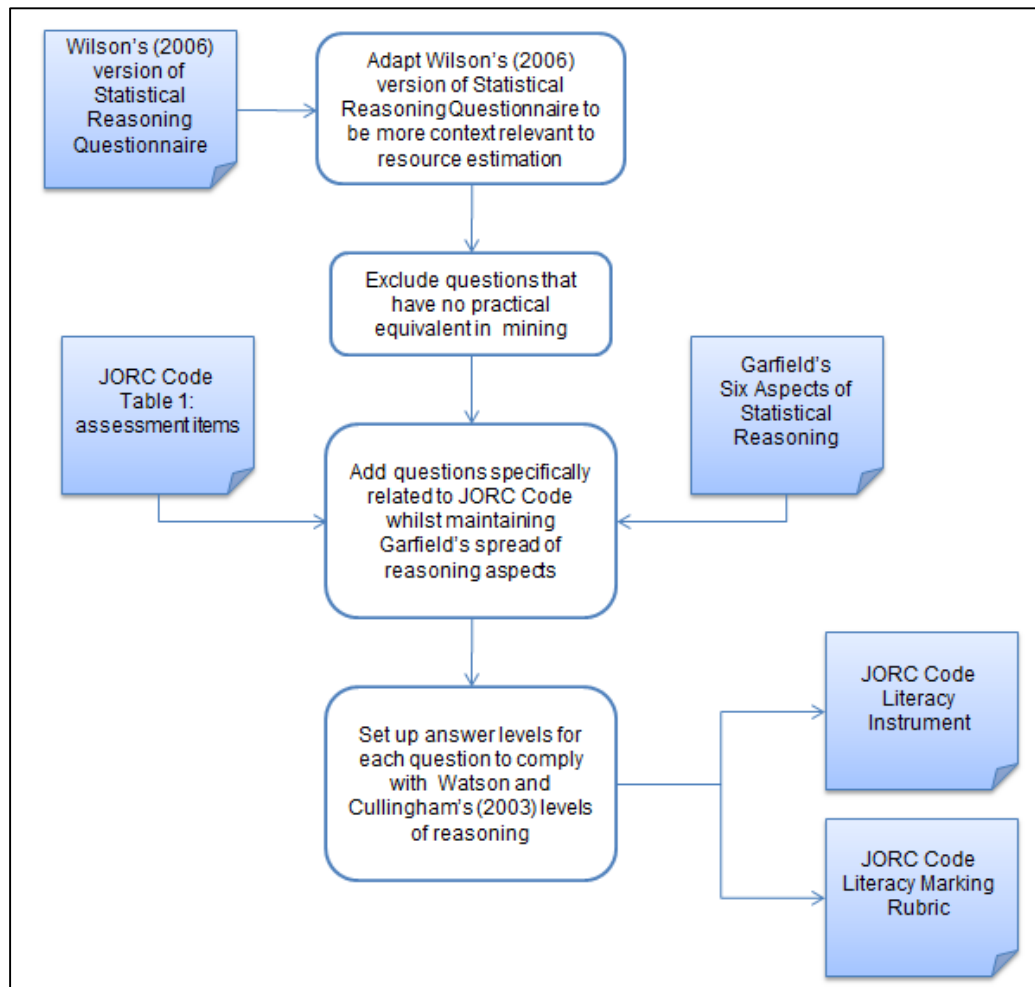


Figure 11 Development of JORC Code Reasoning Questions

The reasoning levels and the associated descriptors used in statistical reasoning research (Garfield, 1998; Watson & Callingham, 2003; Wilson, 2006) were revised for equivalents in reasoning levels that reflect resource estimation and the JORC Code context (Table 11). The descriptors in Table 11 reflect an increasing level of understanding and engagement with the JORC Code as it applies to the context of risk for a mining business and the industry. At a lower level, the engagement with a JORC Code related task is purely functional with limited appreciation for context and consequence. Higher levels of reasoning reflect an engagement with the tasks within a deeper understanding of context and consequence.

Questions extracted from Wilson's (2006) statistical reasoning questionnaire were, where possible, adapted to reflect the mining context and adapted reasoning levels. Questions with limited practical applicability to the JORC Code were excluded and the remaining questions compared with the criteria listed in Table 1 of the JORC Code. New questions were included to ensure full coverage of the JORC Code Table 1 criteria that require reasoning. Twelve questions were selected out of the resulting thirty questions. Each of the twelve questions was evaluated for degree of difficulty, including the style of responses that would invoke the reasoning levels (Table 12) and coverage of criteria in Table 1 of the JORC Code (Appendix 5). Rather than provide a range of responses through multiple choice format, the twelve scenario style questions included a mix of practical examples requiring interpretation, open-ended questions regarding fundamental principles and questions designed to elicit each participant's understanding of and reasoning in the specific requirements for mineral resource classification definitions.

A scoring rubric was created to reflect concepts that resource geologists, if they are Competent Persons, should address in accordance with the principles and specific criteria itemised in the JORC Code 2004 (Table 13). In the final assessment, each response item was scored according to a dichotomous measurement:

- a value of "1" was allocated if the concept in the item was addressed, and
- a value of "0" if the concept was not addressed.

Table 11 Mapping JORC Code Reasoning to Wilson's Reasoning Levels

	Watson & Callingham (2003) Levels	Descriptions of Levels of Statistical Reasoning (Wilson, 2006, p. 135)	Levels revised for JORC Code	In the JORC context these levels are exhibited in the following ways:
1	Idiosyncratic	"relying on Idiosyncratic engagement with context, tautological use of terminology and fundamental mathematical skills"	Idiosyncratic	Plain wrong
2	Informal	"relying on informal engagement with context, reflecting intuitive beliefs, single aspects of terminology and basic one-step calculation"	Informal	description within context with implicit/qualitative/rudimentary evaluation of quality
3	Inconsistent	"requiring selective engagement with context, conclusions without justification, qualitative use of statistics"	Inconsistent	description within context and explicit qualitative evaluation of quality
4	Consistent non-critical	"requiring non-critical engagement with context, multiple aspects of terminology, some appreciation of variation, basic quantitative statistical skills"	Consistent non-critical	detailed description within context and use of simple statistics to evaluate quality and compare between collections, some qualitative indication of risk
5	Critical	"requiring critical engagement with context, appropriate use of terminology, qualitative statistical skills but not including proportional reasoning"	Critical	detailed description within context and use of comparative statistics to evaluate quality and compare between collections, some qualitative indication of risk
6	Critical mathematical	"requiring critical and questioning engagement with context; understanding of subtle aspects of language, use of proportional reasoning"	Critical, cross-contextual	detailed description within context and use of comparative statistics to evaluate quality and compare between collections, includes cross reference to other aspects of JORC table, may include quantitative measure of risk; context is sensed at the scale of mining rather than just the resource

Table 12 Preliminary Question Difficulty and Potential Reasoning Levels for JORC Code Reasoning

Reasoning levels	Idiosyncratic	Informal	Inconsistent	Consistent non-critical	Critical	Critical, cross-contextual	difficulty
1 What role does Geology play in Resource Estimation?	is important	domains/ limits	validation of estimates	validation of estimates			M
2 What are the implications of drill angle relative to domain orientation?	is important	bias in width/ volume and grade	validation of estimates	validation of estimates			L
3 What do you do to check you have a clean database (database recording integrity) rather than sampling integrity?	transfer responsibility	transfer responsibility with some reference to importance	+transcription of checks/peer audit	Basic QA/QC –description of tools	advanced description of tools and interpretation		H
4 Evaluate the charts below. What do you observe? What are the implications of your observations? What actions would you recommend? QA/QC charts.	no comment	Bias	general comments on data quality and suggested physical actions	+Accuracy correctly interpreted	+Precision correctly interpreted	extend to implications for estimation	E
5 Examine the statistics presented below. What steps would you recommend for domaining? Is there any additional information you would like to use?	no comment	mixed populations -3 or more	mixed pops noted + need for additional geology	2 mixed populations identified + need for more geology	use of spatial plot provided to get sense of location of mixed pops	+ implications discussed and/or Advanced domaining analyses	E
6 Below are statistics of RC and DDH drilling for a gold project. What can you conclude? What other information would help you?	no comment	automatic response to drilling type and assumed quality	simple reference to bias	reasoned reference to bias, incl basic interpretation of graphs	need for spatial/geological segregation	implications of bias for estimation	E
7 How do you select an estimation method?	single use approach	systematic alternatives only for testwork	recognizes alternatives available, but unsure of how to choose	reference to selection by context/statistics	reasoned contextual analysis of data and implications for choice between several methods/ adaptation to context		H
8 How do you choose search parameters?	industry standard/what I'm told	geological continuity	data spacing	variography/continuity measures	testwork (QKWA) with indication of reasoned application		H
9 What makes you confident in the estimation parameters you select?	industry standard/what I'm told	seems to work for other projects	looks reasonable against data- no ref to statistical tools	validation -in mimics out /reconciliation	testwork (QKWA) with indication of reasoned application		H
10 How do you validate a Resource Estimate?	don't	follow a site based process	looks reasonable against data- no ref to statistical tools	validation -in mimics out /reconciliation	advanced testwork on parameters/ validation; application of risk assessment	data quality assessments/ref to other aspects of JORC code (especially accuracy (precision and quality of geology	E
11 What is your preferred process for Resource Classification?	follow a site based process	data spacing only	data spacing and grade continuity	data spacing and grade continuity and geological continuity	data spacing and grade continuity and geological continuity and data quality	all belonged to JORC Table 1 items	E
12 How do you consider mining and metallurgy factors or assumptions in resource classification?	don't	general reference to mining (met concepts)	application of qualitative risk	physical limitations and/or reference to adjustment to estimates in light of known /assumed mining/ met issues			M
	L	L	M	M	H	E	M

Survey Questions

Table 13 Competency Assessment Questions and Rubric for Response Items

Question	Response Items to be Identified	Reference
1. What role does Geology play in Resource Estimation?	◦ Context/control	1a
	◦ Limits/domain/boundary	1b
	◦ Validation	1c
2. What are the implications of drill angle relative to domain orientation?	◦ Bias interpretation /data/quality/boundary	2a
3. What do you do to check you have a clean database (database recording integrity rather than sampling integrity)?	◦ QAQC Practices	3a
	◦ Audit processes	3b
	◦ Transcription	3c
4. Evaluate the charts below. What do you observe? What are the implications of your observations? What actions would you recommend?	◦ Accuracy/bias	4a
	◦ Precision	4b
	◦ Recommend action	4c
5. Examine the statistics presented below. What steps would you recommend for domaining? Is there any additional information you would like to use?	◦ Histogram -mixed pop	5a
	◦ Need for geology	5b
	◦ Spatial pattern reference	5c
6. Below are statistics of RC and DDH drilling for a gold project. What can you conclude? What other information would help you?	◦ Bias	6a
	◦ Location-common?	6b
	◦ Geology-common?	6c
7. How do you select an estimation method?	◦ Adapt to context/geology	7a
	◦ Range of methods	7b
8. How do you choose search parameters?	◦ Geological context	8a
	◦ Data spacing	8b
	◦ Grade continuity	8c
	◦ Testing methods/ sensitivity tests	8d
9. What makes you confident in the estimation parameters you select?	◦ Mimics geological expectation	9a
	◦ Validation (out mimics in)	9b
	◦ QKNA or sensitivity test work	9c
10. How do you validate a Resource Estimate?	◦ Out mimic in	10a
	◦ Geologically sensible	10b
	◦ Reconciliation	10c
11. What is your preferred process for Resource Classification?	◦ Data quality	11a
	◦ Geological continuity	11b
	◦ Grade continuity	11c
	◦ Data spacing relative to ...	11d
	◦ Estimation quality relative to items on Table 1	11e
12. How do you consider mining and metallurgy factors or assumptions in resource classification?	◦ Mining selectivity	12a
	◦ Recovery	12b
	◦ Economic limitation	12c
	◦ Risk analyses /classification	12d

The reasonableness of the questions and rubric was confirmed through independent robust review of the instrument by three industry experts. One expert has in excess of three decades experience and is employed as a global reviewer and technical specialist within a global mining company. The other two experts are both representatives on JORC – one an AusIMM representative and one an AIG representative. Of these two, one expert is employed in a corporate role whilst the other is a global expert in an international consulting company. Each reviewer was first provided with an explanation of the context of the reasoning assessment tool and the basis for the format. Subsequent discussions with all three reviewers included dialogue regarding the style of questionnaire (e.g. suitability of multiple choice and/or open-ended format), length of assessment and connection back to the JORC Code. Each item and the associated expectation in the rubric were scrutinised by all three reviewers to ensure the instrument spans Table 1 of the JORC Code and that the rubric reflects reasonable expectations of Competent Persons. Minor suggestions included expanding the question set to include reference to bulk density and tonnage sensitivity. Whilst an important aspect of estimation, an instrument question on bulk density may preclude Competent Persons working in deep underground operations where there is little sensitivity to this aspect of estimation and, on the basis of the ‘Universal and Inclusive’ design criteria (Table 10), was not included in the instrument.

On completion of the assessment tool, reviewers were shown the results from the Rasch Analysis. The item difficulties and the associated interpretations were reviewed for reasonableness. Beyond minor suggestions, all three assessment reviewers supported the instrument in its current form as well as the corresponding rubric and the post analysis interpretation of reasoning levels.

4.3.2.3 Experiences of Competency Development

Questions emerging from the conceptual model (see §3.2, page 58) were considered in the survey design. In particular, there was an apparent need to address potential source of competency development from entry requirements (such as the value gained through an undergraduate degree, and the value arising from a mathematical or statistical education); the contribution from both formal and informal workplace learning opportunities; the influence of professional learning networks, and opportunities available through different styles of organisations.

The following open-ended questions were included in the survey to facilitate the exploration into the experiences and processes that contribute to competency development. The questions provide participants with an avenue to describe their professional experiences and to link these to their perceived competency levels.

Survey participants and interviewed resource geologists were asked to comment on the following:

6. How has your **professional qualification** helped you learn how to generate resource estimates?
7. How has **attendance on training courses** helped you learn how to generate resource estimates?
8. In what way has your **maths background** helped or hindered your learning about and running resource estimates?
9. What **work experiences** have been critical to your development of reporting competency?
10. In what ways do you use your **professional network** to develop your own competency?
11. In your experience, how do mining/exploration **companies** help or hinder development of reporting competency?

These questions provide context to the analysis of competency and provide greater depth in terms of workplace entry experiences, workplace learning experiences and competency development opportunities. The question on mining/exploration companies enables evaluation of organisational context.

4.3.2.4 *Demographics*

In keeping with the requirement to ensure maximum representation to afford generalizability, it is imperative that the sample set reflects the contributions from resource geologists operating across all commodities. Moreover, the sample set should reflect a cross-section of both experience and responsibilities. The survey therefore included requests for the following demographic information (Table 14):

- Current role
- Professional organisation membership and level
- Highest level of education
- Highest level of mathematics or statistics education
- Location of undergraduate education
- Profession
- Mining industry experience (in years)
- Resource estimation experience(in years)
- Resource estimation experience (in number of models per commodity)
- Reconciliation experience (in number of reconciliations per commodity)

In addition, the demographic and context data provides further opportunity to dissect both the qualitative and quantitative data.

Table 14 Demographic and Context Questions

Your Name (optional)	Your current job title
Country where you do most of your work	
Member of professional institute (AIG, AusIMM, ROPO): <ul style="list-style-type: none"> • None • Graduate • Member • Fellow 	Chartered Status <ul style="list-style-type: none"> • CP AusIMM • RPGeo AIG • ROPO
What is your highest level of education? <ul style="list-style-type: none"> • High School • Technical Diploma • Bachelor Degree • Honours Degree • Post-graduate Diploma • Master's Degree • Doctorate 	What is your highest level of Mathematics education <ul style="list-style-type: none"> • High School (year 10) • High School (year 12) • one semester undergraduate unit • one year undergraduate unit • second year unit • majored in mathematics • Post graduate mathematics
Where did you complete your undergraduate studies? <ul style="list-style-type: none"> • Australia/New Zealand • Africa • Asia • Europe • North America • South America 	What is your profession? <ul style="list-style-type: none"> • Geologist • Geostatistician • Surveyor • Mining Engineer • Metallurgist • Other
How many years have you worked in the mining industry? <ul style="list-style-type: none"> • Less than 5 years • 6 to 10 years • 11 to 15 years • 16 to 20 years • 21 to 25 years • More than 25 years 	How long have you been generating resource estimates or grade control estimates? <ul style="list-style-type: none"> • less than 5 years • 6 to 10 years • 11 to 15 years • 16 to 20 years • 21 to 25 years • More than 25 years
Please give an indication of the number of JORC Code style resource estimates you have done, by commodity. <ul style="list-style-type: none"> • Copper • Gold • Iron Ore • Mineral Sands • Nickel • Platinum/Palladium • Silver • Uranium • Other 	How many of your resource estimates have you reconciled with production (by commodity)? <ul style="list-style-type: none"> • Copper • Gold • Iron Ore • Mineral Sands • Nickel • Platinum/Palladium • Silver • Uranium • Other

4.4 Overview of Data Analysis

The main purpose of this study is to understand how resource geologists develop sufficient competency to estimate, classify and report Mineral Resources in accordance with the JORC Code. Ahead of exploring competency development paths, however, it is worth understanding the operational context or structure within which these resource geologists operate since this context clarifies expectations, constraints on development and opportunities to moderate the system.

Data on the JORC system was primarily collected through interviews with JORC Code experts. Various discussions in these interviews on the development and influence of the JORC Code elicited information regarding the overall JORC system. Further input was sourced from the Rae Commission reports (Rae, et al., 1974, 1975), the JORC, AIG and AusIMM websites and the AIG and AusIMM newsletters.

Next, the notion of JORC Code competency was explored by examining the meaning experts place on the definition and their implicit expectations of Competent Persons' qualifications beyond the standard JORC Code requirements. Overwhelmingly these expectations extend well beyond the minimum of five years' industry experience. Experts also shared their concerns regarding self-assessment and weaknesses in the current sanctioning process.

The survey contributions were then analysed to provide a measure of self-assessed competency. Survey participants' reasoning in the JORC Code was then assessed, including a Rasch Analysis to confirm internal consistency in and validity of the instrument. After confirming the validity of the instrument, the difficulty measures of the items were analysed to establish associated reasoning levels. Essentially more difficult items required resource geologists to comment on the risk implications at a broader mining context level whilst easier questions correlated with more process implementation skills. A cut-off difficulty score was set in accordance with the experts' expectations. Participants were categorised as either having sufficient mining context reasoning or not. This provided a basis for testing the current Competent Persons' qualifying criteria using quantitative statistical tools. The analysis shows the current criteria are insufficient to identify resource geologists who are capable of reasoning through the JORC Code items at the levels expected by the JORC Code experts. Alternative qualifying criteria were therefore tested and a new set of qualifying criteria presented.

The participants were then grouped according to the alternative qualifying criteria as well as their ability to reason through the JORC Code. Four groups result:

1. Those who meet the new qualifying criteria and score highly in the JORC Code reasoning assessment;
2. Those who meet the criteria but do not score highly in the reasoning assessment;
3. Those who do not meet the criteria, but reflect an ability to reason at the mining context level; and
4. Those who do not meet the criteria and do not score highly.

This enabled a comparative analysis of the competency development of the resulting four groups and an opportunity to clarify useful contributions to competency development as well as potential factors that undermine the proper development of competency.

The comparative analysis of resource geologists' competency development provides a basis from which to develop a generalised model of competency development to support resource geologists who intend qualifying as Competent Persons.

The next three chapters of this thesis each deal with a component of the above aspects of the data analysis. The focus in Chapter 5 is on an analysis of the JORC system, which provides the social framework or structure within which JORC Code competency is developed in the mining industry. Chapter 6 deals solely with an analysis of the notion of competency and includes an analysis of experts' expectations, measures of JORC Code reasoning, and tests of the current criteria and tests of alternative criteria. The emphasis in Chapter 7 is on the processes and experiences that contribute to the development of competency.

Note on referencing participants in the data analysis chapters

Note that quotes from experts are referenced as '(e#)' and from survey participants as '(p#)'. Grouped survey participants are referenced as '(p# Group *)' to protect anonymity of contributors. In addition, specific company or individual names shared by experts or survey participants in their qualitative contributions have been replaced by 'XYZ' for company and 'ABC' for individuals. The de-identification of the data is important to protect the participant anonymity.

5 Analysis of the JORC System

The JORC system provides the structure within which resource geologists develop their competency. The purpose of this chapter is to describe the analysis of the systems and the structures surrounding competent persons. These systems and structures govern the expectations, the behaviours and the standards of the structure within which the resource geologists operate. The analysis of the JORC system therefore provides an appreciation of the context and concerns that influence priorities and experiences as well as the context for subsequent analysis of competency in Chapter 6 and the analysis of competency development in Chapter 7.

The two main findings of the analysis of the JORC system are, firstly, the significant reliance of the system on the Competent Persons, and, secondly, the vulnerabilities associated with the lack of technical sanctioning within the JORC system. The sanctioning processes focus more on the ethics and behaviours of the members of professional bodies without attention to technical competence. This leaves the JORC system vulnerable to unsuitable claims to competence.

The first section of this chapter describes the analytical process adopted. The next four sections essentially follow an examination of the JORC system within a Structuration Theory lens: first, the overall structure of the JORC system is examined; second, the system processes within this system are explored; third, the human interactions within the JORC system are studied; and finally the evolution of the JORC Code is examined.

The chapter closes with a summary of the findings and interpretations.

5.1 Analytical Process

The participating experts represent a cross section of geologists, engineers, corporate leaders, accountants and lawyers. Their operating platforms include membership on the JORC, ASIC, ASX and industry experts²⁷. The participants were drawn from a range of operating contexts including large and small mining companies, consulting firms and regulatory bodies. Both the AusIMM and AIG were represented in the interviews, although the views expressed were personal rather than of the professional bodies.

²⁷ The views expressed by these experts were personal rather than of the organisations they belong to.

The expert interviews were iteratively coded²⁸, analysed and eventually themed with due respect for Englund & Gerdin's (2008) four Structuration Theory forces (encoding, enacting, reproduction and institutionalisation). Analysis of the coded and themed data enabled a description of the structure and its evolution as well as the interplay between structure and agent.

The description below provides a complete picture of the JORC system as reflected by the processes and rules or norms governing the human interaction, as well as the modalities of the JORC Code and the associated reporting and complaints processes (Figure 12). These are described as:

1. the structure of the JORC system
2. the formal and informal system processes
3. the human interaction and responses within the JORC system, and
4. the evolution of the JORC Code in response to the structural and human interaction.

These are explored in the sections that follow.

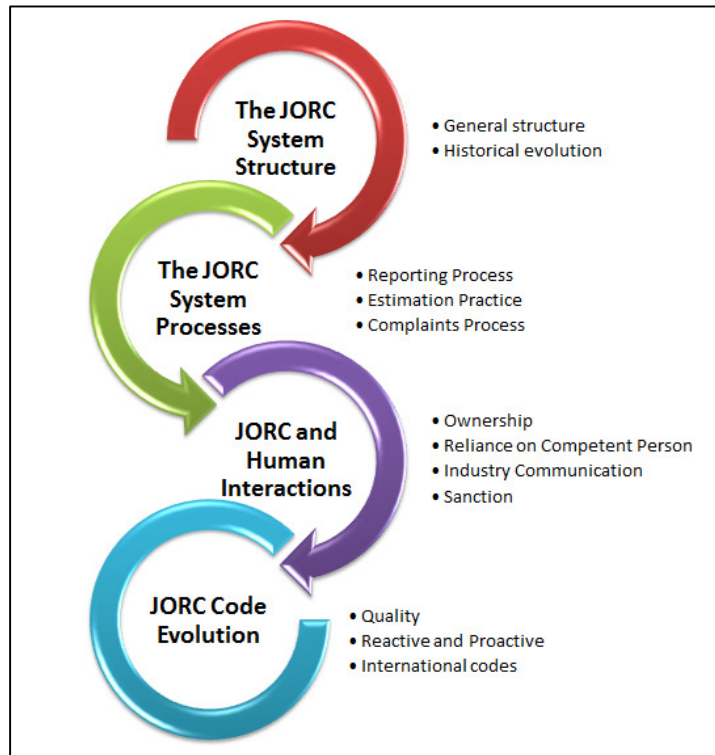


Figure 12 The JORC System as Structure, Human Interaction and Modalities

²⁸ Coding was conducted in NVIVO10.

5.2 The Structure of the JORC System

The current structure of the JORC system described below highlights the co-operation between a government agency (ASIC), the financial industry (ASX and mining investors) and technical scientists (the Competent Persons and their professional bodies). To fully appreciate the current general structure, one needs to understand the historical development and the imperatives that surround the establishment of that structure.

When viewed through a Structuration Theory lens, the general structure and its historical development can be understood as the social patterns that give rise to the “Structure of Signification and Codes” within Systems of Knowing and Meaning (Figure 13 – reproduced from Figure 6 on page 34).

Structuration Theory	Systems of Knowing and Meaning	Systems of Ordering Resources and Power	Systems of Rules of Doing
Structural Patterns	Structures of Signification and codes	Structures of Control	Structures of Legitimation
	⇕	⇕	⇕
Modalities	Interpretive Schemes	Authority and Rules distribution	Traditions and Norms Embedded in Context
	⇕	⇕	⇕
Human Interaction	Through Communication	Through Power	Through Sanctions

Figure 13 Dynamic Components of Structuration Theory (after Barratt-Pugh, 2004)

5.2.1 The General Structure

It is on the ASX that Australian listed mining and exploration companies compete for share trading attention amongst the investment community while ASIC monitors corporate behaviour and disclosure in these transactions. The value of the shares is influenced by the declared Exploration Results and/or estimates of Mineral Resources and Ore Reserves. Since the JORC Code is incorporated into ASX’s listing rules there are clear expectations regarding definitions of Exploration Results, Mineral Resources and Ore Reserves and the associated levels of confidence (or classification). The JORC Code is thus a reporting code that governs how corporate executives communicate the work of Competent Persons. The JORC Code is a subset of the ASX’s listing rules (Figure 14) and is maintained by the Joint Ore Reserves

Committee (JORC) with representatives from AusIMM, AIG, ASX and Minerals Council of Australia (MCA).

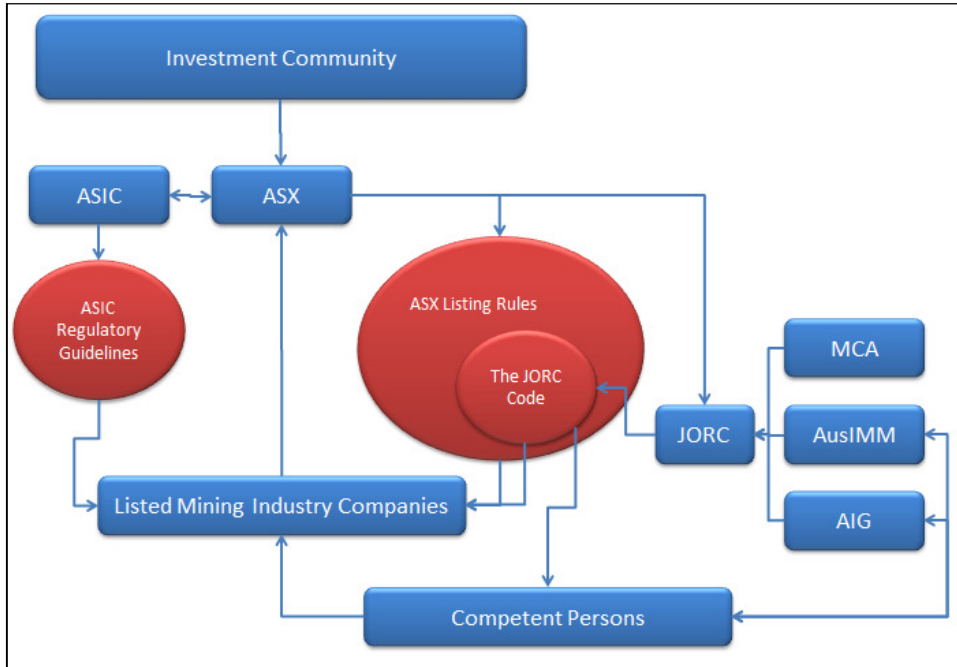


Figure 14 The JORC System

Corporate executives delegate the estimation and classification of Mineral Resources and Ore Reserves to Competent Persons who provide written technical reports to support their estimates. Competent Persons are members of AusIMM and/or AIG (or a ROPO²⁹). As members of these organisations, Competent Persons are expected to adhere to the JORC Code, which is also incorporated into both the AusIMM's and AIG's Code of Ethics. This infers all professional association members, including Competent Persons, are expected to abide by the JORC Code³⁰.

Critical Finding 1:

A systematic structure that includes expectations, roles and responsibilities has emerged to govern the public reporting of mineral resources and ore reserves.

²⁹ Recognised Overseas Professional Organisation

³⁰ AusIMM and AIG members are required to abide by the JORC Code for all disclosure of estimates, including those for non-listed companies and prospectus.

5.2.2 History of the JORC System

In the early 1970s, a committee was established by the Australian Mining Industry Council, now the Minerals Council of Australia (MCA), to examine unacceptable reporting and disclosure practices in the minerals industry in Australia. The AusIMM joined the committee at its inception (AIG joined later in 1992). This Australasian Joint Ore Reserves Committee (JORC) was tasked with developing guidelines for reporting Ore Reserves and subsequently Mineral Resources and Exploration Results. Nearly two decades later, the JORC guidelines were incorporated into the ASX listing rules as ‘the JORC Code’ in 1989. Adherence to the JORC Code subsequently became binding for all members of AusIMM (and for members of AIG from 1992).

The trigger for the formation of the committee, known as JORC, was the Poseidon Nickel boom-bust crisis of 1970s. In contrast to regulatory and statutory responses such as Canada’s NI43-101³¹ to the Bre-X scandal, and the United States of America’s Sarbanes-Oxley Act of 2002 (SOX) in response to the Enron crisis, the JORC response is lauded as being “more constrained”(e9) and measured. The Rae Commission, which laid the foundations for the Australian Securities and Investment Commission (ASIC) in response to investigation into behaviours surrounding the Australian stock exchanges (including the Poseidon Nickel affair that pre-empted the JORC Code) noted how other events in history “brought forth regulatory responses” (Rae, et al., 1974, p. 15.13):

“The practices we have referred to cannot be dismissed as part of that exceptional series of events known as the Poseidon boom and, therefore, as having no implications for legislative action. Many of the promotional and manipulative techniques we observed have been well known and documented in other industrialised countries and have long ago brought forth regulatory responses by governments. Some were known at the time of the ‘South Sea Bubble’ in Britain in the early eighteenth century. Many of them were described by the U.S. Senate Committee on Banking and Currency’s inquiry into the Stock Exchange Practices which followed the Wall Street Crash of 1929. Such evidence as is available about previous periods of high and rising activity in company securities in Australian markets suggests that similar patterns of abuse and shortcomings in disclosure have occurred before, though sometimes concentrated in other areas of the securities market.”

The committee, however, took a more measured and sensitive approach by developing an evolving set of guidelines. Although there were some early adopters prior to inclusion in the

³¹ Canada’s equivalent of the JORC system.

listing rules, the guidelines were voluntary and thus had limited force amongst the corporate executives publically reporting mineral assets. Incorporation into the ASX listing rules in 1989 was hailed as the “biggest influence on the success of the Code” (e7) as this required mandatory adoption of common definitions as well as the requirement for the work to be based on the work of a Competent Person. From 1989, the JORC Code and the associated JORC system became mandatory for all listed mineral industry companies and, notably, for all members of the AusIMM (and by 1992 members of the AIG).

Since incorporation into the ASX listing rules, the JORC Code has undergone updates in 1992, 1993, 1996, 1999, 2004 and most recently in 2012 (JORC, 2012b).

Critical Finding 2:

The structure of the JORC system has evolved in response to a boom-bust economic crisis not unlike those experienced in the establishment of other international codes. Since the incorporation into the ASX listing rules in 1989, the JORC Code continues to evolve whilst the structure has yet to experience a major modification.

5.3 The JORC System Processes

There are two formal enacting processes within the JORC system: The Reporting Process (Figure 15) and The Complaints Process (Figure 16). When viewed through a Structuration Theory lens (see Figure 6 on page 34), the Reporting Process describes the “Systems of Ordering Resources and Power”, while the Complaints Process describes the formal “System of Rules and Doing”. These two processes together reinforce the overall structure of the JORC system by controlling and legitimising actions of Competent Persons and corporate executives.

The third process is the resource estimation process. Whilst not formalised, the estimation process is embedded within the social fabric through human interaction, industry norms and peer sanctioning processes.

These three processes are discussed in more detail below.

5.3.1 The Reporting Process

The Reporting Process governs how estimates are classified in accordance with the JORC Code definitions, and then shared with the investment community through the ASX. The steps in the reporting process are emphasised in Figure 15 and described below:

1. A mining industry company commissions a report on Exploration Results, a Resource Estimate and/or a Reserve Estimate.
2. A Competent Person, who may be employed by the company or may be an external consultant, uses their technical expertise and resources to estimate a Mineral Resource (and/or Ore Reserve). The risk associated with the geological confidence (and modifying factors in the case of Ore Reserves) is subjectively determined and the estimates apportioned according to the classification definitions and guidelines in the JORC Code. The Competent Person documents their analyses and findings in a technical report, which they sign and present to the company’s board of directors.
3. The board of directors produces a public report of Mineral Resources (and/or Exploration Results and/or Ore Reserves) based on the information supplied by the Competent Person.
4. The Competent Person reviews the public report and, if they agree with the statements, provides signed consent for release of the public report to the ASX.
5. The directors’ public report and the Competent Person’s consent form are filed with ASX.

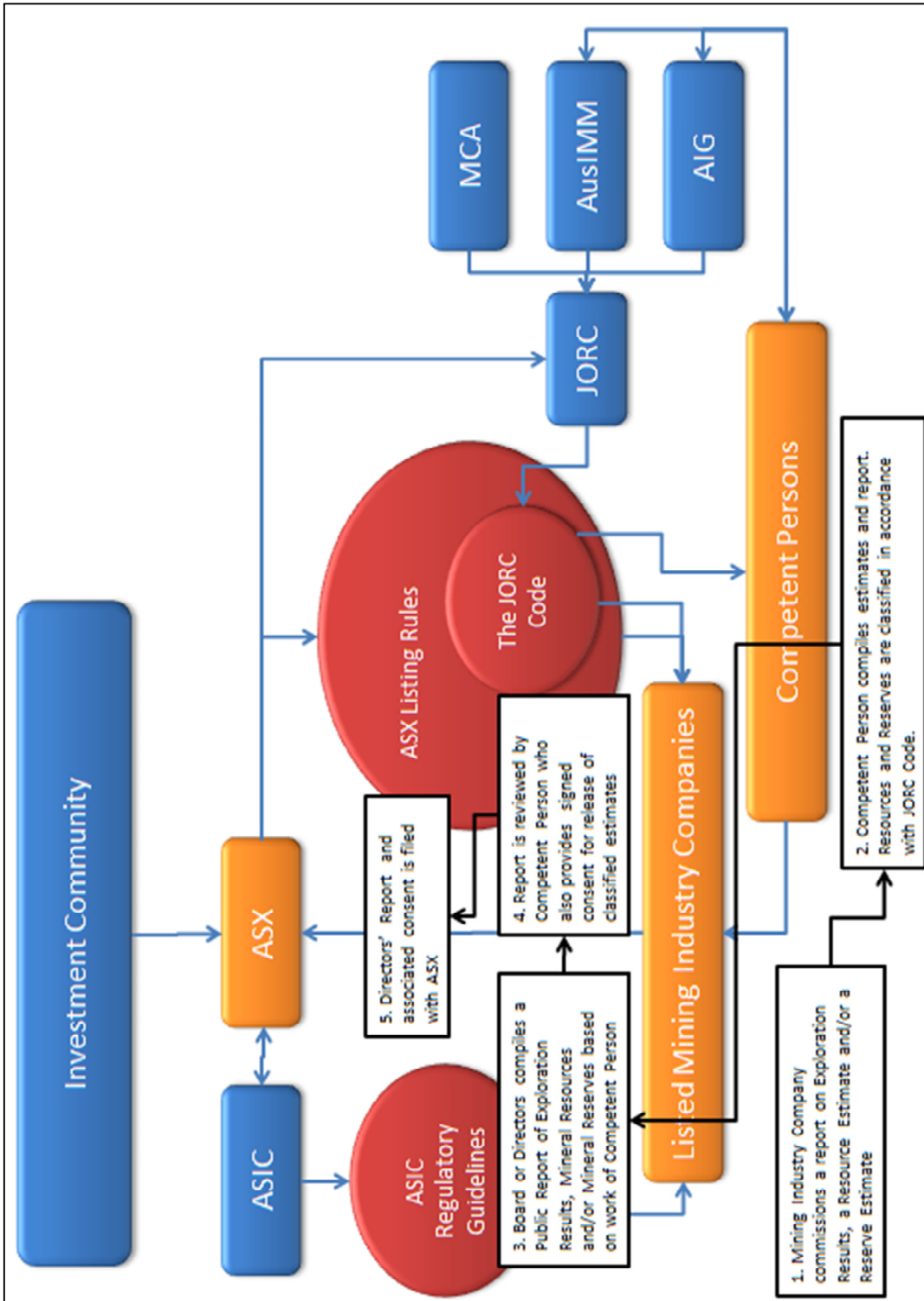


Figure 15 Enacting the JORC Reporting Process

Critical Finding 3:

The JORC system includes a specific well-defined reporting structure.

5.3.2 Resource Estimation Practice

The actual process of creating a resource estimate is contextual and, when viewed through a Structuration Theory lens, can be considered located within the ‘System of Rules and Doing’.

The JORC Code itself is not prescriptive – practitioners are not told how or what techniques to implement - instead “it's all at the discretion of the Competent Person” (e10). There has been an evolution in techniques and processes: “It was simpler in the early days with pencil and paper calculations. Now the process is more technical, more complex” (e8). This has occurred in tandem with advances in computing and available software, but potentially too often at a price: “There is a tendency to trust the machine more than personal judgement” (e8). An over-reliance on estimates spat out by the computer programs is disconcerting: “I think the software vendors are to blame. They've made things easier, but it's become more hands off and black box” (e11). “(P)eople need to use their experience and judgement as an override on what the software cranks out” as “(t)he advances in technology ... don't on their own equate to a better estimate” (e8). “Today people are doing geostats³² without really knowing what they are doing – they're just pushing buttons” (e11). There is a concern that “(i)t may be a beautiful process on the computer, but what are the practicalities?” (e16).

“It's like a story ABC told me – there was a bloke in Vancouver who wanted to own a Winnebago. He got the top of the range Winnebago and the first weekend he took it out up into the mountains he switched on cruise control and went to make a cup of coffee! And that is the way people are – they treat cruise control as auto pilot! But we have to keep control on what is the truth and what is reality!” (e11)

Fortunately, the mining industry “doesn't suffer from the generation gap in other industries because the older people are still high end users whose skills have grown with and through technology; they've never really moved out. There is this intersection of experience and wisdom, and the right tools” (e8).

Some lament the lack of discipline among geologists generating estimates and the potential miscommunication with those who use the estimates: “Many geologists are not as disciplined as accountants and their systems are flexible, relying on judgement rather than discipline” (e9). These very estimates are then used by accountants who view the estimates as fact. “Reserves are extremely important in the accounting world (including on-site accountants), however, many don't understand what a resource and, more importantly, a reserve represents. Whilst it is not JORC's responsibility to educate directors and accountants, there does need to be an improved awareness among directors and accountants” (e9).

³² ‘geostats’ is an abbreviation for geostatistics, the spatial statistical processes within resource estimation.

JORC prides itself on defending a principles-based approach. Given the reliance of this approach on Competent Persons, it becomes imperative that the actions of Competent Persons do not undermine JORC's efforts to maintain a high level of flexibility.

Critical Finding 4:

The JORC system remains principles-based and, as such, there is no prescriptive evaluation, estimation and classification process.

5.3.3 The Complaints Process

The Complaints Process is a formal enactment process that is crucial to the stability of the JORC system and provides avenue for legitimising the actions of the agents within the structure. The steps in the process are highlighted in Figure 16 and summarised below:

1. The board of directors' public report and associated consent is peer reviewed by investors and members of the mining community.
2. Complaints against the board of directors are lodged with the ASX.
3. Complaints against Competent Persons are lodged with the Competent Person's professional body (either the AusIMM or AIG). These complaints can only be reviewed within the context of the respective professional bodies' codes of ethics. The sanctioning process is therefore limited to inappropriate professional or unethical conduct or incorrect claims of membership.
4. Complaints against Competent Persons are handled by the respective Complaints and Ethics Committee of the Competent Person's professional organisation.
5. The Complaints and Ethics Committees liaise with the Competent Persons directly. This is all handled in confidence with the Competent Person.

Critical Finding 5:

The JORC system includes an articulated sanctioning process that focuses on ethical behaviours in accordance with professional bodies' codes of ethics.

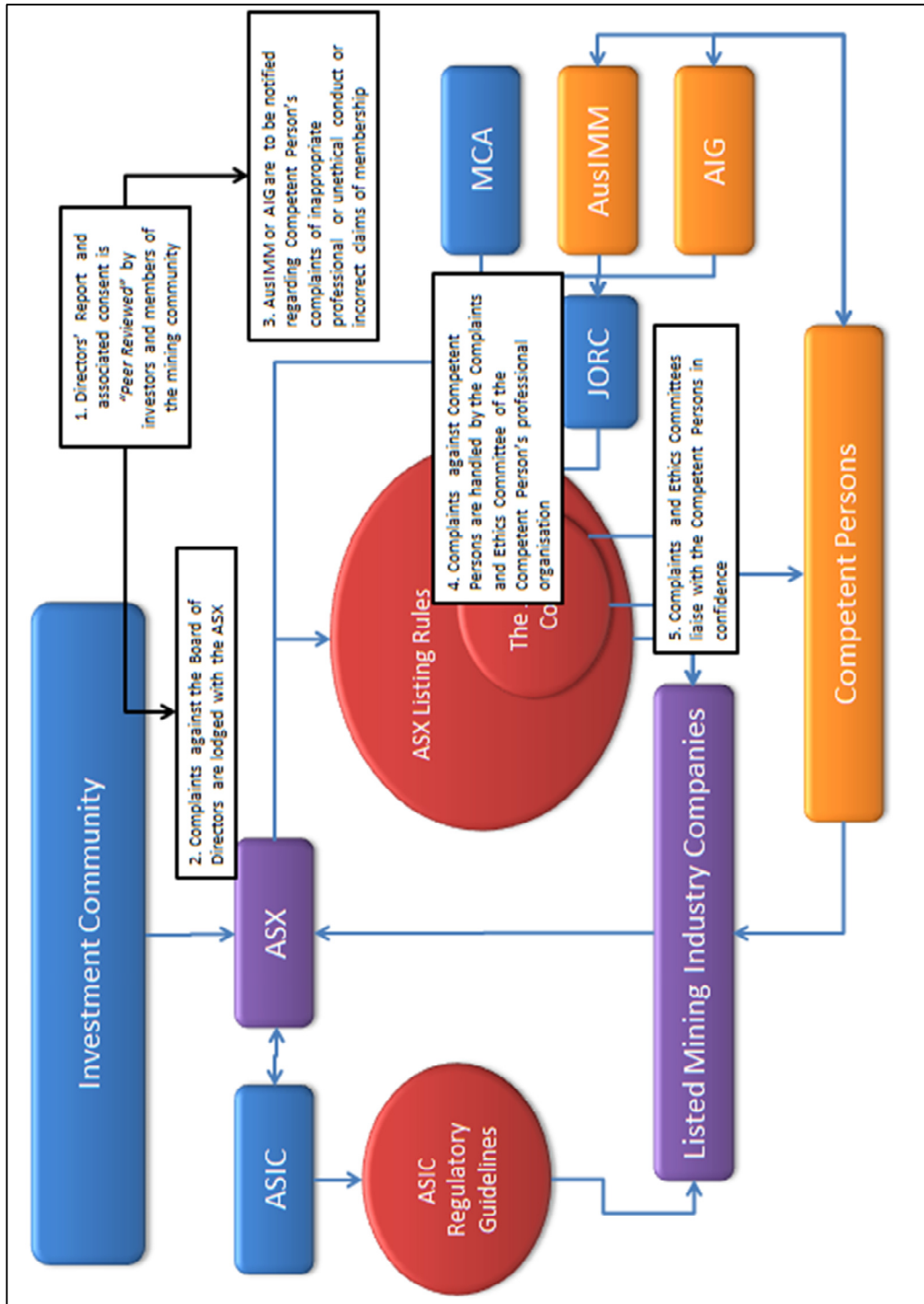


Figure 16 Enacting the Complaints Process

5.4 Human Interactions within the JORC System

Structuration theory contends the human interaction within a structure is enacted in three ways: through communication, through power relationships and through sanctioning processes (see Figure 6 on page 34).

Whilst considered separately below, it is worth noting how interlinked these interactions are. Communication within the system to increase general awareness of the processes and expectations is vital for the dissemination of expectations and standards. This naturally leads to an expression of conflicting philosophies, especially between disciplines with different understandings and perceptions of uncertainty and risk. These come to the forefront when these conflicts challenge the power and perceived ownership of the JORC Code by the professional community.

The JORC system is not, however, without fault. In particular, the lack of technical competency sanctioning processes presents the greatest risk to the JORC system. For example, experts raise concerns regarding loopholes and limited retaliation for deliberate breach of the spirit of the JORC Code and associated system through inferior technical applications.

Within a Structuration theory lens, these human interactions relate to communication of structure and systems, through power distribution and resources and through sanction. These contributions of human interaction with the JORC Code and systems are discussed in more detail below.

5.4.1 Communication

Knowledge and understanding of the JORC system is achieved through education and discussion at various industry forums. The ASX, in particular, is credited with a general increase in awareness that has resulted in a change in behaviours. Since 'JORC' is part of the mining industry *lingua franca* "no professional can claim they don't know what is required" (10). "As more people take the reports seriously, they drag the standards along" (e7). This, coupled with ASX's continual listing updates, ensures the JORC Code and its use, is at the forefront of practitioners' minds when they approach data and generate estimates.

"Education and regulation have helped the ASX and ASIC to be tougher in their implementation of the law. JORC allows them to have more clout and there are consequences. So people are now getting it" (e1). Changes in the ASX's listing rules are continually reviewed and incorporated into JORC Code updates: "Part of the logic in naming the Competent Person in the JORC Code was that it came out of the listing rules and it wasn't

seen as the professional bodies telling the ASX what to do” (e7). This review has the added benefit of enabling JORC to monitor the reporting world and keep track of “how reporting entities are dealing with the code and listing rules” (e6). By responding to changes in the ASX listing rules, the JORC Code is able to adapt to functional changes designed for “clarifying and closing loopholes” (e2).

There is a confidence about the JORC system: “Today there is no discussion about why JORC exists” (e8) and a call for the ASX to be more involved in improving the sanctions: “The world is a better place because of JORC. I would like it to go further, but the ASX would have to take that on” (e9).

Whilst the ASX and ASIC are both credited with having a significant role in the dissemination of JORC system and process, including education of the investment stakeholders, the challenges of combining different philosophies are evident.

Geologists are more comfortable with the inherent variability of the data and information with which they work. This is a stark contrast to the more prescriptive accounting and legal practices of the ASIC and ASX systems. Differences in philosophies challenge communication, especially at the union of these two disciplines at the stock exchange. Whilst geologists voice their concerns:

“As lawyers they worry about being challenged legally, even though the code that is in place is not understood to the same degree by everyone” (e7),

there is potential for the geologists’ evaluation of risk to be misinterpreted or misunderstood:

“In contrast to accounting systems where the discipline in accounting practice is reflected in the systems, the technical discipline in geologists’ systems is not evident. So whilst JORC allows and encourages flexibility in application of the Code, the end-users of their reports believe they are working with facts” (e9).

Both the AusIMM and AIG are also active participants in dissemination, development of the JORC Code and systems through the promotion at conferences and seminars.

Critical Finding 6:

Dissemination regarding the JORC Code and the associated systems and processes occurs through both deliberate and implicit communication between the various bodies. However, the intent and results may be misinterpreted due to different discipline perspectives.

5.4.2 Power and Resources

For several JORC members the experience of being on the committee is deeply personal and the contributions from different personalities and positions are both noted and respected. There is a view that the strengths and varieties of personalities of the committee members influence the development of the code: “We need the patriarchs. ABC-1 has a lot of drive and complements ABC-2. ABC-3 and ABC-4 are more considered. ABC-5 is passionate. It's like a ying and yang” (e1).

Special mention was made of Norman Miskelly³³ who is credited as being “instrumental in setting up the code to address a disaster in the face of no regulatory code and a duping of ignorant public. He did this without financial reward, merely a love and desire to improve” (e9). “Norm was a champion of transparency. He was also a champion of the internationalisation of the code” (e7). Miskelly’s spirit of selfless contribution continues in the volunteer status of all committee members. However, this also is seen as a potential risk – the volunteer contribution can be strained when members have limited availability, especially in boom times. However, their volunteer contribution is balanced by shared focus on the underlying purpose of the provision and maintenance of a framework to uphold a minimum standard for Competent Persons and company directors in the interests of the industry and the investors: *“The whole point of the Code is to ensure public reporting of resources and reserves is properly done and that the reports are adequate for investors to rely on”* (e6).

The strength of the JORC system is seen as its reliance on the Competent Person. There is a high regard for the role and contribution of the Competent Person as ultimately “It’s really up to the Competent Person to make a call” (e6) and a strong belief that the JORC Code provides sufficient guidance: “Table 1 is a good checklist of whether you’ve done a good job. It’s up to the Competent Person to comment on these things” (e7). The emphasis on the Competent Person runs deep – there is a significant reliance on Competent Persons’ personal principles and agreement to abide by the JORC Code in accordance with its proper intent, especially as the Competent Person is expected to act with integrity indirectly enforced through pressure to uphold their personal professional integrity.

However, in some respects reliance on a Competent Persons may also be the JORC system’s greatest vulnerability. Intimidation of Competent Persons is a real concern among both experts and Competent Persons. Competent Persons who are timid are especially vulnerable to corporate bullying “by the archetypal alpha male” (e3). Since the Competent Person relies

³³ Norm Miskelly’s name is included here in honour of his contributions and driving force behind initiating and developing the JORC code.

on the mining company management for employment, they risk loss of income when times are lean:

“If a competent person digs his/her heels in during boom time, when there are other jobs, they may find themselves concerned during busts. Keeping a job during a financial crisis means a more difficult balance between corporate desires and those based in true science. There may be concern for where the next pay-check is coming from” (e3).

Tensions can exist between a Competent Person and the mining executives:

“Generally there is a tug of war between corporate objectives of CEOs and Competent Person’s view of what is fair and reasonable interpretation of reality in any public statement. The majority of Competent Persons are practitioners who behave in a legitimate and competent manner but there are rogues, and this is probably more true of MDs and CEOs” (e3)³⁴.

This behaviour has the potential to undermine the impetus of the JORC Code. On top of a solid foundation of experience, Competent Persons therefore may also need to develop strength of character to withstand corporate bullying.

On a more positive note, “Most CEOs are mature enough to trust a person’s competence” (e3). For most Competent Persons it would appear that the principles and risk to their reputations are sufficient deterrent – the Competent Persons, along with their professional association, are named with the Mineral Resource estimates that appear in the associated public reports. “The premise is that geologists’ primary asset is their reputation and it is this reputation within a relatively small industry that is on the line should they provide misleading results” (e9). This call to protect one’s reputation has influenced how geologists behave. Membership of a professional association “ensures the avenue to use the respective ethics committees to handle infringements provides sufficient consequence. There needs to be a big stick and JORC has it” (e9).

Critical Finding 7:

Despite the reliance on the professional to uphold their professional integrity, there is a risk in the system of corporate bullying. This can be either through implicit or explicit power dominance.

³⁴ MD is a Managing Directors and CEO is a Chief Executive Officer. Both represent positions of power within mining companies.

5.4.3 Sanction

There is also concern about who is responsible for sanctioning inadequate work by Competent Persons. Therefore, whilst the ASX reviews reports under the assumption of competency, some experts are concerned there is insufficient auditing on the competency of the underlying technical work. There is no “mechanism to say an approach is not appropriate. They don’t have the capacity to do proper technical reviews. They don’t have the power to contradict a Competent Person. The ASX essentially has no teeth when it comes to competent reporting” (e3).

The sanctioning process relies on a broader peer review of Competent Persons. The system assumes a Competent Person’s peers will complain when public announcements do not reflect the work of the Competent Person, or if the peer has reason to believe the Competent Person has contravened the professional body’s code of ethics. The standard of review was recently raised with the 2012 JORC Code update where Competent Persons now have to support their estimates and classifications through reporting against JORC Code Table 1. This will enable industry peers to interrogate the Competent Persons’ justifications for approaches and choices. Membership of a recognised institute is thus critical to the self-regulating process, especially when the only realistic peer evaluation of competency is through submission of complaints to the Complaints and Ethics Committees of the professional associations. “AusIMM and AIG are good at picking up deviations from the Code and there is willingness in the professional community to make formal complaints and in that way the process is self-policing” (e3). These usually result in one of a range of reprimands, the most severe of which is being named and expelled from the relevant institute. This approach to sanctioning relies on the value of professional integrity as perceived by one’s peers. “It’s a discipline, and the fact that your name appears should be a deterrent to doing the wrong thing” (e10). “You have to understand the seriousness of putting your name to something” (e10).

But there is a sense that “(T)he process actually has no firepower. It is a delicate situation” (e3). In part this is because the members of committees and the institutes themselves have no legal protection which compromises the implementation of the exposure and exclusion reprimand “... when the ethics committee has recommended a reprimand and public naming, the AIG has been threatened with legal action” (e3).

In addition, the current system allows Competent Persons to belong to one of AusIMM, AIG or a ROPO (Recognised Overseas Professional Organisation). Expulsion from one (either through disciplinary action or self-imposed exclusion) does not necessarily prevent the person from taking up membership of an alternative institute:

“There is an example of a person willing and confident enough to sign off as competent and although he has been reprimanded several times by the AIG Ethics Committee for highly optimistic processes adopted during estimation, he has subsequently dropped his AIG membership and now cites his AusIMM membership on resource statements” (e3).

There are a “number of cases where people sign off incorrectly” (e17). People “who signed off on resources ... (but have) no knowledge of what (they are) doing” and have consequently been “struck off” from their institutes (e17). “The problem is that these cases are not made public. That is why CIM³⁵ want AusIMM members to be Fellows – because the AusIMM are not policing Competent Persons” (e17). This statement is in itself interesting since, by implication, the expert expects the AusIMM to regulate Competent Persons. However, according to the sanctioning processes described on page 96, the policing only occurs when a complaint is laid against the Competent Person with the AusIMM or AIG Complaints and Ethics Committees.

Whilst critical to respectful peer review, another issue raised is the requirement for confidentiality by the Complaints and Ethics committees and so “there is no requirement to inform the ASIC and ASX. There is no process to report back on outcomes of complaints to ASX and ASIC” (e3). The sense of an “unclosed loop, which undermines the credibility of the process” (e3) is highlighted as a weakness that destabilizes the process. “It is my strong view that the best indemnity is to make it a legal requirement to inform ASIC and ASX of the outcomes” (e3).

Another issue raised is that the members of the Complaints and Ethics committees are volunteers and “so there is an issue with the timeliness of their responses” (e3). Reprimand delays undermine the link between reporting and consequence.

Critical Finding 8:

The JORC system sanctioning process is vulnerable to a lack of technical sanction, institute switching and delays between announcement and reprimand.

³⁵ CIM is the Canadian Institute of Mining, which is the Canadian equivalent of the AusIMM.

5.5 Evolution of the JORC Code

The JORC Code plays a pivotal role in the JORC system as it provides the interpretative scheme to link the structural pattern and the human interactions. The JORC Code is identified as an “interpretative scheme” within Structuration Theory (see Figure 6 on page 34). Structuration Theory primarily concerns itself with the symbiotic evolution of structure and human interaction and places the interpretative schemes between these two as mechanisms that act in a dual role to reinforce practices and to evoke change in either or both structure and human interaction. These changes are reflected in changes in the interpretative schemes themselves and are understood to be responses to changes in the social order.

Whilst recognised as a benchmark of quality, the JORC Code has adapted through both reactions to misrepresentation and pro-actions in anticipation of misrepresentations. Moreover, the code has influenced other international codes, whilst JORC updates have also included responses to evolutions and updates in these international codes.

These evolutionary processes and outcomes are discussed in more detail below.

5.5.1 Process of Evolution and Updating

Both nationally and internationally, the JORC Code is perceived as a hallmark for public reporting, whilst others remind that the JORC Code reflects a “minimum standard” (e6, e7, e9). However, the focus is on public reporting, not the technical aspects of generating and classifying Resources and Reserves. “JORC is a mark of quality, but it doesn’t set out to set a compliance standard for estimating of Resources and Reserves. JORC is after all a minimum standard for reporting, not for estimating” (e6).

The JORC system is perceived as “embedded in the industry” (e6) and has affected all agents in the system “from how entities report all the way through to how everyone in the industry behaves” (e6).

The JORC Code continues to evolve as is evidenced in several updates and interim updates and adjustments provided as amendments to the ASX listing rules and periodically attached to the JORC Code. However, there is a sense that these adjustments are subtle, minor and evolutionary in accordance with changes in technology and behaviours (both real and perceived potential behaviours). There is a general view that, even though the JORC Code may have some “wrinkles in the system” (e8), “the basis for the code is stable” (e8) and the updates are merely “tinkering at the edge” (e8) and evolving “through incremental challenges and adaptations” (e9). “The JORC Code still functions; the 2004 code works. It doesn't need a massive change, just to include the ASX updates” (e1). No major structural changes have

resulted from changes within the system. This could be due to the construction of a framework that works sufficiently well for the needs of the agents, or because the strength of the JORC system has yet to be truly tested.

Reactive changes in JORC Code updates are attributed to misrepresentations of the original intent in the definitions and/or guidelines: “although there are those who seek to take opportunities by dancing around the edges (and the size of the prize increases with boom-times), now there is no argument about core content, rather the focus is on interpretation around the edges” (e8). However, there is a sense that overall, the “shonky dealers are really in the minority” (e10). “There still is some dodgy reporting and JORC focuses on avoiding and pre-empting it” (e6). “When a player tries to make something sound better than it is, it influences the development of the Code. Because of the framework, it’s jumped on quickly and this influences the development of the Code” (e10). The rogue reporters are described as greedy, especially in boom times and that “within that space causes some to push the envelope and try to exploit the gaps” (e8). The JORC therefore has to respond within a volatile industry where “there is much opportunity for gain and loss” (e9). Within this environment “JORC needs to be attuned to them and to lead from the front to prevent misleading representation of resources and reserves” (e9).

The “iterative response to circumstances” (e6) is expanded through examples shared by an expert (e7):

1. *“In 1992 we had “Pre-Resource Mineralisation” category. But that was abused. So in 1996 that was withdrawn and we had to send an edict that you were not able to use it. From then only Inferred Resources (or better) could be declared.”*
2. *“In 1999 we had to include Exploration resources. Then in 2004, because people were talking about large exploration models – a prime example was Bendigo where they had this model of repeated veins, but based on isolated drillholes. There was a significant body of geological evidence to suggest mineralisation was repeated at depth and they had an inventory of 10 Million ounces of “Potential Resource”! It got confusing. We had discussions with Bendigo about whether the concept was or is reasonable. There probably is a heap more gold and yet they couldn’t classify them as Resources or Reserves. So the category of Exploration Target was included where ranges of resources were to be reported. But at Bendigo this downgraded too much of the project, so they called it Inferred Resources. This is an example of how the needs must be reflected in the code.”*

3. *“If you go back to 1975 a Resource was effectively an inventory of mineralisation that, over time, may have “reasonable prospect for eventual extraction”. For majors this means doing a scoping study, while juniors do a back of the envelope estimate.”*
4. *“Since 2004 there has been a lot of abuse of clause 18 and JORC has considered withdrawing the clause. From the feedback the overwhelming response is to retain it, but it needs more guidance as to how it can be used. It effectively becomes a lower level resource.”*
5. *“Clauses like “Exploration target” are another example of how the code has responded to the needs. It’s good that people talk about their projects and there is value in people talking about mineralisation outside of the Resources definitions that needs to be reported.”*

The JORC takes a pro-active stance in response to industry discussions and interpretations. Members of JORC regularly review announcements and use these in “an attempt to anticipate and to watch to make sure reports are reasonable” (e6). “The focus in reviewing questionable reports is on what people are trying to do to circumvent JORC requirements – the focus is on the exception rather than the norm” (e6). Overall the view was to take a positive stance in a changing world “and JORC needs to change and respond to it” (e9). “The challenges facing JORC are continuous and the discussions and responses never cease” (e9).

Often these challenges relate to clarifying understanding of the role of the Code and of the committee. “It’s a framework, a code of practice and we have to comply” (e1). The JORC Code does not exist “to gag people, rather it was a code to help people abide by the ASX listing rules” (e1). The ASX is seen as the “policeman” (e1) and “if a company attempts any form of malpractice” (e1) the ASX can take action to limit their trading, including “suspend companies from trading, fine them, halt trading and/or ask for a retraction and renouncement” (e1). Modifications in the code are thus seen as a means to ensure transparency in expectations and intent for all parties.

Critical Finding 9:

The JORC Code is constantly evolving in response to internal factors, such as misrepresentations of intent by participants in the system, and to perceived anticipated misrepresentations.

5.5.2 Interaction with External Codes

The JORC Code is recognised as a leading example for subsequent principles-based mineral reporting codes and there is much overlap between the definitions and guidelines. A major outcome of the JORC system is the spawning of reporting codes in other countries: “JORC has been adopted almost exclusively as the international benchmark for SAMREC, PERC etc.” (e11). This has contributed to a merging of ideas from the various principles-based reporting codes into the international reporting template (CRIRSCO’s template). Development and modifications of other reporting codes has in turn influenced updates in the JORC Code. Whilst the codes themselves are not substantially different, “NI43-101 was written by lawyers after Bre-X” (e11) and so the frameworks within which the Resources and Reserves are reported are different. In 2011 and 2012, ASX attempted to incorporate aspects of the Canadian NI43-101 system into the JORC Code. This, however, caused tension in the Australian mining community. The friction galvanised an unequivocal anti-prescriptive stance from within the Australian mining industry: “We just must not lose the three principles” (e1) and an emphatic call to not evolve to a more prescriptive style reporting, which would detract “from the integrity of the code and the responsibility a Competent Person needs to take when signing off” (e3). The ASX moves were rejected. This highlights both a contrast in philosophies as well as an ownership power tension between the industry bodies and the investors as represented by the ASX as expressed earlier.

Critical Finding 10:

The JORC Code evolves in response to adaptations in other international codes. However, changes are not absorbed *en bloc*, but are instead evaluated for suitability to the JORC system.

5.5.3 *Emerging Profession: Resource Geology*

An interesting outcome of the JORC system is the creation of “a profession within economic geology, resource geology, that didn’t exist 20 years ago” (e8). Comparing the estimation and reporting process to “20 years ago people were just geologists moving in and out of estimation occasionally, but now resource geology has become more of a skilled speciality” (e8). There is a tendency for geologists to enter the field of resource estimation as a viable career path: “now people are more technical and more specific” (e8). This alters the landscape by encouraging greater participation in the field and begs the question of suitability of the candidates as well as expectations regarding competency development. Job titles of *Resource Geologist* abound, but with a wide range of connotations and perceptions of the role. “It’s about having a specific job title that exists for people who want to specialise in resource estimation” (e15) and this allows them to identify with a current state or future responsibility of Competent Person.

Critical Finding 11:

The JORC Code and the associated system has spawned the emergence of a sub-discipline in geology that focuses on the evaluation, estimation and classification of mineral resources.

5.6 Findings and Interpretations

The context within which resource geologists operate can be articulated as the JORC system in accordance with Structuration Theory. Structural patterns of signification and codes, control and legitimisation are evidenced in the analyses above. Similarly, the tensions around communication, power distribution and sanction provide a meaningful description of the human interactions within the social order. The JORC Code as well as the reporting and complaints processes are proffered as modalities within the system. Structuration Theory has therefore provided a useful lens through which to examine the environment, processes and social order within which the resource geologists operate.

The original overarching research question is ‘What does it take to develop Competent Persons for the JORC Code?’ In light of the analyses presented above, Competent Persons should have due regard and respect for the systems that govern and sanction their conduct and products. Beyond understanding the technical processes that are core to their productivity, resource geologists should develop an insight into the JORC system. This is more likely to enable them to develop their competency and maintain a suitable standard as the JORC Code and system evolves.

Of particular relevance to the articulation and development of the competency of resource geologists is the emphasis on the reliance on Competent Persons as significant contributors of reliable estimates and associated descriptions of risk. The system does not prescribe techniques and technology, nor does the system prescribe any competency development processes. The next chapter focuses on articulating and testing the notion of competency within the JORC Code system.

6 Analysis of Competency

The previous chapter provides a comprehensive description of the environment within which resource geologists operate. The thesis now turns to the notion of competency of the resource geologists claiming to be Competent Persons. The specific purpose of this chapter is to establish a meaningful articulation of target competency that can be used to identify resource geologists who are suitably qualified to claim Competent Persons status.

After a summary of the analytical processes adopted for the analysis of competency, this chapter offers a synopsis of the JORC Code criteria, followed by an analysis of experts' expectations beyond these criteria. These together provide a baseline for further competency interrogation.

Next, the online survey contributions to the 12 scenario questions are evaluated through a Rasch Analysis. This provides an opportunity to revise the reasoning levels proposed earlier and to evaluate participants' reasoning levels.

The ability of the JORC Code criteria to differentiate between higher and lower reasoning levels is then tested using statistical tools such as t-tests and ANOVA³⁶. Alternative criteria proposed through the experts and demographics contributions are then tested.

The chapter closes with a revised set of qualifying competency criteria that can be used to identify resource geologists who could more justifiably qualify as Competent Persons.

The key finding of this analysis is that the current criteria are insufficient to differentiate context reasoning across the JORC Code in line with industry expectations. Alternative criteria can be established by combining the expectations of industry experts and the development of a suitable reasoning assessment mechanism.

6.1 Analytical Process

Data for this analysis is drawn from the JORC Code, the semi-structured interviews and the online surveys. A synopsis of the JORC Code competency criteria consolidates the current official requirements for Competent Persons. This is augmented with the interview responses to the question: *Beyond the JORC Code requirements, what signals indicate to you that a person is "ready" to be a Competent Person?*

³⁶ ANOVA is the standard acronym for Analysis of Variance.

The responses to this question were iteratively coded and themed in using a combination of reading, note-taking and coding tools and processes available in NVivo10. No pre-conceived themes were used. Instead, the data was open-coded, themed, re-read, re-coded and re-themed. Finally, the themes were analysed for core expectations in the three emerging themes: (1) experience levels, (2) experience content and (3) workplace learning. It is important to note that although the experts represent JORC, ASX, ASIC, AusIMM, AIG and various mining and consulting companies, their contributions were specifically personal.

Online survey responses to the 12 situational questions, where participants were expected to apply the JORC Code rationale, were scored against the rubric design (originally presented in Table 13 on page 83). Each question was scored in turn across all participants to ensure consistency in interpretation of responses. The dichotomous scores are defined as a score of “1” if the item concept identified in the rubric is present in the response; otherwise, a score of “0” applies. On completion, the process was repeated and the scores compared to ensure consistency in the interpretation of the rubric across all participants.

A Rasch Analysis was conducted on the dichotomous item scores. This analysis was initially performed in an Excel spread-sheet developed from first principles, and then repeated using Winsteps software. The results of the two approaches were close enough to be considered identical, thereby confirming the researcher’s understanding of the process. The Rasch Analysis results provide measures of difficulty associated with each item in the assessment. In addition, the Rasch Analysis provides scores reflecting person ability as measured by the assessment and that are consistent with the item difficulty scores. Since the two scores are measured on the same scale (a logit scale), these in turn provide a direct link between individual capability and the reasoning levels associated with the item difficulty scores. The resulting item difficulty scores were then analysed against the reasoning levels originally proposed in Table 11 on page 81. Reasoning levels were reviewed and updated to reflect the style of questions emerging in the difficulty scoring. The individual Rasch Analysis scores reflect individuals’ abilities to perform at these reasoning levels when applying the JORC Code, thereby providing a proxy to measure competency in application of the JORC Code.

The JORC Code reasoning levels were then used as a basis for testing the current and alternative qualifying criteria using a combination of t-tests and ANOVA tests. Included is a comparison against the self-assessed competency across Table 1 of the JORC Code, which was also analysed using raw scoring and Rasch Analysis.

6.2 Synopsis of the JORC Code and Guidelines Criteria

The stability of the JORC system relies on the Competent Persons. The current qualifying criteria in the JORC Code for Competent Persons estimating, classifying and reporting Mineral Resources are:

1. **Membership of an acceptable professional association** that has an enforceable disciplinary committee to uphold the associations' code of ethics" (JORC, 2012a) and
2. **A minimum of five years' experience** which is relevant to the style of mineralisation and type of deposit under consideration and in the estimation, assessment and evaluation of Mineral Resources" (JORC, 2012a).

The JORC Code provides further guidelines, which "do not form part of the Code, but should be considered persuasive when interpreting the Code" (JORC, 2004, p. 2):

3. **Content of five years' experience:** Five years' experience is not expected "in each and every type of deposit in order to act as a Competent Person if that person has relevant experience in other deposit types." (JORC, 2004, p. 5) This would indicate that a minimum of five years in one style of deposit is necessary to report in all similar styles of deposit. From there incremental experience would apply across other styles of deposits.
4. **Sampling and Analytical Techniques:** The experience levels should include "sufficient experience in the sampling and analytical techniques relevant to the deposit under consideration to be aware of problems which could affect the reliability of data." (JORC, 2004, p. 5) This indicates a depth in understanding and exposure to the potential issues arising from sampling and assaying the commodity within the style of deposit.
5. **Extraction and Processing:** Beyond the estimation and classification, there is an expectation that the Competent Person has "(s)ome appreciation of extraction and processing techniques applicable to that deposit type" (JORC, 2004, p. 5).
6. **Self-Assessment:** There is an element of self-assessment since Competent Persons are encouraged to "be clearly satisfied in their own minds that they could face their peers and demonstrate competence in the commodity, type of deposit and situation under consideration" (JORC, 2004, p. 5).
7. **Full Responsibility for the Estimate:** In the case of the Competent Person relying on contributions from a team they are still "responsible and accountable for the whole of the documentation" (JORC, 2004, p. 5) and they should be "satisfied that the work of the other contributors is acceptable" (JORC, 2004, p. 5). Most importantly, there is a high level of responsibility accompanying the role of Competent Person who "should appreciate that they are accepting full responsibility for the estimate and supporting documentation" (JORC, 2004, p. 5).

Ultimately, a willingness to take on the mantle of Competent Person is a personal decision. It is up to the Competent Person to evaluate themselves against the definition and supplementary guidelines provided within the JORC Code. However, opinions and uncertainty abound as to what signals a person's readiness to act as Competent Person. Industry experts' expanded indications are presented below. A comprehensive analysis of the competency assessment follows. This lays the foundation for testing the current JORC Code criteria for competency as well as alternative criteria. This chapter closes with a summary of the set of competency criteria best able to differentiate Competent Persons in accordance with their JORC Code reasoning levels.

6.3 Experts' Expectations

Expert opinion was sought to clarify the notion of Competent Person beyond the standard expectations summarised above. Three themes of criteria emerge:

1. Experts challenge the minimum 5 years' experience criteria:
 - The minimum of five years' experience is a bare minimum and is usually more in the order of 10 years' mining industry experience;
2. Experts emphasise the importance of the content of workplace experiences:
 - The quality of experience matters. Competent Persons should have both breadth and depth of experience, which includes appreciable operational experience and due regard and appreciation for the geological context of the project they are commenting on;
 - Competent Persons have a holistic appreciation for the mine value chain. They then have an appreciation of the potential risk associated with a project from data collection through to processing;
 - Competent Persons' experience should include a longer service stint in their experience. By working on a project for an appreciable amount of time they have the opportunity to learn from corrected mistakes;
3. Workplace learning:
 - Competent Persons are better prepared when they have undergone an apprentice style arrangement with an expert;
 - Competent Persons should continue to learn throughout their professional service and thereby continue to test their understanding and experiences;
 - Competent Persons should actively seek expert review and in turn contribute to the competency development of others.

6.3.1 Challenging the Minimum Five Years' Criteria

In most cases, experts emphasised more than five years' experience is necessary to comment competently on the risk associated with resource estimation and classification. Although the standard five year' criteria are accepted as necessary as minimum criteria, experts expanded on this requirement to insist that it was the quality of the experiences leading up to and lived through those 5 years that matter:

"It was never intended that 5 years after graduation you could sign off. In theory you could, but it was never the intention. Rather the 5 years needs to be sitting on top of a body of experience. Most competent persons have at least 10 years' experience."(e8)

"You don't suddenly wake up competent. It's an evolving process."(e1)

“(W)hat you do in your 5 years matters. You can either have 5 x 1 years’ experience or 5 years’ experience.” (e18)

“Competency is a very loose term. “Which 5 years?” is a problem - what is the actual time spent doing the work? Or are we talking about a time lapse? I don’t find the time thing is all that valid.” (e11)

“In the case of 5 years’ experience – it’s about the quality of that experience.”(e6)

Experts therefore tend to challenge the notion of that a minimum 5 years’ experience is sufficient to suggest a resource geologist is ready to pronounce himself/herself a Competent Person.

Critical Finding 12:

Experts challenge the sufficiency notion of a minimum of 5 years’ experience.

6.3.2 Content of Workplace Experiences

Beyond the criteria for a minimum of five years’ experience, there is a call for those five years’ experience to have contributed to the development of both the depth and breadth of the Competent Person’s professional capabilities.

“A mine geo works on all sorts of stuff and may have some involvement with estimation, but unless they are heavily involved it cannot count as an experience block. In terms of a 2 year grad program followed by more experienced roles, you might still be too light on the 5 year experience requirement.” (e6)

Critical experiences are those that are embedded in geological context and exposure to the whole mine value chain as these experiences enable the Competent Persons to assess potential consequences in estimates because they can “see clues in the data” (e8) and incorporate a “judgment/experience overlay” (e8) when classifying and assessing the risks: “Risk blindness is only resolved by experience and having a specific background” (e8). This depth and breadth ensures the Competent Person “understands the context of the business beyond the mechanical act of estimation” (e8).

The quality of experience that engages with the geological context is considered especially more valuable than simply exposure to the process of estimation: “If you can put data into the computer, and if you ignore the geology, you get rubbish results” (e7). There is a very real perception among experts that the younger generation operate within the virtual world of the computer. This is evidenced by an apparent disconnect between the virtual world within the

software and the real in-ground deposit. For example, in contrast to hand mapping, where lines “indicate a sense” (e19) of a structure in the area, the precision dictated by a line within the computer builds an expectation of precise existence: “Just because a feature in our (hand) mapping went off the page, didn’t mean it no longer existed” (e19).

Mining experience, particularly underground experience helps the geologist “think in 3D when they are underground” (e19). Geologists “need to understand how an estimate is going to be used – what decisions will be made using that estimate?” (e17). The geological experience should thus precede any foray into resource estimation: “... if you have a geostatistics focus and go straight into a geostats role and never spend any time on the ground and have never dealt with real mining issues, you’ll also be a bit light on for the 5 year experience requirement” (e6). Ideally the Competent Person is “intimately involved with the data, the geology and the mining issues ... (and so)... is best placed to generate accurate resource estimates” (e4). “(W)hen there is a marriage of geology and the resource model the quality is better” (e1). “They have to demonstrate an understanding to me of all the different components that go in to developing a resource statement, and have done all of them at some stage in their career” (e2). So more than simple exposure of five years to a style of geology and activity, the experts identified: “*It’s about the quality of that experience*” (e6) and “*It’s both breadth and depth that is important*”(e2).

More specifically, Competent Persons’ “breadth of experience” (e18) should enable them “to really understand the combinations and consequence” (e18) and to be able to deal with the variations in deposits: “Every project is a little bit different and there is no one answer that suits all cases” (e12). Experience in both open pit and underground mine styles as well as a mix of single and multi-element commodities is recommended, with an emphasis in having sufficient “mining related experience” (e18) as this is the only way to “understand the business implications” (e16). This “coal-faced” (e5) engagement by the Competent Person is expected to be linked to the project being reported: “They have to have direct experience” (e7); “The fundamental geological behaviour of an orebody must be understood” (e16). This is contrary to a call for independence by some parties: “(The) requirement for independence is totally flawed because independence doesn’t make you a better judge” (e7). Although “external audits ... in some way deals with independence” (e16).

These experiences contribute to a better understanding of the implications and consequences of providing resource estimates and technical reports to support public declarations. Competent Persons “realise the consequences of signing a public statement” (e2). There is recognition among the experts that Competent Persons have attained a level of “professional maturity” (e10) where the Competent Person recognises the gravity of their signature on a

consent form with all the underlying “accountability and responsibility” (e1), where responsibility means “knowing the requirements” (e1) and having “the confidence to say ‘I can do this’ ” (e1), while accountability means “understanding the systems and be willing and able to defend your position” (e1). In this context the Competent Person is able to “understand the bigger picture” (e10) and the “implications of not doing it well” (e10). There is an emphasis that the Competent Person needs to “understand the scale and ramifications” (e16) of the estimate, its classification and the eventual public release. They have the experience and exposure to understand the implications and know “what could go wrong” (e7). The expectation is that the Competent Person is the “custodian of the orebody” (e16).

Core to professional maturity is the opportunity to learn through exposure, reflection and “experience in making mistakes” (e7). There is much emphasis on having “the time to experience the existence and consequences ... of decisions, because that is where you grow” (e16). “By staying in one place I got to apply the lessons from mistakes I’ve made.” (e15). “I learnt what to do next time and got a chance to avoid them” (e15). Unfortunately, “(t)hese days it seems that people are transient” (e16) and “because there is a shortage of people, we seem to keep promoting too quickly” (e16). “I’ve seen enough rubbish to suggest 5 years is not enough, especially if it’s fragmented” (e17). “If you move around you never get the chance to ... make a mistake, fix it and apply the fix so you can perform to expectation” (e15). This suggests the Competent Person’s work experience should include a long enough stint at an operation that allows them to make mistakes, learn the consequences, correct and experience the consequence of the improvement. Reconciliation between estimate and production provides a concrete process to learn from estimation mistakes.

Critical Finding 13:

Experts note the valuable contribution of workplace experiences to the development of competency. Of particular importance to resource estimation and classification is exposure to geological contexts to provide both breadth and depth of understanding and opportunity to learn through reflection and correction.

6.3.3 *Workplace Learning*

Whilst the initial process may be formal: “Relevant training and experience are the building blocks, and you need a lot of this until you get to a certain point” (e12). There is an expectation of the Competent Person to engage in continuous competency development: “A good Competent Person does not rest on their previous knowledge, but is constantly testing their own knowledge. It’s all part of continuous professional development” (e12) and “You have to learn for yourself; you have to ask questions and find your answers” (e12). Competent Persons “should feel comfortable to ask questions” (e16) so they can “keep up with best practice” (e2).

A deliberate process of exposure and support is reminiscent of the preparation usually provided in the form of an apprenticeship: “It is important in my mind that the person has actually progressively been exposed to resource estimation. Starting with boots on the ground understanding the distribution of the commodity and how it behaves; progressively exposed to all aspects. There needs to be mentoring before one can stand on one’s own two feet” (e3).

The support may be through deliberate training programs that may or may not include deliberate structured responsibilities. An expert provided an example of how this apprentice style approach was formalised within his organisation: “Each Competent Person has an understudy and they are included in the workshops so they develop the necessary grounding in the process and a grounding in the value of the entire business” (e8) or through external Competent Persons: “They might just get there, but be thin on experience so as a backstop we support them with external experience to provide the necessary experience” (e6).

The value of reflection and discussion with others in the industry is important: “You have to work with peers and with more experienced people” (e1) and be able to “accept robust peer review” (e2). The sense of peer acceptance plays a major role in whether a person should be deemed competent: “Internal to our company, some may comply with the requirements, but there is a level of discussion with their peers who know them as to whether they are actually competent” (e6). “They should be able to put their arguments to peer opinion” (e6). “A Competent Person also needs to be recognised by their peers, so they need to publish and sign off on resources. They have to demonstrate their expertise” (e12). Peer review provides opportunity to demonstrate “critical thinking” (e2). Exposing ideas through publication and peer review provides opportunity to build confidence in one’s technical work. There is an element of practice and reflection, as well as a sense of developing communication skills through the experience of sharing interpretations, ideas and having to justify positions.

An ability to communicate to a wide range of mining professionals becomes important in understanding and conveying technical and business consequences and associated risks. Experts agree Competent Persons “need to be able to present reports” (e11) and, by publishing papers and writing reports, Competent Persons “demonstrate their expertise” (e12). Moreover, reports provide evidence of a person’s competency: “You can tell very often by reading a report ... The competency will show in the way they defend their Resource” (e13). So “three aspects (necessary for individual competence are) “technical, business and communication” (e17).

Ultimately, a willingness to stand before one’s peers translates to a reliance on individuals to self-assess their competency accurately: “In practice the (peer) test is not applied, so the onus is on the individual to self-assess. I doubt anyone could actually ask their peers if they are competent” (e3). “(I)t’s a judgment call an individual makes – a self-assessment type process” (e6) and “Even with relevant experience does the person themselves feel confident to take on the role?” (e6). “The fact that you have worked on similar projects and it gives you confidence to say “I understand the system. I can take this on” (e1). Notably, it reduces to “more a case of confidence than competence” (e3). However, self-confidence and competence are not interchangeable.

Given the enormity of capability required, Competent Persons will inevitably rely on contributions from teams. However, for this team approach to work, Competent Persons “must have experiences in leading a team, because it’s hard to imagine anyone having all the skills required of a Competent Person as they have to demonstrate an understanding of all the different components that go into developing a resource statement, and have done all of them at some stage in their career” (e2). This suggests an important requirement for Competent Person to have exposure across the mine value chain to be able to evaluate and comment on the risks associated with the classified resource estimate they sign off on.

Critical Finding 14:

Resource estimation and classification capability is developed through apprentice style workplace learning. This style of learning allows development through exposure to practical contexts.

6.3.4 Discussion and Implications

According to industry experts, the notion of Competency extends beyond the standard JORC criteria and includes:

1. Expectations of more than five years' experience,
2. An emphasis on the quality of the competent person's experience, including depth and breadth and engagement with a range of geological contexts, and
3. A component of engaged exposure to experienced mentors and peers, and continual competency development.

Experts note there is a risk of over-confidence when resource geologists self-assess their competency.

The implicit expert expectations and associated concerns highlight firstly, the need to evaluate Competent Persons' competency, secondly, the need to evaluate the suitability of the self-assessment criteria and, thirdly, the need for an evaluation of the sufficiency of the current Competent Persons criteria. In addition, alternative criteria that encompass elements of depth, breadth and operational experience need to be tested.

The remainder of this chapter addresses these issues by analysing resource geologists' reasoning levels and the criteria that can successfully differentiate resource geologists with appropriate reasoning levels in accordance with JORC Code expectations.

6.4 Assessing Competency

An analysis of the factors that contribute to competency necessitates an assessment of competency. Unfortunately, the accuracy of a resource estimate can never be comprehensively validated. In part, this is because only the perceived economic portion of the estimated mineralised deposit is targeted for extraction. Moreover, during the process of extracting the rock, that portion is subject to mining dilution (waste material is included either by design or through poor mining practices), ore loss (poor mining practices can sterilise access to economic portion of the mineral deposit) and metallurgical processing, which if sub-optimal may not fully liberate the contained mineral from the host rock. Moreover, many operations blend their material prior to processing, thereby destroying the opportunity to measure the outcome from a single source or estimate.

The only comparison that can be made between estimate and production is through a reconciliation study, but this involves team contribution and investigation of multi-disciplinary (and often multi-operational) factors, including the issues raised above. It is

therefore nearly impossible to provide a true reflection of the ability of an individual resource geologist through the product of their labours.

Recall, however, that the task here is to understand and be able to assess the competency of individual resource geologists as it pertains to the JORC Code. There are two ways of assessing this competency. Firstly, resource geologists can provide a self-assessment as indicated in the guidelines of the JORC Code, and secondly, resource geologists can be assessed according to their responses to a range of typical issues and scenarios Competent Persons need to address when they apply the JORC Code to their interpretation and application of the JORC Code classification definitions. The premise is that more competent resource geologists will be better able to reason across the full range of issues identified in table 1 of the JORC Code (as established in the methodology outlined in §4.3.2.2 on page 78).

A Rasch analysis of the JORC Code reasoning assessments follows.

6.4.1 Rasch Analysis

Rather than apply raw scores based on the item rubric, a Rasch Analysis was conducted to evaluate the test's internal consistency. A Rasch Analysis is a mechanism for testing the suitability of an assessment to reflect the intended measure. Of particular relevance is the internal consistency that occurs when high scores consistently include correct answers to easy questions. In addition, lower scores are based consistently on the easier questions. Difficult questions should also show lower probabilities of correct answers across the cohort. If the Rasch Analysis indicates the instrument is invariant to both item and person, the resulting logit values are a measure of item difficulty and person capability (Wright & Stone, 1999). A Rasch Analysis, which tests both the validity and objectivity of the assessment test, provides an ability score which is independent of the sample set (Wright & Stone, 1999) and can then be used to categorise both the question styles and the participants.

As part of the Rasch Analysis process, a Mean Square Error (MSE) is calculated for the test. This effectively measures the difference between the model and the data. The objective is to iterate the Rasch process until the MSE converges to zero. The initial attempt at the Rasch Analysis failed to converge to 0.0, even after 15 iterations. However, further investigation identified item "6a" as an item that was correctly answered by all participants and so provided no meaningful contribution to the analysis. Item "6a" related to the question concerning bias between two data sets as identified on a Q-Q plot. This is a basic comparison and so, not surprisingly, all participants were able to identify the bias between the two data sets. When this item was removed from the analysis, the MSE converged to zero within four iterations.

The instrument, excluding question 6a, is invariant to items and participants and can thus be used for further assessment of the questions and individuals.

An overall normalised Chi-squared goodness of fit between the Rasch Expected and the Observed results gives a value close to 1.0 (0.98 at 1403 degrees of freedom³⁷), indicating an acceptable fit between the observed values and the Rasch expected values, which again supports use of the Rasch item difficulty and Rasch person ability measures.

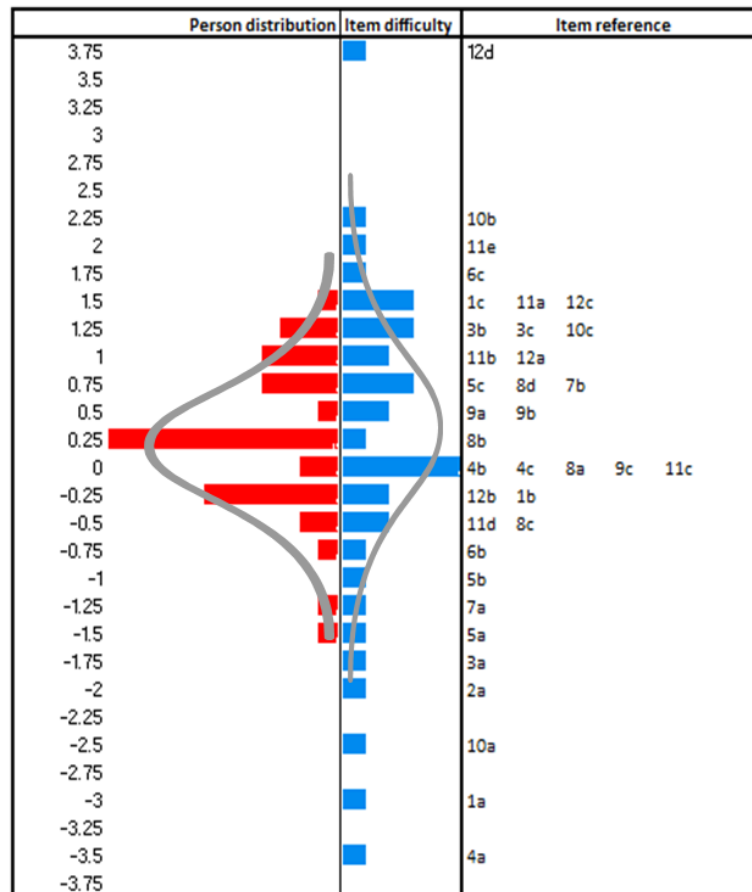


Figure 17 Wright Map – JORC Code Reasoning Assessment

A Wright Map presents items arranged by difficulty as frequency bars on the right hand side and person ability as frequency bars on the left hand side (Figure 17). The ranking is scaled to logit values (on far left) with lower difficulty reflected by negative scores and higher degrees of difficulty reflected by positive scores. Similarly, participants who are more capable present higher ability scores, and participants who are less able receive a lower logit score. Although the sample size is small, both the person and item distribution show reasonable potential for normal distributions. The instrument is suitable for testing this group of participants since the item difficulties span the person abilities.

³⁷ Number of degrees of freedom = (number of items x number of participants) - 1

Table 15 Item Reasoning Analysis

Question	Rubric	ref	item difficulty	Comment	*RL
12. How do you consider mining and metallurgy factors or assumptions in resource classification? 10. How do you validate a Resource Estimate? 11. What is your preferred process for Resource Classification? 6. Below are statistics of RC and DDH drilling for a gold project. What can you conclude? What other information would help you? 1. What role does Geology play in Resource Estimation? 11. What is your preferred process for Resource Classification? 12. How do you consider mining and metallurgy factors or assumptions in resource classification? 3. What do you do to check you have a clean database (database recording integrity rather than sampling integrity)? 3. What do you do to check you have a clean database (database recording integrity rather than sampling integrity)? 10. How do you validate a Resource Estimate?	Risk analyses /classification	12d	3.953	considering the broader mining context linking end of the process back to the beginning addressing the full range of criteria in Table 1 broader context of geology in data comparisons broader context of geology in data comparisons addressing the data collection (early stage) in the latter stage of the process considering the broader mining context value in peer and external review considering the early stage non-obvious potential for errors broader context in model comparisons	High Order Mining Reasoning
	Geologically sensible Estimation quality relative to items on Table 1	10b	2.192		
	Geology-common?	11e	1.774		
	Validation	6c	1.599		
	Data quality	1c	1.290		
	Economic limitation	11a	1.290		
	Audit processes	12c	1.290		
	Transcription	3b	1.016		
	Reconciliation	3c	1.016		
	10c	1.016			
11. What is your preferred process for Resource Classification? 12. How do you consider mining and metallurgy factors or assumptions in resource classification? 5. Examine the statistics presented below. What steps would you recommend for domaining? Is there any additional information you would like to use? 8. How do you choose search parameters? 7. How do you select an estimation method? 9. What makes you confident in the estimation parameters you select? 9. What makes you confident in the estimation parameters you select?	Geological continuity	11b	0.888	geological relevance and input to classification mining relevance and input to classification stepping back and visualising the data and relating this to statistics accepting a broader view than a standard process accepting a broader view than a standard process matching selection of parameters back to geology linking output with input in validation	Mining Context Reasoning
	Mining selectivity	12a	0.888		
	Spatial pattern ref Testing methods/ sensitivity tests	5c	0.646		
	Range of methods Mimics geological expectation	8d	0.646		
	Validation (out mimics in)	7b	0.529		
		9a	0.300		
8. How do you choose search parameters? 4. Evaluate the charts below. What do you observe? What are the implications of your observations? What actions would you recommend? 4. Evaluate the charts below. What do you observe? What are the implications of your observations? What actions would you recommend? 8. How do you choose search parameters? 9. What makes you confident in the estimation parameters you select? 11. What is your preferred process for Resource Classification? 12. How do you consider mining and metallurgy factors or assumptions in resource classification? 1. What role does Geology play in Resource Estimation? 11. What is your preferred process for Resource Classification? 8. How do you choose search parameters? 6. Below are statistics of RC and DDH drilling for a gold project. What can you conclude? What other information would help you?	Data spacing	8b	0.187	context of data for estimation parameters correctly interprets precision in QAQC transfers analysis to action for data analysis considers geological context in search parameters applies process testing tools or alternative approach checks for estimation parameters links grade continuity to classification incorporates recovery considerations in classification uses geology to constrain study uses data spacing in classification links search to grade continuity understands need for common volume in data comparisons	Process Reasoning
	Precision	4b	-0.039		
	Recommend action	4c	-0.153		
	Geological context QKNA or sensitivity test work	8a	-0.153		
	Grade continuity	9c	-0.153		
	Recovery	11c	-0.153		
	Limits/domain/boundary	12b	-0.268		
	Data spacing relative to ...	1b	-0.386		
	Grade continuity	11d	-0.507		
	Location-common?	8c	-0.631		
6b	-0.760				
5. Examine the statistics presented below. What steps would you recommend for domaining? Is there any additional information you would like to use? 7. How do you select an estimation method? 5. Examine the statistics presented below. What steps would you recommend for domaining? Is there any additional information you would like to use? 3. What do you do to check you have a clean database (database recording integrity rather than sampling integrity)? 2. What are the implications of drill angle relative to domain orientation? 10. How do you validate a Resource Estimate? 1. What role does Geology play in Resource Estimation? 4. Evaluate the charts below. What do you observe? What are the implications of your observations? What actions would you recommend? 6. Below are statistics of RC and DDH drilling for a gold project. What can you conclude? What other information would help you?	Need for geology Adapt to context/geology	5b	-1.038	recognises importance of geology in domaining uses geological context to select estimation parameters identifies mixed populations recognises need for QAQC practices recognises implication of sampling direction recognises comparison of output model to input data identifies geology as an important aspect to resource estimation correctly interprets accuracy in QAQC correctly identifies bias	Foundation Reasoning
		7a	-1.353		
	Histogram -mixed pop	5a	-1.731		
	QAQC Practices	3a	-1.957		
	Bias interpretation /data/quality/boundary	2a	-2.225		
	Out mimic in	10a	-2.557		
	Context/control	1a	-3.008		
	Accuracy/bias	4a	-3.746		
	Bias	6a			

*RL = Revised JORC Code Reasoning Levels

6.4.2 Analysis of Reasoning Levels

Closer examination of the questions and their item difficulty score reveals four distinct themes in thinking style or reasoning required to address the respective items of the questions (Table 15 and Table 16).

Table 16 Reasoning Themes

Item Difficulty	Reasoning Level	Description
> 1.0	High Order Mining Reasoning	High order consideration of mining context and estimation purpose
0.3 to 1.0	Mining Context Reasoning	Connection of process to mining context
-1.0 to 0.3	Process Reasoning	Lower level linking of task to process
< -1.0	Foundation Reasoning	The basics preparation knowledge in resource estimation

These four bands of reasoning are:

- (1) **Foundation Reasoning:** Questions with the lowest Rasch item difficulty (less than -1) tend to correlate with the first rubric items for each question and reflect the basic, foundation or process responses. Examples include basic recognition of bias in graphs, outline of checklists (such as QAQC), and recognition that geology is important. These lower item difficulty questions (scores less than -1.0) recognise basic foundational concepts in resource estimation and classification, without regard to mine value chain context or implementation processes. These questions correspond to the original reasoning category proposed as “Inconsistent” reasoning (Table 17).
- (2) **Process Reasoning:** The questions with Rasch item difficulties of between -1.0 and 0.3 reflect process implementation – participants have recognised the steps that need to be followed to implement partial solutions to the problems posed in the survey. Examples include identifying a process or set of tools to address QAQC, linking grade continuity and search parameters, and correctly interpreting precision in analysis of QAQC questions. These item questions relate to linking of tasks to processes in resource estimation. This level recognises a degree of context, but focuses on the process of the task rather than the purpose of the task. These questions compare to the original reasoning category proposed as “Consistent Non-Critical” reasoning (Table 17).

- (3) **Mining Context Reasoning:** The distinct difference in questions with Rasch item difficulty values higher than 0.3, is the connection to broader context, which escalates with increasing Rasch item difficulty. Here the mine value chain context is recognised - at a more functional and practical level for questions with a score between 0.3 and 1.0. Here the items relate to the components of the question associated with whole process thinking and reasoning within the context of the mine value chain. These items correspond to the original reasoning category proposed as “Critical” reasoning (Table 17).
- (4) **High Order Mining Reasoning:** Rasch item difficulties higher than 1.0 suggest a higher order mining reasoning that incorporates consequence risk factors such as connecting geology and data quality to the classification process, addressing the full range of criteria in Table 1 when classifying resources, and the confidence associated with mature reflection such as recommending external and/peer review. These questions govern the consequences of risk assessments and mining business context. The associated higher order difficulty reflects the need for participants to apply an understanding and a reasoning of information and data beyond the job of resource estimation and classification into the broader realm of purpose and consequence. These questions compare to the original reasoning category proposed as “Critical-Cross-Contextual” reasoning (Table 17).

The reasoning levels originally proposed in the development of the JORC Code Reasoning instrument can be updated to reflect the reasoning levels established in Table 17. Whilst linked to the reasoning levels proposed within statistical reasoning education, the levels and their descriptions are updated to reflect the context of the JORC Code.

The four orders of item difficulty span the spread of participants. The individual scores can therefore be used to differentiate between participants with lower and higher order JORC Code reasoning. The difficulty categories of High Order Mining Reasoning and Context Reasoning directly apply to the JORC Code guidelines call for Competent Persons to ensure their experience includes an appreciation of the whole mine value chain – from potential sampling and assaying problems through to extraction and processing techniques(JORC, 2012a). The remaining categories identify items that relate knowledge and skills around the resource estimation tasks, but do not necessarily encompass expertise that relates to broader experience. The premise therefore is that a Competent Person should have a high probability of correctly answering item difficulties above 0.3. The participants with an ability score of 0.3 or higher are therefore identified as having sufficient capability to reason through the JORC Code considerations. The minimum reasoning score of 0.3 is henceforth used as a

minimum reasoning score expected of Competent Persons operating within the JORC system for estimation, classification and reporting of Mineral Resources.

Table 17 Re-evaluation of JORC Code Reasoning Levels

Levels revised for JORC Code	Original descriptor	Post Rasch Analysis Reasoning Levels	Description	Rasch Score
Idiosyncratic	Plain wrong	Nil	Nil	Nil
Informal	description within context with implicit/qualitative/rudimentary evaluation of quality	Nil	Nil	Nil
Inconsistent	description within context and explicit qualitative evaluation of quality	Foundational Reasoning	Provides evidence of concept recognition without process or context	< -1.0
Consistent non-critical	detailed description within context and use of simple statistics to evaluate quality and compare between collections, some qualitative indication of risk	Process Reasoning	Places description with step-wise process, but does not offer mining context for decisions or consequences	-1.0 to 0.3
Critical	detailed description within context and use of comparative statistics to evaluate quality and compare between collections, some qualitative indication of risk	Mining Context Reasoning	Provides early stage recognition of the importance of mining context, but is limited in terms of contextual implications	0.3 to 1.0
Critical, cross-contextual	detailed description within context and use of comparative statistics to evaluate quality and compare between collections, includes cross reference to other aspects of JORC table, may include quantitative measure of risk; context is sensed at the scale of mining rather than just the resource	High Order Mining Reasoning	Reasons through full mine value chain context, including implications and consequences wider than the problem as hand	> 1.0

Critical Finding 15:

There are four levels of questions evident from the Rasch Analysis that reflect increasing levels of reasoning in the application of the JORC Code to resource estimation and classification.

6.4.3 External Review

In addition to the Rasch Analysis, three independent industry experts reviewed the assessment questions against Table 1 of the JORC Code, the rubric design and expectation and against the Rasch Analysis results. All three independent industry experts supported the assessment tool, the expectations articulated by the rubric and all three concurred with the results and the themes. This lends credibility to the measures and provides confidence in subsequent analyses.

6.5 Testing the Competency Criteria

The resource geologists' Rasch measures provide a means to evaluate Competent Persons qualification criteria. This section addresses the standard JORC Code criteria:

1. Membership of a professional association – in particular examining the difference between Fellow and ordinary member status;
2. Minimum five years' 'relevant' experience; and
3. Self-assessment.

The analyses that follow demonstrate that these criteria are insufficient to identify resource geologists who have at least mining content reasoning levels. The only potential indicator of competency is a minimum of five years' experience specific to resource estimation.

The analysis for each criterion is presented below.

6.5.1 Membership of a professional association

The JORC Code requires membership of an institute primarily to facilitate disciplinary actions.

Both the AusIMM and AIG have several grades of membership. New graduates or students have the lowest grade of membership (student or graduate members). Ordinary members have Member status for which a minimum of three and five years working experience is required by the AusIMM and AIG respectively. Members with at least 10 years' experience may apply for optional member status of Fellow. AusIMM offers a Chartered Professional status, which requires members to maintain records of their professional development. This record is reviewed by the AusIMM every three years. The Registered Professional status is an equivalent offered through the AIG. Members are required to submit evidence of their experience, which is evaluated by the AIG for acceptance as a Registered Professional Geoscientist (RPGeo).

Recent updates to the Canadian reporting requirements require Qualified Persons³⁸ to have a degree in their field of expertise and a commitment to professional development as indicated by either Fellow status or Chartered Professional (CP) status for members of AusIMM. The reasoning measures were thus also compared across these levels of membership.

³⁸ A Qualified Person is equivalent to a Competent Person operating within the Canadian reporting system.

The difference in average person ability for those with or without Member, Fellow or Chartered Professional³⁹ status (Table 18 and Figure 18) is **not statistically significant**. There may be some indication of higher reasoning levels in members with Fellow status, but this is not distinctly different from non-Fellows since there may be professionals who would qualify as Fellows, but have not formally applied for Fellow status.

Across all three membership criteria, the t-tests have p-values in excess of the α -level⁴⁰ of 0.05 indicating the differences of the three independent tests are all not statistically different. That is:

1. There is no statistically significant difference in reasoning levels between resource geologists who are members of professional organisations and those who are not.
2. There is no statistically significant difference in reasoning levels between resource geologists who have attained a status of Fellow members or equivalent and those who have not.
3. There is no statistically significant difference in reasoning levels between resource geologists who are Chartered Professionals (or equivalent) and those who are not.

Table 18 Test of Membership

Statistic	Ordinary Member	Fellow Member	Chartered Professional
Difference in Reasoning Measure	-0.349	0.711	0.115
Pooled Standard Deviation	0.7631	0.7467	0.7756
Degrees of Freedom	39	39	39
T-Value	-1.21	1.81	0.42
p-Value	0.232	0.078	0.676
Significance at 95% Confidence Level	Not Significantly Different	Not Significantly Different	Not Significantly Different

These results are clarified in the Box-and-Whisker plots that highlight no distinct difference in reasoning levels according to different segregations (Figure 18).

Critical Finding 16:

Higher membership of a professional institute, such as Fellow or Chartered Professional is insufficient to differentiate between higher and lower order JORC Code reasoning.

³⁹ The AIG equivalent of RPGeo (Registered Professional Geoscientist) is included in the Chartered Professional group for this analysis.

⁴⁰ An α -level is the probability of rejecting a false Null Hypothesis.

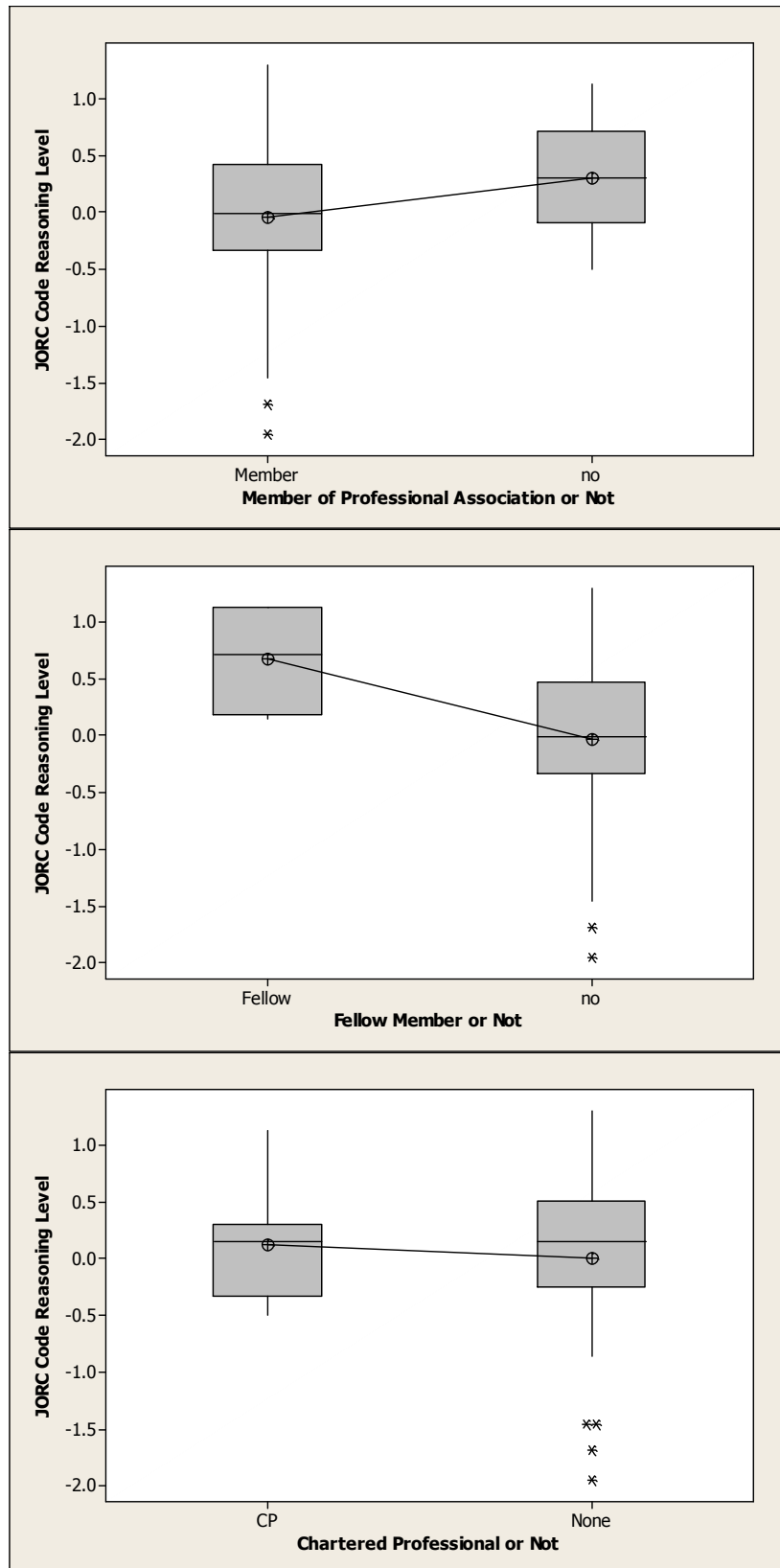


Figure 18 Reasoning Measure by Membership (a) Member or not (b) Fellow or not (c) Chartered Professional or not

6.5.2 Minimum Five Years' Relevant Experience

A minimum of five years mining industry is not sufficient to identify a high level of JORC Code reasoning (Table 19). A t-test reports a p-value of 0.218, which is higher than the α -level of 0.05, indicating the difference between reasoning levels between resource geologists with less than five years' experience and those with more than five years' experience is not significantly different. At least five years' experience specific to resource estimation, however, does show significant difference in JORC Code reasoning measure, with the corresponding t-test p-value of 0.008. These differences and their significance are demonstrated in the corresponding box-and-whisker plots (Figure 19).

Table 19 Test of Five Years' Experience

Statistic	Minimum 5 years' Mining Industry Experience	Minimum 5 years Estimation Experience
Difference in Reasoning Measure	-0.503	-0.646
Pooled Standard Deviation	0.7622	0.7088
Degrees of Freedom	39	39
T-Value	-1.25	-2.18
p-Value	0.218	0.008
Significance at 95% Confidence Level	Not Significantly Different	Significantly Different

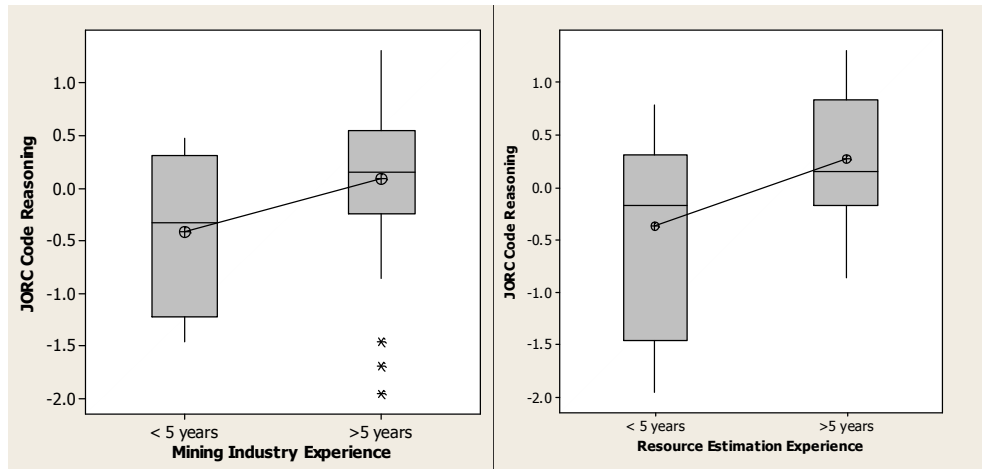


Figure 19 Boxplots of Reasoning by (a) Mining Experience and (b) Resource Estimation Experience

Critical Finding 17:

A minimum of five years' mining industry experience is insufficient to differentiate between higher and lower order JORC Code reasoning.

Critical Finding 18:

On average, resource geologists with a minimum of five years' resource estimation experience tend to have higher levels of JORC Code reasoning.

6.5.3 Suitability of Self-Assessment

Resource geologists provided self-assessments of their competency in the online survey. Overall most participants have marked themselves relatively high in knowledge, skills and experience across most categories of Table 1 of the JORC Code (Figure 20). The only exceptions are in the area of the Mining/Metallurgy where participants tend to rate themselves high in knowledge but lower in skills and experience, and the area of Cost where participants tend to rate themselves higher in experience than knowledge and skills (Figure 21).

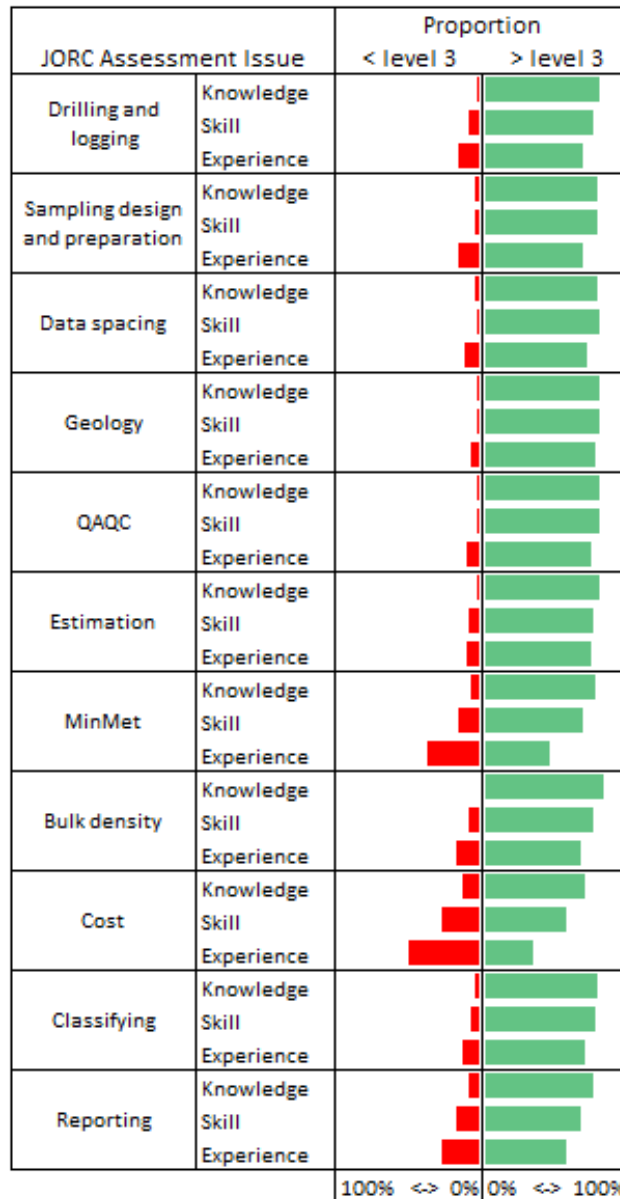


Figure 20 Proportions of Participants Above and Below Critical Level 3 in Knowledge, Skills and Experience

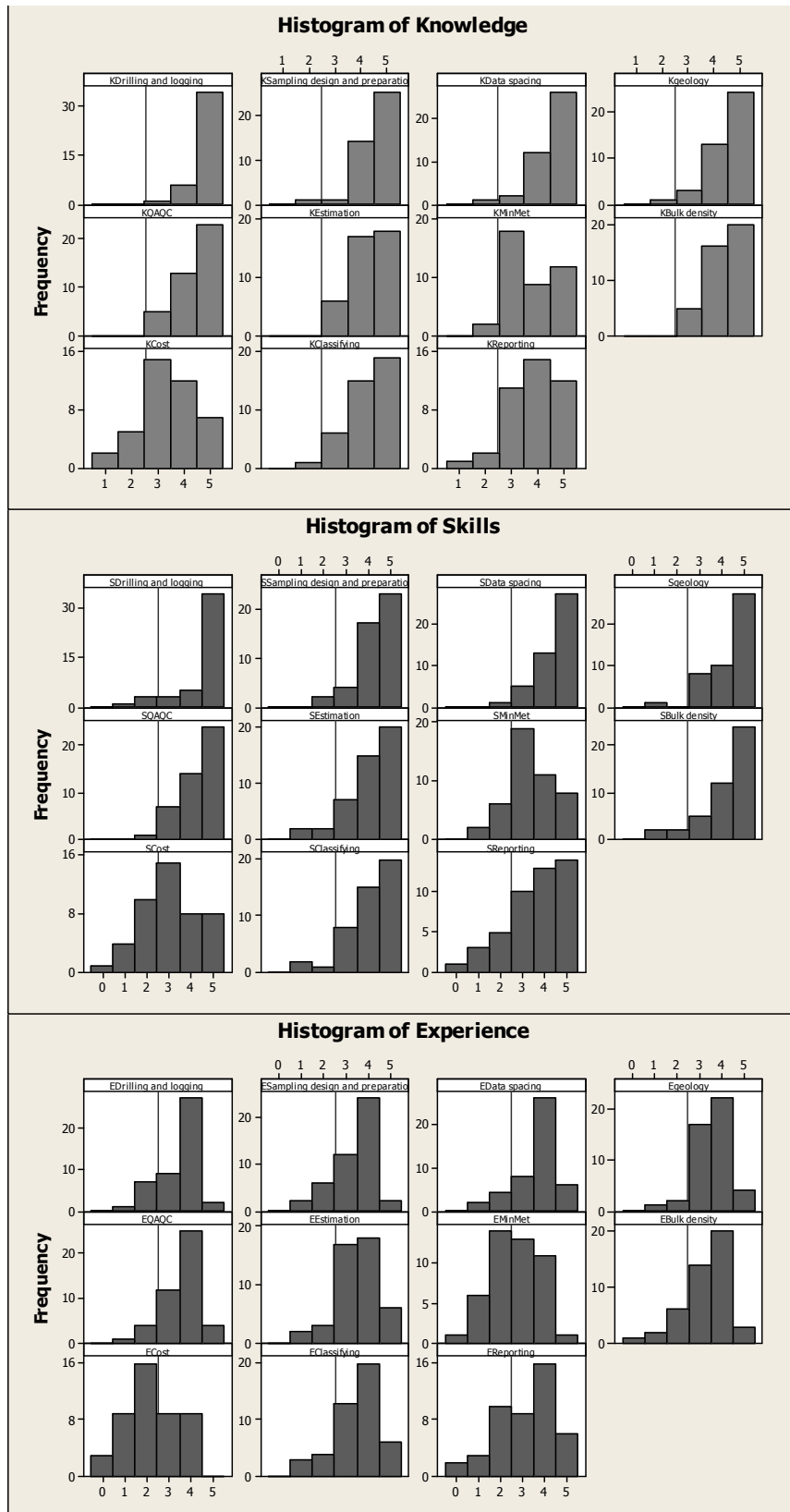


Figure 21 Distribution of Self-Assessed (a) Knowledge, (b) Skills and (c) Experience across JORC Table 1 Categories

According to the criteria set up in §4.3.2.1 (page 76) most of the participants regard themselves as Competent Persons: 90% of participants have an average self-assessment score of '3' or higher (Figure 22). This high proportion reflects either that the sample set lacks variability, or that the self-assessment scoring mechanism is too lenient, or that resource geologists tend to overrate their abilities.

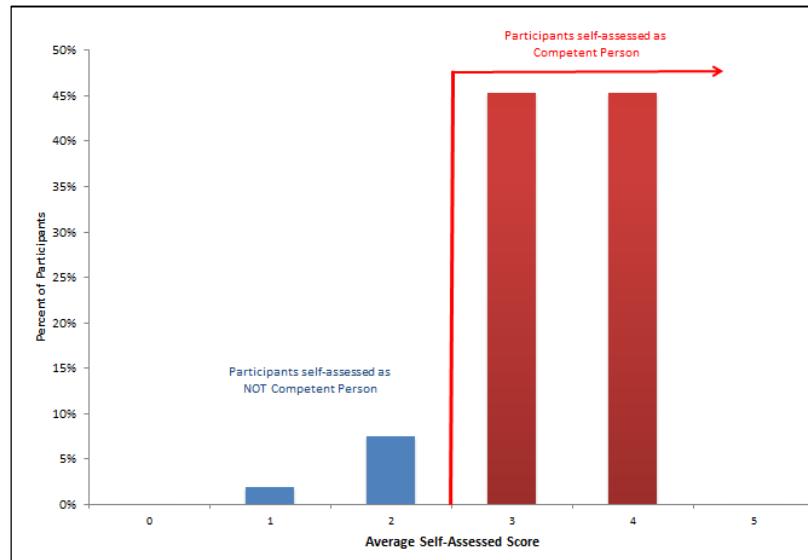


Figure 22 Distribution of Overall Score of Self-Assessed Competency

These issues are particularly evident in the Rasch Variable Map⁴¹ (Figure 23) where individuals (left) score themselves higher than the ability of the questions to differentiate Competency (right). The information in Figure 23 highlights a measurement whose difficulty measures tend to be lower than the person ability measures. Although the Rasch Analysis indicates internal consistency (persons reflecting higher scores in harder items score themselves highly in easier items and vice versa), the self-assessment for this sample set indicates that overall the group consider themselves Competent. However, this is not unexpected. By design, the sampling strategy was deliberately to focus on a range of resource geologists who identify themselves as either Competent Persons or emerging Competent Persons.

Given the lack of range in self-assessed competency, self-assessed scores are unlikely to be useful for differentiating between higher and lower reasoning participants.

⁴¹ A Rasch Analysis Variable Map is also known as a Wright Map. This diagram reflects the individual and item difficulty scores on the same scale in a text-like histogram. The scale is presented between the two histograms. The person ability histogram is presented on the left and the item difficulty measure is presented in the right. Ideally, the two sides each reflect bell-shaped 'Normal' distributions. Moreover, the item range should span the range of individual scores to ensure opportunity to segregate groups of individuals in accordance to the test mechanism.

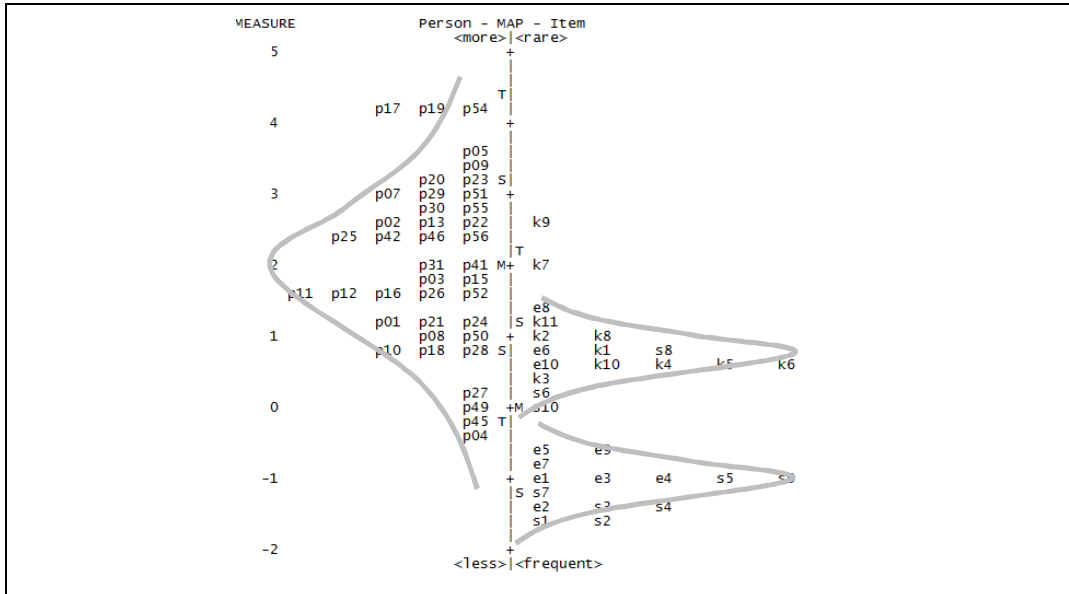


Figure 23 Rasch Variable Map - Self-Assessed Competency

Closer examination of the individual reasoning levels and their self-assessed competency scores shows a broad, offset relationship between the reasoning levels and self-assessment (Figure 24). This is reflected in the low, but significant, correlation of 0.423.

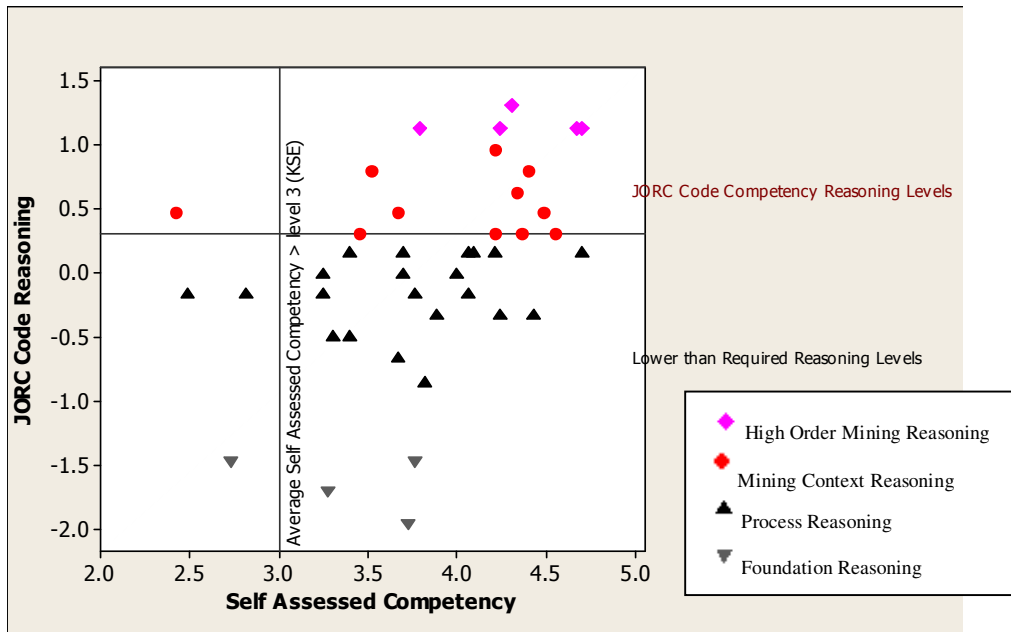


Figure 24 JORC Code Reasoning Levels Against Self-Assessment Levels

Closer comparison of JORC Code reasoning levels and self-assessment scores highlights an underlying mismatch. Over two thirds of those claiming to be Competent (self-assessment score higher than level 3) have reasoning levels below the critical value of 0.3. Only about 10% of the participants rate themselves lower than a self-assessment score of '3' and correspondingly score low on the JORC Code reasoning assessment. The remaining 23% rate themselves as Competent and have reasoning levels in excess of 0.3.

A relative standardised score was created for each of the self-assessment and reasoning scores to facilitate a paired test between the two scores. The new scores are calculated by subtracting the score from the respective target measures of 3 and 0.3 for the Self-Assessment and JORC Code reasoning levels. These differences were then scaled against the respective minimum and maximum scores for each measurement system. These relative standardized scores thus reflect a ranking (positive or negative) relative to a target for the self-assessment score of '3' and to a Rasch Score of 0.3. This does not change the order of the scores, but standardises them to between -1 and +1 as a relative proportion away from the target value. This is evidenced in the one-to-one match between the standardised and original scores, which kink at the standardised value of zero to reflect symmetry around self-assessed and reasoning scores at the brink of competency (Figure 25). A negative standardised score indicates a relative value below competency (either self-assessed or JORC reasoning assessed), while a positive score indicates increasing degrees of competency. Identical patterns of difference are evident when the JORC reasoning score is plotted against the self-assessed score for both the raw and standardised scores (Figure 26). The standardised score, however, allows the differences between JORC reasoning and self-assessed scores to be evaluated.

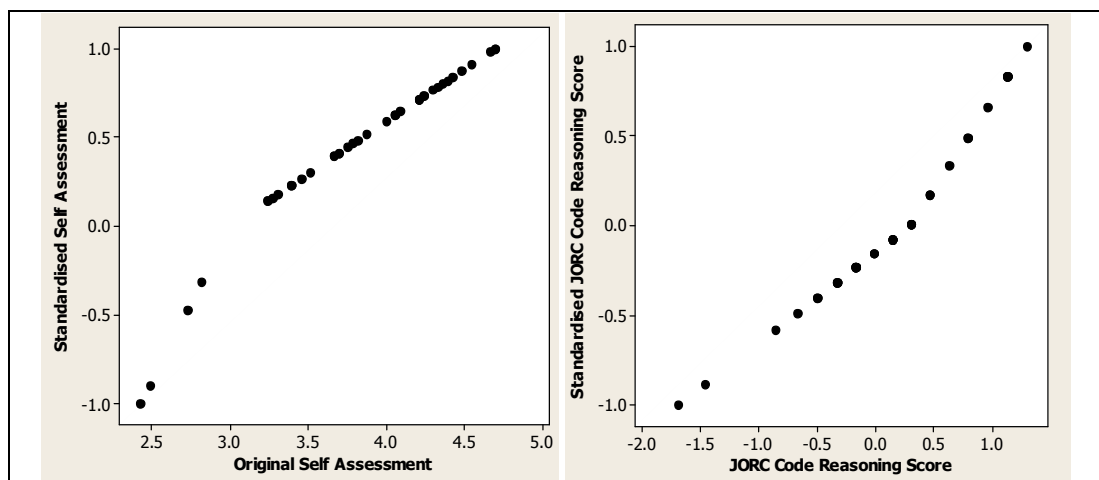


Figure 25 Comparison of Standardised and Original Scores (a) Self-assessment, (b) Rasch Score

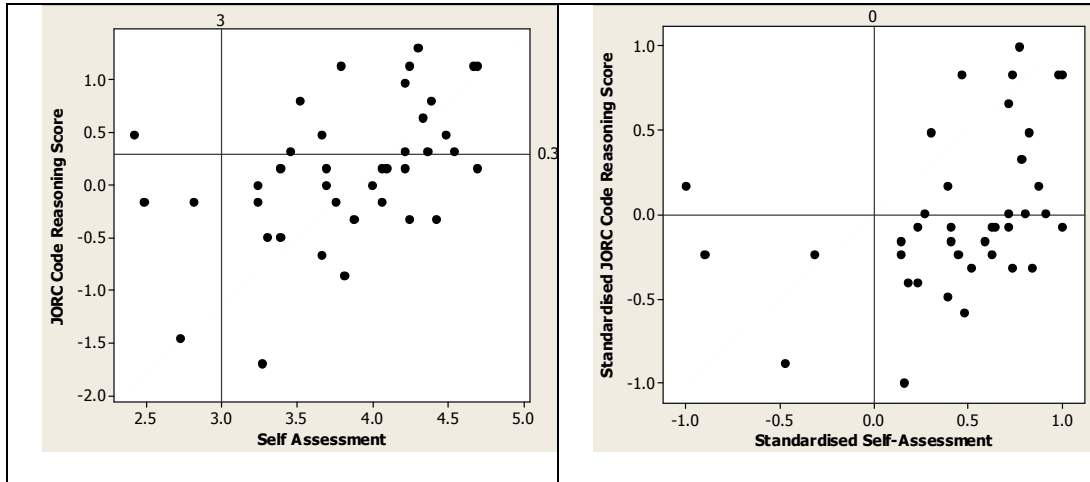


Figure 26 Comparison of JORC Code Reasoning Scores Against Self-assessment Scores
(a) Original values), (b) Standardised Values

Figure 26 compares JORC Code reasoning levels on the vertical axis plotted against self-assessed competency levels on the horizontal axis for the individual participants. Whilst most participants place themselves above acceptable competency levels (to the right of the vertical line), the sample set is generally divided into a cluster with lower than acceptable JORC Code reasoning levels and a group of above acceptable JORC Code reasoning levels (the horizontal line in Figure 26).

The t-test of the paired JORC Code reasoning and self-assessment scores (all standardised) produce a p-value of 0.000, less than the α -level of 0.05, indicating the paired differences are statistically significantly different from zero (Table 20). This is evident in the histogram of paired differences (Figure 27). Since the paired differences are formed by subtracting the standardised JORC Code reasoning from the standardised self-assessment scores, the predominantly positive differences (to the right of the vertical line at zero in Figure 27) highlights an over-confidence in self-assessed competency in resource geologists. This comparison confirms the JORC Code experts concerns of a potential risk of over-confidence in the competence self-assessment process (§6.3.4 page 123).

Table 20 Paired t-Test: Self-Assessment and JORC Reasoning

Level	N	Mean	StDev	SE Mean
Standardised Self-assessment	39	0.4454	0.4661	0.0746
Standardised Rasch JORC Reasoning	39	0.008	0.4665	0.0746
Estimated Difference		0.4446		
95% Lower bound for mean difference		0.3062		
T-Test of difference = 0 (vs. > 0)				
T-Value	5.42			
P-Value	0.000*			
DF	38			

*p-value < 0.05 so is significantly different from zero at 95% confidence level

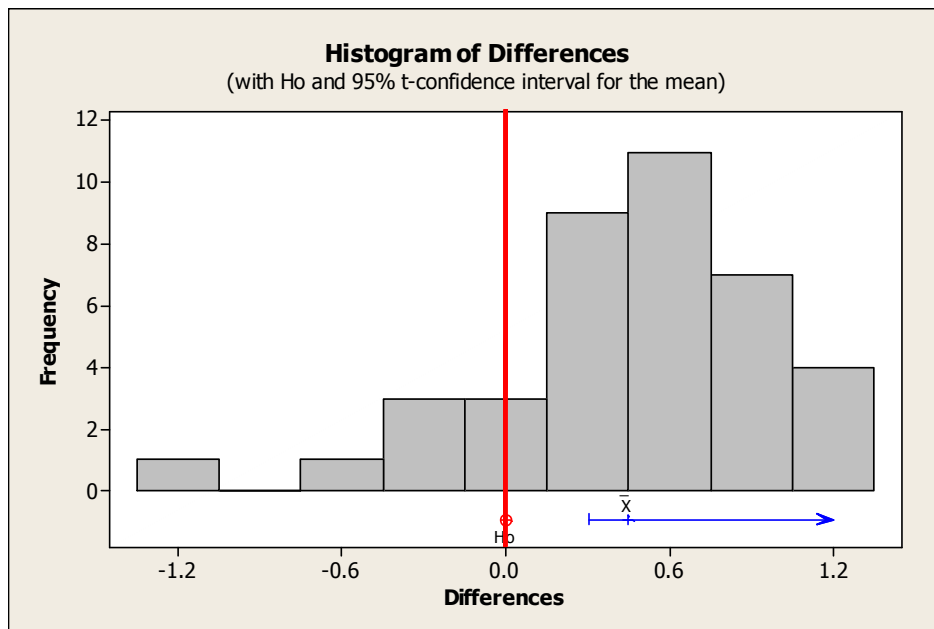


Figure 27 Histogram of Paired Differences
 (Standardised Self-Assessment subtract Standardised JORC Reasoning)

Critical Finding 19:

Resource geologists tend not to be able to accurately self-assess their competency.

6.5.4 Summary

Membership of a professional association does not indicate a person's ability to reason across the JORC Code Table 1 items. Neither Fellow-status nor Chartered Professional status indicate higher levels of JORC Code reasoning.

Similarly, there is no statistical difference in reasoning between participants with more or less than 5 years' mining industry experience. There is, however, a statistically significant difference in reasoning levels for participants with at least 5 years' experience specific to resource estimation. This is not unexpected since industry experts have raised issue with the flat requirement of a minimum 5 years' 'relevant' experience, without more specific regard for relevance. There is clearly more to the notion of experience than is indicated by five years' employment in the industry.

Experts' concerns regarding reliance on Competent Persons' self-assessment are confirmed.

Overall, therefore, the current criteria for Competent Persons are conclusively insufficient to differentiate between those who are better able to reason across the broader mining context and those who operate at a more functional level. The next section explores alternative criteria that may be more effective in discerning competency levels.

6.6 Alternative Qualifying Criteria

The findings regarding the current qualifying criteria are not surprising given the JORC Code experts concerns that it is the quality of the experience and the need for both depth and breadth of experience beyond a standard requirement for a minimum of 5 years that matters. There is potential for an alternate improved set of qualifying criteria. Factors that may influence increased reasoning in the JORC Code include increased years of mining industry experience, a minimum number of resource estimates, a minimum number of commodities, and a minimum number of reconciliations. Each of these factors is explored in the sections that follow.

The analysis demonstrates that the set of criteria (the '15-2-5' criteria), which improve the likelihood of discerning between high and low JORC Code reasoning levels, are:

- **A minimum of 15 models across at least two commodities and five reconciliations**
- **with at least 10 years' mining industry experience, inclusive of a minimum of at least 5 years' resource estimation experience.**

6.6.1 Expanding the Notion of Experience

The data indicates that there is an upward trend in reasoning with increasing years of mining industry experience (Figure 28). A distinct change is noted around 10 years mining industry experience. Participants were therefore grouped by more or less than 10 years' experience.

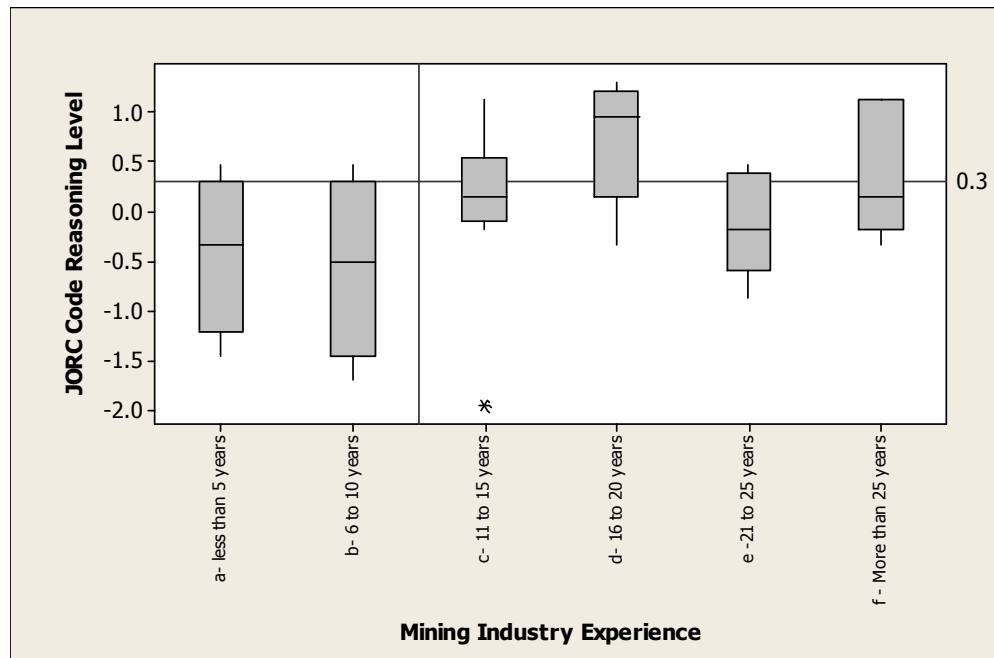


Figure 28 Reasoning and Mining Industry Experience

A statistical t-test on the reasoning levels and an analysis of the variances (ANOVA) corroborates this observation since the p-values for both tests are 0.01 and are less than the α -level of 0.05 (Table 21, Table 22 and Figure 29). This indicates there is a statistically significant difference in both the mean and the spread in reasoning around the 10 years' mining industry experience level and therefore that 10 years' mining industry experience is a necessary requirement for higher levels of JORC Code reasoning (Figure 29).

Table 21 t-Test: Mining Industry Experience (10 years)

Level	N	Mean	StDev	SE Mean
<10 years Industry Experience	11	-0.459	0.7962	0.24
>10 years Industry Experience	30	0.221	0.6824	0.12
Estimated difference		-0.680		
95% CI for difference:		(-1.189, -0.172)		
T-Test of difference = 0 (vs. not =)				
T-Value		-2.70		
P-Value		0.010*		
DF		39		
Pooled StDev = 0.7133				

*p-value < 0.05 so is significantly different from zero at 95% confidence level

Table 22 ANOVA: Mining Industry Experience (10 years)

Source	DF	SS	MS	F	P
Mining Industry Experience	1	3.723	3.723	7.32	0.01*
Error	39	19.845	0.509		
Total	40	23.567			

*<0.05 so is significant at the 95th% Confidence Level

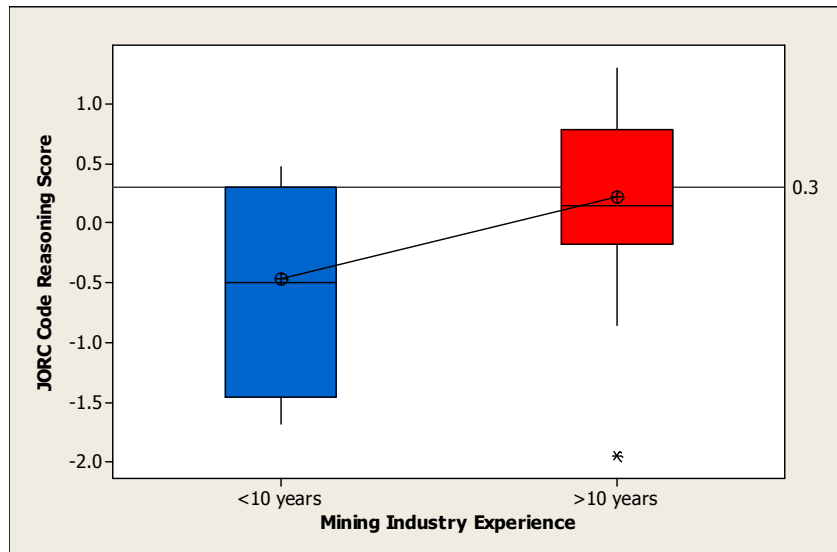


Figure 29 Boxplot – Reasoning and Minimum 10 years' Mining Industry Experience

Critical Finding 20:

There is a significantly higher reasoning in resource geologists with at least 10 years' mining industry experience.

6.6.2 *Minimum number of models, commodities and/or reconciliations*

Higher levels of reasoning generally correlate with an increase in the number of times an activity is conducted (Figure 30). The main activity involved in estimating and classifying a resource estimate is the generation of resource models or estimates. Higher reasoning levels are expected with an increased number of resource estimates. Similarly, higher reasoning levels are expected with greater exposure to a variety of situations. Working with different commodities provides an opportunity to broaden a Competent Person's experiences and therefore their ability to reason through a range of situations. Reconciling actual mineral production with resource and grade control estimates is the only real opportunity a practitioner has to learn from errors in their estimation processes. The four potential experience factors tested here are:

1. Number of resource estimates generated;
2. Number of commodities estimated;
3. Number of reconciliation studies on own estimates; and
4. Number of commodities for which reconciliation studies have been conducted.

Overall, there is a moderate correlation between reasoning levels and the number of resource estimates, the number of reconciliations, the number of commodities estimated and the number of commodities reconciled (Table 23 and Figure 30).

Table 23 Pearson Correlations between Reasoning and Practical Experience

Experience Measures	Reasoning Level	(p-values)
Number of Estimates	0.482	(0.001*)
Number of Reconciliations	0.463	(0.002*)
Number of Commodities Estimated	0.436	(0.004*)
Number of Commodities Reconciled	0.402	(0.009*)

Distinct differences in reasoning are evident around:

- 15 resource estimates (Figure 30a),
- Two commodities estimated (Figure 30b),
- Five reconciliations of practitioners own estimates (Figure 30c), and
- At least one commodity reconciled (Figure 30d).

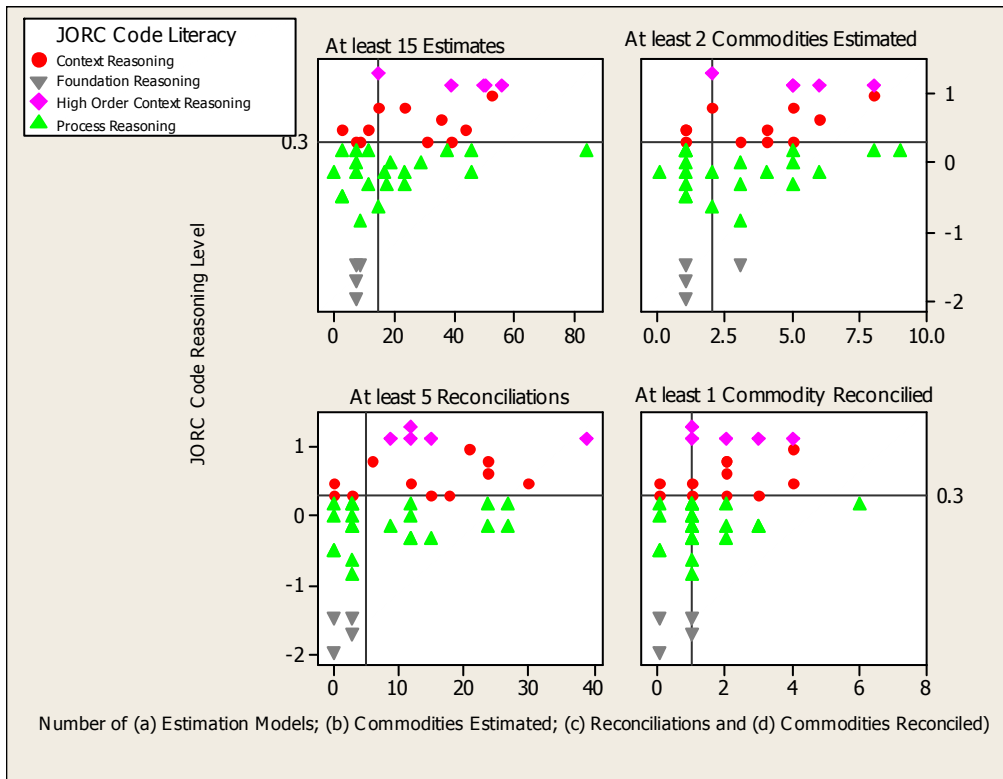


Figure 30 Reasoning Levels and Critical Experience Measures

Statistical tests on the significance of these four criteria all result in p-values less than 0.05 (Table 24, Table 25, Table 26, Table 27,

Table 28 and Table 29). The last criteria, however, is superfluous if at least five reconciliations are necessary for higher order reasoning.

These findings are confirmed in the corresponding box-and-whisker plots (Figure 31).

These criteria are significant since they provide practical and measurable criteria for establishing readiness to reason through the JORC Code criteria and, therefore, a more confident basis on which to pronounce a resource geologist is a Competent Person.

Table 24 t-Test: Number of Estimates

Level	N	Mean	StDev	SE Mean
Fewer than 15 Estimates	16	-0.230	0.645	0.16
At least 15 Estimates	23	0.377	0.577	0.12
Estimated difference		-0.607		
95% CI for difference:		(-1.007, -0.207)		
T-Test of difference = 0 (vs. not =)				
T-Value	-3.08			
P-Value	0.004*			
DF	37			
Pooled StDev = 0.6058				

*p-value < 0.05 so is significantly different from zero at 95% confidence level

Table 25 ANOVA: Number of Estimates

Source	DF	SS	MS	F	P
Number of Estimates	1	3.476	3.476	9.47	0.004*
Error	37	13.579	0.367		
Total	38	17.056			

*<0.05 so is significant at the 95th Confidence Level

Table 26 t-Test: Number of Commodities Estimated

Level	N	Mean	StDev	SE Mean
Only one commodity estimated	14	-0.224	0.654	0.17
At least two commodities estimated	25	0.325	0.605	0.12
Estimated difference		-0.548		
95% CI for difference:		(-0.970, -0.127)		
T-Test of difference = 0 (vs. not =)				
T-Value		-2.64		
P-Value		0.012*		
DF		37		
Pooled StDev = 0.6229				

*p-value < 0.05 so is significantly different from zero at 95% confidence level

Table 27 ANOVA: Number of Commodities Estimated

Source	DF	SS	MS	F	P
Number of Commodities	1	2.699	2.699	6.95	0.012*
Error	37	14.357	0.388		
Total	38	17.056			

*<0.05 so is significant at the 95th Confidence Level

Table 28 t-Test: Number of Reconciliations

Level	N	Mean	StDev	SE Mean
Fewer than 5 reconciliations	16	-0.281	0.63	0.16
At least 5 reconciliations	23	0.413	0.546	0.11
Estimated difference		-0.694		
95% CI for difference:		(-1.077, -0.310)		
T-Test of difference = 0 (vs. not =)				
T-Value		-3.67		
P-Value		0.001*		
DF		37		
Pooled StDev = 0.5815				

*p-value < 0.05 so is significantly different from zero at 95% confidence level

Table 29 ANOVA: Number of Reconciliations

Source	DF	SS	MS	F	P
Number of Reconciliations	1	4.543	4.543	13.43	0.001*
Error	37	12.513	0.338		
Total	38	17.056			

*<0.05 so is significant at the 95th Confidence Level

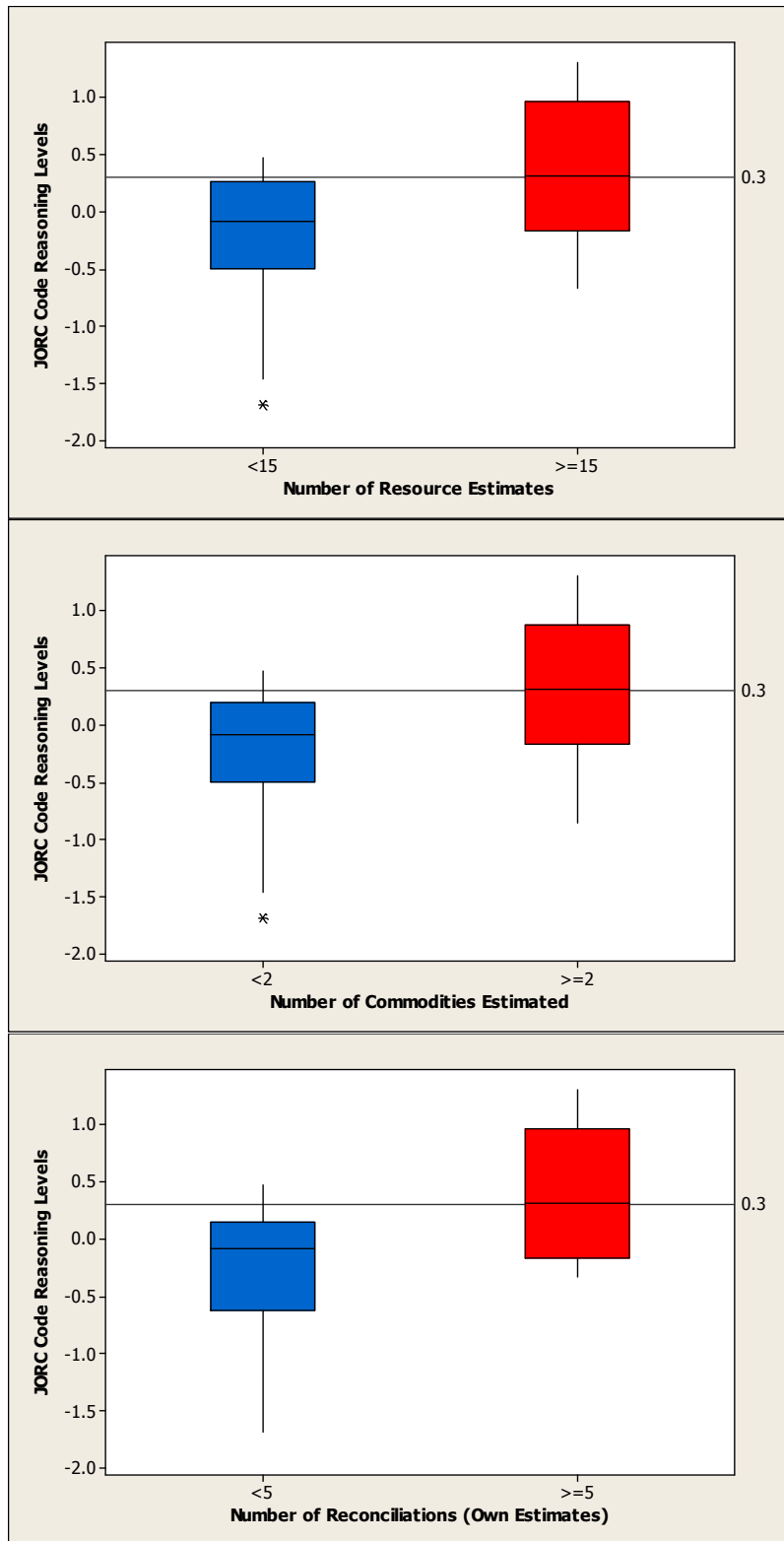


Figure 31 Boxplots - Reasoning Comparisons
(a) Number of Resource Estimates, (b) Number of Commodities and (c) Number of Reconciliations

Critical Finding 21:

There is significantly higher reasoning in resource geologists who have conducted at least 15 resource estimates.

Critical Finding 22:

There is significantly higher reasoning in resource geologists who have generated estimates across at least two commodities.

Critical Finding 23:

There is significantly higher reasoning in resource geologists who have conducted at least five reconciliations on their own estimates.

6.6.3 Combined Alternative Criteria

The criteria tested individually in the preceding analysis indicates several minimum criteria for mining context reasoning that need to be tested in combination to provide a stronger set of qualifying criteria. About two out of every five of the survey participants meet a revised combination of the minimum criteria that indicate higher levels of reasoning (Figure 32).

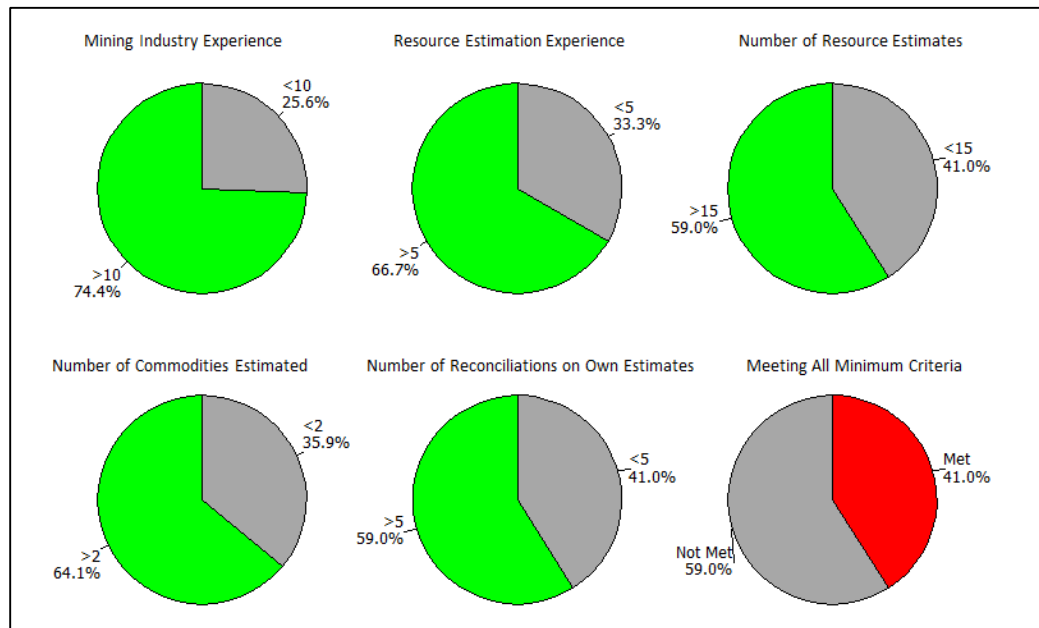


Figure 32 Proportions of Participants Meeting Alternative Minimum Criteria

The combined criteria of at least 15 resource models, across at least two commodities, with at least five reconciliations studies, a minimum of 10 years' mining industry and five years' resource estimation experience are notated as the '15-2-5' criteria.

Reasoning levels of resource geologists who meet the ‘15-2-5’ criteria are significantly higher on average than those who do not meet the criteria. This is evidenced in both the t-tests and ANOVA tests where the p-values are both 0.001, well below the α -level of 0.05 (Table 30 and Table 31). The associated box-and-whisker plot highlights the differences in JORC Code reasoning levels when participants are grouped according to the ‘15-2-5’ criteria (Figure 33). Note that the bulk of non-qualifying resource geologists’ reasoning levels lie around the Process Reasoning level, in contrast to the qualifying resource geologists whose reasoning levels tend to be at the Critical Reasoning Level.

The ‘15-2-5’ criteria therefore provide a conclusive and meaningful alternative minimum basis from which to distinguish competency (Figure 33).

Table 30 t-Test: Combined Criteria

Level	N	Mean	StDev	SE Mean
Meet Combined Criteria	16	0.517	0.583	0.15
Do Not Meet Combined Criteria	25	-0.268	0.72	0.14
Estimated difference		0.785		
95% CI for difference:		(0.351, 1.220)		
T-Test of difference = 0 (vs. not =)				
T-Value	3.66			
P-Value	0.001*			
DF	39			
Pooled StDev = 0.6708				

*p-value < 0.05 so is significantly different from zero at 95% confidence level

Table 31 ANOVA: Combined Criteria

Source	DF	SS	MS	F	P
Criteria Meeting	1	4.117	4.117	11.77	0.001*
Error	37	12.939	0.35		
Total	38	17.056			

*<0.05 so is significant at the 95th% Confidence Level

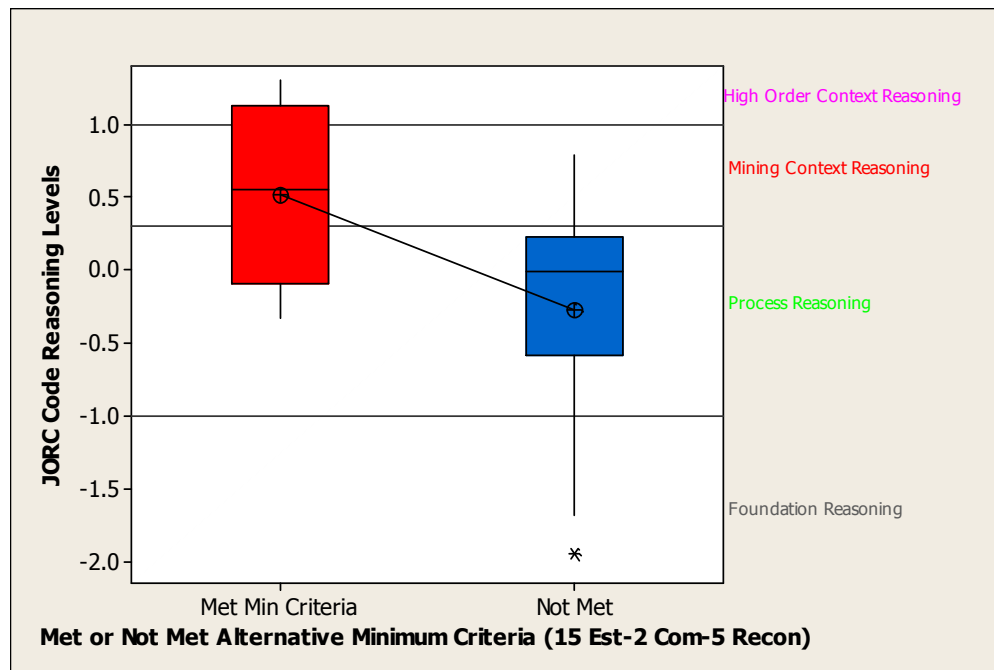


Figure 33 Boxplot - Meeting Alternative Minimum Criteria

Critical Finding 24:

Resource geologists meeting the '15-2-5' criteria, who have at least 10 years' mining industry experience and at least 5 years' resource estimation experience have a higher probability of having higher JORC Code reasoning levels.

6.6.4 Comparing Alternative Criteria with Experts' Expectations

An alternative minimum of 15 models, across two commodities and five reconciliations (the '15-2-5' criteria) indicates a statistically significant difference in reasoning levels in Competent Persons for persons with at least 10 years' mining industry experience, inclusive of a minimum of at least 5 years' resource estimation experience.

Whilst membership of a professional association provides a mechanism for moderating the behaviour of its members, membership of a professional association of itself does not imply a high JORC Code reasoning. Similarly, neither the Chartered Professional⁴² nor the higher membership grade of Fellow are indicators of high JORC Code reasoning.

As the experts intuitively argued, five years' mining industry experience is insufficient to enable resource geologists to reason across the JORC Code. Resource geologists with at least 10 years' mining industry experience are better at reasoning through the JORC Code. In addition, at least five years' resource experience (concurrent with the mining industry experience) improves resource geologists' ability to reason across the JORC Code.

Furthermore, as experts indicated, resource geologists should be able to operate across the mine-value-chain. This is evidenced in the reasoning levels deduced from the Rasch Analysis and supported by decomposing the question scores in accordance with the items they apply to in Table 1 of the JORC Code (Appendix 5). The '15-2-5' qualifying group shows reasoning mine-value-chain scores consistently higher than the non-qualifying group (Figure 34). Notice that the drop in mine-value-chain scores towards the latter end of the process that tends to be associated more with the practice of mining and processing.

The remaining experts' expectations are explored through a qualitative analysis of resource geologists' competency development experiences.

⁴² Or equivalent in its current form

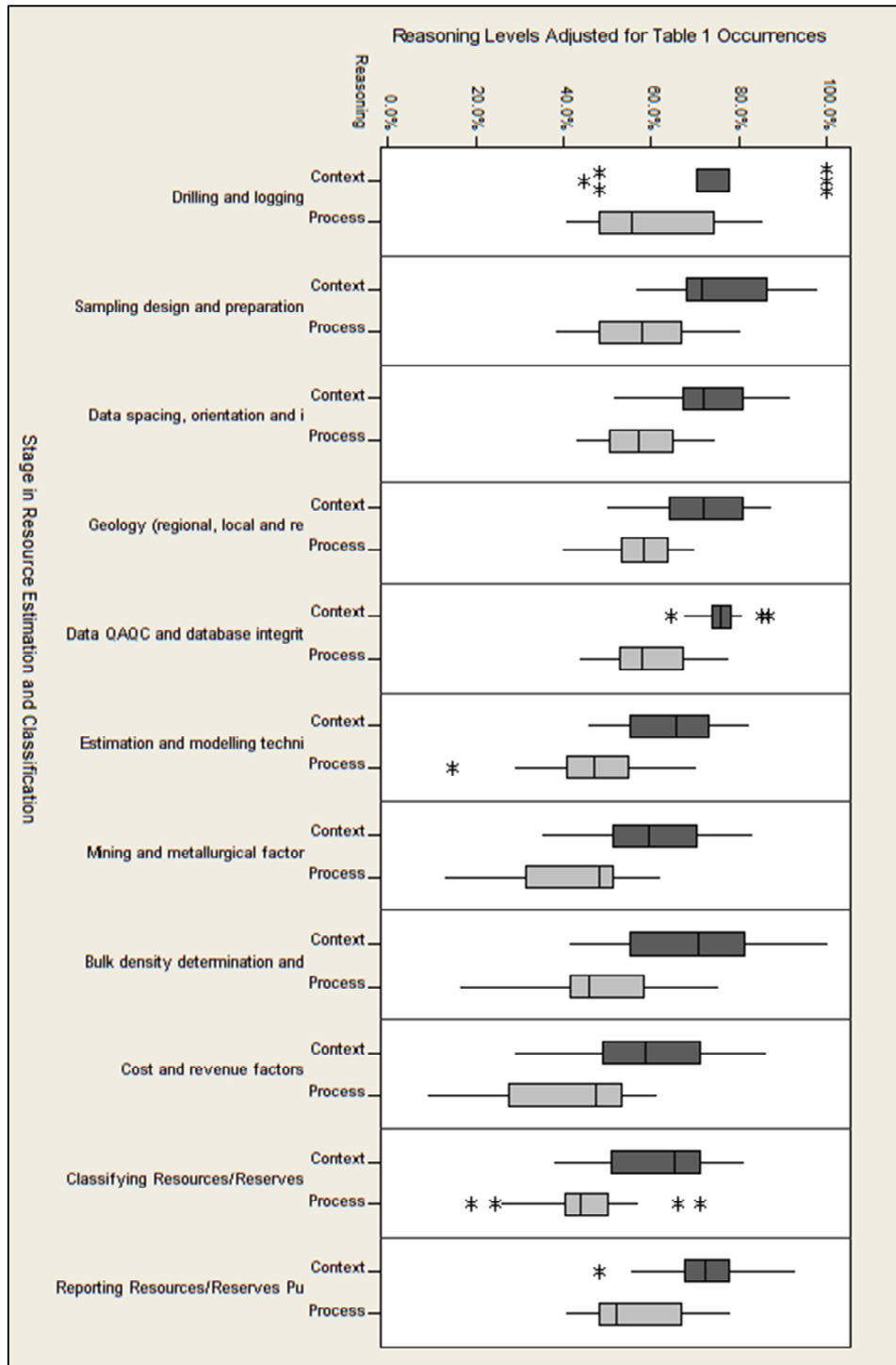


Figure 34 Comparison of Reasoning Across Mine Value Chain

Critical Finding 25:

Resource geologists meeting the '15-2-5' criteria, who have at least 10 years' mining industry experience and at least 5 years' resource estimation experience have a higher levels of JORC Code reasoning across the mine value chain, as reflected by the items in JORC Code Table 1.

6.7 Findings and Interpretations

The analyses of qualifying criteria indicate the norms of competency definitions within the JORC system community exceed the criteria documented within the JORC Code. Experts allude to the need for quality experience that exceeds the minimum 5 years' experience criteria. Moreover, this quality experience should allow the resource geologist to accumulate exposure to both breadth and depth of geological and mining scenarios. Clearly, the development of competency cannot occur in a vacuum. Experts emphasise the need for resource geologists to be introduced to the processes within an apprentice style relationship and to continue to develop their competency by exposure to a variety of circumstances within a supportive professional network.

The need for elevated levels of reasoning is evidenced in the findings of the Rasch Analysis of the competency assessment. Elevated levels of reasoning correspond with an appreciation for and practical integration of the breadth of the mining value chain in the estimation and classification of resources and the mining business context.

It appears that the current set of JORC Code criteria do not sufficiently differentiate elevated levels of JORC Code reasoning. An alternative set of criteria that increase the likelihood of a resource geologist's reasoning is provided by the '15-2-5' criteria:

- *At least 10 years' mining industry experiences*
- *inclusive of at least five years' resource estimation experience*
- *with at least 15 estimation models*
- *across at least two commodities and*
- *five reconciliation studies.*

The criteria presented above need to be supported with sufficient deliberate practice engagement in both geology and resource estimation. The expert should have sufficient wisdom to evaluate potential risks across the mine value chain in accordance with the items in JORC Code's Table 1. Competent Persons' reasoning development requires exposure to both the breadth in issues, methodical practice depth, and an ability to contextualise the issues within the mine value chain.

The analyses presented in this chapter convincingly indicate the criteria for attainment of acceptable competency need to be revised. In terms of the research questions, the analyses above provide redefined target competency criteria for resource geologists to pronounce themselves as Competent Persons (Figure 35).

In terms of the conceptual framework for this research, the target competency is now better articulated to support further investigation into the competency development processes and experiences addressed in the next chapter.

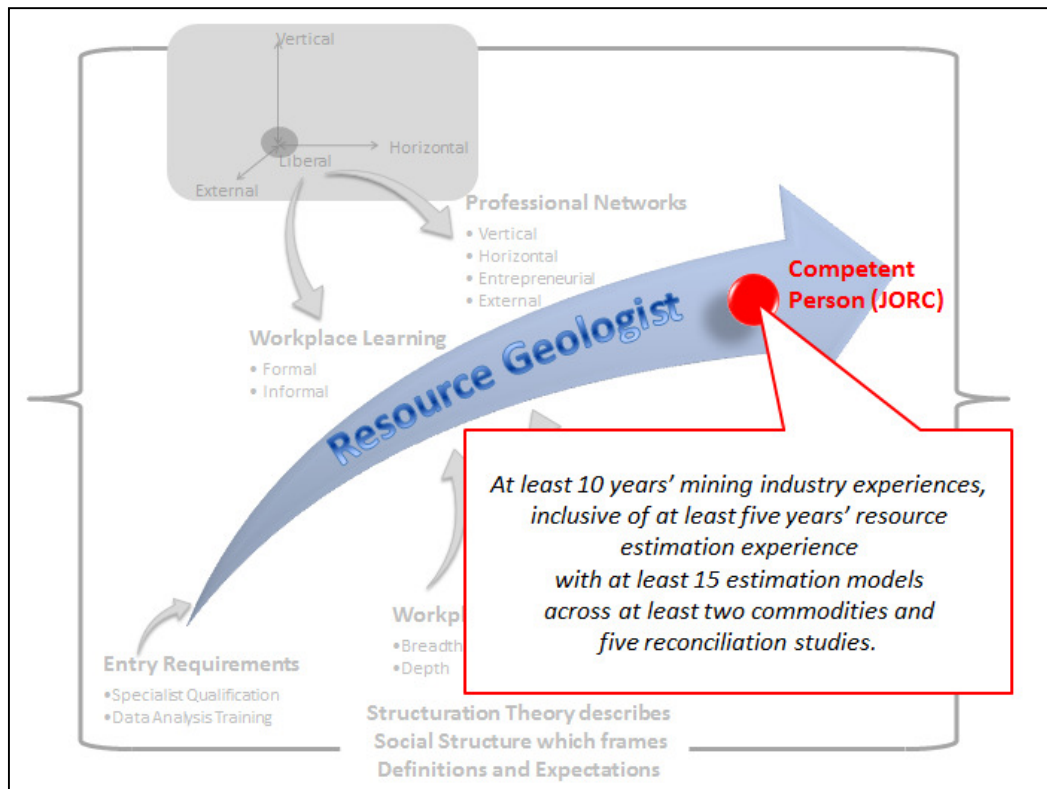


Figure 35 Conceptual Framework and Improved Articulation of Competency Criteria

7 Analysis of Competency Development

The previous chapter confirmed experts' intuitions that Competent Persons qualifying standards need to be raised. Furthermore, a major outcome of the data analysis was an alternative set of criteria that can be used as a target level of experience for resource geologists before they consider themselves Competent Persons. The study now turns directly to the original overarching research question:

What does it take to develop Competent Persons for the JORC Code?

Recall the four more explicit research questions that emerged:

1. *What formative qualifications enable professionals to qualify as Competent Persons according to the JORC Code?*
2. *What workplace experiences facilitate development of Competent Persons' competency?*
3. *How do professional networks stimulate the development of Competent Persons' competency?*
4. *What organisational factors influence Competent Persons' competency development?*

These four questions relate directly to the factors identified in the conceptual framework (Figure 36).

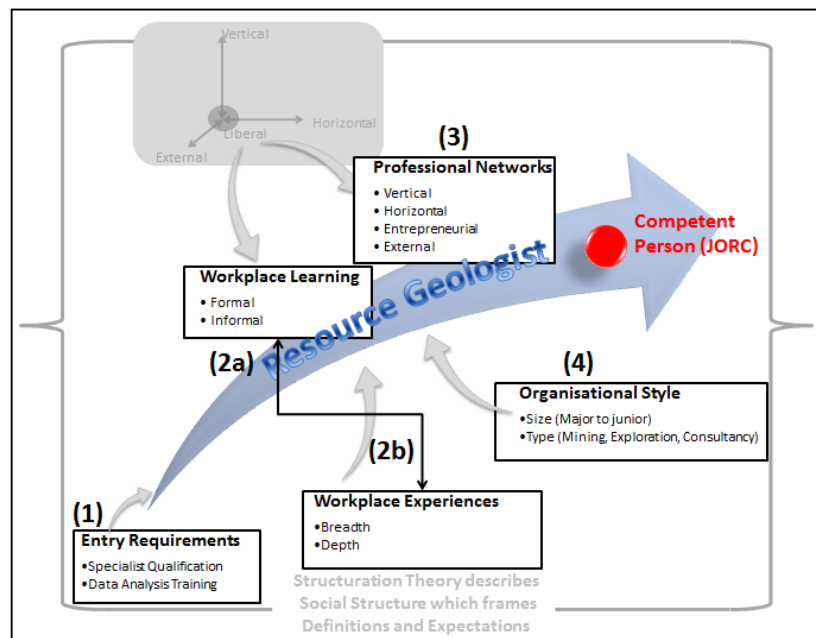


Figure 36 Research Questions within the Conceptual Framework

The focus of this data analysis chapter is to examine the link between these four factors and the competency development process, thereby seeking to address the research questions directly. The key outcomes of this analysis include models of competency, competency development and a revised model of learning networks for transient professionals.

The structure of this chapter is as follows:

1. A summary of the analytical process;
2. A grouping of the participants according to the '15-2-5' criteria and their JORC Code reasoning levels;
3. A re-framing or clarification of the competency development question in light of the grouping; and
4. An exploration of each of the four factors identified above.

The chapter closes with a discussion of the findings and implications.

7.1 Analytical Process

Prior to analysing the competency development experiences, survey participants were grouped according to whether they met the '15-2-5' qualifying criteria (presented in §6.6 on page 143) and according to whether their JORC Code reasoning levels were above or below the critical Rasch score of 0.3 (as presented in §6.4.1 on page 124). This grouping enables comparative analysis of the factors that inform recommendations for competency development programs.

The grouping of participants provokes a re-framing of the competency development question posed at the outset of this research. Rather than address the group as a whole, the question now needs to reflect the differences in competency development experiences between resource geologists who qualify as Competent Persons according to the '15-2-5' criteria in combination with their ability to reason through the JORC Code.

7.2 Competency Grouping

Whilst the alternative '15-2-5' and minimum experience criteria provide an indication of minimum factors necessary to achieve JORC Code reasoning, there are some discrepancies in reasoning levels. There are four groups of participants (Table 32).

Table 32 Group Characteristics

		'15-2-5' Criteria Not Met	Meets '15-2-5' Criteria
At least Mining Context Reasoning Level	Reasoning Level ≥ 0.3	Group B	Group A
At best Process Reasoning Level	Reasoning Level < 0.3	Group D	Group C

In essence, participants in Group A represent the type of Competent Person that is suitable to provide expert opinion on resource estimates and the associated risks through classification in accordance with the JORC Code. Participants in Group B have the reasoning ability to operate under the JORC Code and their credibility would be strengthened by additional experience. Participants in Group D do not meet the '15-2-5' minimum criteria nor are they able to sufficiently reason through the JORC Code to provide meaningful contextualised risk assessments. Group C participants pose the most concern since they meet the necessary '15-2-5' experience criteria, but their JORC Code reasoning levels are at best at the process reasoning level.

This subdivision in the style of participants necessitates a repositioning of the competency development questions, which is discussed next.

7.3 Repositioning the Competency Development Question

In light of the differences in the grouping above, it becomes necessary to re-position the question of competency development (Figure 37). Instead of asking overall questions about the experience factors that have contributed to the development of Competent Persons, the question becomes:

What is the difference in competency development experiences between participants in Group A and Group C?

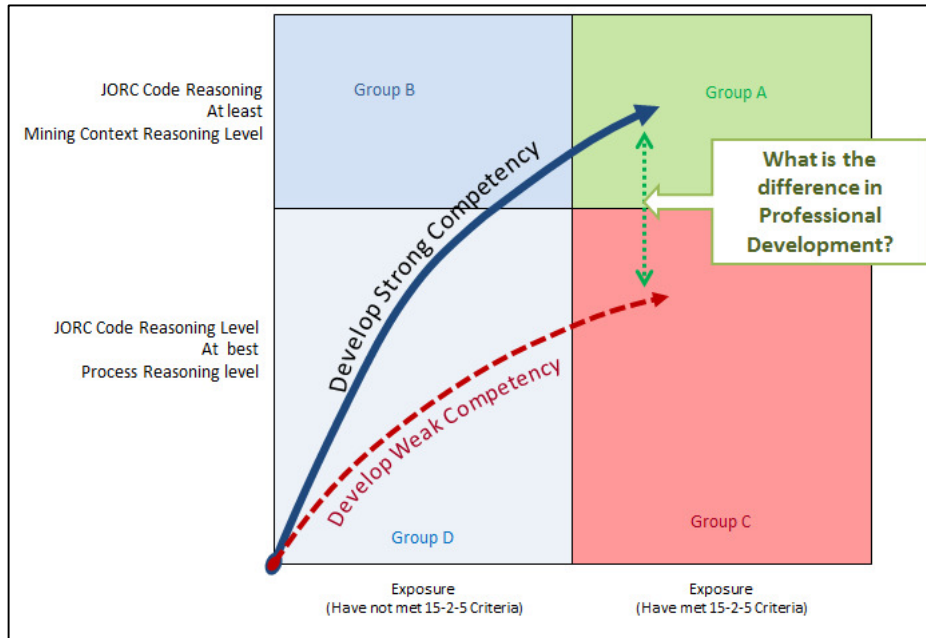


Figure 37 Reframing the Question of Competency Development

In effect, how are Group A's competency development experiences different to those of Group C? Moreover, can these differences guide improvements in how resource geologists are developed?

The analysis that follows shows similar professional experiences across all four groups in terms of training, workplace opportunities, professional networks and organisational styles. However, Group A resource geologists experience:

- greater scientific depth in their undergraduate degree;
- place greater value in their tertiary experiences in mathematics and/or statistics;
- seek out practical industry courses and augment them with situational learning under formal guidance of a technical mentor; and
- have a heightened appreciation for the full mine-value-chain developed through long service and opportunities to learn through correcting their own mistakes.

The analysis to support these findings is presented below.

7.4 Analysis of Competency Development Variables

The survey participants provided insight into their competency development by answering the questions regarding their competency development experiences. The analysis that follows explores the themes in their contributions, with the specific purpose of contrasting the experiences between Group A and Group C. Examination of expert interviews also contributes context and an appreciation of more experienced experts' perspectives.

Four themes are explored:

1. Entry requirements, namely tertiary education;
2. Workplace learning, with an emphasis on learning through workplace experiences;
3. Learning networks and how these influence competency development; and
4. Workplace organisations' styles and provision of opportunities.

Investigation of these four themes provides basis for formulating a competency development framework and associated recommendations for individuals, organisations and the professional bodies representing the interests of competent resource geologists.

7.4.1 System Entry Requirements

Experts value tertiary education for providing scientific thought processes that enable interpretation, breadth of application and an ability to learn more about specialisation through the geological community. One expert acknowledged that he did not value his classical university training "until later on in my career. As a grad I hadn't been taught mine geo 101 skills. But that is not what unis are for. What it did give me was that it taught me to teach myself: how to read a paper, understand the geology and apply it; how to look at a rock and interpret what it might be" (e15). He went on to lament the lack of classical training in graduates from more vocational style universities and notes "... they don't have the classic training and after a while as they progress in their careers it begins to show" (e15). He goes on to suggest "The best ones have the classical training from the well-known unis. This helps with interpreting geology, mapping. That's where the key is." In contrast, another expert felt disappointed that his classical training did not provide training that was more practical.

Data analysis is core to resource estimation - from the evaluating the quality of the samples through to deriving a sense of geological and grade continuity and an assessment (albeit qualitative) of the risks associated with an estimate of mineral resources. The focus of this aspect of the survey was to gather a sense of whether a mathematical or statistical background had indeed helped Competent Persons estimate Mineral Resources, especially in the face of experts lamenting that "(t)he level of maths of geologists today is dismal" (e13). The value in both geology and mathematics(or statistics) are explored below.

1. Tertiary Education - Geology

Resource geologists enter their fields with at least an undergraduate degree with a geology major. Their geology major provides the fundamental geological concepts, which they use to drive their interpretations and modelling. Three themes emerged from the resource geologists participating in the survey (Figure 38).

The first theme - fundamentals of a geological trade - is valued across all four groups. Studies in geology provide the fundamental tools of the trade enabling resource geologists to understand and apply their geological knowledge and data collection to the interpretations and constraining estimation models.

The second and third themes, however, are almost mutually exclusive. Whilst most participants in Group A and B value their tertiary education for the opportunity to develop scientific thinking, participants in Groups C and D indicated their degree was of limited value to the practice of resource estimation. This is concerning since scientific thinking provides the foundations from which practitioners can apply a process of rigor in hypothesis testing, modelling and problem solving, thereby developing their practice reasoning levels.

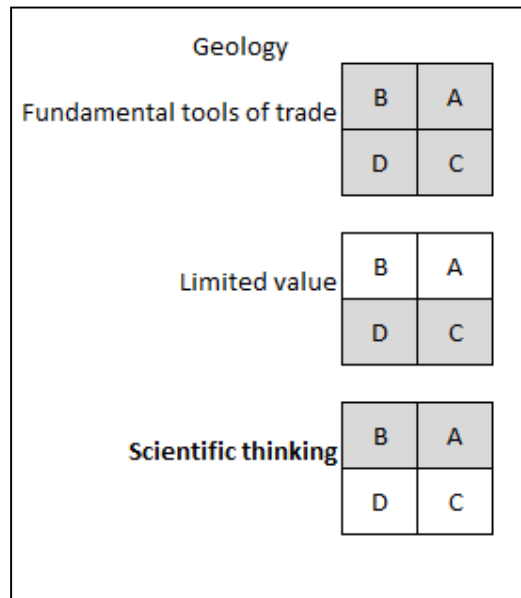


Figure 38 Grouped Emerging Themes - Geology Degree

Whilst there is general consensus across all four groups that a tertiary degree in geology is fundamental to understanding the frameworks and controls on mineral deposits and the subsequent estimate of resources, participants whose scores meet the minimum reasoning criteria (groups A and B) also tend to value the scientific thinking and rationale which a university degree provides.

Those in Group A recognise the underlying “scientific process of learning through investigation” (p20, Group A) and how this enables the “use of setting hypotheses and changing (the) process based upon the result of the investigation” (p20, Group A). They value their tertiary education for the broader curiosity skills that allow resource geologists “to research, study, investigate, ask questions, learn and develop reporting skills” (p29, Group A) and credit their tertiary education for providing professional skills that form “the basis for earth science, scientific thinking and documentation” (p17, Group A).

Those in Group B have yet to attain the ‘15-2-5’ criteria but already show promise in their higher reasoning levels. For some members of this group the academic aspect of their undergraduate education is recognised, but they possibly do not yet appreciate it: “My degree course was entirely academic with very little economic focus” (p04, Group B) and “(m) primary degree was strictly academic” (p11, Group B). For others the value of their education is at the skills engagement level: “I use my science training a lot, e.g. creating/evaluating geological models, wire framing, general statistical analysis” (p21, Group B).

In contrast, participants in groups C and D believe their undergraduate degree offers limited value to how they interpret, model and estimate resources:

- “My professional qualifications involved geostatistical basics only” (p38, Group C)
- “Initial qualification has not helped a great deal as its focus had next to nothing to real world application in a production environment or any slant towards resource estimation or interpretation” (p53, Group D).

Post-graduate qualification is valued among the higher reasoning groups (“Masters was more relevant.” (p51, Group A)) and they note that “(a)dditional post-graduate studies, especially in mining and Geostatistics have proven directly applicable.” (p17, Group A) and: “My grad cert in Geostatistics was directly relevant to the statistical analysis of data and determination of estimation parameters using spatial data analysis methods.”(p54, Group A). In contrast, Group D participants indicate that “...post graduate studies have had limited contribution to my understanding of resource estimation.”(p10, Group D).

The value of undergraduate education is interpreted at the task level for those with lower reasoning levels: “*Other than basic geological understanding, my qualification has not helped me generate geological estimates*” (p46, Group C).

Quantitatively, however, there is no statistically significant relationship between qualification of participants and reasoning levels (Table 33 and Figure 39). The p-value of the ANOVA, at 0.509, is greater than the α -level of 0.05, which indicates the variability in the residuals is greater than the differences in reasoning according to qualification levels. However, the data collection did not allow for exploration of the style of university education. The differences in attitudes to undergraduate education does raise a question on whether university courses that offer a broader scientific thinking basis affects participants differently, especially with regards to the development of thinking required for broader mining context understanding, thereby fostering the style of reasoning required to use the JORC Code. Is it possible that universities offering more vocational style geology degrees may be limiting the higher order reasoning? Additionally, is there opportunity to develop and embed the fundamental scientific thinking in work practices through competency development of Competent Persons? These questions are worthy of research in future studies that could examine the link between tertiary education and workplace competency.

Table 33 ANOVA: Reasoning and Education Level

Source	DF	SS	MS	F	P
Education	3	1.413	0.471	0.79	0.509*
Error	37	22.154	0.599		
Total	40	23.567			
* >0.05 so is not significant at the 95 th % Confidence Level					
Level	N	Mean	StDev		
Bachelors' Degree	11	-0.1200	0.7987		
Post-graduate Diploma	3	0.5300	1.0392		
Honours' Degree	17	0.1429	0.6664		
Masters' Degree	10	-0.1120	0.8505		
Pooled StDev = 0.7738					

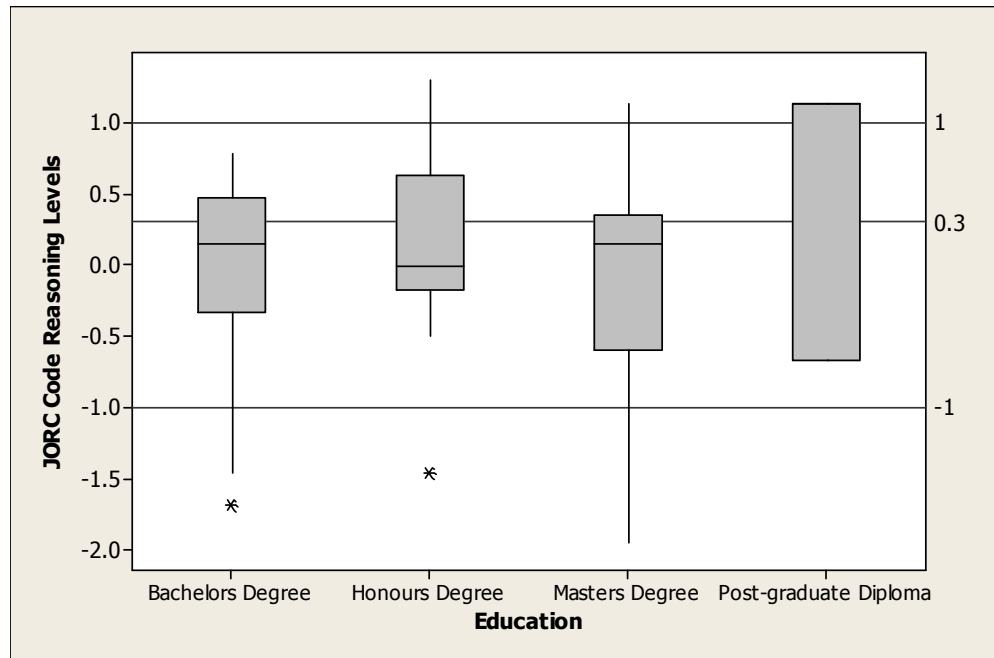


Figure 39 Comparison of JORC Code Reasoning Levels by Education Level

Critical Finding 26:

Whilst an undergraduate degree in geology provides resource geologists with the fundamental tools of geological interpretation, resource geologists with higher reasoning levels tend to value the scientific thinking skills developed in their tertiary training.

2. Tertiary Education - Mathematics/Statistics

Experts note that resource geologists “need to understand conceptual and logical pattern generation” (e17). Being able to visualise the patterns is essential for building a better understanding of the unsampled volumes of the orebody, including being able to “read graphs, understand sets, think in a number of dimensions – conceptual mathematics” (e17). When the field of three-dimensional resource estimation was in its infancy “there were very few computer programs, so you needed the skills to be able to write your own programs” (e13). With the advent of computer software “people don’t know how to do things or they forget about the limitations. Now it is a push-button experience” (e13) and training focuses on making them better uses of the software without enabling them “but it is better to train them in the concepts and train them to understand. Nowadays the trend is to force the problem within what the software gives, without solving the problem within its own merits” (e13).

Experts observe the impact of a lack in mathematics or statistics background: “I see how difficult it is for my peers” (e21). The level of mathematics background need not be significantly high: “I’m not a math genius, but it is an advantage” (e21). In particular, it

affords opportunity to explore technology more deeply: “When I read about things in textbooks I can work it out and validate what I am doing. Initially I read about things and think about them. Then when I attend the classes I have confidence and am able to implement it in practice” (e21).

Four themes emerge from the analysis of participants’ views on their mathematics and/or statistical tertiary education (Figure 40). The suggestion that a background in either mathematics or statistics provides a stronger basis for understanding concepts and the background to estimation theory is supported across groups A, B and D but does not feature for Group C.

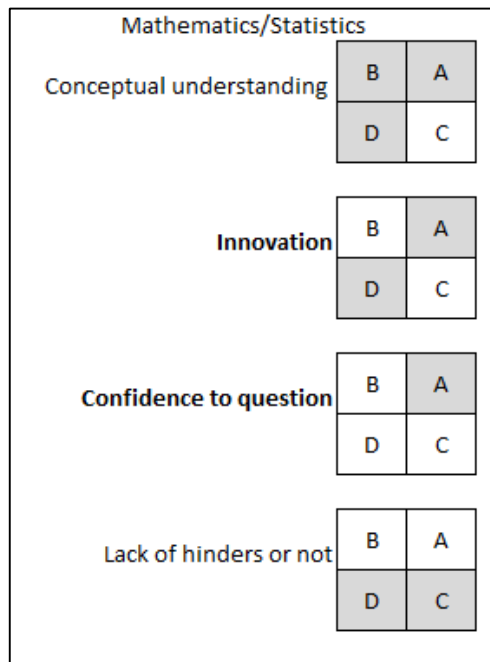


Figure 40 Grouped Emerging Themes – Mathematics/Statistics Training

Importantly, a background in mathematics and/or statistics does give resource geologists the confidence to seek out innovative solutions, to challenge processes and norms and to laterally transfer or modify concepts, especially for participants in Group A and for some participants in Group D.

Participants in Group A typically note that their confidence in their mathematics background gives them the confidence to challenge and question processes.

The comments about whether a lack of mathematics hinders the work of resource geologists or not is evident only in comments by participants in the lower JORC Code reasoning Groups C and D. The concerns raised only by these two groups raises the question of whether a lower JORC Code reasoning level is associated with a lack of mathematics or statistics training. However, there is a wide variation in mathematics or statistics education among the

participants (Figure 41). Groups A and B generally comprise participants with at least some undergraduate training in either mathematics or statistics. Groups C and D, though, include participants across a spectrum of mathematics/statistics backgrounds. More telling are the perceptions participants have of their mathematics or statistics training (Figure 42).

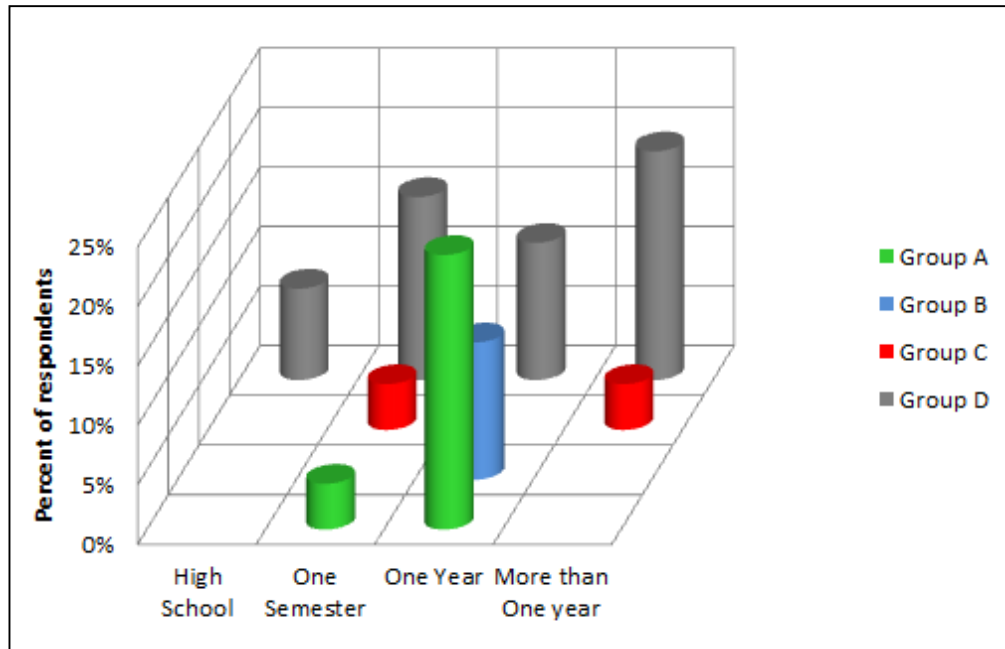


Figure 41 Participants' Mathematics/Statistics Background

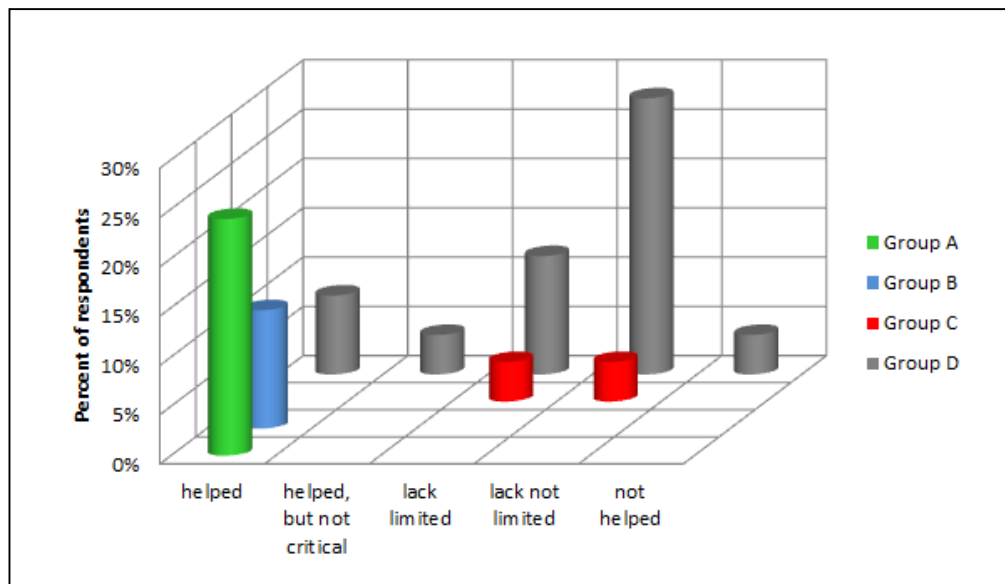


Figure 42 Participants' Perceptions Regarding Their Mathematics/Statistics Background

All participants with high reasoning levels perceive their mathematics or statistics background has helped them:

- *“Definitely helped, but for me (and possibly most?) it is more about understanding the concepts of the difficult equations, than being able to use or derive them directly. Being able to calculate volumes, length weighted averages, tonnes/grade/ounces, balance simple equations, use a scale ruler and protractor are important skills for a mine geologist”* (p07, Group A)
- *“Has been useful in identifying independent solutions to problems and provided assistance to help understand the mathematical/statistical theory”* (p09, Group A)
- *“The statistics A level has certainly helped me in understanding the statistical foundation of resource estimates.”* (p15, Group A)
- *“Comfortable and seek to analyse data QAQC, stats, and geostats for modelling preparation and generation”* (p51, Group A)
- *“Having an understanding of stats helped me enormously as a geologist as well as a resource geo”* (p05, Group B)
- *“It has given me the background necessary for resource estimation.”* (p13, Group B)

In contrast, those with lower reasoning levels are ambivalent about their lack of mathematics:

“I do not have a strong maths background, but I do not think this has hindered my ability to run a resource” (p52, Group D)

or

“a little more maths may have helped, but my advancement hasn’t been hindered by my lack of a math background” (p12, Group D).

Resource geologists emphasised conceptual statistical style mathematics as more useful than pure mathematical training. However, even when a resource geologist recognises their lack of mathematics or statistics they comfortably note that “it has probably hindered it to a degree but (it is) not insurmountable” (p10, Group D) since there is “a degree of intuition when estimating resources and with experience and strong geological knowledge you can gauge the accuracy of an estimate. There are also many tools now that assist with the computing of the estimates” (p52, Group D). There is a perception that “...a good grasp of the principles and processes of estimation and an understanding of what each part of the process does and inputs required and how they affect results and the pitfalls and limitations of various methods is probably more important than highly detailed mathematical knowledge of the inner workings” (p27, Group D).

There is the potential that a lack in mathematics or statistics limits the technical choices resource geologists make. For example:

“My "standard" maths background ... has possibly limited my understanding of some of the more complex geostatistical concepts which can be used in trying to unravel the multi-faceted complexities of resources ... Some of the more complex algorithms were perhaps beyond my scope of understanding how the grade of the block was estimated and therefore I was hesitant to use the methodology without additional help from a qualified source” (p53, Group D).

This gap in mathematics or statistics “has limited my ability to really come to terms with statistics. Some of the formulas scare the living daylights out of me!” (p56, Group C). It could be argued that a lack in mathematics or statistics could lead to erroneous selection of techniques and associated parameters since a “stronger mathematical background would help in understanding the mathematical theories that underpin resource estimation” (p27, Group D).

Generally, resource geologists without tertiary mathematics claim their lack of mathematics has not hindered their progress. Resource geologists with some undergraduate units in some mathematical course (including general mathematics, engineering mathematics or statistics) respond that their exposure to mathematics, whilst limited, has helped them in their ability to understand concepts more fully and has allowed them to make more confident choices and evaluations. An extension of this confidence is evident in geologists with postgraduate qualifications in mathematics-type subjects who claim to have an increased ability to apply their understanding “laterally to new circumstances” (p16, Group D).

At least half of the respondents to the mathematical section of the survey noted that their mathematics background either limited their confidence to apply a broader range of techniques to solve complex problems or, for those with a stronger background in mathematical type subjects, an increased confidence and willingness to seek independent solutions and apply techniques more laterally.

Coupled with a lack of confidence in seeking out a broader range of solutions (in the case of limited maths) is an expressed fear of mathematics and statistics. Two resource geologists felt their geological intuition compensated for their lack of mathematics. One resource geologist deferred to computer tools as sufficient supplement to a lack of mathematics. In contrast, an experienced respondent lamented the declining trend in young geologists to be able to run basic calculations critical to resource estimation.

Generally, the pattern in awareness and confidence tends to vary according to level of mathematics or statistical education (Figure 43). In general, the attitudes to the value in mathematics or statistics education changes after at least one semester of unit in the subject.

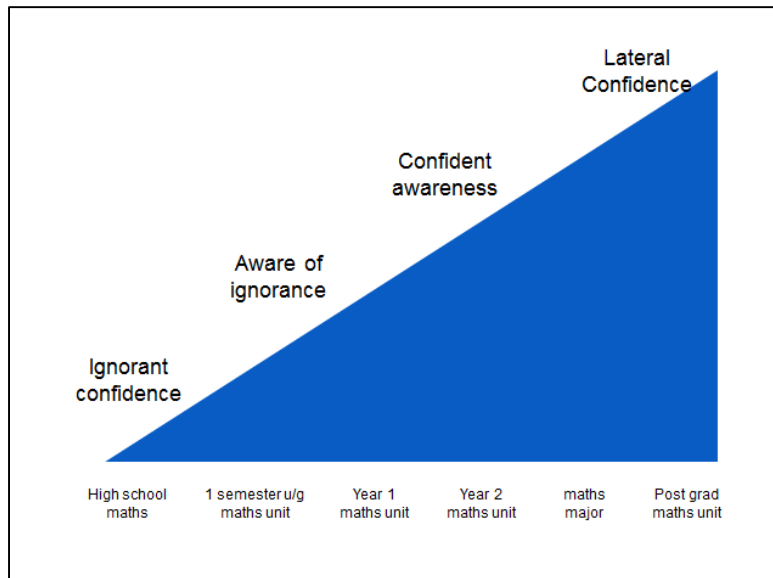


Figure 43 Model of Confidence and Awareness relative to Mathematical/Statistical Education

Future research may focus on understanding the relationship between these attitudes, competency and the differences in the content and style of courses.

Critical Finding 27:

Resource Geologists with at least a semester unit in mathematics or statistics have a more mature appreciation of the contribution of mathematics or statistics to their understanding of the techniques as well as their ability to transfer and adapt alternative techniques.

7.4.2 Workplace Learning and Experiences

There is no formal qualification required for resource geology. Instead, expertise is developed through attending formal industry courses (generally between two to five days), participating in formal mentoring programs and informal learning through workplace experiences.

Experts see value and merit in both formal and informal processes: “I’ve attended two to three courses, but there’s nothing more critical than sitting down and doing hands on with a mentor” (e22). Other experts agree: “It’s more important to have the hands on doing with peers and mentors. At each training course I’ve attended, I learnt different things on each one. On their own the courses were not enough. You can’t just attend a course and then do a resource” (e26).

Learning in the workplace is examined by exploring participants’ experiences in both formal learning or training, and informal opportunities to learn through workplace experiences.

a. Formal Training

Several consulting firms and software vendors present industry courses, which typically run for between two to five days. These training courses focus on developing knowledge and skills around resource estimation. Some larger mining organisations run their own in-house courses which follow a similar format to the public courses, although the attendees may tend to be more open with their data when working with their company colleagues.

Four themes on formal training emerge (Figure 44).

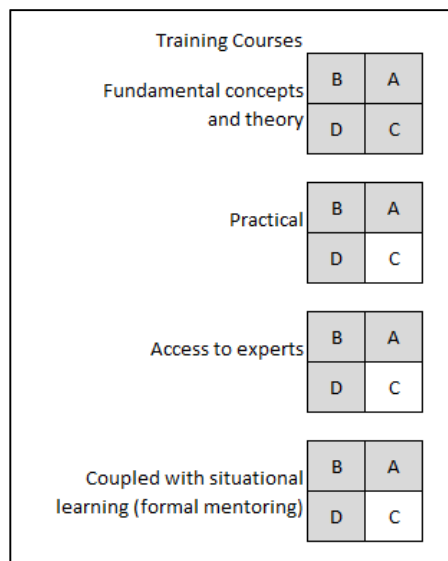


Figure 44 Grouped Emerging Themes – Training Courses

There is a common view across all four groups that training courses provide valuable exposure to concepts, theories, principles and processes. Generally, participants appreciate the opportunity to understand the knowledge behind the process of resource estimation:

- *“Provided the theoretical background for good decision making when selecting techniques and parameters”*(p19, Group C)
- *“The importance of domaining, estimation methodologies and applications”* (p56, Group C)
- *“By understanding the mechanics of estimation it’s a big help when it comes to the real thing.”*(p18, Group D)

Training to develop the practical skills to implement the knowledge in a software package is particularly valuable and provides the means to implement tasks:

- *“Training in specific software ... has given me further insight to estimation techniques and ability to manipulate models while formal resource estimation training courses has detailed how to create and fit appropriate variogram models and choose the most applicable estimation technique”* (p16, Group D)
- *“By covering the basics of Geostatistics and supporting software”*(p31, Group D)

These industry training courses increase practitioners’ confidence in their own work, even when they do not meet the ‘15-2-5’ criteria: “(T)rainning courses have allowed me to learn different techniques and have confidence to apply different parameters” (p49, Group D) and “exposure to methodologies and new techniques” (p50, Group D) which for several participants develops “step-change improvements in understanding” (p25, Group D).

There is thus an emphasis that training courses are valuable for establishing terminology, techniques and software skills, but these courses need to be augmented with practical application since “on the job training is important” (p25, Group D). Attending courses and augmenting training with “a dedicated mentoring program built my skills over a period of time... helped develop a strong understanding of what I was doing” (p12, Group D) and “Courses combined with work experience have provided greatest contribution to my understanding of resource estimation” (p10, Group D) and it is through “practical application of the knowledge that the learnings (are) made” (p45, Group D). This suggests training courses alone are insufficient for the low reasoning level group who do not meet the ‘15-2-5’ criteria.

The Group C comments focus on training as an opportunity for exposure to concepts, theory, processes and principles. For example, training course provide opportunity to learn “(t)he importance of domaining, estimation methodologies and applications” (p56, Group C). In

addition, training courses provide “the theoretical background for good decision making when selecting techniques and parameters” (p19, Group C) or to learn about “(m)ore of the advanced resource estimates” (p37, Group C). So while training courses provide a backdrop to learning the theory and the implementation skills, the quality of learning “depends on the type of course focus” (p38, Group C). Attending a range of courses including industry courses, internal company courses and software courses all help improve “knowledge and understanding of resource estimations” (p41, Group C). However, this group relies on sourcing their learning predominantly from training courses: “All of my resource estimate generation experience has been developed through post university training courses” (p46, Group C)

Beyond commenting on having access to experts and the opportunity for interaction and focus without distractions of daily responsibilities, the higher reasoning level groups (Group A and B) highlight the importance of situating the learning in the workplace as an opportunity to learn practical implementation of concepts. Situational learning enables “(l)earning about real deposits, sometimes the very ones one is currently working on, is very helpful in understanding key themes” (p15, Group A). Training courses tend to use data that is “clean and validated” (p20, Group A) and this limits the actual “problem solving steps (needed to) match the geology of the ore body” (p20, Group A). Resource estimation learning “needs to be applied to specific workplace tasks” (p29, Group A) since there are “many problems which may arise during the estimation” (p20, Group A).

Participants in both Groups A and B also make specific reference to formal mentoring programs: “Definitely the best method of learning through training was using a mentoring program as you are actually undertaking a resource estimate. The reason why this method works so well is that you have an experienced person to actually ask when you encounter a problem” (p20, Group A). “Completing ABC⁴³’s mentoring course was invaluable to me in learning resource estimation.” (p11, Group B). Training is vital when augmented with a formal mentoring program “ABC’s mentoring program has greatly improved both my appreciation and ability to generate resource estimations. This has been the key to providing both theoretical and practical knowledge and know how” (p04, Group B).

Critical Finding 28:

Resource geologists with higher JORC Code reasoning levels value formal training courses that are augmented with timely situational learning.

⁴³ Mentors names removed for confidentiality purposes

b. Informal Learning and Workplace Experiences

The business of professional practice is a primary source of competency development: “You get to learn and generate new ideas all the time, you work out new answers and your knowledge keeps expanding” (e26). Learning through doing is recognised as critical to developing proficiency in resource estimation: “Work experience is probably the most important aspect of competency” (p20, Group A)

Participants note how critical operational experience under suitably qualified, experienced and mindful managers is to developing a breadth of understanding through exposure to the relevance of the various stages of the mine-value-chain. In addition, there is a sense that consolidation of understanding through exposure to a variety of geological contexts contributes to an ability to contrast and explore potential risks in the application of the resource model. Fundamental to this is the opportunity to learn through making mistakes and living through the consequences of corrected mistakes. Situational learning is thus essential for developing resource estimation and JORC Code classification competency.

One expert expands on how important an appreciation of the mine-value-chain is to accepting a mantle of Competent Person:

“I think one of my judgement calls to consider myself a Competent Person is whether I can comment on the implications for the whole mine-value-chain: You have to understand the implications for the met/processing⁴⁴ side ... The biggest part of being a Competent Person is having enough of an understanding of the environment and that there may be much more that is critical to the success of the project. If you don't know the full project implication for the mine-value-chain for the commodity; you need to understand the normal ballpark expectations (and) the “bounds of expectation” for the commodity style. If you're not competent in that arena then you can't see mistakes as a problem and you are not a Competent Person. Unless you understand the ball park you're operating in you can't be considered Competent.” (e18)

⁴⁴ Met/processing refers to the metallurgical and mineral processing components of the mine-value-chain.

Workplace experiences provide the “the practical opportunity to actually do the estimation work and is possibly the most important development opportunity” (p17, Group A). The eight themes (Figure 45) emerging from the data are:

1. **Operational experiences** enable resource geologists to experience the consequences of errors and corrections in the resource estimation process;
2. **Internal workplace networks** provide a local community of practice that support resource geologists’ learning and understanding;
3. Formative practices in **data collection** (sampling, logging and QAQC) provide a foundation for understanding the limitations of data quality and uncertainties placed on the final estimates;
4. **Reconciliation** in the mining context refers to the comparison of production against estimates at various stages of the process. A reconciliation study requires the resource geologist to engage with multiple disciplines in the mine-value-chain as well as understand the inherent and explicit technical and practical issues within the production process. Beyond assisting with future planning at a mine, reconciliation studies also provide the opportunity for reflective learning – adaptations to estimates can be evaluated for improvement in the accuracy of updated predictions. The process of reconciliation involves comparing production estimates of grade and tonnes against various predictions, including resource estimates and grade control estimates. Proper reconciliation exposes a geologist to the mining extraction and processes issues and enables the geologist to evaluate a full range of process steps where errors can occur;
5. **Responsibility for resource estimation** provides opportunity to learn through the process of doing the resource estimation under the constraints of the data, information and tools;
6. **Peer reviews** provide opportunity to discuss and improve on the process and parameters. Throughout, participating in peer reviews (either receiving or conducting) are appreciated as having a positive effect on competency development for all involved;
7. **Mine-value-chain** experience enables resource geologists to more fully appreciate the context of the estimates, their uses and implications from data quality through to extraction and processing and develops a breadth in capability;

8. Working on a **variety** of mineralisation styles, commodities and contexts helps develop a broader and deeper appreciation of the context of the resource estimate and the variability in interpretations, parameters and subsequent effects; and
9. **Long service** with a project enables resource geologists to develop a depth of understanding through the opportunity to learn from mistakes as well as subsequent corrections.

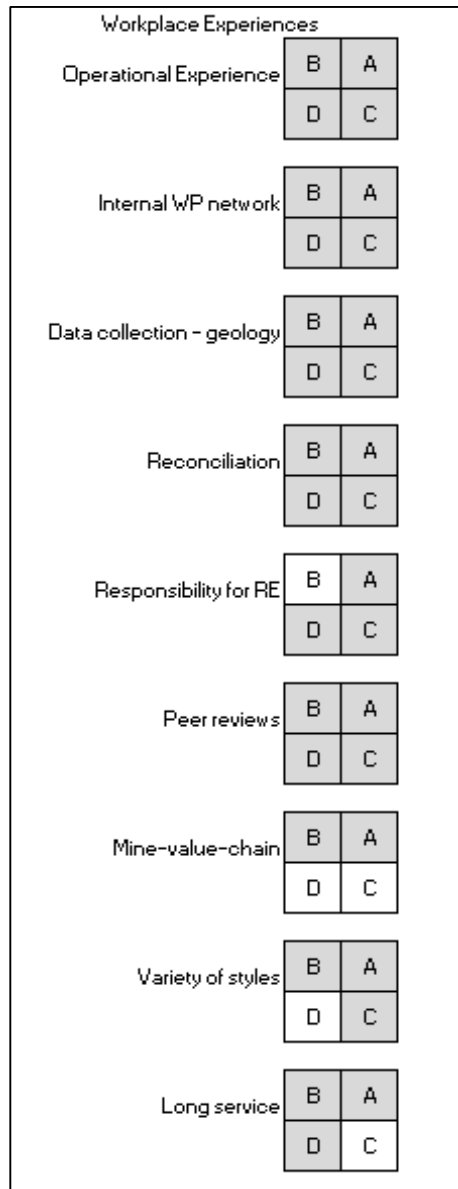


Figure 45 Grouped Emerging Themes – Workplace Experiences

The first four themes (operational experience, internal workplace networks, formative data collection and reconciliation) are valued across the groups. Group A participants value all the remaining themes, while participants Group C fail to recognise the value of mine-value-chain experience and the benefits of long service on projects.

Mine site and operational experience provides a fundamental basis and understanding of the process, expectations and nuances and is central to the development of practical skills and capabilities in resource estimation (Table 34).

Table 34 Example Comments - Value of Operational Experience

Importance of Operational Experience	
Group A	<ul style="list-style-type: none"> • “On site exploration, mine geology, grade control” (p51, Group A) • “Work experiences have been a big part in my development process” (p15, Group A) • “This represents the practical opportunity to actually do the estimation work and is possibly the most important development opportunity” (p17, Group A)
Group B	<ul style="list-style-type: none"> • “Being in an operating mine ... is critical in learning where resource estimates can and do go more wrong than one expects.” (p13, Group B)
Group C	<ul style="list-style-type: none"> • “Working with the deposit ... made me understand the limitations of resource estimates.” (p23, Group C) • “Getting the experience on ground zero” (p37, Group C) • “UG mine experience has been vital in keeping my resource estimates 'real'” (p56, Group C)
Group D	<ul style="list-style-type: none"> • “Working in a mining environment ... has helped a lot” (p08, Group D) • “Time spent undertaking field work prior to resource estimation” (p25, Group D) • “Spending appreciable amount of time (months to years) on deposits” (p26, Group D) • “Years spent in grade control have given an understanding of the numbers coming out of the ground.” (p28, Group D) • “All of them! It’s the on the job training which helps to mould and formulate your ideas and interpretation style / level of understanding of that particular style of mineralisation.” (p53, Group D) • “Strong geological understanding of the ore bodies I am reporting on, as well as ownership of the QAQC validation” (p49, Group D)

Participants across all groups highlighted that operational experience forms the basis of understanding estimation work. There is little in the comments to differentiate between groups. Work experience is recognised as “possibly the most important development opportunity” (p17, Group A) as this is where Competent Persons can experience “where resource estimates can and do go more wrong” (p13, Group B). Operational experience, especially underground experience is recognised as invaluable for “keeping ... resource estimates 'real'” (p56, Group C). A key criteria in the JORC Code definition of competency is the notion that the Competent Persons’ experience is ‘relevant’ to the style on mineralisation and it is the time spent on a mine with a particular style of mineralisation that “helps to mould and formulate your ideas and interpretation style (and) level of understanding of that particular style of mineralisation” (p53, Group D).

Resource geologists who have spent time collecting, logging and interpreting data have a stronger basis from which to develop their resource estimation competency. Having responsibility for the data on which estimates are based provides deeper understanding of the limitations of the data, an expectation of the quality of the interpretations based on the data and are better informed when selecting and establishing estimation processes.

Reconciliation in the mining context refers to the comparison of production against estimates at various stages of the process. A reconciliation study requires the resource geologist to engage with multiple disciplines in the mine-value-chain as well as understand the inherent and explicit technical and practical issues within the production process. Beyond assisting with future planning at a mine, reconciliation studies also provide the opportunity for reflective learning – adaptations to estimates can be evaluated for improvement in the accuracy of updated predictions. The process of reconciliation involves comparing production estimates of grade and tonnes against various predictions, including resource estimates and grade control estimates. Proper reconciliation exposes a geologist to the mining extraction and processing issues and enables the geologist to evaluate a full range of process steps where errors can occur. Not surprisingly, participants across all groups recognise and emphasise the value of reconciliation to the development of their competency:

- “... involvement in the resource estimation outcome based on that data, was really helpful” (p15, Group A)
- “ ... creating resource estimates and reconciling those resources against production” (p13, Group B)
- “... working with the deposit after the estimate, showed me how well it reconciled, and so made me understand the limitations of resource estimates” (p23, Group C)
- “... reconciliations of earlier models versus production, sampling techniques and geology” (p08, Group D)
- “... reconciling the models to production/mill outputs and investigating the intricacies of the resource model” (p16, Group D)
- “Years spent in grade control have given an understanding of the numbers coming out of the ground” (p28, Group D)
- “The proof of the pudding is in the RECON!!” (p22, Group D).

Resource estimation capability is more commonly gained through the practice of conducting estimates. Ideally, resource geologists are guided through the process by the internal network of peers, their supervisors and/or technical mentors. Ultimately, however, participants in all four groups agree that resource geologists must engage in the process to learn the process.

Learning through operational experience is enhanced when it is conducted under the careful guidance of mentors and peers internal to the workplace. Peers provide “valuable feedback and hence encourage improvement.” (p04 Group B) and opportunities to “shadow Senior Resource Geologists when completing resource estimates” (p15 Group A). For many, their internal networks are a subset of their wider professional network. These are discussed in more detail on page 183). Peer reviews offer insights into possible loopholes or gaps in processes and alternative approaches or parameters and their potential implications. This broadens a resource geologists understanding of the work they do as well as provide some context to the value it has in the overall scheme of the business.

It is especially important that the geologist has opportunity to experience the life cycle of a mined resource by spending sufficient time at an operation to gain an understanding of the full mine-value-chain. “I’ve seen many projects turn over from discovery to closure and being dug up again. I’ve seen the impact on projects of fluctuations in gold price and costs; and different companies at the same mine” (e15) and “(b)y staying in one place I got to apply the lessons from mistakes I’ve made” (e15). “Spending several years on a particular project or terrain has enabled me to understand the deposit type, metallurgical issues, and data issues that arise over time. Having an understanding of how this data may be used in a resource estimate has ensured that I have been aware of QAQC, data management and good field practices. Also, having an understanding of how this information is reported to the ASX has been invaluable” (p05, Group B). When this depth of experience at an operation is coupled with exposure to the various technical disciplines in mining such as “Exploration experience on a drill rig; Visiting analytical laboratories to review and understand sampling and assaying processes; Visits to site with other professionals to gain an understanding of metallurgical and mining processes; Reviewing resource estimates prepared by other professionals” (p55, Group A) the geologist is able to leverage their work experiences to develop competency in context since “Reporting competency is developed through exposure to a variety of issues (and) deposits” (p29, Group A). When a geologist has opportunity to work on a variety of projects this also allows them “to become familiar with a lot of geological settings and the spectrum of work practises being implemented within the industry” (p15, Group A) and they are then able to contrast “differences and similarities ...(which) have certainly helped in developing ... reporting competency” (p11, Group B). “The more exposure we get ... the more experienced we become” (p29, Group A). Notably, no members of Groups C and D comment on the mine-value-chain.

Work experience is fundamental to developing competency in resource estimation. Rather than focus on a single style of mineralisation, however, it is important that Competent Persons also works “within different styles of orebodies to understand the intricacies of the mineralisation to produce an estimation that reflects the grade distribution within the orebody” (p20, Group A). Beyond developing an appreciation for the task of data collection, quality control and interpretation “exposure to the different orebody types cements the fact that each orebody and/or domain needs to be treated separately and one estimation method will not suit all deposit types/domains” (p20, Group A).

Notably, participants in Group C offer limited recognition of the value gained from diverse experiences. Instead this variety is reduced to a simple checklist of achievements rather than an opportunity to reflect on the potential value in contrasting the variety of experiences:

- “While working at X Mine for ~7 years I did 2-3 resource estimations and many grade control models” and then lists numerous commodities (p41, Group C);
- “The critical work experiences enabling me to be competent is a full understanding of the mine geology and drilling/sampling processes, good understanding of the deposition/structural processes of the resources and a strong understanding of lithology/domain.” (p46, Group C)
- “UG mine experience has been vital in keeping my resource estimates 'real' Also exploration experience has helped me in making determinations about the quality of drilling results and given me an understanding of how samples can be contaminated/affected during drilling” (p56, Group C)

Beyond this checklist of commodity, geological and/or data collection, Group C offer limited recognition of the importance of the situational or operational exposure extending beyond the silo of the task assigned to them.

Only participants in Group A recognise the value of long service to their competency development. In particular, long service offers opportunity for reflective learning:

“By staying in one place I got to apply the lessons from mistakes I’ve made. I’ve made some large errors beyond JORC (not technically major) and lived the consequences. So I learnt what to do next time and got a chance to avoid them - so applied what I learnt too. If you move around you never get the chance to do anything or be around long enough to make a mistake, fix it and apply the fix so you know how to perform to expectation. You get a chance to remember the pain. When XYZ⁴⁵ and I leave, there may be a problem with the memory of the pain.” (p07 Group A).

Long service at an operation also provides an intimate connection with the geology and the extraction and processing aspects, which all ultimately improve the quality of the resource estimate.

Critical Finding 29:

Learning through operational experiences is valued by all levels of resource geologists.

Critical Finding 30:

Resource geologists with higher levels of JORC Code reasoning are more likely to appreciate the opportunities for reflective learning gained through longer term service at an operation.

Workplace Learning Summary

The preceding analysis highlighted the importance of learning preceding the workplace as well as both formal and informal learning in the workplace. In general, the formal courses

⁴⁵ Name removed for confidentiality reasons.

introduce the concepts, terminology and, in particular, the software to enable resource geologists to apply the concepts they have learnt. However, attending courses is only valuable when it is augmented with situational learning, supported through either formal or informal mentoring since core technical learning is best achieved through the actual engagement of the practice of resource estimation and classification. Resource geologists learn their practice through their professional network, mentoring, peer review, discussions and exposure to a variety of situations. These can be organised through both formal and informal avenues (Table 35). Rather than adopt either formal or informal workplace learning, there is a need for both. The timing of the connection between the formal and formal is important and can be linked in a dualism where each contributes to the success of subsequent learning events (Figure 46).

Table 35 Dualism of Informal and Formal Workplace Learning

Learning Source	Formal Learning	Informal Learning
The generic resource estimation process	<ul style="list-style-type: none"> - Courses – industry, software and internal 	<ul style="list-style-type: none"> - Situational experiences such as doing the job of data collection, sampling and QAQC, interpretation, modelling, estimation and reconciliation
Professional Network	<ul style="list-style-type: none"> - Internal hierarchy – supervisors, colleagues, multi-disciplinary peers 	<ul style="list-style-type: none"> - External network
Mentoring	<ul style="list-style-type: none"> - Formal technical mentoring program 	<ul style="list-style-type: none"> - Informal mentoring
Peer review	<ul style="list-style-type: none"> - Formal internal and external peer reviews (usually by superiors) 	<ul style="list-style-type: none"> - Informal checks through discussions with peers - Digital peer group (LinkedIn groups)
Communication	<ul style="list-style-type: none"> - Report writing - Papers for conferences and publications 	<ul style="list-style-type: none"> - Informal discussions with peers – defending technical positions
Exposure to variety	<ul style="list-style-type: none"> - Conferences and seminars - Visits to laboratories, mill and plants - Visits to other sites 	<ul style="list-style-type: none"> - Working in one place to gain mine-value-chain exposure - Working on different projects and commodities - Informal discussions with multidisciplinary teams

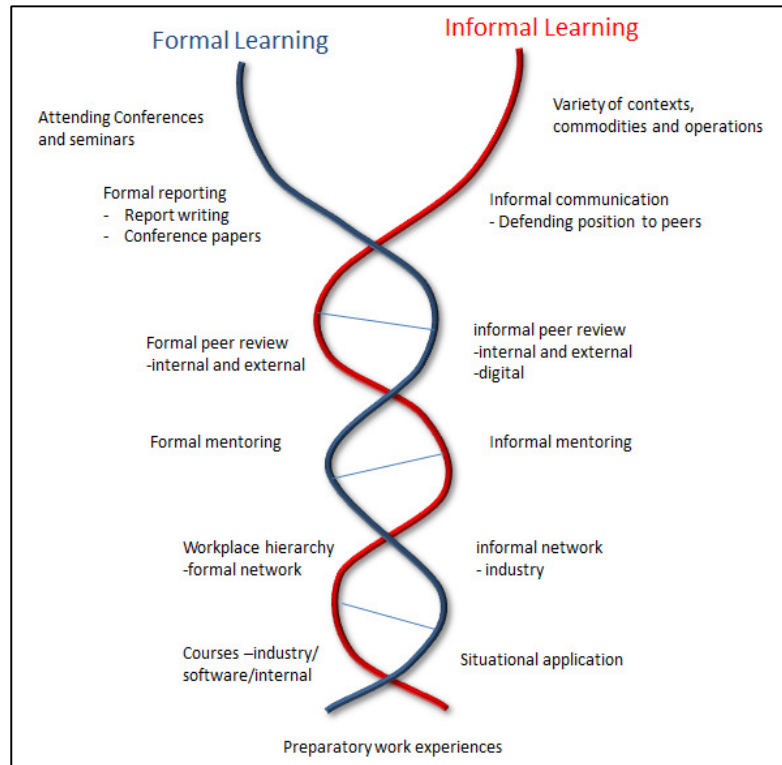


Figure 46 Dualism of Formal and Informal Workplace Learning

7.4.3 Learning Networks

Professional networks provide a significant contribution to the development of competency. Geologists note their reliance on their professional networks for access to expertise so they can “bounce ideas” off their trusted advisors, validate their technical ideas or choices. Working with experts in their networks provides opportunity to learn through watching the expert as they engage with the practice.

Overwhelmingly, resource geologists rely on their professional networks for access to expertise. In addition, there is a sense of shared responsibility to contribute to discussions both formally and informally. Professional networks tend to extend beyond organisations and resource geologists rely significantly on external validation of technical decisions – be it through formal or informal relationships. Given the transient nature of resource geologists, a loyalty to past and present supervisors, mentors, peers and colleagues appears stronger than to the organisations that employ professionals. This commitment to professionalism and the professional community is at the heart of the power of the JORC Code, which depends on Competent Persons’ commitment to their reputation to provide guidance for public reporting.

Eight themes emerge from the data to describe how resource geologists use their professional networks (Figure 47).

The discussions and access to expertise are valued across the participants. More specifically, however, the theme described as ‘professional networks having limited value’ can be traced back to participants in Group D only and reflects their emerging status in the industry. The only other major discrepancies are in the themes relating to digital discussions and courses. It would appear that Group A participants are more open to a variety of channels for discussion than Group C participants are. In contrast, the ‘accessing professional networks by attending courses’ theme is only valued by Group C participants.

Professional networks enable access to both expertise and the opportunity to develop expertise across all four groups. These experts may be internal to the organisation, former colleagues or managers, consultants (more typically known personally) or the wider community through social media such as LinkedIn groups.

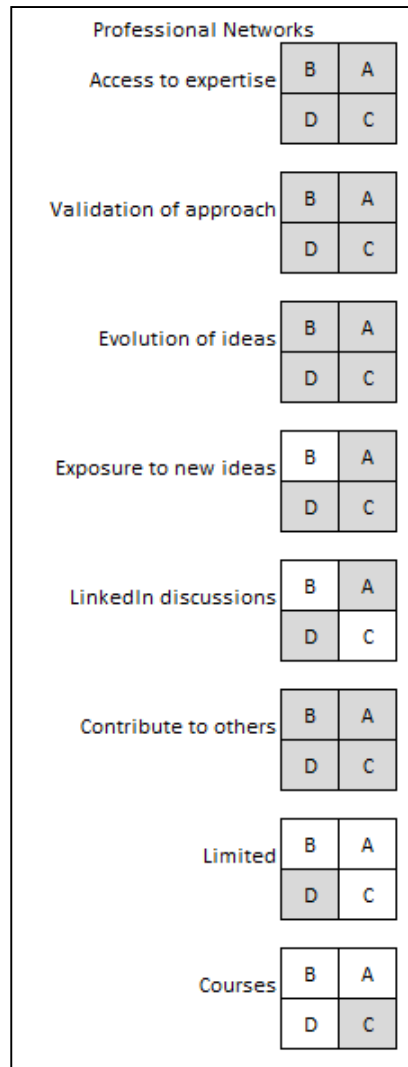


Figure 47 Grouped Emerging Themes – Professional Networks

Experts within professional networks provide opportunity for resource geologists to validate the technical approaches they have adopted. This opportunity to “bounce ideas and ground truth ideas” conjures images of seeking experts’ approval, which is not unusual given the highly interpretative and non-prescriptive processes for resource estimation. Discussion with various experts allows ideas to evolve and is valuable for confidence building:

“Unfortunately no two people will create the same estimation from one set of data, however by listening to, and learning from other professionals I can chose best practice methods to produce a high quality model. By having different people, who will have different interests and focus points to review models I can gain a better understanding of each facet of resource estimation. I don't believe any one person is an expert in every detail of estimation from sampling to interpretation and statistics to validation, however by using lots of people you get a broader picture” (p11, Group B).

Moreover, discussions are a creative process that help with “formulating different approaches to solve estimation issues” (p20, Group A). Of particular value are the discussions that highlight what has been learnt through mistakes.

Accessing the broader professional community through conferences and seminars exposes resource geologists to new ideas and approaches. In addition, expectations to contribute through presenting at conferences are an “important mechanisms for professional development, expanding upon current knowledge and introducing new concepts” (p04, Group B). More recently, social media (specifically LinkedIn groups) allow both anonymous observation and integrated participation. This form of network is in its infancy and offers direct access to the broader resource geology community, beyond the scope of the more personal professional network.

The style of participation changes as resource geologists mature. Confident resource geologists are enthusiastic to contribute through their professional networks and thereby help others. These resource geologists speak of “sharing’ and “giving back”, highlighting a deep sense of community and responsibility to participant in the development of others.

Comments about professional networks being of limited value or still emerging were only shared by Group D participants. Further investigation highlights these participants are in the formative stages of their careers.

Only Group C participants suggested attending courses was a means to access their professional networks. However, unless attending courses is coupled with situational

learning, there is limited embedding of learning. Therefore, in contrast to the other forms of access, the concern here would be that this access might only be valuable when contextualised in the moment of need.

Interestingly, the manner in which participants access their networks does not follow the structure provided by Learning Network Theory. As such, the data was reviewed to better understand how participants access experts through their professional networks.

a. Resource Geologists' Construct of Learning Networks

In light of the above analysis, professional networks are valuable as an avenue for learning to all resource geologists. Some resource geologists have fully formed and mature networks, whilst the learning networks for other resource geologist are either very new or in the early stages of development. A meaningful exploration for the research then is an investigation into the constructs of these networks. More specifically, there are five aspects of learning networks revealed in the data that are worthy of further analysis:

1. How resource geologists establish and develop their professional networks;
2. The mentoring engagement and access within these networks;
3. The form that discussions take within these networks;
4. The contributions resource geologists make to their professional networks; and
5. The importance of peer review as a source of learning.

These are now explored in more detail below.

Professional networks are a dominant and primary source of learning for resource geologists. Initially these networks are small and are based on formative personal experiences with internal supervisors and mentors. Over time, and with more experience, the network evolves to include external connections. Eventually, these egocentric networks operate within the professional community in both access and contributory forms. These networks are highly personalised and the connections are enduring.

Interestingly, several participants attribute their early career connections as serendipitous:

- “In the beginning I was lucky – I had fantastic teachers” (e13)
- “I have been fortunate to have been able to surround myself with very experienced geologists” (p15, Group A)
- “I have been fortunate to have worked alongside some people with excellent skills and been able to teach and be taught” (p09, Group A)
- “I have been lucky to work under some knowledgeable and experienced geologists” (p04, Group B)
- “I have been fortunate to work with some talented people” (p52, Group D).

Clearly initial mentors can “change your entire outlook” (e13), which emphasises the need for emerging resource geologists to access suitable expertise. Building networks is achieved through relationships at a deeper level than simply a momentary meeting. Trust clearly plays a significant role in both the establishment and the maintenance of these connections. This is evidenced in the personal references whom resource geologists describe as “trusted *go to* persons” (e23) or because “I am aware of their experience levels” (p02, Group A) and “I value their experience” (p03, Group C). Network connections are most often described in terms of specific people and many participants named specific people they respect and trust, suggesting highly personalised networks.

Throughout a resource geologist’s career, having mentors to “review process for all work completed has ... a positive impact on the improvement of ... work” (p29, Group A). Competence is developed by relying on “a group of Competent Persons” (p31, Group D) as a geologist goes “through the entire resource estimation process through using ‘live’ datasets” (p10, Group D) as part of a formal mentoring programme. This formal “supervision of a competent person” (p24, Group D) whilst “completing a resource report to a JORC standard” (p24, Group D) is seen an invaluable to developing the deeper understanding of the process and implications of decisions within the process.

There is a shared sense of respect for technical integrity and the community is described as “incredibly supportive” (e11). There is recognition by most participants that significant learning can occur through participation in the professional community: “By learning off others around me ... I am learning to develop my own competency” (p18, Group D). Indeed, “It’s an incredibly small community and if you do something wrong, news gets around fast” (e11).

Group A have a more mature view of their network, identifying their experiences akin to apprenticeships: "... having the opportunity to co-author several Technical Reports before becoming sole author allowed me to develop my geological information collection skills and report writing skills, providing a firm foundation for reporting competency" (p15, Group A). In addition, there is a sense of camaraderie: One's professional network enables one to "share ideas, present and attend at discussion forums, used as peer reviewer and to pass opinion on related matters which highlights common issues" (p51, Group A). Moreover, only participants in Group A emphasise contributing back into the pool of knowledge through helping others, which is probably indicative of their more mature views on competency within a mine-value-chain context.

Participants in Group D are predominantly deferential to the mostly external experts they draw on for guidance and review rather than for expanding on ideas and concepts. Similarly Group B participants present respectful comments about experts in their networks, however, they expect more "exchange of ideas" (p05, Group B) than is evident in Group D.

Group C (the participants who qualify according to the '15-2-5' criteria but have lower JORC Code reasoning scores) are the only participants to mention training course attendance as a source of network learning.

Mentoring is understood to be critical to competency development and that "a series of mentors is critical" (e17). In "the formative stages (mentors) impress upon you the process of how to approach the resource estimate as each one has its own unique challenges and idiosyncrasies" (p53, Group D) and can inspire your career choices (as noted above): "In the beginning I was lucky – I had fantastic teachers and this decided what I would do" (e13). The mentoring is both formal and informal. For some the mentoring is from direct supervisors: "I have been fortunate enough to have received excellent geological (and the subsequent business impact) mentoring by my supervisors over the years, in things that matter most (applying geology, integrating data, understanding the business context)" (p09, Group A). For others the supervisors create an environment for learning "I had a good mentor and was allowed sufficient time to shadow senior resource geologists when completing resource estimates" (p15, Group A). One expert shared how he deliberately identified and sought opportunity to work with respected mentors "I was lucky to work with a series of very good mentors and this was critical. As a senior geologist at mine site I identified and pursued top-shelf mentors ... I spent time working with each of them" (e17). He went on to share the importance of mentors for the development of expertise: "You need these mentors with 15/20 years' experience. But there has been a fundamental structural shift – there are not many experienced people around. A series of mentors is very important. I have always had the

philosophy that I wanted to work with very bright people and expose my ignorance. I have always sought people out.” (e17) and most telling he asks “How can you grow competency if you don’t have mentors?” (e17).

In addition, formal discussions take the form of both internal and external peer or supervisory reviews, attendance and presentations at conferences and seminars and within formal mentoring programs. Informal discussions include ad hoc access to professional networks that can extend to trusted sources beyond the organisation as well as through digital professional social networks such as groups on LinkedIn. Discussions take many forms and the variety of opportunities offers resource geologists a mosaic of views, contributions and different experiences: “The thing I prize most of all are the other people who are in the same peer group. Anyone can teach you. I reflect off my peers and learn from them. Other people provide many heads rather than just one. I am amazed at the different ways people can see things in the same thing – they bring alternative positions that I haven’t considered.” (e18).

This strong sense of *quid pro quo* is especially prevalent as resource geologists become more experienced and feel confident to contribute. This is evident in the experts who attribute the act of training or mentoring as an additional avenue for learning: “When I run training courses, I find the presentation of material and interaction of the participants broadens the view. Sometimes these views are indirectly related to the topic, but often these are gems I hadn’t thought about before and they are clearly valid and sometimes this is at odds to the way people go about solving particular tasks” (e18). Resource geologists recognise the need for constant challenge of their stock of knowledge and experience. Professional networks enable exposure to alternative approaches, methods and learning. Additional opportunistic learning occurs through reviewer, management and teaching/mentoring roles. These supervisory style roles, which exist internally and externally, provide opportunity to learn through the learning experiences of another: “Only when you mentor someone else do you realise how much you learn through mentoring” (e23).

Technical reviews and “the opportunity for peers to review work completed.”(p17, Group A) exposes participants to a deeper understanding in their knowledge and understanding” (p54, Group A) and is recognised as “the most important aspect (of work experience)” (p54, Group A). Learning from peer review is identified as necessarily ongoing: “Peer review has been invaluable as my skills and career has developed” (p15, Group A) and provide opportunity for testing “ideas and solutions for problems” (p12, Group D). Peer review takes three forms – having one’s work peer reviewed; being the reviewer and observing a peer being reviewed. Each form provides an opportunity to learn from the process:

- Being peer reviewed: Having one's work peer reviewed by more experienced Competent Persons as "a solid auditing and review process for all work completed has ... a positive impact on the improvement of ... work" (p29, Group A) and "in particular, having to explain and justify each step to an informed and interested party" (p54, Group A). Learning comes from the interrogation of "being questioned about the hows and whys (in) resource audits" (p45, Group D).
- Acting as reviewer: "Reviewing resource estimates prepared by other professionals" (p55, Group A) and "peer reviewing other people's models" (p16, Group D) also provides opportunity to learn from the work of others.
- Observing peer reviews: A peripheral avenue for developing a better understanding of the resource estimation process is "... the opportunity to be involved in resource model peer reviews, where experienced persons review all aspects of the modelling process" (p52, Group D). "By attending internal and external audits (to) understand the critical components of estimation models and ...feel more confident in reviewing/completing or signing off on models" (p11, Group B).

Critical Finding 31:

Mentoring is viewed as critical to the development of resource estimation competency.

Critical Finding 32:

Resource geologists access their immediate and previous connections for learning.

Critical Finding 33:

Access to learning networks is highly personalised.

b. Alternative Structure of Learning Networks

Whilst Learning Network Theory was originally proposed to provide structure for exploring learning relationships (§3, page 55), it became evident during data analysis that the way resource geologists access their networks was inconsistent with Poell et al.'s (1998) theory (Figure 48). The four characteristics of networks within Learning Network Theory (highlighted in Figure 48) are explored below.

Dominant actor: Resource geologists typically own and orchestrate access to expertise.

With a preference to work alongside knowledgeable peers and have access to expert mentors, resource geologists will move organisations to broaden access to expertise. Their peer group grows as they move between organisations and therefore their learning network is not bounded by organisations. Instead their networks endure relocations of the individual and all of the connections. Resource geologists access their professional networks through the broader mining industry associations and social networks such as LinkedIn. Resource geologists can therefore appear as operating as “individual learners”, but with support from vertical, horizontal and external networks connections, which simultaneously relocate within the global mining industry.

Organisation of learning processes: Learning how to estimate and generate resource estimates occurs from a combination of formal and informal learning processes. Learning from training courses is only useful when augmented by situational learning. The organisation of these learning events is predominantly organic, although some linear planning may be necessary and can be isolated events. This means the organisation of learning processes is both vertical and horizontal, but could be liberal. The learning networks, however, tend to be egocentrically managed.

Content Structure: The content of workplace learning is not structured. More typically, it is embedded in the practice of doing. Parts of the process are task or function oriented, but predominantly the work is oriented around organisational needs. Processes are sanctioned through peer-review. The organisation of learning therefore traverses vertical, horizontal and external networks and does not follow fixed content. Instead the learning content adapts to the immediate workplace requirements.

Organisational Structure: The organisational structure for resource geology learning is at best “loosely coupled”. Imposing an organisational learning structure that parallels organisational processes is challenged by the transient nature of the resource geologists within the system.

Four theoretical types of learning networks

	Liberal learning network	Vertical learning network	Horizontal learning network	External learning network
Dominant actor	individual learners	managers and trainers	learners as a group	professional associations outside
Organization of learning processes	isolated activities	linear planning	organic	externally coordinated
Content structure (profile)	unstructured	task or function oriented	problem or organization oriented	profession oriented
Organizational structure	loosely coupled	centralized	integrated	externally inspired

Figure 48 Evaluation of Workplace Learning against Learning Network Theory (after Poell, et al., 1998)

Learning Network Theory requires learning to mirror work functions and to be structured along organisational responsibilities. Instead, resource geologists access egocentric professional networks along trust lines and access connections according to a hierarchy of trust and respect for the technical work of experts ahead of corporate hierarchy.

Moreover, resource geologists value the relationships established at temporal learning moments. Of particular value is the relationship with experts – referenced from either senior people such as managers, mentors and peer-reviewers, or from external former industry colleagues or through experts who are consultants. Access to experts in both formal and informal frames is critical to the development of resource estimation and classification capability through transfer of knowledge, skills and experiences. Learning about resource estimation is a symbiotic accumulation from experiences within a professional network or community.

Relationships external to organisations can develop through formal contractual arrangements between the organisation and the external expert. Beyond these formal connections, previous internal connections evolve into external connections due to the transient nature of professionals and their network connections within the mining industry. Professionals’ networks therefore continually expand and interconnect based on past and evolved professional engagements that are both internal and external to organisations, and persist beyond the business engagement. Professional networks are thus not structurally static, but rather persistently variable in accordance with the respect and trust afforded the connection.

Whilst resource geologists describe their professional networks in terms of both internal and external connections, participants refer to specific people in their network, emphasising firstly

a level of intimacy in the relationships that transcends a crude hierarchical responsibility, and secondly the endurance of these relationships beyond the organisational movements of the network members. “I mostly use internal networks and as people move on they become external networks” (e19).

Internal networks are fundamental to the way resource geologists work. There is a need to ask peers questions, discuss concepts and essentially validate and develop ideas according to the data and context at hand. “Geologists basically work best in groups, sitting near each other ... it’s invaluable to ask questions and physical proximity is important” (e22). “They don’t need to be physically present, just accessible – I couldn’t have done it by myself” (e26). A peer group provides access to a range of viewpoints and interpretations. A quote used earlier emphasised:

“Unfortunately no two people will create the same estimation from one set of data, however by listening to, and learning from other professionals I can chose best practice methods to produce a high quality model. By having different people, who will have different interests and focus points to review models, I can gain a better understanding of each facet of resource estimation. I don't believe any one person is an expert in every detail of estimation from sampling to interp⁴⁶ and stats to validation, however by using lots of people you get a broader picture” (p11, Group B)

This level of support is not available to resource geologists working in isolation. When working alone, resource geologists face more pressure and are at a greater risk: “The risks are that the answer is wrong and in isolation you would become disgruntled. You need lots of people to talk to and get your questions answered. You have to find someone who will support you and get answers to your questions” (e24). Without access to an internal network, resource geologists become isolated and feel disconcerted: “When ABC⁴⁷ left, I felt I needed a mentor. The group that remained were not passionate about resource estimation. It was frustrating. I needed someone to discuss ideas with. Discussing ideas gives me confidence. I like to validate my thinking and ideas” (p03, Group C). Even though “(c)orporately they keep trying to build networks ... people get isolated on mines.” (e19). One approach used to support resource geologists is to “use consultants in this mentoring or supervising role” (p54, Group A). These external mentors “take the place of more senior personnel in many operations and are probably a much better option than simply farming out your resource model” (p53, Group D).

⁴⁶ ‘interp’ is the abbreviation for geological and domain interpretation

⁴⁷ Name removed.

Whereas Learning Network Theory reflects a more static organisational view of professional learning networks, resource geologists' professional networks are not permanently located within an organisational context because all connection nodes, including the resource geologists themselves, are transient. A new model is necessary to accommodate mobile professional learning networks.

Based on the participants' contributions, there appears to be a hierarchy of access within the professionals' networks (Figure 49). Resource geologists will first attempt to resolve issues on their own, then access their immediate colleagues followed by internal experts. Once these avenues are exhausted, the resource geologists will informally access former colleagues or external consultants they have worked with before. Beyond these more intimate connections, the resource geologist then accesses the broader professional LinkedIn networks. If informal avenues are exhausted, resource geologists access external consultants (escalating from known to unknown connections as access demands). More broadly, but less formally, resource geologists learn through attending industry conferences and professional association seminars. Confidence to access this hierarchy grows as resource geologists become more engaged in their practice community. The network interactions described here are egocentric and the trust in the connection expertise endures relocation of both resource geologist and expert.

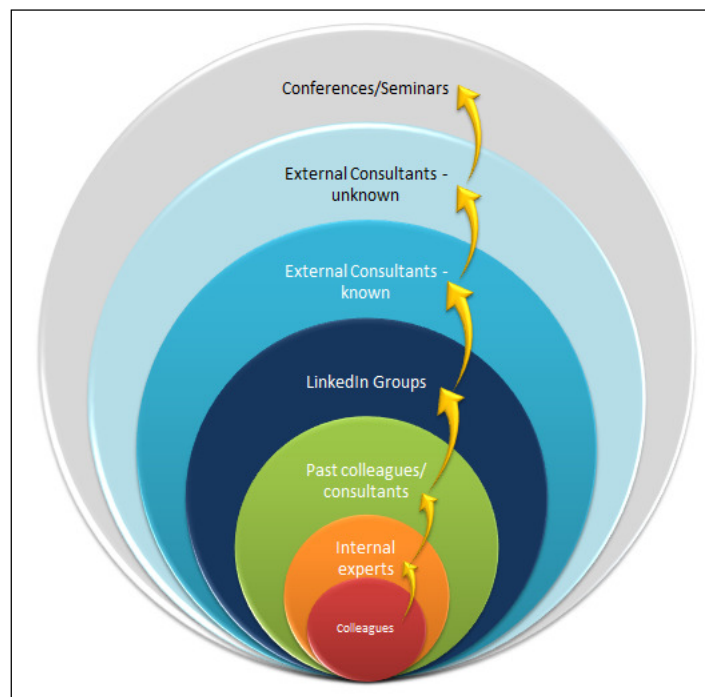


Figure 49 Network Access Hierarchy

An enduring, transient and egocentric learning network provides a more accurate reflection of how resource geologists use their professional networks to develop their competency.

Whilst Communities of Practice offer the flexibility required by resource geologists in the way they access their professional community, the model described here is deliberately egocentric.

Critical Finding 34:

Resource geologists' learning networks are egocentric, enduring and transient.

7.4.4 Workplace Organisations

Organisational style was identified as a potential factor in the development of competency in the conceptual framework. In response to the question regarding the influence of organisations on competency development, participants contributed positive and negative comments. These were split during coding. Four constructive themes and eight negative themes surfaced (Figure 50).

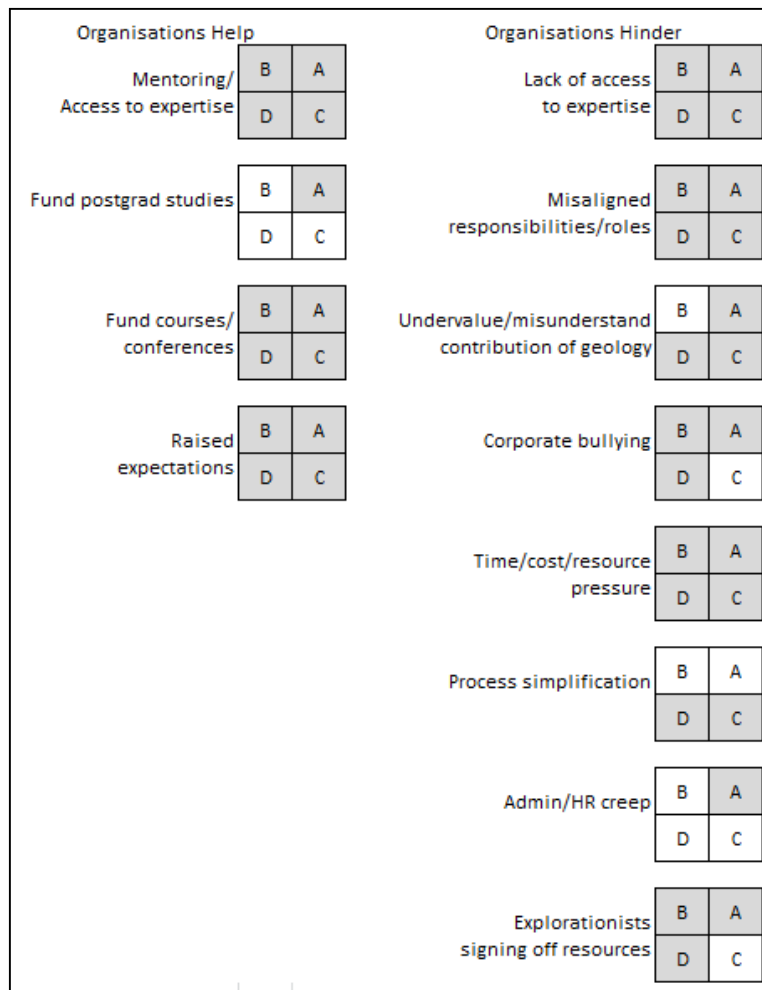


Figure 50 Grouped Emerging Themes – Organisations Help or Hinder

The constructive themes are:

1. Organisations support competency development by **providing access to expertise**, either through internal networks or through consultants, as mentors and collaborative managers;
2. **Funding post-graduate studies and research** provides opportunity and means to further knowledge and understanding;
3. Organisations provide **funds to attend** training courses, conferences and seminars;
4. By **raising expectations** of practice and supporting this through sanctioning processes, organisations provide a benchmark for professional attainment.

The constructive themes are common across all four groups, except for the theme relating to organisations funding post-graduate studies and general research, which is identified only by participants in Group A.

The eight negative themes are:

1. A **lack of access to expertise** is noted as a major hindrance to competency development. In a sense, this is the same theme as the first constructive theme, except for its negative delivery. However, there is special mention of the deliberate withdrawal of support or pretence of expertise by senior geologists.
2. Organisations limit opportunities for competency development when roles assignment results in **compartmentalised or limited responsibility**. On the other extreme, competency development is compromised when organisations demand more responsibility from individuals than they can manage;
3. Some participants are concerned about the **undervaluation of geology** in the resource estimation process and that this is exacerbated when organisations adopt a more aggressive philosophy towards resource estimation;
4. **Corporate bullying** occurs when idealised estimates and classifications are demanded and the resource geologist is not experienced enough to resist. This corporate bullying compromises the classified estimate as well as the resource geologist's credibility;
5. Operating under **pressure**, especially time pressure, undermines the quality of the resource estimate and the confidence of the resource geologist. Cost pressure undermines the quality of the input data, which cannot be undone;

6. Organisations where **processes are simplified**, or codified to the point of inflexibility, prevent resource geologists from learning by exploring alternative processes for technical improvements;
7. Over the years, geologists have had to take on **increasing levels of administration** work. This creeps into the time available for practicing the trade of resource estimation and encroaches on available time to explore and reflect on technical developments and implementations;
8. There is concern that, because **exploration geologists** have no operational experience, the resource estimates they create will be overly optimistic.

Group A participants consider organisations that conduct corporate bullying practices, allow administration creep, and encourage geologists without operational experience to sign off as Competent Persons are a hindrance to competency development of resource geologists. Group C participants do not comment on these issues. Instead, Group C participants contribute concerns regarding the over simplification of the resource estimation process.

Organisations, especially larger organisations, are commended by participants for funding access to expertise, however, there is still wide concern that organisations do not provide sufficient access to expertise or are unaware of the limited expertise of senior ranking geologists. Participant p09 (Group A) describes the issue succinctly:

“Many senior technical staff do not have the technical skills to provide good mentoring to people they supervise, and often do not want to be perceived as not knowing what they are assumed to know. There is insufficient mentoring of less skilled/experienced staff by technically competent people ... (T)he resource companies’ technical areas are so poorly managed/supervised and this ignorance breeds an arrogance that everything is under control. Management has an attitude of “style over substance” - the general reduction of hard won geological and mining experience is undervalued in senior management positions.”

A review of the participants and their role title indicates participants in more senior and executive management roles (director, manager and chief geologist) comprise expertise either Group A or in Groups B and D. Project geologists readily identify as less experienced in Groups B and D. More disturbing, however, is the proportion of Group C participants in the roles of Consultant, Principal and Senior Geologists: a quarter of the participants in each of these roles are categorised in Group C – the experienced but low JORC Code reasoning group (Figure 51). This means one out of every four geologists in middle management (responsible

for operational guidance and technical supervision), and who has sufficient experience to qualify as Competent Persons, is not able to reason through the JORC Code. This is concerning given the mentoring and guidance required of these people by their subordinates.

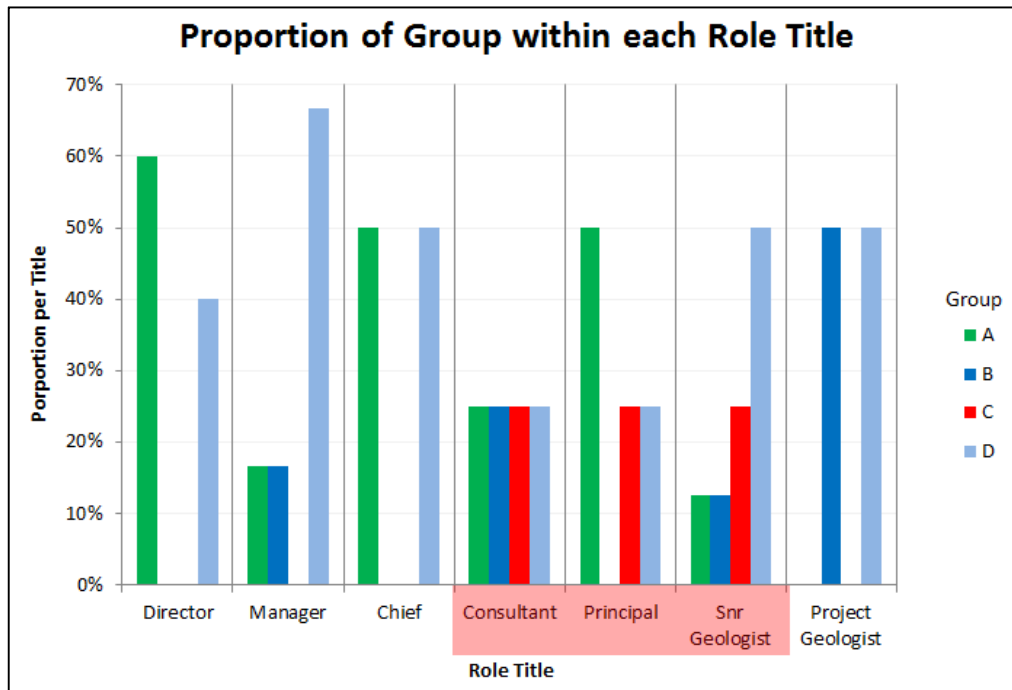


Figure 51 Distribution of Groups Per Role Title

On top of providing workplace experiences, organisations provide funds for external competency development such as attendance at training courses, conferences and seminars; registration and study time for post-graduate studies and membership fees for professional associations. While all groups note organisations’ financial contributions for attendance on training courses, conferences and seminars, Group A participants especially note and value contributions towards postgraduate studies. Financial support is not always forthcoming: “I think geologists have to really fight to get the training required to gain the necessary development for resource estimation because non-direct managers do not see the short term benefits to the department (and their own KPI’s); this is especially the case with larger mining companies” (p40, Group D). Participants observe a general downward trend in support and investment in academic research and raise concerns at the apparent disconnect between industry and academic pursuits. Some hanker to a bygone era: “The days of companies that were innovative and supportive of academic pursuit and research such as Geopeko and WMC seem gone” (p16, Group D).

Organisations set the standards through their expectations, processes, support and their sanctioning policies and actions. Participants have had mixed experiences of the expectations organisations set for resource geologists. Sadly, a few experiences are negative and result in accusations of organisations “only interested in what minimal competency is required” (p38 Group C). More common is the appreciation for those organisations that articulate clear guidelines and provide systems and structures to support thorough review and consistency: “(W)orking in XYZ is a great opportunity to see well-established systems” (p21, Group B). Participant p07 (Group A) described the systems and structures in his company:

“Each company is going to interpret the code differently. Across our company the interpretation is applied evenly - Indicated on one mine is equivalent to Indicated on another. We have ABC who sees all the models. There are others too ...so someone goes around and sees virtually every resource model the company has. So they see the setting and ensure the systems and structures are maintained. The XYZ systems and structures fit the corporate directive, the code guidelines, peer reviews ... These all fit the company requirements, but they are specific enough to be relevant for our situation. I think this all sets the bar in how we develop competency. To get a sign off is not easy. You have to go through the validation, peer review. And it's not just resource estimation. It's also QAQC, the geology. There are lots of boxes to tick. You have to be developed so you can sign off. I guess the key to developing people who can sign off is having the processes in place, then giving them the confidence and understanding so they can sign off” (p07, Group A).

Access to a structure that still encourages intellectual flexibility is critical to resource geologists' learning: “It was very different in my previous employment. Here we have all the facilities and I can find all the software. I'm not limited by the availability of what I need. It also gives me a chance to try new things. I want to try other things, to improve things. Personally, if I'm not allowed to do this, to take on project research, how can we improve things? I'm always looking for ways” (p03, Group C).

Engagement in the process of producing estimates is necessary to develop competency. However, when workplace roles are aligned to the compartmentalised components of the process, resource geologists are not exposed to the connectivity between action and consequence and this limits their exposure to both breadth and depth of issues. For some organisations this compartmentalisation is extreme. For others the compartmentalisation occurs between data collection, interpretation and estimation. But by “separating the mining and resource geology functions, with resource departments often not even based on site, sitting in a centralised office ... estimators become somewhat disconnected from the rocks so

to speak, and simply receive a validated wireframe from site, or make only infrequent and/or short visits to site, with minimal understanding of the controls on mineralisation and site procedures (Sampling, QAQC, Grade Control etc.). How can people become truly competent if this disconnect exists?” (p24 Group D)

Another area of concern is the inability of management to guide and review the process, thereby undermining both the quality and the opportunity for competency development. As highlighted earlier: “resource companies’ technical areas are so poorly managed/supervised and this ignorance breeds an arrogance that everything is under control” (p09 Group A). Furthermore, concerns about misaligned roles extend to organisations that allow geologists to sign off as Competent Persons when they have “no resource or mining experience ... (because) ... to understand the risks involved in a resource it is critical that they have mine experience at a level where they have been involved in developing the resource and reconciling against production. Exploration geologists without mine experience tend to be over optimistic on what a resource can deliver. Often geologists will assume that mineralisation is continuous and I have seen several examples of companies losing large investments because the geological interpretation was not correct” (p13 Group B).

Perhaps the issue is due to a lack of appreciation of the inputs, processes and inherent variability in geology at the higher ranking management levels. Management and executives in some organisations “see resource estimates as things that can be generated to provide a prescribed (often corporate) objective which is often unrealistic and based on assumptions that show a lack of understanding in the process.” (p15, Group A). When they do not understand the process, they limit the time and funds and, thereby, undermine the geological quality. Corporate bullying has a significant negative influence on both the competency development and the quality of resource estimates. This corporate bullying takes the form of pressure, especially on less experienced or timid resource geologists, to produce a specific target estimate to a target level of risk allocation or classification. “Whilst obviously those competent and experienced practitioners can always explain the resource estimation process in terms people can understand, and therefore temper expectations with a dose of reality and so avoid these pressures, those new in to the area trying to develop their skills in estimation can often be bullied by corporate decision makers” (p15, Group A). Corporate executives who express target estimate values ahead of the estimation process “do not necessarily bring out the best behaviours in people” (p25, Group D). Pressure “to be a little more expansive in their interpretations to reach a predetermined target set by directors/exploration managers ... is usually brought to bear on younger inexperienced personnel” (p53, Group D). Group C participants do not note the risks of corporate bullying. Clearly, the professional community

needs to find ways to protect the quality of the estimates as well as the reputations and development of less-experienced resource geologists. One participant shared positive moves by their organisation: “(The company) very clearly stated that their expectation was that as a competent person they wanted me to report transparently and honestly. They had a confidential hotline for reporting of breaches” (p23 Group C).

All groups agree that attempting to produce a quality estimate is challenging when time and/or funds are limited. This can undermine resource geologists’ confidence in their work: “models are required by engineers and planning departments as soon as they have finished running. There is huge pressure on geologists to produce models by a deadline. Unfortunately, geology doesn't always behave and often interpretations are rushed, including time spent on statistics, variography and even validation. As a result, mistakes are made and, when found, can lead to embarrassment and a feeling of incompetency on the part of the geologist” (p11, Group B). This time pressure is experienced predominantly by resource geologists in junior companies and is exacerbated by limited funding. More than undermine the actual estimation process, limited funding and associated shortcutting affects the data quality, database integrity and the opportunity to validate the work properly. Limited funding also results in more isolation from expertise and more “pressure to rapidly develop estimation skills on site” (p12, Group D). When coupled with limiting access to expertise, this lack of funding means “sometimes key understandings may be missed” (p12, Group D). Moreover, the pressure to produce within time and funding constraints causes resource geologists to “stick to what (they) know rather than rigorously exploring how to get the most out of the data” (p45, Group D). This limits opportunity for reflective learning and for the evaluation of alternative and potentially more suitable processes. Development is further impaired when competency development is constrained during the lean economic times:

“During periods of downturn, there is a tightening of developmental budget and a period of time where it becomes difficult to keep up with developments in resource generation. Similarly, it is more difficult to get training in the general aspects of the geology to develop basic careers. Many people leave the industry and therefore the pool of potential resource geologists becomes reduced and the mentoring process has to start again for new industry starters for the next industry upturn. Some companies don't necessarily appreciate the more specialist development required for resource geology and consider the position less important to put effort into training and development” (p46, Group C).

Only participants in Groups C and D raise the issue of process simplification. They describe the limiting influences of ‘black box’ approaches where there is limited exploration or evaluation of alternative approaches. In part, process simplification is a response to financial/resourcing and time constraints and pressure. Interestingly, however, Groups C and D also tend to have limited mathematics or statistics training and there is potential that ‘black box’ approaches are also limited by a lack of confidence to explore alternative techniques or create innovative solutions.

Administration creep refers to the growing non-core responsibilities expected of geologists. These non-core responsibilities add to the workload and displace opportunity to reflect and engage more intellectually with the resource estimation process: “(C)urrent day geologists tend to spend more time doing administration and a lot less geology. I think the pressures of a mine environment and the use of computers and the need of more and more detailed reports and contractor management etc. tends to take the geologist time away from undertaking more geologically focused tasks.” (p20, Group A). Given the discussion above concerning deadlines and funding pressures, it is imperative that resource geologists safeguard the time they do have to concentrate on producing quality estimates.

As intimated before, exploration organisations may find themselves disadvantaged since “Exploration geologists without mine experience tend to be over optimistic on what a resource can deliver” (p13, Group B). In addition, “mining companies appear to be more stringent with reporting practices than exploration companies. Exploration companies tend to be more focused on costs, and areas for cost cutting measures ... this is where reporting and work standards are usually affected the most” (p29, Group A). Moreover, the time and effort spent on the quality of the data collection is different for exploration and mining geologists: “Geologists with a mining background always seem to have a stronger focus on QAQC and stringent sampling controls than exploration geologists” (p29, Group A).

All four groups recognise the support and resourcing available for competency development in larger organisations:

- “... larger companies tend to offer more resources to assist in developing competency and also have mentoring available ... Smaller companies tend not to be able to offer the opportunities required to develop in this area” (p15, Group A)
- “I found the mining companies I have worked for have been generous and supportive with training while I was learning (mostly majors, and one mid-cap).” (p21, Group B)
- “In my experience mining/exploration companies, if they are large, are often good for providing training, work experience and mentorship...I would imagine that in smaller

companies that training, work experience and mentorship may be harder to get...

(p41, Group C)

- *“Mining companies have finally caught on and have to ensure that the resources are compliant - The larger companies have established departments with experienced personnel to assist and control the resource processes of individual mines or business units”* (p22, Group D)

More experienced participants, however, note that larger organisations constrain development by limiting responsibilities: “Some majors may not share the responsibility with junior staff, (they are) too compartmentalised” (p51, Group A) and they hinder competency development “when they are not prepared to promote for extra responsibilities” (p41, Group C). In contrast, resource geologists working in smaller companies may find “...promotion for extra responsibilities may be more achievable” (p41, Group C). However, there is concern that the quality of practice is compromised since “smaller companies often do not have an inkling of what is really required” (p42, Group D). Within smaller organisations, there is greater access and contact between resource geologists and corporate executives, which could be responsible for “the pressure that some practitioners are often under to meet corporate objectives with regard to reporting resources” (p15, Group A). This is exacerbated when corporate or management Key Performance Indicators (KPIs) are linked to Mineral Resource and Ore Reserve targets, which (as noted earlier) “do not necessarily bring out the best behaviours in people” (p25, Group D). These executives are “aggressive with their demands and sometimes not very cognisant of the technical issues” (p21, Group B). This pressure then forces “younger inexperienced personnel to be a little more expansive in their interpretations to reach a predetermined target set by directors/exploration managers” (p53, Group D). In contrast, “competent and experienced practitioners can always explain the resource estimation process in terms people can understand, and therefore temper expectations with a dose of reality and so avoid these pressures” (p15, Group A). In part, this pressure can be attributed to corporate executive and management who lack technical backgrounds necessary to appreciate the variation and the meaning of ‘risk’ resource geologists place on the classification. Specifically, “interpretations change through the process and some can't understand the variability between an Inferred and Measured Resource could change with additional information, new information, different information” (p25, Group D).

Resource geologists working as consultants applaud the opportunity for exposure to a breadth of mineralisation styles and commodities as well as the opportunity to explore alternative techniques and approaches and talk about “being exposed to new commodities and styles of mineralization ... (that allow them to) ... gain depth of experience” (p21, Group B). The consulting projects are diverse and challenging and allow resource geologists to “review and

research into areas of importance to resource estimation that may not have been undertaken working for a single client on one or two projects” (p15, Group A). In addition, working in consulting firms provides direct and immediate access to “many peers/mentors of considerable experience” (p19, Group C) and “I think that consulting provides much more of the 3 key things ... (mentoring, opportunities and responsibility)... which is probably why I am doing it now” (p41, Group C). However, the distancing of resource geologist from the operation does beg the question of how often consultants have the opportunity to reconcile their estimates and how well their estimates account for the geological setting.

Management and operational systems feature as important aspects for competency development. Ultimately the quality of the work “depends on the people who drive the business” (p29, Group A). “The general culture of the company has a big influence on the resource reporting e.g., is company run by accountants/lawyers or technical people striving for technical excellence?” (p21, Group B). More than purely a power/resource influence on opportunity for competency development, organisations provide the resources to enable professional learning through training, mentoring and peer review. There is therefore an expectation that managers or superiors provide technical leadership through a demonstrated guidance. However, many participants noted their managers and corporate leaders lack the expertise or the understanding and appreciation of the requirements and process (corroborated early with the finding that one in four senior managers have lower than expected levels of JORC Code reasoning). This results in unrealistic expectations in terms of delivery deadlines and the associated impact on quality in the estimates. Therefore, whilst there is a need for resource geologists to develop their understanding and appreciation of the mine-value-chain, resource geologists suggest a reciprocal understanding may be necessary to foster improvements in resource estimation quality.

Competency development opportunities differ according to corporate focus. Exploration companies offer limited opportunity to build an understanding of the mine-value-chain (through lack of reconciliation and operational opportunities). In contrast, mining companies are better positioned to provide this exposure. However, mining companies range between large multi-operational and multi-commodity companies through to junior single site operation companies. The participants expressed diverging views on the pros and cons of different scales of organisations. In general, larger organisations are credited with providing more resources for training and mentoring, but with a limited range of responsibilities and longer term career opportunities, while smaller companies allowed resource geologists to take on greater responsibility and more fully experience and interact within multidisciplinary teams, thereby building their learning through exposure to the mine-value-chain. Consulting

companies offer an alternative employment option for resource geologists. These firms employ resource geologists to either act as or support Competent Persons by estimating and classifying resource estimates on behalf of mining or exploration companies. The primary advantage of employment in consulting firms is the opportunity for exposure to a wide range of commodities, mineralisation styles and corporate imperatives. However, concerns are raised that consultants may be too removed from the geology of the various projects.

Regardless of organisation type or size, there is an overwhelming view that the mining industry as a whole operates with a short-term view. This is evidenced by the organisations' common reaction to cut competency development resourcing during economic downturns. This contributes to the skills shortage and further exacerbates lack of access to expertise in subsequent boom markets.

Within organisations, there are varieties of technological systems to support the business of generating resource estimates. Some of these are more rigid, while others are more flexible and, in some cases, non-existent, which requires the Competent Person to be more creative with their tools.

On reflection, the ideal organisation for resource geologists to develop their competency should provide (Figure 52):

1. Funding to resource access to expertise through either internal or external technical mentors, attendance on courses, at conferences and seminars as well as support postgraduate studies or research;
2. High standards for reporting resources as well as maintain these expectations through formal peer-review processes, regular and unambiguous articulation of expectations, supported through sanctioning processes that seek to uphold those standards; and
3. Roles that offer suitable degrees of responsibilities and support across the internal network to ensure high standards.
4. Organisations provide more opportunity for competency development when they offer a variety of mineralisation styles and opportunities for multi-disciplinary collaboration.

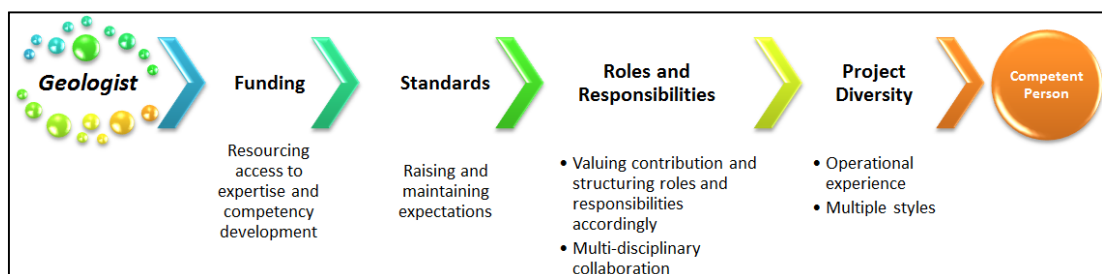


Figure 52 Ideal Organisation and Competency Development

Critical Finding 35:

Organisations provide opportunity through funding of learning opportunities and access to expertise.

Critical Finding 36:

Organisations contribute to Resource geologists' learning through the standards they set and uphold.

Critical Finding 37:

Organisations facilitate learning and support through the provision of appropriately defined and allocated roles and responsibilities.

Critical Finding 38:

Organisations provide competency development through the provision of diverse projects.

7.5 Findings and Interpretation

7.5.1 Competency Development Themes

Overall, resource geologists in all four competency groups identify similar factors in their paths to competency. There are, however, factors that could differentiate resource geologist in Groups A and C (shown with ticks in Table 36). In summary, the differentiating comments between Groups A and C are:

- Group A participants value their undergraduate degree for providing scientific thinking skills, while group C sees limited value in their degree.
- Group A attributes their analytical skills to their mathematics and/or statistical education. In contrast, participants in Group C offer comments arguing either that their lack of skills has not hindered their progress or that their mathematics and/or statistical education is of limited value to their estimation processes.
- Group A participants seek out training courses that develop their practical skills and augment their training with situational learning – either through formal mentoring or through support from their peers.
- Group A recognise the importance of mine-value-chain experience for developing breadth of understanding and long service with single projects for developing a depth of experience by learning from mistakes.
- There is little difference in the way groups A and C access their professional networks, except that Group A makes added use of social media, while group C access use training courses as an additional avenue to access expertise.
- Beyond the common issues regarding organisations raised by the two groups, Group A raises the additional issues of corporate bullying, administration creep and lack of operational experiences, which undermine competency development. Group C comments on the limiting influence of simplified processes.

Core differences between the competency development of participants in Groups A and C relate to a broader appreciation for the business of mining. Group A participants appear to have a more mature perspective of experiences, opportunities and the need to cultivate an intellectual rather than procedural approach to the broader context of the business of mining within which resource estimation fits.

Table 36 Comparison of Themes by Competency Group

Theme		Group			
		A	B	C	D
Geology	Fundamental tools of trade				
	<i>Limited value</i>			✓	
	Scientific thinking	✓			
Maths/Stats	Conceptual understanding	✓			
	Innovation	✓			
	Confidence to question	✓			
	<i>Lack of hinders or not</i>			✓	
Training	Fundamental concepts and theory				
	Practical	✓			
	Access to experts	✓			
	Coupled with situational learning (formal mentoring)	✓			
Experiences	Operational Experience				
	Internal WP network				
	Data collection - geology				
	Reconciliation				
	Responsibility for RE				
	Peer reviews				
	Mine-value-chain	✓			
Variety of styles					
	Long service	✓			
Professional Networks	Access to expertise				
	Validation of approach				
	Evolution of ideas				
	Exposure to new ideas				
	LinkedIn discussions	✓			
	Contribute to others				
Limited					
	<i>Courses</i>			✓	
Organisations help	Provide mentoring				
	Fund postgraduate studies	✓			
	Pay for courses/conferences				
	Raise Expectations				
Organisations hinder	Lack of access to expertise				
	Misaligned responsibilities/roles				
	Undervalue/misunderstand contribution of geology				
	Corporate bullying	✓			
	Time/cost/resource pressure				
	<i>Process simplification</i>			✓	
	Admin/HR creep	✓			
	Explorationists signing off on resources	✓			

Clearly developing competency in group B is simply a matter of time (in the case of mining industry and resource estimation experience) and exposure (to fulfil the '15-2-5' criteria). For Group B resource geologists, the concepts within the JORC Code are understood and qualification to Competent Persons status is limited merely by lack of experience. Time and exposure will increase the credibility of members in Group B.

Developing competency of a resource geologist in Group C is altogether a different matter. Resource geologists in Group C have already met the time and exposure criteria, but lack JORC Code contextual reasoning. The significant differences in the experiences of competency development between Group A and Group C lies firstly in Group C resource geologists' lack of appreciation of the mining business and, secondly, in their lack of recognition for the value of inter-disciplinary relationships. Furthermore, Groups C and D are limited in their professional silos and neither group has sufficient recognition of the mine-value-chain. There is thus a responsibility within the industry to ensure a greater multi-disciplinary awareness and broaden the business focus for people it deems Competent Persons.

Developing a group D resource geologist requires a combination of time and exposure. Beyond aiming to attain the minimum time and '15-2-5' requirements, resource geologists would benefit from the following competency development opportunities to help develop JORC Code reasoning levels:

- Attend practical training courses augmented with situational learning under knowledgeable technical mentors;
- Develop scientific philosophy and enquiry through exposure to discussions and forums that extend beyond immediate role requirements;
- Resource geologists would benefit from a tertiary credit in mathematics or statistics to develop insight into the thought processes in data analysis;
- Explore the business of mining by curiously seeking to understand the full mine-value-chain at every operation they work in;
- Deliberately grow egocentric professional networks by engaging in local experts and contributing to the learning of others;
- Work for organisations that maintain high standards and expectations and who support competency development through operational experience, diversity and collaboration between disciplines and amongst geologists. Moreover, the roles on offer should be accompanied by appropriate levels of responsibility and support.

Next, these findings are compared with the experts' expectations.

7.5.2 *Comparison with Experts' Expectations*

The competency development themes summarised above corroborate those identified by the experts (§4.3.1, page 73), namely:

1. Competency development across a range of experiences is important for developing breadth and mining industry context to resource geologists' understanding and competency. Operational experience with due regard for a range of geological styles is necessary;
2. Long service is important. Even though many resource geologists are transient (sometimes moving between operations with no more than 12 months experience at each operation) long service on a project provides opportunity to experience the consequences of corrections to mistakes. This contributes to a depth in understanding through experiential learning that cannot be accommodated through formal training. In addition, resource geologists gain competency through experiencing a variety of mineralisation styles.
3. Workplace experiences and learning through those experiences are the primary means of developing competency;
4. Learning through training courses is of limited value unless augmented with timely situational learning under a technical mentor. This approach is akin to learning through an apprenticeship or internship;
5. Working within a professional network is critical for accessing and contributing to expertise. Resource estimation expertise cannot be developed without regular peer review and exposure to alternative approaches;

In addition, the data analysis suggests a potential difference between the different styles of tertiary geology education. Moreover, there is a potential that a lack of mathematics or statistics training can undermine the competency of resource geologists. Whilst there is insufficient data to comment confidently on these two issues, they are worthy of further research because of their potential influence to cap resource geologists' reasoning levels.

7.5.3 *Interpretation and Research Questions*

The original overarching research question was:

What does it take to develop Competent Persons for the JORC Code?

However, as evidenced in Chapter 6, there are differences in JORC Code reasoning levels, even within the group that qualify under the '15-2-5' criteria. The overarching research question therefore had to be reframed to address this evidence. The reframed question is:

What is the difference in competency development experiences between resource geologists with higher and lower JORC Code reasoning levels?

The factors emerging as contributing to higher reasoning levels in resource geologists are summarised according to the four research sub-questions.

1. *What formative qualifications enable professionals to qualify as Competent Persons according to the JORC Code?*

Resource geologists should have at least an undergraduate science degree with a major in geology. These geologists benefit greatly when they have credit in at least one semester of either mathematics or statistics.

2. *What workplace experiences facilitate development of Competent Persons' competency?*

Development of resource geologists involves both formal and informal workplace learning. Industry training courses should be augmented with situational learning, supported through either formal or informal mentoring. Workplace support, in terms of a community of experts, enables resource geologists to learn their practice through mentoring, peer reviews, technical discussions and exposure to a variety of situations.

3. *How do professional networks stimulate the development of Competent Persons' competency?*

A network of competent professionals is critical to the development of resource geologists' competency. Access to expertise and situational review is critical to the development of both breadth and depth of understanding and ability. Given the transient nature of resource geologists as well as the network members, these networks are located beyond the organisational construct and are placed as global industry-based egocentric networks.

4. What organisational factors influence Competent Persons' competency development?

Organisations provide the workplace opportunities to develop resource geology competency. Furthermore, organisations provide funding for access to competency development (such as access to expertise through either internal or external technical mentors; attendance on courses, at conferences and seminars or through funding of postgraduate studies or research). The standards and expectations set by organisations facilitate the target aspirations of the employed resource geologists.

8 Practical Findings and Discussion

The analyses in the previous three data analysis chapters provide a wealth of findings, including both practical findings that are immediately applicable within the mining industry and theoretical findings that challenge the current thinking in workplace learning theory.

The focus of this section is to consolidate these findings, develop the interpretations and discuss the implications from practical perspectives as they relate to resource geologists, organisations and mining industry professional bodies.

The discussion firstly focuses on the findings, implications and recommendations in accordance with the analysis, namely: (1) the JORC system; (2) Articulation of competency; and (3) Competency Development.

Next, the findings, implications and recommendations are framed from the perspectives of key stakeholder in order to facilitate dissemination. The key stakeholders addressed here are (1) resource geologists, (2) organisations employing resource geologists and (3) professional bodies.

8.1 Overall Findings, Implications and Recommendations

The analyses and practical implications of this research are summarised in a Findings-Implications-Recommendations matrix (Table 37). There are three aspects that need to be addressed:

1. Implications for the JORC system,
2. Implications for JORC Competent Persons' qualifying criteria, and
3. Implications for the development of JORC Code reasoning competency.

Table 37 Findings-Implications-Recommendations Matrix

Focus	Key Findings	Implications	Recommendations
The JORC System	Stability of the JORC system rests on the technical competence of Competent Persons	The JORC system is vulnerable to unsuitable claims of competency	Revise qualification criteria
	There is no sanctioning process for technical competency within the JORC system	The JORC system is vulnerable to unsuitable claims of competency	Revise sanctioning processes
Articulation of Competency	Current qualifying criteria are insufficient to identify competency in accordance with industry expectations	Resource geologists without appropriate reasoning levels are claiming themselves as Competent Persons	Review the current JORC Code competency criteria
	Alternative criteria in general provide improved identification of resource geologists with appropriate JORC Code context reasoning	Improved practical qualifying criteria are possible	Revise the JORC Code competency criteria
Competency Development	Higher reasoning resource geologists identify value in undergraduate training in scientific reasoning	The development of scientific thinking in undergraduate training is necessary	Future research should include an investigation into the difference between styles of universities preparing geologists
	Higher reasoning resource geologists identify value and benefit in at least one semester credit in mathematics or statistics at university level	At least one semester of mathematics or statistics may be required to develop higher levels of mining context reasoning	Future research should include an investigation into the content of the mathematics/statistics units that best suits and assists in the development of higher levels of reasoning
	Deliberate operational experience across the mine-value-chain and within a variety of contexts contributes to the development of competency	Competency requires exposure to practice, including the development of multi-disciplinary understanding and multi-contextual application	Criteria for competency should include demonstration of both breadth and depth exposure
	Formal training must be augmented by situational learning under the guidance of an expert	Training courses alone are ineffective and, similarly, exposure to situation learning is improved with timely formal structured knowledge transfer	Development of Competent Persons should follow an apprentice style model that leverages off timely formal training
	Competency development requires the deliberate creation, development and nurturing of enduring egocentric learning networks that extend beyond the confines of organisations	Competence cannot be developed in isolation nor can it be constrained within or by organisations	Professional bodies should invest in the deliberate creation and nurturing of communities of practice styled to accommodate the transient egocentric learning networks individual professionals create
	Organisations fund competency development opportunities	Organisations must see benefit from the competency development	Individuals should seek to contribute to organisations through the judicious application of competency
	Organisations provide practice opportunities through breadth and depth of projects	Resource geologists' competency is constrained by the available opportunities	Resource geologists should, over time, work for a variety of organisational styles and operations
	In the absence of an industry sanctioning mechanism, resource geologists operate to organisational standards	Standards are vulnerable to variations in organisational expectations	Standards need to be set by the professional bodies through the establishment of a technical competency sanctioning mechanism

8.1.1 *The JORC System*

The stability of the JORC system rests on the technical competence of Competent Persons and the potency of the sanctioning process. However, the current sanctioning process, which does not include evaluation of the technical work underpinning public reports, nor does it include an evaluation of the quality of the claims to competency, leaves the JORC system vulnerable to misrepresentation or unsuitable claims to competency. A revision of the qualification criteria and sanctioning process are recommended to address these concerns.

8.1.2 *Competency Criteria*

The current Competent Persons' qualifying criteria are insufficient to identify competency in accordance with industry expectations. According to the sample set, two thirds of resource geologists claiming to be Competent Persons lack the style of reasoning implicitly expected within the JORC system.

This study has identified an alternative set of criteria that increase the likelihood of a resource geologist's reasoning is provided by the '15-2-5' criteria:

- *At least 10 years' mining industry experience*
- *inclusive of at least five years' resource estimation experience*
- *with at least 15 estimation models*
- *across at least two commodities, and*
- *five reconciliation studies.*

The criteria presented above need to be supported with sufficient deliberate practice engagement in both geology and resource estimation. The expert should have sufficient wisdom to evaluate potential risks across the mine-value-chain in accordance with the items in JORC Code's Table 1. Competent Persons' reasoning development requires exposure to both breadth and depth in practice application, and an ability to contextualise the issues within the mine-value-chain.

8.1.3 *Competency Development*

Resource geologists with higher levels of reasoning recognise the value of developing scientific reasoning in their undergraduate training. This suggests future research in competency development within systems such as the JORC system should include an investigation into the difference between styles of universities preparing geologists.

These higher reasoning resource geologists also appreciate the value and benefit in attaining at least one semester credit in mathematics or statistics at university level. Where absent, it may therefore be necessary to develop mathematical or statistical skills to this level within the

workplace. Geology students should also be encouraged to attain at least a semester unit in mathematics or statistics. Future research should also consider including an investigation into the content of these units that best suits and assists in the development of higher levels of reasoning.

This research has identified that deliberate operational experience across the mine-value-chain and within a variety of contexts contributes to the development of competency. Geologists considering a career in resource geology should thus ensure exposure to practice, including the development of multi-disciplinary understanding and multi-contextual application. The criteria for competency should also include a requirement for resource geologists to demonstrate both breadth and depth in their operational experience.

Formal training in resource estimation is enhanced when it is augmented with situational learning under the guidance of an expert, since training courses alone are ineffective. Similarly, exposure to situation learning is improved with timely, formal and structured knowledge transfer. Development of Competent Persons should follow an apprentice style model that leverages off timely formal training.

Competency development requires the deliberate creation, development and nurturing of enduring, egocentric learning networks that extend beyond the confines of organisations. Competence cannot be developed in isolation, nor can it be constrained within or by organisations. There is thus a mining industry community responsibility to encourage resource geologists to deliberately develop quality networks from which they can draw learning, support and review. Professional bodies could invest in the deliberate creation and nurturing of communities of practice styled to accommodate the transient, egocentric learning networks individual professionals create.

Organisations that fund competency development opportunities deserve a return on their investment. As such, individuals should seek to contribute to organisations through the judicious application of their competency, including the development of others within organisations' workplaces.

Organisations provide practice opportunities through breadth and depth of projects. Resource geologists' competency, therefore, is constrained by the available opportunities. Resource geologists should, over time, seek to work for a variety of organisational styles and operations, whilst ensuring the time spent on operations is sufficient to gain learning through consequences of correcting their own mistakes.

In the absence of an industry sanctioning mechanism, resource geologists operate to organisational standards, which are vulnerable to variations in organisational expectations. There is an opportunity for professional bodies to establish and uphold technical standards through the establishment of a technical competency sanctioning mechanism.

8.2 Stakeholder Recommendations

The practical recommendations for resource geologists, organisations and professional bodies are reframed in the discussion that follows.

8.2.1 Resource Geologists

The most basic outcome of this research is the articulation of a more measurable mechanism for differentiating between Competent Persons who can apply a mining contextual reasoning when operating within the JORC Code definitions and guidelines, and those who cannot. In summary, the requirements for Competent Persons signing off on classified mineral resource estimates for use within the JORC Code framework should be revised to:

Competent Persons are resource geologists with at least a Bachelor's degree that includes a major in geology and at least one semester of a mathematics or statistics unit. Their experience is based on at least 10 years' mining industry experience that includes at least 5 years' experience in resource estimation. The resource geologist has generated at least 15 resource estimation models over at least two commodities and at least five reconciliation studies. The geologist's workplace experiences should include operational experience where they have had opportunities to develop an appreciation of the context of the resource estimate within the full mine-value-chain (from sample collection through to mineral processing). Resource geologists should attend a range of practical training courses and time these with situational learning under the guidance of an expert resource geologist. Resource geologists should deliberately seek to develop their professional learning network by accessing experts within their organisations and beyond. They should also seek to work for a range of organisational styles to develop an appreciation of the business of mining and the range of imperatives this necessitates. Given the transient nature of resource geologists, the onus is on the individual to become their own career manager, and to use the above revised criteria as a benchmark when seeking out the opportunities that best provide them with the foundations for eventual competence.

8.2.2 Organisations

Organisations play a significant role in the development of resource estimation competency, primarily through the creation of workplace opportunities, through funding to enable access to expertise and by setting the standards to which resource geologists aspire. Importantly, organisations only contain a temporal subset of resource geologists' learning networks and there is perhaps opportunity for organisations to leverage off these networks by contributing more proactively to the development of these networks and nurturing the networks outside the confines of the organisation context. Rather than proffer career management for resource geologists, organisations should position themselves as opportunity providers within the transient pathways of emerging Competent Persons.

8.2.3 Professional Bodies

The professional bodies to some extent represent the amalgamation of the various professional and learning networks. Therefore, these professional bodies have significant influence on the professional and technical standards and expectations within the industry. The description of the JORC system highlights the influence that these professional bodies have on setting the standards for ethical and professional engagement. Whilst the JORC system relies heavily on the peer review, the analyses in this research highlight the considerable potential vulnerabilities that result. In reality, the community is too close-knit and the guidelines for competency too vague for deliberate and constructive intervention. Moreover, the formal sanctioning process within the JORC system operates on contraventions of ethics and behaviours. There are no mechanisms for formally developing, monitoring and approving technical competency. The introduction of a professional development monitoring system, such as the current form of the AusIMM's Chartered Professional status, does not guarantee the professional is competent in applying the JORC Code. This study shows there is no difference in reasoning levels for those with or without Chartered Professional (or equivalent) status. This is not surprising given the necessity for resource geologists to build their competencies through active workplace participation and exposure. Training or attendance at seminars and conferences adds to the individuals' knowledge base, but the actual doing of the work is where the reasoning levels have opportunity to develop. The professional bodies should therefore consider revising how the reasoning competency required within the JORC system is measured and monitored.

9 Competency Development Model

The original impetus for this research was founded on practical mining industry concerns. By drawing on the theories of Structuration Theory, Learning Network Theory, Communities of Practice and Statistical Reasoning, and the factors evidenced in this research, it is possible to construct a model of competency development that could be applied more generally to transient professional scientists.

The purpose of this chapter is to consolidate the emerging patterns in the data analyses and the theory to provide a framework for future researchers to explore more general competency development.

The first section generalises the models established during the data analysis and explores these within the context of the associated theories. The second section provides a generalised summary of the above before the chapter closes with a discussion on the implications and recommendations for future research.

9.1 Models Grounded in Data Analyses

The generalisations and patterns emerging from the data analyses and interpretations in Chapters 5, 6 and 7 can be broadly summarised into four themes (Figure 53):

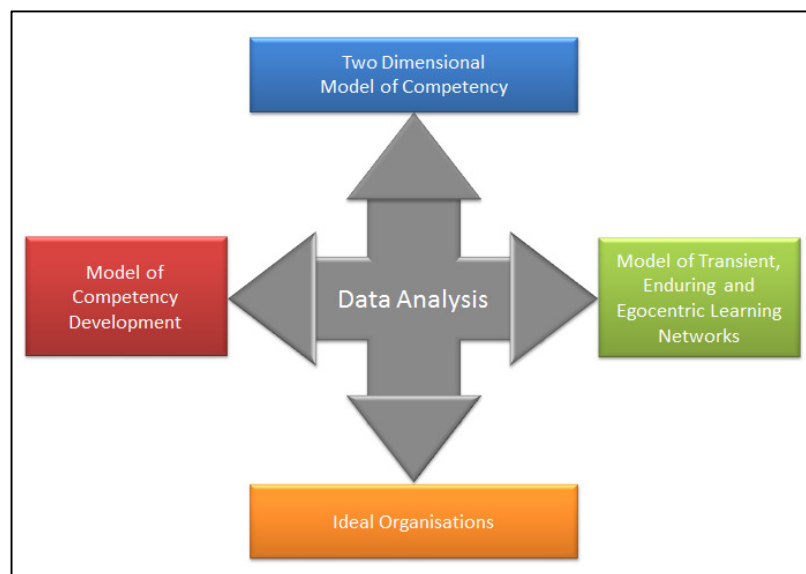


Figure 53 Themes Emerging From Data Analyses

1. **A Model of Competency Development:** This first model is created from the themes established in the comparative analyses between higher reasoning and lower reasoning qualifying professionals. Competency development is framed within the practice community. In this study, the practice community (the JORC system) was described using Structuration Theory.
2. **A Two-Dimensional Model of Competency:** The second model revises Dall’Alba & Sandberg’s (2006) dimensions of skill accomplishment and embodied understanding to dimensions of practice exposure and contextual reasoning. More than simply understanding a task or set of tasks, expert professional scientists in particular require a higher level of reasoning that enables them to contextualise their work as well as the consequences of their findings and recommendations within the broader business within which they operate.
3. **Enduring, transient, egocentric networks:** Rather than position learning networks within organisations, such as Learning Networks Theory, this model focuses learning networks at the individual level for transient professionals. These egocentric learning networks endure relocations of the individual and the network connections. In some respects, the agglomeration of these learning networks is akin to a Community of Practice. However, rather than have the power base operate from the community inwards towards the individual, these egocentric networks are managed by the individuals themselves. As a result, there is variation in access to experts that may be linked to the confidence of and opportunity experienced by the individual.
4. **Ideal Organisations:** Organisations employing professionals have a significant influence on the learning and experiential opportunities for competency development. Ideal organisations set the benchmark of expectations, provide funding for access to expertise, dictate roles and responsibilities and offer the types of experience opportunities for situational learning.

These models are now discussed in the context of the associated theories, including:

- an examination of the industry system structure in terms of Structuration Theory,
- a consolidated competency development model, a revised definition of competency,
- a model of egocentric learning networks,
- a contribution to the discussion on informal/formal workplace learning, and
- an outline of what constitutes an ideal organisation for competency development.

9.1.1 Industry System Structure

The style of competency explored in this thesis is that of an expert-reasoning competency. The requisite reasoning enables experts to apply judicious combinations of knowledge, experience and professional anticipation to a series of unique events. The reasoning is framed within a set of institutionalised principles, guidelines and definitions. Invariably these principles, guidelines and definitions evolve in response to and in anticipation of actors' behaviours. The changes invoked in the principles, guidelines and definitions also influence the subsequent behaviours of the community to which they apply.

As presented in §5 (page 89), Structuration Theory provides a valuable lens for exploring an example of such an environment. The key difference in the approach adopted for this study, contrary to the studies reviewed in the literature, was to begin the exploration of the social construct from a wider perspective and then to drill down through the social processes and then the human interaction. This approach provides a more encompassing and systematic exploration of the social order. This drill down approach demonstrates a successful application of Structuration Theory without having to hold either the structure or agent static (see review of criticisms in §2.3.3 on page 32). Indeed, the use of Englund & Gerdin's (2008) four forces of Encoding, Enacting, Reproduction and Institutionalisation provided a valuable springboard for coding and theming of the interview data. On reflection, Giddens' Structuration Theory provides a valid and accessible mechanism for exploring social constructs.

The central concept of dualism within Structuration Theory is evident in the evolution of the JORC system. In particular, the behaviours within the mining industry investment community in the early 1970s ultimately spawned a new sub-discipline within geology, creating a new set of technical and behavioural requirements within the mining industry. This process required symbiotic adjustments in structural controls, modalities and behaviours and highlights the gradual and diverse influences inherent in social change. A persistent aspiration of the JORC system is to uphold the quality and credibility of the professionals operating in the system. The JORC system describes the structures, processes and human interactions around public reporting of Mineral Resources and Ore Reserves that work together to sustain these aspirations. The order and systemisation of the JORC system is evident when viewed through a Structuration Theory lens (Figure 54).

Structuration Theory	Systems of Knowing and Meaning	Systems of Ordering Resources and Power	Systems of Rules of Doing
Structural Patterns	The JORC Code and guidelines	JORC reporting process and Definitions of Competent Persons	ASIC; AusIMM and AIG Ethics and Complaints Process
	↕	↕	↕
Modalities	Various publications (e.g. Monograph 23); JORC, ASX, AusIMM and AIG Websites; conferences/seminars; public review; public reporting; industry courses; corporate training programs and systems	ASX listing rules and ASIC regulatory guidelines Corporate guidelines	Norms in resource estimation; AusIMM and AIG's Codes of Ethics
	↕	↕	↕
Human Interaction	Peer reviews, training and competency development	Corporate executives and Competent Persons engagement and practice	Peer Review; Complaint and Ethics Committees

Figure 54 The JORC System Organised within a Structuration Theory Framework

The JORC systems can quite clearly be described in terms of the three core systems:

1. Systems of knowing and meaning: The JORC Code and guidelines;
2. Systems of ordering resources and power: the reporting processes and rules; and
3. Systems of rules and doing: the resource estimation and sanctioning processes.

Key to the JORC system is a reliance on Competent Persons, whose estimates and risk classification of mineral resources directly affect the value of the associated shares on the stock exchange. However, the analyses in §5.6 (page 111) highlight the vulnerability in the JORC system to a lack of control on self-assessed competency and an associated lack of sanction of technical competency. The mapping of the information using Structuration Theory has therefore highlighted both the key stability factor (the Competent Person) and the key vulnerability in the system (the lack of technical sanction). Beyond the practical value of these findings, this process emphasises the importance of exploring the social context of the community within which the unit of study operates.

9.1.2 Competency Development Model

A deeper analysis of the human interaction and experiences within industry system structures reveals that the following factors are necessary to support the development of requisite practice-based reasoning competency:

1. Entry requirements,
2. Workplace learning,
3. Workplace experiences,
4. Learning networks, and
5. Organisational systems and structures.

The first factor describes the qualifications that allow entry into the field of practice. For the JORC system, resource geologists should have a university degree with a geology major, preferably from an institution that encourages scientific philosophy and investigation. In addition, a tertiary unit in mathematics and/or statistics will enable broader problem solving and innovation. Each specialist practice area will require a specific and appropriate set of pre-requisite qualifications. The quality of entry requirements is likely to influence the ability of individuals to progress their competency development. It is imperative, therefore, that practice fields articulate and evaluate, beyond the content, the qualities expected from these entry qualifications to ensure advances in competency development. For example, resource geologists who appreciate the scientific thinking foundations developed within their undergraduate degrees are better placed to develop the necessary JORC reasoning.

Whilst the literature highlights many distinctions and debates between the dominance and value of informal and formal learning, the analysis of this research suggests both informal and formal learning contribute to competency development. Indeed, competency development cannot be pursued with a single-minded preference for either informal or formal learning. Instead, formal learning needs to move out of the classroom and position itself in the workplace as formal apprenticeships or internships. More than unifying the theories on informal workplace learning, this research has signalled diversity in workplace learning that translates to a broader focus on timely competency development. Therefore, rather than requiring the dominance of either formal or informal workplace learning, competency development requires formal and informal workplace learning to co-exist and to be synchronised with specific augmentation of informal development under the deliberate guidance of an expert. In this study, the overriding factor contributing through workplace learning is timely access to expertise. Unless augmented with situational learning, formal training courses are of limited value. There is thus an emphasis on developing competency within the process of practice-based exposure.

Beyond the business of deliberate learning through either formal or informal exchange of knowledge and skills, the specific workplace learning experiences required to develop reasoning are impossible to itemise, especially in a field where each situation provides a unique set of challenges. However, critical components of workplace experiences can be identified. Clearly, experiences relating to the specialisation are necessary to build competency in an area. However, specialisation on its own is insufficient. Competency development requires work experiences within a range of situational and multi-disciplinary contexts that provide the opportunity to experience the business consequences of both mistakes and corrections. These experiences also develop the specialists' skills to navigate and communicate within the business and industry. In addition, a variety of contexts, demands and responsibilities contribute experiences that develop appreciation of both breadth and depth in their practice. For resource geologists this means sufficient operational experience to build an understanding of mining context through exposure to the consequences of the practice of resource estimation, including multi-disciplinary contexts and reconciliation studies for exposure across the mine-value-chain. Moreover, competency development requires exposure to several operations. This provides an opportunity to contrast practices, and develops breadth and appreciation for diverse contexts.

Professional learning networks form a critical component of competency development. Access to experts, either through formal or informal connections, is vital to the development of professional expertise. More than transference of skills, professional networks provide an opportunity to discuss concepts, potential consequences and to leverage off a broader experience base. Formal avenues range from classroom-style training courses to more situational, formal mentoring programs. Informal networks include current and past colleagues, supervisors, internal and external specialist consultants as well as juniors who, through their questions, provide opportunities to develop and advance unrealised understanding and skills. The model of professional networks for transient workers is egocentric and endures beyond organisational confines, because members of the network relocate within the industry.

Organisations play a significant role in competency development. In particular, access to expertise is governed by organisational funding. Organisations set and maintain technical standards and expectations through their systems and actions. Organisations structure responsibilities and fill roles accordingly. Moreover, organisations provide practice opportunities from which learnings can be drawn.

These factors are summarised in a model of competency development with the following components (Figure 55):

1. A set of entry requirements specific to the area of expertise;
2. A range of workplace experiences that ensure exposure to
 1. the breadth of business value-chain, including the associated industry practices, decisions, and general functional processes,
 2. the depth of specialisation area, and
 3. the multiple-disciplinary interactionsacross a variety of industry contexts.
3. The workplace experiences are supported with well-timed training courses that are augmented by situational learning under the deliberate guidance of an expert.
4. The professional develops an enduring, egocentric professional network that is accessed for guidance, support and review. The emerging expert eventually feeds back into this evolving network by sustaining the learning of other emerging experts.
5. Organisations support the development of competency through setting standards, maintaining expectations and providing access to learning networks.

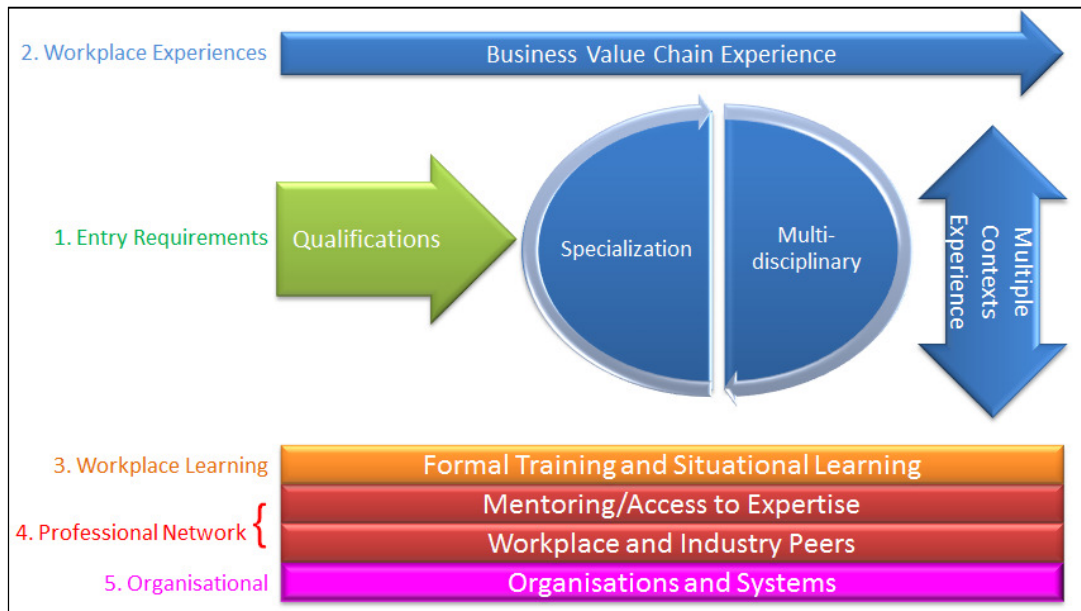


Figure 55 Competency Development Model

This model provides a synthesis of the requirements for developing practice-based reasoning competency. The next section defines an associated model of competency that describes the combination of exposure and reasoning that this model of competency development strives to attain. The section thereafter expands on the supporting learning networks within this competency development model.

9.1.3 Competency Definition Model

The literature review explored many definitions of competency. From the data analyses, it is evident that the style of competency required of resource geologists exceeds a simplistic measure based on attainment of a skill set. The evidence suggests that resource geologists claiming to be Competent Persons within the JORC system should have a minimum level of exposure to their practice or the business of resource estimation that should not simply be measured by time served in the industry. In the process, moreover, resource geologists should have developed a heightened level of reasoning in the JORC Code. These two criteria together provide a basis for establishing the following competency definition model (Figure 56).

The minimum levels for competency for resource geologists practicing within the JORC system include a minimum level of exposure (the '15-2-5' criteria discussed in §6.6.4 on page 153) and at minimum a mining context reasoning level as described by the revised reasoning levels that arise from the Rasch Analysis (§6.4.2 on page 127). This competency model asserts that context reasoning should be developed ahead of exposure to ensure value in every learning experience and is represented as the "Develop Strong Competency" trajectory in contrast to the "Develop Weak Competency" in Figure 56. The experiences to support the development of these competencies are discussed above in §9.1.2.

A general form of this competency definition model, therefore, is to ensure that industry context reasoning is developed during exposure through business practice.

The competency described here can be compared to the biaxial model presented by Dall'Alba & Sandberg (2006). Their horizontal axis, describing skills progression, is replaced here by an axis of practice exposure with a marker indicating the minimum number of times a practice has been conducted to warrant a higher probability of competency. In this case, the axis describes a combination of exposure defined by the '15-2-5' criteria.

Dall'Alba & Sandberg use the vertical axis in their model to describe the embodied understanding of practice. Instead, the model emerging from this research study uses the reasoning levels as predicted by the Rasch Analysis to describe increasing levels of context reasoning.

A competency model using the two axes of exposure and reasoning, as described here, therefore supports the competency Dall'Alba & Sandberg's (2006) seek to describe.

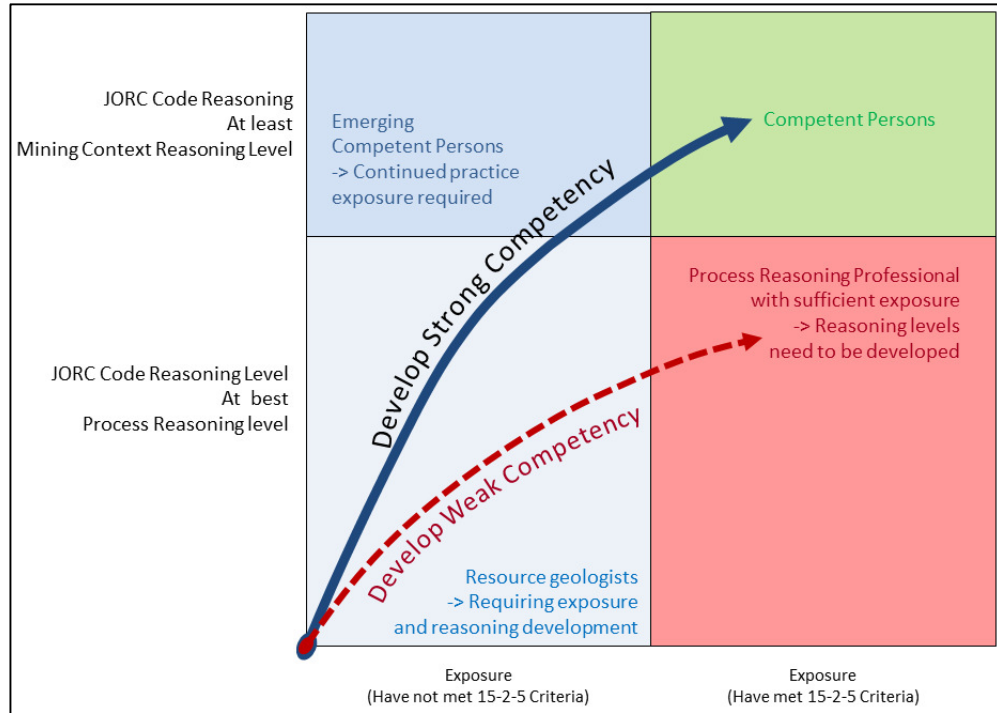


Figure 56 Competency Definition Model - Competent Person within JORC System

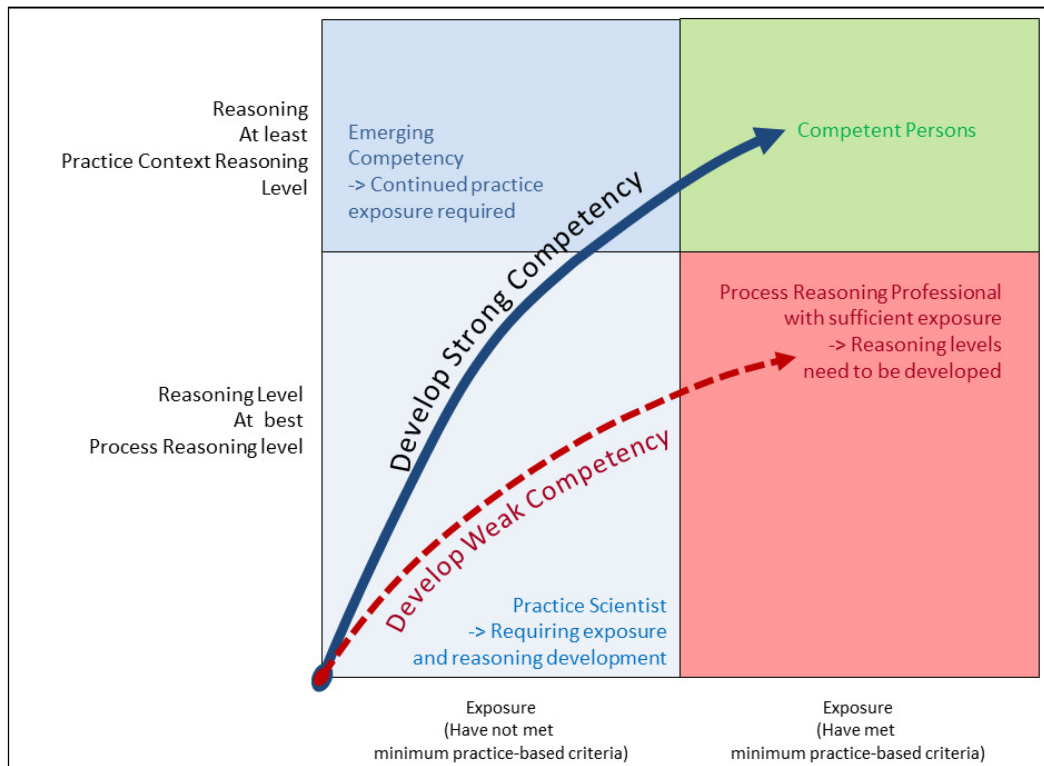


Figure 57 Competency Definition Model - Generalised

9.1.4 Learning Networks

In addition to a target competency level described above, the competency development model requires a suitable learning network. Early on in this study, Poell's (1998) Learning Network Theory promised to provide a useful framework for exploring workplace relationships. In particular, the order and systematic descriptions of diverse styles of learning networks, specifically the entrepreneurial, vertical, horizontal and external network descriptions, appealed as a potential lens for exploring the different styles of networks that resource geologists could leverage off for their learning. In retrospect, however, the researcher should have anticipated that the transient nature of resource geologists would undermine a commitment to a single style of organisationally constrained learning process. During the data analysis, it became clear that Learning Network Theory applies as a theory contained within organisations to correlate with the management structures and systems, rather than to individuals, especially transient individuals.

A more flexible model is necessary to describe the dynamics of the networks that the study participants were describing. The connections that participants described in their learning networks are highly personal and are typically based on encounters of trust. Personal networks evolve through exposure and practice encounters with peers and experts. Stronger connections seemed to occur when encounters with experts were more direct (Figure 58). These networks grow as resource geologists become more exposed to the work of others, and as the resource geologists become more experienced and thus more confident. These egocentric connections also transcend organisations and tend to endure relocations of both the individual and the network connection. The networks therefore operate above organisational loyalty.

The egocentricity of these networks requires resource geologists to take charge of establishing and developing their own learning network connections. More successful connections are likely to lead to more competent resource geologists by virtue of their ability to strengthen their access to experts and hence to a wider range of technical expertise. Rather than a community run, developed and endorsed network, such as a Lave & Wenger's (1991) Community of Practice model, the onus of creating and developing the learning network is placed very much on the individual resource geologist. The mining industry community could be viewed as an agglomeration of overlapping egocentric networks, which together reinforce and evolve the norms and expectations of the broader community. The community therefore accounts for the human interaction evidenced in the structure of the social construct explored above.

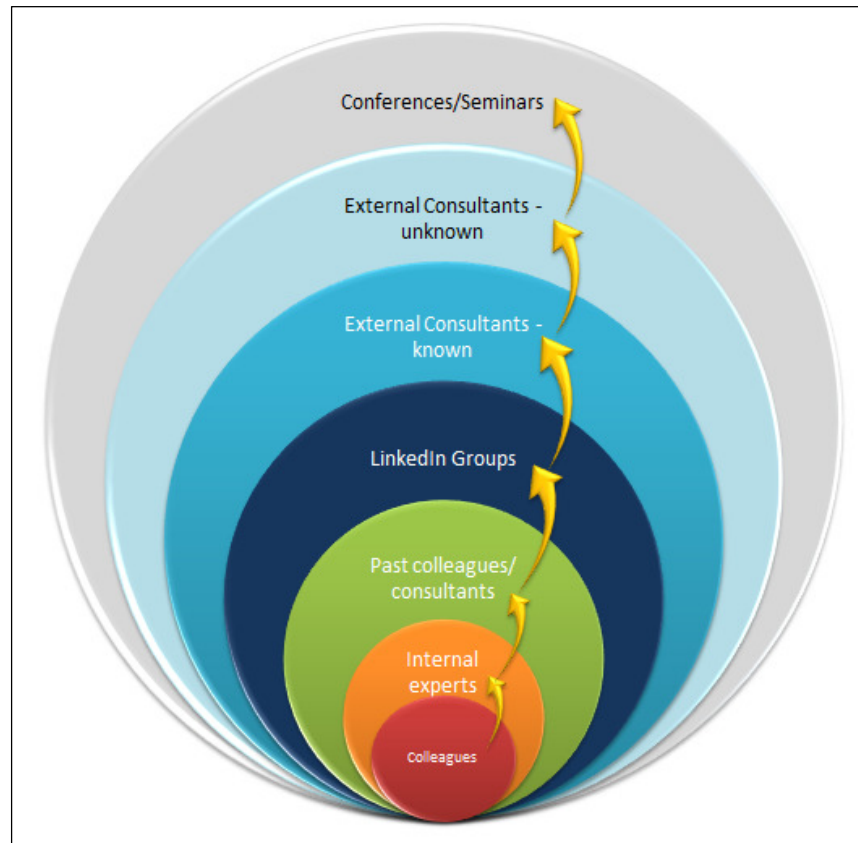


Figure 58 Network Access Hierarchy

There are opportunities for the community of resource geologists to harness theories to support the competency development. Perhaps the lack of formalised structure of a general competency development program is in part due to the infancy of the sub-discipline. The researcher recommends industry engagement in the development of a systematic program to develop resource geologists to the level of competency expected by the community. This will require industry discussion as well as formalised alternative competency criteria and more formalised mechanisms to evaluate competency achievement.

Future research could consider the development of enduring, transient, egocentric learning networks at the embryonic stages of a discipline.

9.1.5 Workplace Learning

The analysis of the informal and formal learning processes identified a combination of learning avenues that contribute to the development of competency. Whilst formal avenues equip professionals with the language of concepts, informal learning provides situational context that is vital for development of an ability to apply learning. Furthermore, the connection between formal learning and informal learning through application is contingent on timely exposure and, importantly, under the accessible guidance of an expert akin to an apprentice style arrangement. The strategic combination of formal and informal learning needs to be managed to ensure appropriate and timely exposure and application. The model presented in Figure 59 provides a basis for managing this learning strategy.

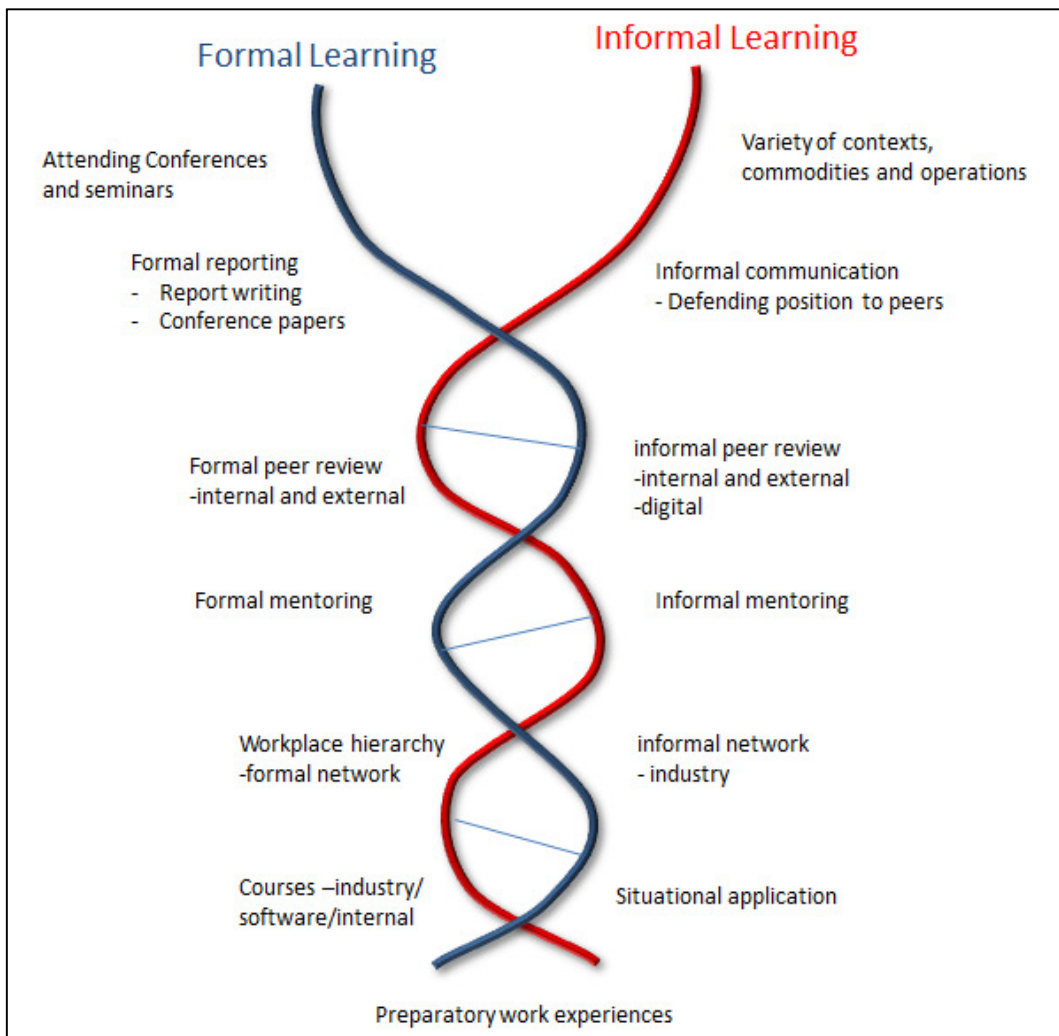


Figure 59 Dualism of Formal and Informal Workplace Learning

9.1.6 Ideal Organisation

Mining and exploration companies provide the workplace environments within which work and learning co-exist. Within Learning Network Theory the variations in organisational structures and contributions to workplace learning is evidenced in the learning processes, which mirrors work processes (Lidewey & Poell, 2003; Poell, 1998; Poell, Chivers, Van Der Krogt, & Wildemeersch, 2000; Poell, et al., 2003; Poell & van der Krogt, 1997; Poell, et al., 2006; Poell, et al., 1998; F. J. van der Krogt, et al., 1998). Learning Network Theory provides mechanisms to leverage off the mapping of these work processes to develop learning processes. However, the scale of this mapping and investigation was not the primary focus of this research. Instead, this study offers a more general view of the contributions that organisations make to competency development.

The components of an ideal organisation are presented in Figure 60 and include:

1. Deliberate and targeted funding for resourcing access to expertise that delivers competency development;
2. Articulation of a set of professional standards that draws on the industry standards and is interpreted in the language and purpose of the organisation and supported by constructive sanctioning processes;
3. Allocation of roles and responsibilities that are structured, supported and managed to achieve the corporate standards; and
4. Considered project and role diversification to enable development of both breadth and depth in competency, including multi-disciplinary interaction and purposeful technical review.



Figure 60 Ideal Competency Development Organisation

The actual learning processes within individual organisations are likely to vary according to corporate cultures and business imperatives. Learning Network Theory offers a mechanism to explore this in more detail within individual organisations.

9.2 General Model of Competency Development

The models presented above form components of an overall general model of Competency Development as it applies to transient professional scientists. The general model is presented in stages below.

Firstly, the general model of competency development requires the articulation of the social structure within which the competency is developed. Structuration Theory provides a useful lens through which to examine the structures, processes and human interactions that encompass the competency development. The structural analysis provides an appreciation of the context and importance of the competency to the overall operational environment.

Secondly, the competency targets need to be established. The competency model provides two dimensions that professional scientists are required to develop to achieve target competency. The competency model requires two dimensions of achievement: (1) exposure in accordance with deliberate practice applications and (2) attainment of practice context reasoning. The first dimension provides a more deliberate measure of experience than simply years in the industry and reflects the opportunities for learning through workplace engagement. The second dimension reflects an ability to contextualise the practice and so contribute more purposefully as a competent industry expert.

Lastly, the generalised competency development process is to address the competency development factors summarised in the Competency Development Model. Professionals striving to achieve the target competency defined above should address:

1. Entry requirements specific to the practice;
2. Workplace experiences that seek to develop breadth and depth, with specific attention to balancing both specialisation and multi-disciplinary experiences and operating across the business value chain at several sites;
3. A symbiotic weaving of both informal and informal workplace learning methods;
4. Deliberate development of learning networks that strive for breadth and depth in experts that can be accessed to guide, review and develop competency; and
5. Work in ideal organisations.

9.3 Discussion and Implications for Future Research

The generalised model presented above contributes a cohesive and integrated framework for the development of competency. Since the model is grounded in the practice of resource geology it provides immediate value to the mining industry.

The generalisation of this model is constrained by the limitations of the study. Further research is necessary to test whether the generalised model can be applied beyond these limitations. Since the focus of this thesis is on resource geologists acting as Competent Persons, there is an opportunity to evaluate whether the model can be applied, for example, to mining engineers who elect to act as Competent Persons for reporting Ore Reserves in accordance with the JORC Code. The key requirements for such a study would be to evaluate the requirements for reasoning and the associated practice exposure levels required to attain contextual reasoning. An evaluation of the competency development factors would also be necessary.

Similarly, there is an opportunity to examine and test the levels of reasoning, exposure requirements and competency development factors required for exploration geologists acting as Competent Persons for reporting exploration results.

This study is limited to the Australasian mineral reporting environment, which begs the question of whether the generalised competency development model can be applied in other jurisdictions, such as the Canadian or newly formed Russian reporting environments. Moreover, this study is limited to so-called hard rock mining.

Does the generalised competency development model apply when developing competency in other scientific professions?

These questions provide challenges for future research.

10 Conclusion

The original pretext of this research was to explore what it took to develop resource geologists' competency in accordance with the JORC Code. Structuration Theory provided a framework to examine the JORC system, within which resource geologists operate. This enabled the notion of practice-based competency to be formalised, clarified the importance of Competent Persons within the JORC system, and has highlighted the associated vulnerability in the system due to a lack of technical sanctioning processes.

A competency assessment mechanism was developed and used firstly to test the current qualifying criteria in the JORC Code, and secondly to test alternative qualifying criteria proposed in §6.6 (page 143). The alternative criteria improved the probability of identifying Competent Persons with higher JORC Code reasoning levels. Differences in the associated competency development experiences between higher and lower reasoning levels of qualifying resource geologists provided insight into those experiences that contribute to constructive competency development. These experience factors were then formalised through the creation of a competency development model.

This competency development model underpins a reframed model of competency, which is based on two dimensions: (1) practice-based exposure and (2) degree of context reasoning associated with the practice. For the practice of resource geology, exposure is measured through the completion of at least 15 resource estimates over two commodities with five reconciliation studies over at least 10 years that includes at least five years' experience in resource estimation (the '15-2-5' criteria). The context reasoning, for resource geologists, is measured through the ability of the resource geologists to reason through the resource estimation relevant criteria listed in Table 1 of the JORC Code.

Beyond the competency model and the associated competency development model, a model was formulated to describe the style of learning network adopted by transient professional scientists. These networks extend beyond the organisational confines, are enduring, transient and egocentric. This model accommodates growth style learning networks that evolve as resource geologists are exposed to experts. These connections are enduring and beyond relocation of various connections within the network. These networks are highly personal and are founded in trust through exposure to the other party's practice engagement.

This research provides practical recommendations for resource geologists, organisations that employ them, and the mining industry professional bodies. These recommendations include the revision of current JORC Code competency qualifying criteria, which effectively articulate recommendations for career development of resource geologists. Recommendations for organisations include adoption and articulation of high standards and expectations, support of industry contextual networks beyond organisational confines, and provision of opportunities to gain both depth and breadth in practice exposure. Professional bodies are encouraged to revisit the current competency sanctioning processes, to review the competency assessment processes and to explore opportunities to contribute to practice networks.

10.1 Response to Research Question

The original research question was:

What does it take to develop Competent Persons for the JORC Code?

Foremost, the competent person should understand the environment and processes that govern the JORC system. Next, the Competent Person should have sufficient experience and exposure to integrate the requirements of the JORC Code fully, including Table 1 of the JORC Code, into their work practices. Exposure to a combination of workplace and professional experiences that offer both breadth and depth in understanding and competency are necessary. Competent resource geologists actively seek input from experts within their transient, egocentric learning networks, which they tend and develop over time. These resource geologists are not limited to specific styles of organisations, instead they seek to work for a range of organisational contexts and stay at operations for long enough to develop their appreciation of the full mine-value-chain in a business.

10.2 Contribution of This Thesis

Beyond merely confirming the original concerns about overstated competency, this research adds to the body of knowledge in several ways. At a practical level, the processes developed and findings provide an alternative approach to the evaluation and selection of Competent Persons to operate within the JORC system. Based on these findings, the research provides direction for resource geologists in their career planning and opportunity evaluations. In addition, the research provides guidance for organisations that employ resource geologists and for the mining industry's professional bodies that provide professional development opportunities.

The research contributes to the theoretical body of knowledge in four ways. Firstly, it provides a successful example of exploration of a social construct using Giddens's (1984) Structuration Theory. Secondly, it presents a competency development model that incorporates the factors that influence the development of reasoning. Thirdly, this research redefines the axes in Dall'Alba & Sandberg's (2006) competency model as dimensions of practice exposure and context reasoning that underpin the competency development model. Lastly, this research delivers a revised model of learning networks that describes the connections that transient professionals use for expert access that has emerged from the analysis of resource geologists' networks.

10.3 Future Research

In an attempt to address the limitations of this research (see §4.2.4, page 71), future research should seek to examine the generalizability of the competency development model. An example would be the compatibility of the competency development model to mining engineers who seek to act as Competent Persons for the reporting of Ore Reserves. More broadly, but still within the mining industry, the model could be tested in other jurisdictions such as the Canadian or even the newly formed NAEN Russian environment.

The applicability of the combination of models presented should also be tested external to the mining industry to examine whether the model can be more generally applied and adapted. An example would be the potential adaptation to the petroleum industry, where the ASX listing rules have been adapted to a process similar to the JORC system in 2012.

There was insufficient data to provide conclusive recommendations on the influence of the style of tertiary education on competency. However, there is sufficient evidence to recommend investigation into the long term benefits of academic breadth over industry-readiness focus in tertiary education, with a specific intent of providing resource geologists with a stronger foothold in the profession. Future researchers could consider whether the teaching style of tertiary institution affects reasoning levels in the scientific professions.

10.4 Postscript

This research was initially driven by personal concerns and experiences within the mining industry. At the heart of the quest was a recognition of something critical surrounding competency that had not been done as well as it could have. Core questions arose when encountering resource geologists claiming to be Competent Persons – some reflected confidence beyond their competency, while others were hesitant but quite clearly were able to address the issues, to reflect on the mine-value-chain and apply the JORC Code as intended.

This research has comprehensively addressed these concerns and has provided practical guidance beyond the initial research expectations. Moreover, the research has contributed and extended models and challenged and supported theories.

On a more personal level, an enjoyable and significant aspect of this research has been the opportunity to engage intellectually on a variety of theories with academics. Immersion into the academic world through attendance at a range of academic seminars, numerous discussions with diverse researchers (within Edith Cowan University, University of Western Australia and Curtin University) and exploration of published theoretical concepts (mostly relevant, but often tangential) stimulated and inspired the researcher much more than was anticipated.

Whilst demanding, the research process has expanded the researcher's perception of the world. In particular, the researcher has developed a greater appreciation of numerous educational theories, workplace learning concepts and organisational knowledge theories, as well as qualitative research methods and the associated efforts required to maintain relevance and validity. This has been a particular challenge in light of the researcher's original positivist perspective borne of her statistics and mathematics tertiary and professional background.

For those contemplating a PhD journey, the researcher hopes this study demonstrates the value in never confining one's curiosity and in pursuing the questions that tug at one's conscience.

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Appendices

APPENDIX 1

THE JORC CODE 2012

Australasian Code for Reporting of Exploration Results, Mineral Resources and Ore Reserves

JORC
Joint Ore Reserves Committee



The JORC Code 2012 Edition



AusIMM
THE MINERALS INSTITUTE



Effective 20 December 2012 and
mandatory from 1 December 2013

Prepared by the Joint Ore Reserves Committee of The Australasian Institute of Mining and Metallurgy, Australian Institute of Geoscientists and Minerals Council of Australia (JORC)

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Foreword

1. The *Australasian Code for Reporting of Exploration Results, Mineral Resources and Ore Reserves* (the 'JORC Code' or 'the Code') sets out minimum standards, recommendations and guidelines for Public Reporting in Australasia of Exploration Results, Mineral Resources and Ore Reserves. The Joint Ore Reserves Committee (JORC) was established in 1971 and published several reports containing recommendations on the classification and Public Reporting of Ore Reserves prior to the release of the first edition of the JORC Code in 1989.

Revised and updated editions of the Code were issued in 1992, 1996, 1999, and 2004. This 2012 edition supersedes all previous editions.

Since 1994, the Committee for Mineral Reserves International Reporting Standards (CRIRSCO) has worked to create a set of standard international definitions for reporting Mineral Resources and Mineral (Ore) Reserves, based on the evolving JORC Code's definitions. CRIRSCO was initially a committee of the Council of Mining and Metallurgical Institutions (CMMI).

Representatives of bodies from Australia, Canada, South Africa, USA and the UK reached provisional agreement on standard definitions for reporting resources and reserves in 1997. This was followed in 1998 by an agreement to incorporate the CMMI definitions into the International Framework Classification for Reserves and Resources – Solid Fuels and Mineral Commodities, developed by the United Nations Economic Commission for Europe (UN-ECE).

CMMI was disbanded in 2002 but CRIRSCO remained as a separate entity and now has a relationship with the International Council on Mining and Metals (ICMM). An initiative was commenced by CRIRSCO to develop a Template, largely based on the JORC Code, that was designed to assist countries to develop their own code in line with world best practice. The Template has been recognised as a commodity-specific code in UNFC 2009.

CRIRSCO's members are National Reporting Organisations (NROs) who are responsible for developing mineral reporting codes or standards and guidelines. The NROs are: Australasia (JORC), Canada (CIM Standing Committee on Reserve Definitions), Chile (National Committee), Europe (PERC), Russia (NAEN), South Africa (SAMCODES) and USA (SME). As a result of the CRIRSCO/CMMI initiative, considerable progress has been made towards widespread adoption of consistent reporting standards throughout the world. In this edition of the JORC Code defined terms are aligned to the CRIRSCO Standard Definitions as revised in October 2012.

Introduction

2. In this edition of the JORC Code, important terms and their definitions are highlighted in bold text. The guidelines are placed after the respective Code Clauses using indented italics. Guidelines are not part of the Code but are intended to provide assistance and guidance to readers and should be considered persuasive when interpreting the Code.
3. The Code has been adopted by The Australasian Institute of Mining and Metallurgy (The AusIMM) and the Australian Institute of Geoscientists (AIG) and is binding on members of those organisations. The Code is endorsed by the Minerals Council of Australia and the Financial Services Institute of Australasia as a contribution to good practice. The Code has also been adopted by and included in the listing rules of the Australian Securities Exchange (ASX) and the New Zealand Stock Exchange (NZX).

The ASX and NZX have, since 1989 and 1992 respectively, incorporated the Code into their listing rules. Under these listing rules, a Public Report must be prepared in accordance with the Code if it includes a statement on Exploration Targets, Exploration Results, Mineral Resources or Ore Reserves. The incorporation of the Code imposes certain specific requirements on mining or exploration companies reporting to the ASX and NZX. There remain a number of other issues outside of the JORC Code associated with Public Reports that are addressed specifically within the listing rules.

As such, it is strongly recommended that users of the Code familiarise themselves with the listing rules of the relevant exchange that relates to Public Reporting of Exploration Results, Mineral Resources and Ore Reserves.

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For Public Reports of initial or materially changed Exploration Results, Mineral Resources or Ore Reserves the JORC Code requires the Competent Person, on whose documentation the Public Report is based, to be named in the Public Report. The Public Report or attached statement must say that the Competent Person consents to the inclusion in the Public Report of the matters based on their information in the form and context in which it appears, and must include the name of the Competent Person's firm or employer.

Users of the Code should refer to Clause 9.

Scope

4. The principles governing the operation and application of the JORC Code are Transparency, Materiality and Competence.
 - **Transparency requires that the reader of a Public Report is provided with sufficient information, the presentation of which is clear and unambiguous, to understand the report and not be misled by this information or by omission of material information that is known to the Competent Person.**
 - **Materiality requires that a Public Report contains all the relevant information that investors and their professional advisers would reasonably require, and reasonably expect to find in the report, for the purpose of making a reasoned and balanced judgement regarding the Exploration Results, Mineral Resources or Ore Reserves being reported. Where relevant information is not supplied an explanation must be provided to justify its exclusion.**
 - **Competence requires that the Public Report be based on work that is the responsibility of suitably qualified and experienced persons who are subject to an enforceable professional code of ethics (the Competent Person).**

Transparency and Materiality are guiding principles of the Code, and the Competent Person must provide explanatory commentary on the material assumptions underlying the declaration of Exploration Results, Mineral Resources or Ore Reserves.

In particular, the Competent Person must consider that the benchmark of Materiality is that which includes all aspects relating to the Exploration Results, Mineral Resources or Ore Reserves that an investor or their advisers would reasonably expect to see explicit comment on from the Competent Person. The Competent Person must not remain silent on any material aspect for which the presence or absence of comment could affect the public perception or value of the mineral occurrence.

5. Table 1 provides a checklist or reference of criteria to be considered by the Competent Person in developing their documentation and in preparing the Public Report.

In the context of complying with the principles of the Code, comments relating to the items in the relevant sections of Table 1 should be provided on an 'if not, why not' basis within the Competent Person's documentation. Additionally comments related to the relevant sections of Table 1 must be complied with on an 'if not, why not' basis within Public Reporting for significant projects (see Appendix 1 Generic Terms and Equivalents) when reporting Exploration Results, Mineral Resources or Ore Reserves for the first time. Table 1 also applies in instances where these items have materially changed from when they were last Publicly Reported. Reporting on an 'if not, why not' basis is to ensure that it is clear to an investor whether items have been considered and deemed of low consequence or are not yet addressed or resolved.

For the purposes of the JORC Code the phrase 'if not, why not' means that each item listed in the relevant section of Table 1 must be discussed and if it is not discussed then the Competent Person must explain why it has been omitted from the documentation.

The Code requires in Clauses 19, 27 and 35 that reporting of first time or materially changed Exploration Results, Mineral Resources or Ore Reserves estimates be accompanied by a technical summary of all relevant sections of Table 1 on an 'if not, why not' basis as an appendix to the Public Report.

A material change could be a change in the estimated tonnage or grade or in the classification of the Mineral Resources or Ore Reserves. Whether there has been a material change in relation to a significant project must be considered by taking into account all of the relevant circumstances, including the style of mineralisation. This includes considering whether the change in estimates is likely to have a material effect on the price or value of the company's securities.

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6. **Public Reports** are reports prepared for the purpose of informing investors or potential investors and their advisers on Exploration Results, Mineral Resources or Ore Reserves. They include, but are not limited to, annual and quarterly company reports, press releases, information memoranda, technical papers, website postings and public presentations.

These Public Reports may be to the Australian Securities Exchange and the New Zealand Stock Exchange, or other regulatory authorities or as required by law.

The Code is a required minimum standard for Public Reporting. JORC also recommends its adoption as a minimum standard for other reporting. Companies are encouraged to provide information in their Public Reports that is as comprehensive as possible.

The Code applies to other publicly released company information in the form of postings on company websites and presentation material used in briefings for shareholders, stockbrokers and investment analysts. The Code also applies to the following reports if they have been prepared for the purposes described in Clause 6 including but not limited to: environmental statements, information memoranda, expert reports, and technical papers referring to Exploration Results, Mineral Resources or Ore Reserves.

For companies issuing concise annual reports, inclusion of all material information relating to Exploration Results, Mineral Resources and Ore Reserves is recommended. In cases where summary information is presented it should be clearly stated that it is a summary, and a reference attached giving the location of the Code-compliant Public Reports or Public Reporting on which the summary is based.

It is recognised that companies can be required to issue reports into more than one regulatory jurisdiction, with compliance standards that may differ from this Code. It is recommended that such reports include a statement alerting the reader to this situation. Where members of The AusIMM and the AIG are required to report in other jurisdictions, they are obliged to comply with the requirements of those jurisdictions.

Reference in the Code to 'documentation' is to internal company documents prepared as a basis for, or to support, a Public Report.

It is recognised that situations may arise where documentation prepared by a Competent Person for internal company or similar non-public purposes does not comply with the JORC Code. In such situations, it is recommended that the documentation includes a prominent statement to this effect. This will make it less likely that non-complying documentation will be used to compile Public Reports, since Clause 9 requires Public Reports to fairly reflect Exploration Results, Mineral Resource and/or Ore Reserve estimates, and supporting documentation, prepared by a Competent Person.

While every effort has been made within the Code and Guidelines (including Table 1) to cover most situations likely to be encountered in Public Reporting, there may be occasions when doubt exists as to the appropriate form of disclosure. On such occasions, users of the Code and those compiling reports to comply with the Code should be guided by its intent, which is to provide a minimum standard for Public Reporting, and to ensure that such reporting contains all information that investors and their professional advisers would reasonably require, and reasonably expect to find in the report, for the purpose of making a reasoned and balanced judgement regarding the Exploration Results, Mineral Resources or Ore Reserves being reported.

The JORC Code is a Code for Public Reporting not a Code that regulates the manner in which a Competent Person estimates Mineral Resources or Ore Reserves. The term 'JORC compliant' therefore refers to the manner of reporting not to the estimates. Use of the words 'JORC compliant' to describe resources or estimates is potentially misleading. The words 'JORC compliant' should be interpreted to mean: 'Reported in accordance with the JORC Code and estimated (or based on documentation prepared) by a Competent Person as defined by the JORC Code'.

7. The Code is applicable to all solid minerals, including diamonds, other gemstones, industrial minerals and coal, for which Public Reporting of Exploration Results, Mineral Resources and Ore Reserves is required by the Australian Securities Exchange and the New Zealand Stock Exchange.

The JORC Code is cited by the 'Code and Guidelines for Technical Assessment and/or Valuation of Mineral and Petroleum Assets and Mineral and Petroleum Securities for Independent Expert Reports' (the 'VALMIN Code') as the applicable standard for the Public Reporting of Exploration Results, Mineral Resources and Ore Reserves. References to 'technical and economic studies' and 'feasibility studies' in the JORC Code are not intended as references to Technical Assessments or Valuations as defined in the VALMIN Code.

8. JORC recognises that further review of the Code and Guidelines will be required from time to time.

Competence and Responsibility

9. A Public Report concerning a company's Exploration Targets, Exploration Results, Mineral Resources or Ore Reserves is the responsibility of the company acting through its Board of Directors. Any such report must be based on, and fairly reflect, the information and supporting documentation prepared by a Competent Person. A company issuing a Public Report shall disclose the name(s) of the Competent Person, state whether the Competent Person is a full-time employee of the company, and, if not, name the Competent Person's employer.

Any potential for a conflict of interest by the Competent Person or a related party must be disclosed in accordance with the Transparency principle. Any other relationship of the Competent Person with the Company making the report must also be disclosed in the Public Report. The report must be issued with the prior written consent of the Competent Person as to the form and context in which it appears.

Where a company is re-issuing information previously issued with the written consent of the Competent Person, it must state the original report name, the name(s) of the Competent Person responsible for the original report, and state the date and reference the location of the original source public report for public access. In these circumstances the Company is not required to obtain the Competent Person's prior written consent as to the form and context in which the information appears, provided:

- The company confirms in the subsequent public presentation that it is not aware of any new information or data that materially affects the information included in the relevant market announcement. In the case of estimates of Mineral Resources or Ore Reserves, the company confirms that all material assumptions and technical parameters underpinning the estimates in the relevant market announcement continue to apply and have not materially changed.
- The company confirms that the form and context in which the Competent Person's findings are presented have not been materially modified. Note that for the subsequent public presentation it is the responsibility of the company acting through its Board of Directors to ensure the form and context has not been materially altered.

This relaxation of the requirement to obtain the Competent Person's prior written consent does not apply to the requirements for annual reporting of Mineral Resources and Ore Reserves contained in Clause 15.

All such public disclosure should be specifically reviewed by the company to ensure that the form and context in which the Competent Person's findings are presented have not been materially modified, and to ensure that the previously issued Exploration Results, Mineral Resources or Ore Reserve remain valid in the light of any more recently-acquired data.

Examples of appropriate forms of compliance statements are provided in Appendix 3.

In order to assist Competent Persons and companies to comply with these requirements a Competent Person's Consent Form has been devised that incorporates the requirements of the Code. The Competent Person's Consent Form is provided in Appendix 2.

The completion of a consent form, whether in the format provided or in an equivalent form, is recommended as good practice and provides readily available evidence that the required prior consent has been obtained.

The Competent Person's Consent Form(s), or other evidence of the Competent Person's written consent, should be retained by the company and the Competent Person to ensure that the written consent can be promptly provided if required.

10. Documentation detailing Exploration Results, Mineral Resource and Ore Reserve estimates, on which a Public Report on Exploration Results, Mineral Resources and Ore Reserves is based, must be prepared by, or under the direction of, and signed by, a Competent Person. If an Exploration Target is included in a Public Report, documentation must also be prepared by, or under the direction of, and signed by, a Competent Person. The documentation must provide a fair representation of the matters being reported.
11. **A 'Competent Person' is a minerals industry professional who is a Member or Fellow of The Australasian Institute of Mining and Metallurgy, or of the Australian Institute of Geoscientists, or of a 'Recognised Professional Organisation' (RPO), as included in a list available on the JORC and ASX websites. These organisations have enforceable disciplinary processes including the powers to suspend or expel a member.**

A Competent Person must have a minimum of five years relevant experience in the style of mineralisation or type of deposit under consideration and in the activity which that person is undertaking.

If the Competent Person is preparing documentation on Exploration Results, the relevant experience must be in exploration. If the Competent Person is estimating, or supervising the estimation of Mineral Resources, the relevant experience must be in the estimation, assessment and evaluation of Mineral Resources. If the Competent Person is estimating, or supervising the estimation of Ore Reserves, the relevant experience must be in the estimation, assessment, evaluation and economic extraction of Ore Reserves.

The key qualifier in the definition of a Competent Person is the word 'relevant'. Determination of what constitutes relevant experience can be a difficult area and common sense has to be exercised. For example, in estimating Mineral Resources for vein gold mineralisation, experience in a high-nugget, vein-type mineralisation (such as tin, uranium, etc) may be relevant, whereas experience in (say) massive base metal deposits may not be. As a second example, to qualify as a Competent Person in the estimation of Ore Reserves for alluvial gold deposits, considerable (at least five years) experience in the evaluation and economic extraction of this type of mineralisation may be needed. This is due to the properties of gold in alluvial systems, the particle sizing of the host sediment, and the low grades involved. Experience with placer deposits containing minerals other than gold may not necessarily provide appropriate relevant experience.

The key word 'relevant' also means that it is not always necessary for a person to have five years experience in each and every type of deposit to act as a Competent Person if that person has relevant experience in other deposit types. For example, a person with (say) 20 years experience in estimating Mineral Resources for a variety of metalliferous hard-rock deposit types may not require five years specific experience in (say) porphyry copper deposits to act as a Competent Person. Relevant experience in the other deposit types could count towards the required experience in relation to porphyry copper deposits.

In addition to experience in the style of mineralisation, a Competent Person taking responsibility for the compilation of Exploration Results or Mineral Resource estimates should have sufficient experience in the sampling and analytical techniques relevant to the deposit under consideration to be aware of problems that could affect the reliability of data. Some appreciation of extraction and processing techniques applicable to that deposit type may also be important.

As a general guide, a person being called upon to act as Competent Person should be clearly satisfied in their own minds that they could face their peers and demonstrate competence in the commodity, type of deposit and situation under consideration. If doubt exists, the person should either seek opinions from appropriately experienced peers or should decline to act as a Competent Person.

Estimation of Mineral Resources may be a team effort (for example, involving one person or team collecting the data and another person or team preparing the estimate). Estimation of Ore Reserves is very commonly a team effort involving several technical disciplines. It is recommended that, where there is clear division of responsibility within a team, each Competent Person and his or her contribution should be identified, and responsibility accepted for that particular contribution. If only one Competent Person signs the Mineral Resource or Ore Reserve documentation, that person is responsible and accountable for the whole of the documentation under the Code. It is important in this situation that the Competent Person accepting overall responsibility for a Mineral Resource or Ore Reserve estimate and supporting documentation prepared in whole or in part by others, is satisfied that the work of the other contributors is acceptable.

Complaints made with respect to the professional work of a Competent Person will be dealt with under the disciplinary procedures of the professional organisation to which the Competent Person belongs.

When an Australian Securities Exchange or New Zealand Stock Exchange listed company with overseas interests wishes to report overseas Exploration Results, Mineral Resource or Ore Reserve estimates prepared by a person who is not a member of The AusIMM, the AIG or a RPO, it is necessary for the company to nominate a Competent Person or Persons to take responsibility for the Exploration Results, Mineral Resource or Ore Reserve estimate. The Competent Person undertaking this activity should appreciate that they are accepting full responsibility for the estimate and supporting documentation under Australian Securities Exchange and/or the New Zealand Stock Exchange listing rules and should not treat the procedure merely as a 'rubber-stamping' exercise.

Reporting Terminology

12. Public Reports dealing with Exploration Results, Mineral Resources or Ore Reserves must only use the terms set out in Figure 1.

Figure 1 sets out the framework for classifying tonnage and grade estimates to reflect different levels of geological confidence and different degrees of technical and economic evaluation. Mineral Resources can be estimated on the basis of geoscientific information with some input from other disciplines. Ore Reserves, which are a modified sub-set of the Indicated and Measured Mineral Resources (shown within the dashed outline in Figure 1), require consideration of the Modifying Factors affecting extraction, and should in most instances be estimated with input from a range of disciplines.

‘Modifying Factors’ are considerations used to convert Mineral Resources to Ore Reserves. These include, but are not restricted to, mining, processing, metallurgical, infrastructure, economic, marketing, legal, environmental, social and governmental factors.

Measured Mineral Resources may be converted to either Proved Ore Reserves or Probable Ore Reserves. The Competent Person may convert Measured Mineral Resources to Probable Ore Reserves because of uncertainties associated with some or all of the Modifying Factors which are taken into account in the conversion from Mineral Resources to Ore Reserves. This relationship is shown by the broken arrow in Figure 1. Although the trend of the broken arrow includes a vertical component, it does not, in this instance, imply a reduction in the level of geological knowledge or confidence. In such a situation these Modifying Factors should be fully explained.

Refer also to the guidelines to Clause 32.

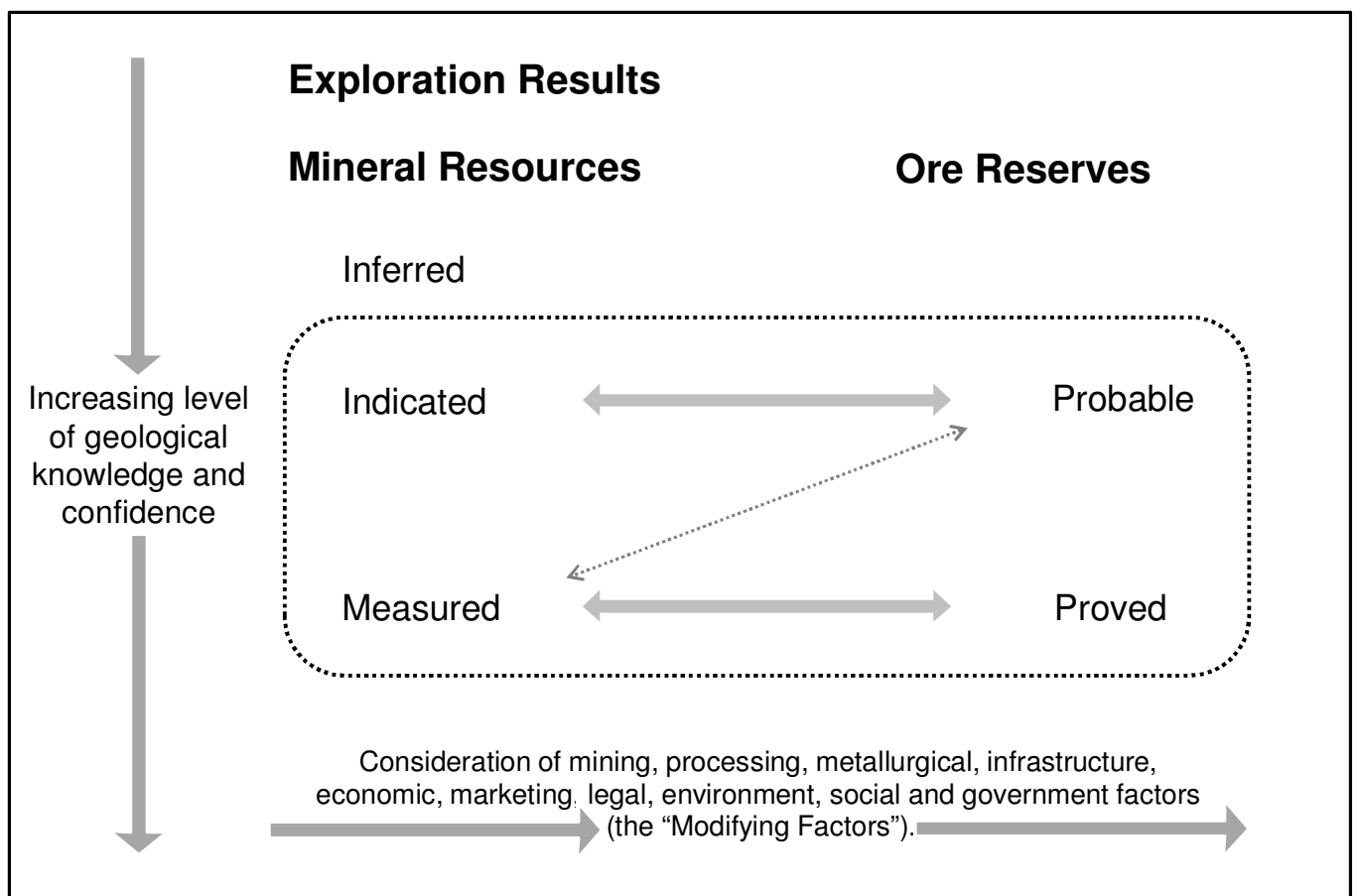


Figure 1 General relationship between Exploration Results, Mineral Resources and Ore Reserves.

Reporting General

13. Public Reports concerning a company’s Exploration Results, Mineral Resources or Ore Reserves must include a description of the style and nature of the mineralisation.

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14. A company must disclose all relevant information concerning Exploration Results, Mineral Resources or Ore Reserves that could materially influence the economic value of those Exploration Results, Mineral Resources or Ore Reserves to the company. A company must promptly report any material changes in its Mineral Resources or Ore Reserves.
15. Companies must review and publically report their Mineral Resources and Ore Reserves annually. The annual review date must be nominated by the Company in its Public Reports of Mineral Resources and Ore Reserves and the effective date of each Mineral Resource and Ore Reserve statement must be shown. The Company must discuss any material changes to previously reported Mineral Resources and Ore Reserves at the time of publishing updated Mineral Resources and Ore Reserves.
16. Throughout the Code, if appropriate, 'quality' may be substituted for 'grade' and 'volume' may be substituted for 'tonnage'. (Refer to Appendix 1 Generic Terms and Equivalents.)
17. It is recognised that it is common practice for a company to comment on and discuss its exploration in terms of target size and type. However, any such comment in a Public Report must comply with the following requirements.

An Exploration Target is a statement or estimate of the exploration potential of a mineral deposit in a defined geological setting where the statement or estimate, quoted as a range of tonnes and a range of grade (or quality), relates to mineralisation for which there has been insufficient exploration to estimate a Mineral Resource.

Any such information relating to an Exploration Target must be expressed so that it cannot be misrepresented or misconstrued as an estimate of a Mineral Resource or Ore Reserve. The terms Resource or Reserve must not be used in this context. In any statement referring to potential quantity and grade of the target, these must both be expressed as ranges and must include:

- a detailed explanation of the basis for the statement, including specific description of the level of exploration activity already completed, and
- a clarification statement within the same paragraph as the first reference of the Exploration Target in the Public Report, stating that the potential quantity and grade is conceptual in nature, that there has been insufficient exploration to estimate a Mineral Resource and that it is uncertain if further exploration will result in the estimation of a Mineral Resource.

Given the level of uncertainty surrounding the supporting data, an Exploration Target tonnage or grade must not be reported as a 'headline statement' in a Public Report.

If a Public Report includes an Exploration Target the proposed exploration activities designed to test the validity of the exploration target must be detailed and the timeframe within which those activities are expected to be completed must be specified.

If an Exploration Target is shown pictorially (for instance as cross sections or maps) or with a graph, it must be accompanied by text that meets the requirements above.

A Public Report that includes an Exploration Target must be accompanied by a Competent Person statement taking responsibility for the form and context in which the Exploration Target appears.

All disclosures of an Exploration Target must clarify whether the target is based on actual Exploration Results or on proposed exploration programmes. Where the Exploration Target statement includes information relating to ranges of tonnages and grades these must be represented as approximations. The explanatory text must include a description of the process used to determine the grade and tonnage ranges used to describe the Exploration Target.

For an Exploration Target based on Exploration Results, a summary of the relevant exploration data available and the nature of the results should also be stated, including a disclosure of the current drill hole or sampling spacing and relevant plans or sections. In any subsequent upgraded or modified statements on the Exploration Target, the Competent Person should discuss any material changes to potential scale or quality arising from completed exploration activities.

Reporting of Exploration Results

18. **Exploration Results include data and information generated by mineral exploration programmes that might be of use to investors but which do not form part of a declaration of Mineral Resources or Ore Reserves.**

The reporting of such information is common in the early stages of exploration when the quantity of data available is generally not sufficient to allow any reasonable estimates of Mineral Resources.

If a company reports Exploration Results in relation to mineralisation not classified as a Mineral Resource or an Ore Reserve, then estimates of tonnages and average grade must not be assigned to the mineralisation unless the situation is covered by Clause 17, and then only in strict accordance with the requirements of that Clause.

Examples of Exploration Results include results of outcrop sampling, assays of drill hole intersections, geochemical results and geophysical survey results.

19. Public Reports of Exploration Results must contain sufficient information to allow a considered and balanced judgement of their significance. Reports must include relevant information such as exploration context, type and method of sampling, relevant sample intervals and locations, distribution, dimensions and relative location of all relevant assay data, methods of analysis, data aggregation methods, land tenure status plus information on any of the other criteria listed in Table 1 that are material to an assessment.

Public Reports of Exploration Results must not be presented so as to unreasonably imply that potentially economic mineralisation has been discovered. If true widths of mineralisation are not reported, an appropriate qualification must be included in the Public Report.

Where assay and analytical results are reported, they must be reported using one of the following methods, selected as the most appropriate by the Competent Person:

- either by listing all results, along with sample intervals (or size, in the case of bulk samples), or
- by reporting weighted average grades of mineralised zones, indicating clearly how the grades were calculated.

Clear diagrams and maps designed to represent the geological context must be included in the report. These must include, but not be limited to a plan view of drill hole collar locations and appropriate sectional views.

Reporting of selected information such as isolated assays, isolated drill holes, assays of panned concentrates or supergene enriched soils or surface samples, without placing them in perspective is unacceptable.

While it is not necessary to report all assays or drill holes, it is a requirement that sufficient information about the omitted data is provided so that a considered and balanced judgement can be made by the reader of the report. Where reports of Exploration Results do not include all drill holes or all intersections of drill holes the Competent Person must provide an explanation of why this information is not considered relevant or why it has not been provided.

As required under Clauses 4 and 5, the Competent Person must not 'remain silent on any issue for which the presence or absence of comment could impact the public perception or value of the mineral occurrence'. For significant projects the reporting of all criteria in sections 1 and 2 of Table 1 on an 'if not, why not basis' is required, preferably as an appendix to the Public Report. Additional disclosure is particularly important where inadequate or uncertain data affect the reliability of, or confidence in, a statement of Exploration Results; for example, poor sample recovery, poor repeatability of assay or laboratory results, etc.

Reporting of Mineral Resources

20. **A 'Mineral Resource' is a concentration or occurrence of solid material of economic interest in or on the Earth's crust in such form, grade (or quality), and quantity that there are reasonable prospects for eventual economic extraction. The location, quantity, grade (or quality), continuity and other geological characteristics of a Mineral Resource are known, estimated or interpreted from specific geological evidence and knowledge, including sampling. Mineral Resources are sub-divided, in order of increasing geological confidence, into Inferred, Indicated and Measured categories.**

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All reports of Mineral Resources must satisfy the requirement that there are reasonable prospects for eventual economic extraction (ie more likely than not), regardless of the classification of the resource.

Portions of a deposit that do not have reasonable prospects for eventual economic extraction must not be included in a Mineral Resource. The basis for the reasonable prospects assumption is always a material matter, and must be explicitly disclosed and discussed by the Competent Person within the Public Report using the criteria listed in Table 1 for guidance. The reasonable prospects disclosure must also include a discussion of the technical and economic support for the cut-off assumptions applied.

Where untested practices are applied in the determination of reasonable prospects, the use of the proposed practices for reporting of the Mineral Resource must be justified by the Competent Person in the Public Report.

Geological evidence and knowledge required for the estimation of Mineral Resources must include sampling data of a type, and at spacings, appropriate to the geological, chemical, physical, and mineralogical complexity of the mineral occurrence, for all classifications of Inferred, Indicated and Measured Mineral Resources. A Mineral Resource cannot be estimated in the absence of sampling information.

The term 'Mineral Resource' covers mineralisation, including dumps and tailings, which has been identified and estimated through exploration and sampling and within which Ore Reserves may be defined by the consideration and application of the Modifying Factors.

The term 'reasonable prospects for eventual economic extraction' implies an assessment (albeit preliminary) by the Competent Person in respect of all matters likely to influence the prospect of economic extraction including the approximate mining parameters. In other words, a Mineral Resource is not an inventory of all mineralisation drilled or sampled, regardless of cut-off grade, likely mining dimensions location or continuity. It is a realistic inventory of mineralisation which, under assumed and justifiable technical, economic and development conditions, might, in whole or in part, become economically extractable.

Where considered appropriate by the Competent Person, Mineral Resource estimates may include material below the selected cut-off grade to ensure that the Mineral Resources comprise bodies of mineralisation of adequate size and continuity to properly consider the most appropriate approach to mining. Documentation of Mineral Resource estimates should clearly identify any diluting material included and Public Reports should include commentary on the matter if considered material.

Interpretation of the word 'eventual' in this context may vary depending on the commodity or mineral involved. For example, for some coal, iron ore, bauxite and other bulk minerals or commodities, it may be reasonable to envisage 'eventual economic extraction' as covering time periods in excess of 50 years. However for the majority of smaller deposits, application of the concept would normally be restricted to perhaps 10 to 15 years, and frequently to much shorter periods of time. In all cases, the considered time frame should be disclosed and discussed by the Competent Person.

Any adjustment made to the data for the purpose of making the Mineral Resource estimate, for example by cutting or factoring grades, should be clearly stated and described in the Public Report.

Certain reports (eg inventory coal reports, exploration reports to government and other similar reports not intended primarily for providing information for investment purposes) may require full disclosure of all mineralisation, including some material that does not have reasonable prospects for eventual economic extraction. Such estimates of mineralisation would not qualify as Mineral Resources or Ore Reserves in terms of the JORC Code (refer also to the guidelines to Clauses 6 and 42).

21. **An 'Inferred Mineral Resource' is that part of a Mineral Resource for which quantity and grade (or quality) are estimated on the basis of limited geological evidence and sampling. Geological evidence is sufficient to imply but not verify geological and grade (or quality) continuity. It is based on exploration, sampling and testing information gathered through appropriate techniques from locations such as outcrops, trenches, pits, workings and drill holes.**

An Inferred Mineral Resource has a lower level of confidence than that applying to an Indicated Mineral Resource and must not be converted to an Ore Reserve. It is reasonably expected that the majority of Inferred Mineral Resources could be upgraded to Indicated Mineral Resources with continued exploration.

Where the Mineral Resource being reported is predominantly an Inferred Mineral Resource, sufficient supporting information must be provided to enable the reader to evaluate and assess the risk associated with the reported Mineral Resource.

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In circumstances where the estimation of the Inferred Mineral Resource is presented on the basis of extrapolation beyond the nominal sampling spacing and taking into account the style of mineralisation, the report must contain sufficient information to inform the reader of:

- the maximum distance that the resource is extrapolated beyond the sample points
- the proportion of the resource that is based on extrapolated data
- the basis on which the resource is extrapolated to these limits
- a diagrammatic representation of the Inferred Mineral Resource showing clearly the extrapolated part of the estimated resource.

The Inferred category is intended to cover situations where a mineral concentration or occurrence has been identified and limited measurements and sampling completed, but where the data are insufficient to allow the geological and grade continuity to be confidently interpreted. While it would be reasonable to expect that the majority of Inferred Mineral Resources would upgrade to Indicated Mineral Resources with continued exploration, due to the uncertainty of Inferred Mineral Resources, it should not be assumed that such upgrading will always occur.

Confidence in the estimate of Inferred Mineral Resources is not sufficient to allow the results of the application of technical and economic parameters to be used for detailed planning in Pre-Feasibility (Clause 39) or Feasibility (Clause 40) Studies. For this reason, there is no direct link from an Inferred Mineral Resource to any category of Ore Reserves (see Figure 1).

Caution should be exercised if Inferred Mineral Resources are used to support technical and economic studies such as Scoping Studies (refer to Clause 38).

22. **An ‘Indicated Mineral Resource’ is that part of a Mineral Resource for which quantity, grade (or quality), densities, shape and physical characteristics are estimated with sufficient confidence to allow the application of Modifying Factors in sufficient detail to support mine planning and evaluation of the economic viability of the deposit.**

Geological evidence is derived from adequately detailed and reliable exploration, sampling and testing gathered through appropriate techniques from locations such as outcrops, trenches, pits, workings and drill holes, and is sufficient to assume geological and grade (or quality) continuity between points of observation where data and samples are gathered.

An Indicated Mineral Resource has a lower level of confidence than that applying to a Measured Mineral Resource and may only be converted to a Probable Ore Reserve.

Mineralisation may be classified as an Indicated Mineral Resource when the nature, quality, amount and distribution of data are such as to allow confident interpretation of the geological framework and to assume continuity of mineralisation.

Confidence in the estimate is sufficient to allow application of Modifying Factors within a technical and economic study as defined in Clauses 37 to 40.

23. **A ‘Measured Mineral Resource’ is that part of a Mineral Resource for which quantity, grade (or quality), densities, shape, and physical characteristics are estimated with confidence sufficient to allow the application of Modifying Factors to support detailed mine planning and final evaluation of the economic viability of the deposit.**

Geological evidence is derived from detailed and reliable exploration, sampling and testing gathered through appropriate techniques from locations such as outcrops, trenches, pits, workings and drill holes, and is sufficient to confirm geological and grade (or quality) continuity between points of observation where data and samples are gathered.

A Measured Mineral Resource has a higher level of confidence than that applying to either an Indicated Mineral Resource or an Inferred Mineral Resource. It may be converted to a Proved Ore Reserve or under certain circumstances to a Probable Ore Reserve.

Mineralisation may be classified as a Measured Mineral Resource when the nature, quality, amount and distribution of data are such as to leave no reasonable doubt, in the opinion of the Competent Person determining the Mineral Resource, that the tonnage and grade of the mineralisation can be estimated to within close limits, and that any variation from the estimate would be unlikely to significantly affect potential economic viability.

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This category requires a high level of confidence in, and understanding of, the geological properties and controls of the mineral deposit.

Confidence in the estimate is sufficient to allow application of Modifying Factors within a technical and economic study as defined in Clauses 37 to 40.

Depending upon the level of confidence in the various Modifying Factors it may be converted to a Proved Ore Reserve (high confidence in Modifying Factors), Probable Ore Reserve (some uncertainty in Modifying Factors) or may not be converted at all (low or no confidence in some of the Modifying Factors; or no plan to mine, eg pillars in an underground mine or outside economic pit limits).

24. The choice of the appropriate category of Mineral Resource depends upon the quantity, distribution and quality of data available and the level of confidence that attaches to those data. The appropriate Mineral Resource category must be determined by a Competent Person.

Mineral Resource classification is a matter for skilled judgement and a Competent Person should take into account those items in Table 1 that relate to confidence in Mineral Resource estimation.

In deciding between Measured Mineral Resources and Indicated Mineral Resources, Competent Persons may find it useful to consider, in addition to the phrases in the two definitions relating to geological and grade continuity in Clauses 22 and 23, the phrase in the guideline to the definition for Measured Mineral Resources: ‘... any variation from the estimate would be unlikely to significantly affect potential economic viability’.

*In deciding between Indicated Mineral Resources and Inferred Mineral Resources, Competent Persons may wish to take into account, in addition to the phrases in the two definitions in Clauses 21 and 22 relating to geological and grade continuity, that part of the definition for Indicated Mineral Resources: **‘sufficient confidence to allow the application of Modifying Factors in sufficient detail to support mine planning and evaluation of the economic viability of the deposit’**, which contrasts with the guideline to the definition for Inferred Mineral Resources: ‘Confidence in the estimate of Inferred Mineral Resources is not sufficient to allow the results of the application of technical and economic parameters to be used for detailed planning in Pre-Feasibility (Clause 39) or Feasibility (Clause 40) Studies’ and ‘Caution should be exercised if Inferred Mineral Resources are used to support technical and economic studies such as Scoping Studies (refer to Clause 38)’.*

The Competent Person should take into consideration issues of the style of mineralisation and cut-off grade when assessing geological and grade continuity for the purposes of classifying the resource.

Cut-off grades chosen for the estimation should be realistic in relation to the style of mineralisation and the anticipated mining and processing development options.

25. Mineral Resource estimates are not precise calculations, being dependent on the interpretation of limited information on the location, shape and continuity of the occurrence and on the available sampling results. Reporting of tonnage and grade figures should reflect the relative uncertainty of the estimate by rounding off to appropriately significant figures and, in the case of Inferred Mineral Resources, by qualification with terms such as ‘approximately’ and to emphasise the imprecise nature of a Mineral Resource, the final result should always be referred to as an estimate not a calculation.

In most situations, rounding to the second significant figure should be sufficient. For example 10,863,000 tonnes at 8.23 per cent should be stated as 11 million tonnes at 8.2 per cent. There will be occasions, however, where rounding to the first significant figure may be necessary in order to convey properly the uncertainties in estimation. This would usually be the case with Inferred Mineral Resources.

Competent Persons are encouraged, where appropriate, to discuss the relative accuracy and confidence level of the Mineral Resource estimates with consideration of at least sampling, analytical and estimation errors. The statement should specify whether it relates to global or local estimates, and, if local, state the relevant tonnage. Where a statement of the relative accuracy and confidence level is not possible, a qualitative discussion of the uncertainties should be provided in its place (refer to Table 1).

26. Public Reports of Mineral Resources must specify one or more of the categories of ‘Inferred’, ‘Indicated’ and ‘Measured’. Categories must not be reported in a combined form unless details for the individual categories are also provided. Mineral Resources must not be reported in terms of contained metal or mineral content unless corresponding tonnages and grades are also presented.

Mineral Resources must not be aggregated with Ore Reserves.

Public Reporting of tonnages and grades outside the categories covered by the Code is not permitted unless the situation is covered by Clause 17, and then only in strict accordance with the requirements of that Clause.

Estimates of tonnage and grade outside of the categories covered by the Code may be useful for a company in its internal calculations and evaluation processes, but their inclusion in Public Reports is not permitted.

27. In a Public Report of a Mineral Resource for a significant project for the first time, or when those estimates have materially changed from when they were last reported, a brief summary of the information in relevant sections of Table 1 must be provided or, if a particular criterion is not relevant or material, a disclosure that it is not relevant or material and a brief explanation of why this is the case must be provided.

For a significant project, when Mineral Resource estimates are first Publicly Reported or when a material change occurs (including classification changes), there is an increased need for transparent discussion of the basis for the new Mineral Resource estimate in order that investors are appropriately informed of the basis for the changes. As noted in Clauses 4 and 5 the benchmark of Materiality is that which an investor or their advisers would reasonably expect to see explicit comment on from the Competent Person, thus the reporting of all relevant criteria in Table 1 on an 'if not, why not' basis is required.

The Code specifies reporting against relevant sections of Table 1 in this Clause. This may be satisfied by reporting against section 3 on the presumption that matters related to sections 1 and 2 will already have been included in a still current Public Report and this Report can be referenced. If this is not the case then these sections are also relevant and should be included in the Public Report.

The technical summary based against Table 1 criteria should be presented as an appendix to the Public Report.

Where there are as yet unresolved issues potentially impacting the reliability of, or confidence in, a statement of Mineral Resources (for example, poor sample recovery, poor repeatability of assay or laboratory results, limited information on bulk densities, etc) those unresolved issues should also be reported.

If there is doubt about what should be reported, it is better to err on the side of providing too much information rather than too little.

Uncertainties in any of the criteria listed in Table 1 that could lead to under- or over-statement of Mineral Resources should be disclosed.

Mineral Resource estimates are sometimes reported after adjustment from reconciliation with production data. Such adjustments should be clearly stated in a Public Report of Mineral Resources and the nature of the adjustment or modification described.

28. The words 'ore' and 'reserves' must not be used in describing Mineral Resource estimates as the terms imply technical feasibility and economic viability and are only appropriate when all relevant Modifying Factors have been considered. Reports and statements should continue to refer to the appropriate category or categories of Mineral Resources until technical feasibility and economic viability have been established. If re-evaluation indicates that the Ore Reserves are no longer viable, the Ore Reserves must be reclassified as Mineral Resources or removed from Mineral Resource/Ore Reserve statements.

It is not intended that re-classification from Ore Reserves to Mineral Resources or vice versa should be applied as a result of changes expected to be of a short term or temporary nature, or where company management has made a deliberate decision to operate on a non-economic basis. Examples of such situations might be commodity price fluctuations expected to be of short duration, mine emergency of a non-permanent nature, transport strike, etc.

Reporting of Ore Reserves

29. **An 'Ore Reserve' is the economically mineable part of a Measured and/or Indicated Mineral Resource. It includes diluting materials and allowances for losses, which may occur when the material is mined or extracted and is defined by studies at Pre-Feasibility or Feasibility level as appropriate that include application of Modifying Factors. Such studies demonstrate that, at the time of reporting, extraction could reasonably be justified.**

The reference point at which Reserves are defined, usually the point where the ore is delivered to the processing plant, must be stated. It is important that, in all situations where the reference point is different, such as for a saleable product, a clarifying statement is included to ensure that the reader is fully informed as to what is being reported.

The key underlying assumptions and outcomes of the Pre-Feasibility Study or Feasibility Study must be disclosed at the time of reporting of a new or materially changed Ore Reserve.

Pre-Feasibility and Feasibility Studies are defined in Clauses 39 and 40 below.

Ore Reserves are sub-divided in order of increasing confidence into Probable Ore Reserves and Proved Ore Reserves.

In reporting Ore Reserves, information on estimated mineral processing recovery factors is very important, and should always be included in Public Reports.

Ore Reserves are those portions of Mineral Resources that, after the application of all Modifying Factors, result in an estimated tonnage and grade which, in the opinion of the Competent Person making the estimates, can be the basis of a technically and economically viable project, after taking account of material relevant Modifying Factors. Deriving an Ore Reserve without a mine design or mine plan through a process of factoring of the Mineral Resource is unacceptable.

Ore Reserves are reported as inclusive of marginally economic material and diluting material delivered for treatment or dispatched from the mine without treatment.

The term 'economically mineable' implies that extraction of the Ore Reserves has been demonstrated to be viable under reasonable financial assumptions. This will vary with the type of deposit, the level of study that has been carried out and the financial criteria of the individual company. For this reason, there can be no fixed definition for the term 'economically mineable'.

In order to achieve the required level of confidence in the Modifying Factors, appropriate Feasibility or Pre-Feasibility level studies will have been carried out prior to determination of the Ore Reserves. The studies will have determined a mine plan and production schedule that is technically achievable and economically viable and from which the Ore Reserves can be derived.

The term 'Ore Reserves' need not necessarily signify that extraction facilities are in place or operative, or that all necessary approvals or sales contracts have been received. It does signify that there are reasonable grounds to expect that such approvals or contracts will eventuate within the anticipated time frame required by the mine plans. There must be reasonable grounds to expect that all necessary Government approvals will be received. The Competent Person should highlight and discuss any material unresolved matter that is dependent on a third party on which extraction is contingent.

If there is doubt about what should be reported, it is better to err on the side of providing too much information rather than too little.

Any adjustment made to the data for the purpose of making the Ore Reserve estimate, for example by cutting or factoring grades, should be clearly stated and described in the Public Report.

Where companies prefer to use the term 'Mineral Reserves' in their Public Reports, eg for reporting industrial minerals or for reporting outside Australasia, they should state clearly that this is being used with the same meaning as 'Ore Reserves', defined in this Code. If preferred by the reporting company,

'Ore Reserve' and 'Mineral Resource' estimates for coal may be reported as 'Coal Reserve' and 'Coal Resource' estimates.

JORC prefers the term 'Ore Reserve' because it assists in maintaining a clear distinction between a 'Mineral Resource' and an 'Ore Reserve', whereas other codes feel it is better to reference Mineral Exploration Results, Mineral Resources and Mineral Reserves.

30. **A 'Probable Ore Reserve' is the economically mineable part of an Indicated, and in some circumstances, a Measured Mineral Resource. The confidence in the Modifying Factors applying to a Probable Ore Reserve is lower than that applying to a Proved Ore Reserve.**

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Consideration of the confidence level of the Modifying Factors is important in conversion of Mineral Resources to Ore Reserves.

A Probable Ore Reserve has a lower level of confidence than a Proved Ore Reserve but is of sufficient quality to serve as the basis for a decision on the development of the deposit.

31. **A ‘Proved Ore Reserve’ is the economically mineable part of a Measured Mineral Resource. A Proved Ore Reserve implies a high degree of confidence in the Modifying Factors.**

A Proved Ore Reserve represents the highest confidence category of reserve estimate and implies a high degree of confidence in geological and grade continuity, and the consideration of the Modifying Factors. The style of mineralisation or other factors could mean that Proved Ore Reserves are not achievable in some deposits.

32. The choice of the appropriate category of Ore Reserve is determined primarily by the relevant level of confidence in the Mineral Resource and after considering any uncertainties in the consideration of the Modifying Factors. Allocation of the appropriate category must be made by a Competent Person.

The Code provides for a direct two-way relationship between Indicated Mineral Resources and Probable Ore Reserves and between Measured Mineral Resources and Proved Ore Reserves. In other words, the level of geological confidence for Probable Ore Reserves is similar to that required for the determination of Indicated Mineral Resources, and the level of geological confidence for Proved Ore Reserves is similar to that required for the determination of Measured Mineral Resources.

The Code also provides for a two-way relationship between Measured Mineral Resources and Probable Ore Reserves. This is to cover a situation where uncertainties associated with any of the Modifying Factors considered when converting Mineral Resources to Ore Reserves may result in there being a lower degree of confidence in the Ore Reserves than in the corresponding Mineral Resources. Such a conversion would not imply a reduction in the level of geological knowledge or confidence.

A Probable Ore Reserve derived from a Measured Mineral Resource may be converted to a Proved Ore Reserve if the uncertainties in the Modifying Factors are removed. No amount of confidence in the Modifying Factors for conversion of a Mineral Resource to an Ore Reserve can override the upper level of confidence that exists in the Mineral Resource. Under no circumstances can an Indicated Mineral Resource be converted directly to a Proved Ore Reserve (see Figure 1).

Application of the category of Proved Ore Reserve implies the highest degree of geological, technical and economic confidence in the estimate at the level of production increments used to support mine planning and production scheduling, with consequent expectations in the minds of the readers of the report. These expectations should be considered when categorising a Mineral Resource as Measured.

Refer also to the guidelines in Clause 24 regarding classification of Mineral Resources.

33. Ore Reserve estimates are not precise calculations. Reporting of tonnage and grade estimates should reflect the relative uncertainty of the estimate by rounding off to appropriately significant figures. Refer also to Clause 25.

To emphasise the imprecise nature of an Ore Reserve, the final result should always be referred to as an estimate and not a calculation.

Competent Persons are encouraged, where appropriate, to discuss the relative accuracy and confidence level of the Ore Reserve estimates with consideration of both underlying estimation and Modifying Factor uncertainties. The statement should specify whether it relates to global or local estimates, and, if local, state the relevant tonnage. Where a statement of the relative accuracy and confidence level is not possible, a qualitative discussion of the uncertainties should be provided in its place (refer to Table 1).

34. Public Reports of Ore Reserves must specify one or other or both of the categories of ‘Proved’ and ‘Probable’. Reports must not contain combined Proved and Probable Ore Reserve figures unless the relevant figures for each of the categories are also provided. Reports must not present metal or mineral content figures unless corresponding tonnage and grade figures are also given.

Public Reporting of tonnage and grade outside the categories covered by the Code is not permitted unless the situation is covered by Clause 17, and then only in strict accordance with the requirements of that Clause.

Estimates of tonnage and grade outside of the categories covered by the Code may be useful for a company in its internal calculations and evaluation processes, but their inclusion in Public Reports could cause confusion, and is not permitted.

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Ore Reserves may incorporate material (dilution) that is not part of the original Mineral Resource. It is essential that this fundamental difference between Mineral Resources and Ore Reserves is considered and caution exercised if attempting to draw conclusions from a comparison of the two.

When revised Ore Reserve and Mineral Resource statements are publicly reported, the Company must discuss any material changes from the previous estimate, and supply sufficient comment to enable the basis for significant changes to be understood by the reader.

35. In a Public Report of an Ore Reserve estimate for a significant project for the first time, or when those estimates have materially changed from when they were last reported, a brief summary of the information in relevant sections of Table 1 must be provided or, if a particular criterion is not relevant or material, a disclosure that it is not relevant or material and a brief explanation of why this is the case must be provided.

For a significant project, when Ore Reserve estimates are first Publicly Reported or when a material change occurs (including classification changes), there is an increased need for transparent discussion of the basis for the new Ore Reserve estimate in order that investors are appropriately informed of the basis for the changes. As noted in Clauses 4 and 5 the benchmark of Materiality is that which an investor or their advisers would reasonably expect to see explicit comment on from the Competent Person, thus the reporting of all criteria in Table 1 on an 'if not, why not' basis is required.

The Code specifies reporting against relevant sections of Table 1 in this Clause. This may be satisfied by reporting against section 4 on the presumption that matters related to sections 1, 2 and 3 will already have been included in a still current Public Report and this Report can be referenced. If this is not the case then these sections are also relevant and should be included in the Public Report.

The Technical summary based against Table 1 criteria should be presented as an appendix to the Public Report.

Where there are as yet unresolved issues potentially impacting the reliability of, or confidence in, a statement of Ore Reserves (for example, limited geotechnical information, complex orebody metallurgy, uncertainty in the permitting process, etc) those unresolved issues should also be reported.

If there is doubt about what should be reported, it is better to err on the side of providing too much information rather than too little.

Uncertainties in any of the criteria listed in Table 1 that could lead to under- or over- statement of Ore Reserves should be disclosed.

Ore Reserve estimates are sometimes reported after adjustment from reconciliation with production data. Such adjustments should be clearly stated in a Public Report of Ore Reserves and the nature of the adjustment or modification described.

36. In situations where figures for both Mineral Resources and Ore Reserves are reported, a statement must be included in the report which clearly indicates whether the Mineral Resources are inclusive of, or additional to the Ore Reserves.

Ore Reserve estimates must not be aggregated with Mineral Resource estimates to report a single combined figure.

In some situations there are reasons for reporting Mineral Resources inclusive of Ore Reserves and in other situations for reporting Mineral Resources additional to Ore Reserves. It must be made clear which form of reporting has been adopted. Appropriate forms of clarifying statements may be:

- *'The Measured and Indicated Mineral Resources are inclusive of those Mineral Resources modified to produce the Ore Reserves.'* or
- *'The Measured and Indicated Mineral Resources are additional to the Ore Reserves.'*

In the former case, if any Measured and Indicated Mineral Resources have not been modified to produce Ore Reserves for economic or other reasons, the relevant details of these unmodified Mineral Resources should be included in the report. This is to assist the reader of the report in making a judgement of the likelihood of the unmodified Measured and Indicated Mineral Resources eventually being converted to Ore Reserves.

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Inferred Mineral Resources are by definition generally additional to Ore Reserves except where included as dilution in the Ore Reserves.

For reasons stated in the guidelines to Clause 34 and in this paragraph, the reported Ore Reserve estimates must not be aggregated with the reported Mineral Resource estimates (eg in graphs, figures or tables). The resulting total is misleading and is capable of being misunderstood or of being misused to give a false impression of a company's prospects.

Technical Studies

37. These definitions are included in the Code to provide clarity on what is expected when reporting using these terms. The definition of a Scoping Study has been included because of the common usage of the term in Public Reports. However attention is drawn to the requirement for a Pre-Feasibility Study or a Feasibility study to have been completed for the Public Reporting of an Ore Reserve in Clause 29. An Ore Reserve must not be reported based on the completion of a Scoping Study.
38. **A Scoping Study is an order of magnitude technical and economic study of the potential viability of Mineral Resources. It includes appropriate assessments of realistically assumed Modifying Factors together with any other relevant operational factors that are necessary to demonstrate at the time of reporting that progress to a Pre-Feasibility Study can be reasonably justified.**

A Scoping Study must not be used as the basis for estimation of Ore Reserves.

If the outcome of a Scoping Study is partially supported by Inferred Mineral Resources and/or an Exploration Target, the Public Report must state both the proportion and relative sequencing of the Inferred Mineral Resources and/or an Exploration Target within the Scoping Study.

For all Scoping Studies, the entity must include a cautionary statement in the same paragraph as, or immediately following, the disclosure of the Scoping Study.

An example cautionary statement follows:

'The Scoping Study referred to in this report is based on low-level technical and economic assessments, and is insufficient to support estimation of Ore Reserves or to provide assurance of an economic development case at this stage, or to provide certainty that the conclusions of the Scoping Study will be realised.'

In discussing 'reasonable prospects for eventual economic extraction' in Clause 20, the Code requires an assessment (albeit preliminary) in respect of all matters likely to influence the prospect of economic extraction including the approximate mining parameters by the Competent Person. While a Scoping Study may provide the basis for that assessment, the Code does not require a Scoping Study to have been completed to report a Mineral Resource.

Scoping Studies are commonly the first economic evaluation of a project undertaken and may be based on a combination of directly gathered project data together with assumptions borrowed from similar deposits or operations to the case envisaged. They are also commonly used internally by companies for comparative and planning purposes. Reporting the general results of a Scoping Study needs to be undertaken with care to ensure there is no implication that Ore Reserves have been established or that economic development is assured. In this regard it may be appropriate to indicate the Mineral Resource inputs to the Scoping Study and the processes applied, but it is not appropriate to report the diluted tonnes and grade as if they were Ore Reserves.

While initial mining and processing cases may have been developed during a Scoping Study, it must not be used to allow an Ore Reserve to be developed.

39. **A Preliminary Feasibility Study (Pre-Feasibility Study) is a comprehensive study of a range of options for the technical and economic viability of a mineral project that has advanced to a stage where a preferred mining method, in the case of underground mining, or the pit configuration, in the case of an open pit, is established and an effective method of mineral processing is determined. It includes a financial analysis based on reasonable assumptions on the Modifying Factors and the evaluation of any other relevant factors which are sufficient for a Competent Person, acting reasonably, to determine if all or part of the Mineral Resources may be converted to an Ore Reserve at the time of reporting. A Pre-Feasibility Study is at a lower confidence level than a Feasibility Study.**

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As noted in Clause 29, formal assessment of all Modifying Factors is required in order to determine how much available Measured and Indicated Mineral Resources can be converted to Ore Reserves.

A Pre-Feasibility Study will consider the application and description of all Modifying factors (as outlined in Table 1, section 4) to demonstrate economic viability and to support an Ore Reserve Public Report. The Pre-Feasibility Study will identify the preferred mining, processing, and infrastructure requirements and capacities, but will not yet have finalised these matters. Detailed assessments of environmental and socio-economic impacts and requirements will also be well advanced. The Pre-Feasibility Study will highlight areas that require further refinement within the final study stage.

40. **A Feasibility Study is a comprehensive technical and economic study of the selected development option for a mineral project that includes appropriately detailed assessments of applicable Modifying Factors together with any other relevant operational factors and detailed financial analysis that are necessary to demonstrate at the time of reporting that extraction is reasonably justified (economically mineable). The results of the study may reasonably serve as the basis for a final decision by a proponent or financial institution to proceed with, or finance, the development of the project. The confidence level of the study will be higher than that of a Pre-Feasibility Study.**

The Code does not require that a full Feasibility Study has been undertaken to convert Mineral Resources to Ore Reserves, but it does require that at least a Pre-Feasibility Study will have been carried out that will have determined a mine plan that is technically achievable and economically viable, and that material Modifying Factors have been considered.

Terms such as “Bankable Feasibility Study” and “Definitive Feasibility Study” are noted as being equivalent to a Feasibility Study as defined in this Clause.

A Feasibility Study is of a higher level of confidence than a Pre-Feasibility Study and would normally contain mining, infrastructure and process designs completed with sufficient rigour to serve as the basis for an investment decision or to support project financing. Social, environmental and governmental approvals, permits and agreements will be in place, or will be approaching finalisation within the expected development timeframe. The Feasibility Study will contain the application and description of all Modifying factors (as outlined in Table 1, section 4) in a more detailed form than in the Pre-Feasibility Study, and may address implementation issues such as detailed mining schedules, construction ramp up, and project execution plans.

Reporting of Mineralised Fill, Remnants, Pillars, Low Grade Mineralisation, Stockpiles, Dumps and Tailings

41. The Code applies to the reporting of all potentially economic mineralised material. This can include mineralised fill, remnants, pillars, low grade mineralisation, stockpiles, dumps and tailings (remnant materials) where there are reasonable prospects for eventual economic extraction in the case of Mineral Resources, and where extraction is reasonably justifiable in the case of Ore Reserves. Unless otherwise stated, all other Clauses of the Code (including Figure 1) apply.

Any mineralised material as described in this Clause can be considered to be similar to in situ mineralisation for the purposes of reporting Mineral Resources and Ore Reserves. Judgements about the mineability of such mineralised material should be made by professionals with relevant experience.

If there are no reasonable prospects for the eventual economic extraction of all or part of the mineralised material as described in this Clause, then this material cannot be classified as either Mineral Resources or Ore Reserves. If some portion of the mineralised material is currently sub-economic, but there is a reasonable expectation that it will become economic, then this material may be classified as a Mineral Resource. If technical and economic studies have demonstrated that economic extraction could reasonably be justified under realistically assumed conditions, then the material may be classified as an Ore Reserve.

The above guidelines apply equally to low-grade in situ mineralisation, sometimes referred to as ‘mineralised waste’ or ‘marginal grade material’, and often intended for stockpiling and treatment towards the end of mine life. For clarity of understanding, it is recommended that tonnage and grade estimates of such material be itemised separately in Public Reports, although they may be aggregated with total Mineral Resource and Ore Reserve figures.

Stockpiles are defined to include both surface and underground stockpiles, including broken ore in stopes, and can include ore currently in the ore storage system. Mineralised material in the course of being processed (including leaching), if reported, should be reported separately.

Reporting of Coal Resources and Reserves

42. Clauses 42 to 44 of the Code address matters that relate specifically to the Public Reporting of Coal Resources and Coal Reserves. Unless otherwise stated, Clauses 1 to 41 and Clause 51 of this Code (including Figure 1) apply. Table 1 should be considered when reporting on Coal Resources and Reserves.

For purposes of Public Reporting, the requirements for coal are those for other commodities with the replacement of terms such as 'mineral' by 'coal' and 'grade' by 'quality'.

For guidance on the estimation of Coal Resources and Reserves and on statutory reporting not primarily intended for providing information to the investing public, readers are referred to the 'Australian Guidelines for Estimating and Reporting of Inventory Coal, Coal Resources and Coal Reserves' or its successor document as published from time to time by the Coalfields Geology Council of New South Wales and the Queensland Resources Council. These guidelines do not override the provisions and intentions of the JORC Code for Public Reporting. Competent Persons should as always exercise their judgement in the application of these guidelines to ensure they are appropriate to the circumstances being reported. They may not be appropriate for use in all situations in Australia or overseas.

Because of its impact on planning and land use, governments may require estimates of inventory coal that are not constrained by short- to medium-term economic considerations. The JORC Code does not cover such estimates. Refer also to the guidelines to Clauses 6 and 20.

43. The terms 'Mineral Resource(s)' and 'Ore Reserve(s)', and the subdivisions of these as defined above, apply also to coal reporting, but if preferred by the reporting company, the terms 'Coal Resource(s)' and 'Coal Reserve(s)' and the appropriate subdivisions may be substituted.
44. 'Marketable Coal Reserves', representing beneficiated or otherwise enhanced coal product where modifications due to mining, dilution and processing have been considered, must be publicly reported in conjunction with, but not instead of, reports of Coal Reserves. The basis of the predicted yield to achieve Marketable Coal Reserves must be stated.

Since investors need to be informed on the products intended to be sold, reporting of Marketable Coal Reserves is required.

Reference to the terms 'coking coal' or 'metallurgical coal', or any reference to coking properties, should not be made until specific coking properties are demonstrated by analytical results for samples from a deposit.

Reporting of Diamond Exploration Results, Mineral Resources and Ore Reserves

45. Clauses 45 to 48 of the Code address matters that relate specifically to the Public Reporting of Exploration Results, Mineral Resources and Ore Reserves for diamonds and other gemstones. Unless otherwise stated, Clauses 1 to 41 and Clause 51 of this Code (including Figure 1) apply. Table 1 should be considered when reporting Exploration Results, Mineral Resources and Ore Reserves for diamonds and other gemstones.

For the purposes of Public Reporting, the requirements for diamonds and other gemstones are generally similar to those for other commodities with the replacement of terms such as 'mineral' by 'diamond' and 'grade' by 'grade and average diamond value'. The term 'quality' should not be substituted for 'grade,' since in diamond deposits these have distinctly separate meanings. Other industry guidelines on the estimation and reporting of diamond resources and reserves may be useful but will not under any circumstances override the provisions and intentions of the JORC Code.

A number of characteristics of diamond deposits are different from those of, for example, typical metalliferous and coal deposits and therefore require special consideration. These include the generally low mineral content and variability of primary and placer deposits, the particulate nature of diamonds, the specialised requirement for diamond valuation and the inherent difficulties and uncertainties in the estimation of diamond resources and reserves.

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46. Reports of diamonds recovered from sampling programmes must provide material information relating to the basis on which the sample is taken, the method of recovery and the recovery of the diamonds. The weight of diamonds recovered may only be omitted from the report when the diamonds are considered to be too small to be of commercial significance. This lower cut-off size should be stated.

The stone size distribution and price of diamonds and other gemstones are critical components of the resource and reserve estimates. At an early exploration stage, sampling and delineation drilling will not usually provide this information, which relies on large diameter drilling and, in particular, bulk sampling.

In order to demonstrate that a resource has reasonable prospects for economic extraction, some description of the likely stone size distribution and price is necessary, however preliminary the analysis of these may be. To determine an Inferred Mineral Resource in simple, single-facies or single-phase deposits, such information may be obtainable by representative large diameter drilling. More often, some form of bulk sampling, such as pitting and trenching, would be employed to provide larger sample parcels.

In order to progress to an Indicated Mineral Resource, and from there to a Probable Ore Reserve, it is likely that much more extensive bulk sampling would be needed to fully determine the stone size distribution and value. Commonly such bulk samples would be obtained by underground development designed to obtain sufficient diamonds to enable a confident estimate of price.

In complex deposits, it may be very difficult to ensure that the bulk samples taken are truly representative of the whole deposit. The lack of direct bulk sampling, and the uncertainty in demonstrating spatial continuity of size and price relationships should be persuasive in determining the appropriate resource category.

47. Where diamond Mineral Resource or Ore Reserve grades (carats per tonne) are based on correlations between the frequency of occurrence of micro-diamonds and of commercial size stones, this must be stated, the reliability of the procedure must be explained and the cut-off sieve size for micro-diamonds reported.
48. For Public Reports dealing with diamond or other gemstone mineralisation, it is a requirement that any reported valuation of a parcel of diamonds or gemstones be accompanied by a statement verifying the independence of the valuation. The valuation must be based on a report from a demonstrably reputable and qualified expert.

If a valuation of a parcel of diamonds is reported, the weight in carats and the lower cut-off size of the contained diamonds must be stated and the value of the diamonds must be given in US dollars per carat. Where the valuation is used in the estimation of diamond Mineral Resources or Ore Reserves, the valuation must be based on a parcel representative of the size, shape and colour distributions of the diamond population in the deposit.

Diamond valuations should not be reported for samples of diamonds processed using total liberation methods.

Reporting of Industrial Minerals Exploration Results, Mineral Resources and Ore Reserves

49. Industrial minerals are covered by the JORC Code if they meet the criteria set out in Clauses 6 and 7 of the Code. For the purpose of the JORC Code, industrial minerals can be considered to cover commodities such as kaolin, phosphate, limestone, talc, etc.

For minerals that are defined by a specification, the Mineral Resource or Ore Reserve estimation must be reported in terms of the mineral or minerals on which the project is to be based and must include the specification of those minerals.

When reporting information and estimates for industrial minerals, the key principles and purpose of the JORC Code apply and should be borne in mind. Assays may not always be relevant, and other quality criteria may be more applicable. If criteria such as deleterious minerals or physical properties are of more relevance than the composition of the bulk mineral itself, then they should be reported accordingly.

The factors underpinning the estimation of Mineral Resources and Ore Reserves for industrial minerals are the same as those for other deposit types covered by the JORC Code. It may be necessary, prior to the reporting of a Mineral Resource or Ore

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Reserve, to take particular account of certain key characteristics or qualities such as likely product specifications, proximity to markets and general product marketability.

For some industrial minerals, it is common practice to report the saleable product rather than the ‘as-mined’ product, which is traditionally regarded as the Ore Reserve. JORC’s preference is that, if the saleable product is reported, it should be in conjunction with, not instead of, reporting of the Ore Reserve. However, it is recognised that commercial sensitivities may not always permit this preferred style of reporting. It is important that, in all situations where the saleable product is reported, a clarifying statement is included to ensure that the reader is fully informed as to what is being reported.

Some industrial mineral deposits may be capable of yielding products suitable for more than one application and/or specification. If considered material by the reporting company, such multiple products should be quantified either separately or as a percentage of the bulk deposit.

Reporting of Metal Equivalents

50. The reporting of Exploration Results, Mineral Resources or Ore Reserves for polymetallic deposits in terms of metal equivalents (a single equivalent grade of one major metal) must show details of all material factors contributing to the net value derived from each constituent.

The following minimum information must accompany any Public Report that includes reference to metal equivalents, in order to conform to the principles of Transparency, Materiality and Competence, as set out in Clause 4:

- individual grades for all metals included in the metal equivalent calculation,
- assumed commodity prices for all metals (Companies should disclose the actual assumed prices. It is not sufficient to refer to a spot price without disclosing the price used in calculating the metal equivalent. However where the actual prices used are commercially sensitive, the company must disclose sufficient information, perhaps in narrative rather than numerical form, for investors to understand the methodology it has used to determine these prices),
- assumed metallurgical recoveries for all metals and discussion of the basis on which the assumed recoveries are derived (metallurgical test work, detailed mineralogy, similar deposits, etc),
- a clear statement that it is the company’s opinion that all the elements included in the metal equivalents calculation have a reasonable potential to be recovered and sold, and
- the calculation formula used.

In most circumstances, the metal chosen for reporting on an equivalent basis should be the one that contributes most to the metal equivalent calculation. If this is not the case, a clear explanation of the logic of choosing another metal must be included in the report.

Estimates of metallurgical recoveries for each metal must be used to calculate meaningful metal equivalents.

Reporting on the basis of metal equivalents is not appropriate if metallurgical recovery information is not available or able to be estimated with reasonable confidence.

For many projects at the Exploration Results stage, metallurgical recovery information may not be available or able to be estimated with reasonable confidence. In such cases reporting of metal equivalents may be misleading.

Reporting of *In Situ* or *In Ground* Valuations

51. The publication of in situ or ‘in ground’ financial valuations breaches the principles of the Code (as set out in Clause 4) as the use of these terms is not transparent and lacks material information. It is also contrary to the intent of Clause 28 of the Code. Such in situ or in ground financial valuations must not be reported by companies in relation to Exploration Results, Mineral Resources or deposit size.

The use of such financial valuations (usually quoted in dollars) has little or no relationship to economic viability, value or potential returns to investors.

These financial valuations can imply economic viability without the apparent consideration of the application of the Modifying Factors, (Clause 12 and Clauses 29 to 36), in particular, the mining, processing, metallurgical, infrastructure, economic, marketing, legal, environmental, social, and governmental factors.

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In determining project viability it is necessary to include all reasonable Modifying Factors (Clauses 29 to 36) to determine the economic value that can be extracted from the mineralisation.

Many deposits with large in ground values are never developed because they have a negative Net Present Value when all reasonable Modifying Factors are considered.

By reporting such financial valuations as a component of Exploration Results or when evaluating deposits that commonly include large portions of Inferred Mineral Resources, companies are not necessarily representing the economic viability of the project, or the net economic value that can be extracted from the mineralisation.

Table 1 Checklist of Assessment and Reporting Criteria

Table 1 is a checklist or reference for use by those preparing Public Reports on Exploration Results, Mineral Resources and Ore Reserves.

In the context of complying with the Principles of the Code, comment on the relevant sections of Table 1 should be provided on an ‘if not, why not’ basis within the Competent Person’s documentation and must be provided where required according to the specific requirements of Clauses 19, 27 and 35 for significant projects in the Public Report. This is to ensure that it is clear to the investor whether items have been considered and deemed of low consequence or have yet to be addressed or resolved.

As always, relevance and Materiality are overriding principles that determine what information should be publicly reported and the Competent Person must provide sufficient comment on all matters that might materially affect a reader’s understanding or interpretation of the results or estimates being reported. This is particularly important where inadequate or uncertain data affect the reliability of, or confidence in, a statement of Exploration Results or an estimate of Mineral Resources or Ore Reserves.

The order and grouping of criteria in Table 1 reflects the normal systematic approach to exploration and evaluation. Criteria in section 1 ‘Sampling Techniques and Data’ apply to all succeeding sections. In the remainder of the table, criteria listed in preceding sections would often also apply and should be considered when estimating and reporting.

It is the responsibility of the Competent Person to consider all the criteria listed below and any additional criteria that should apply to the study of a particular project or operation. The relative importance of the criteria will vary with the particular project and the legal and economic conditions pertaining at the time of determination.

In some cases it will be appropriate for a Public Report to exclude some commercially sensitive information. A decision to exclude commercially sensitive information would be a decision for the company issuing the Public Report, and such a decision should be made in accordance with any relevant corporations regulations in that jurisdiction. For example, in Australia decisions to exclude commercially sensitive information need to be made in accordance with the Corporations Act 2001 and the ASX listing rules and guidance notes.

In cases where commercially sensitive information is excluded from a Public Report, the report should provide summary information (for example the methodology used to determine economic assumptions where the numerical value of those assumptions are commercially sensitive) and context for the purpose of informing investors or potential investors and their advisers.

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Section 1 Sampling Techniques and Data

(Criteria in this section apply to all succeeding sections.)

Criteria	Explanation
<i>Sampling techniques</i>	<ul style="list-style-type: none"> <i>Nature and quality of sampling (eg cut channels, random chips, or specific specialised industry standard measurement tools appropriate to the minerals under investigation, such as down hole gamma sondes, or handheld XRF instruments, etc). These examples should not be taken as limiting the broad meaning of sampling.</i> <i>Include reference to measures taken to ensure sample representivity and the appropriate calibration of any measurement tools or systems used.</i> <i>Aspects of the determination of mineralisation that are Material to the Public Report. In cases where ‘industry standard’ work has been done this would be relatively simple (eg ‘reverse circulation drilling was used to obtain 1 m samples from which 3 kg was pulverised to produce a 30 g charge for fire assay’). In other cases more explanation may be required, such as where there is coarse gold that has inherent sampling problems. Unusual commodities or mineralisation types (eg submarine nodules) may warrant disclosure of detailed information.</i>
<i>Drilling techniques</i>	<ul style="list-style-type: none"> <i>Drill type (eg core, reverse circulation, open-hole hammer, rotary air blast, auger, Bangka, sonic, etc) and details (eg core diameter, triple or standard tube, depth of diamond tails, face-sampling bit or other type, whether core is oriented and if so, by what method, etc).</i>

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Criteria	Explanation
<i>Drill sample recovery</i>	<ul style="list-style-type: none"> • <i>Method of recording and assessing core and chip sample recoveries and results assessed.</i> • <i>Measures taken to maximise sample recovery and ensure representative nature of the samples.</i> • <i>Whether a relationship exists between sample recovery and grade and whether sample bias may have occurred due to preferential loss/gain of fine/coarse material.</i>
<i>Logging</i>	<ul style="list-style-type: none"> • <i>Whether core and chip samples have been geologically and geotechnically logged to a level of detail to support appropriate Mineral Resource estimation, mining studies and metallurgical studies.</i> • <i>Whether logging is qualitative or quantitative in nature. Core (or costean, channel, etc) photography.</i> • <i>The total length and percentage of the relevant intersections logged.</i>
<i>Sub-sampling techniques and sample preparation</i>	<ul style="list-style-type: none"> • <i>If core, whether cut or sawn and whether quarter, half or all core taken.</i> • <i>If non-core, whether riffled, tube sampled, rotary split, etc and whether sampled wet or dry.</i> • <i>For all sample types, the nature, quality and appropriateness of the sample preparation technique.</i> • <i>Quality control procedures adopted for all sub-sampling stages to maximise representivity of samples.</i> • <i>Measures taken to ensure that the sampling is representative of the in situ material collected, including for instance results for field duplicate/ second-half sampling.</i> • <i>Whether sample sizes are appropriate to the grain size of the material being sampled.</i>
<i>Quality of assay data and laboratory tests</i>	<ul style="list-style-type: none"> • <i>The nature, quality and appropriateness of the assaying and laboratory procedures used and whether the technique is considered partial or total.</i> • <i>For geophysical tools, spectrometers, handheld XRF instruments, etc, the parameters used in determining the analysis including instrument make and model, reading times, calibrations factors applied and their derivation, etc.</i> • <i>Nature of quality control procedures adopted (eg standards, blanks, duplicates, external laboratory checks) and whether acceptable levels of accuracy (ie lack of bias) and precision have been established.</i>
<i>Verification of sampling and assaying</i>	<ul style="list-style-type: none"> • <i>The verification of significant intersections by either independent or alternative company personnel.</i> • <i>The use of twinned holes.</i> • <i>Documentation of primary data, data entry procedures, data verification, data storage (physical and electronic) protocols.</i> • <i>Discuss any adjustment to assay data.</i>
<i>Location of data points</i>	<ul style="list-style-type: none"> • <i>Accuracy and quality of surveys used to locate drill holes (collar and down-hole surveys), trenches, mine workings and other locations used in Mineral Resource estimation.</i> • <i>Specification of the grid system used.</i> • <i>Quality and adequacy of topographic control.</i>
<i>Data spacing and distribution</i>	<ul style="list-style-type: none"> • <i>Data spacing for reporting of Exploration Results.</i> • <i>Whether the data spacing and distribution is sufficient to establish the degree of geological and grade continuity appropriate for the Mineral Resource and Ore Reserve estimation procedure(s) and classifications applied.</i> • <i>Whether sample compositing has been applied.</i>
<i>Orientation of data in relation to geological structure</i>	<ul style="list-style-type: none"> • <i>Whether the orientation of sampling achieves unbiased sampling of possible structures and the extent to which this is known, considering the deposit type.</i> • <i>If the relationship between the drilling orientation and the orientation of key mineralised structures is considered to have introduced a sampling bias, this should be assessed and reported if material.</i>
<i>Sample security</i>	<ul style="list-style-type: none"> • <i>The measures taken to ensure sample security.</i>
<i>Audits or reviews</i>	<ul style="list-style-type: none"> • <i>The results of any audits or reviews of sampling techniques and data.</i>

Section 2 Reporting of Exploration Results

(Criteria listed in the preceding section also apply to this section.)

Criteria	Explanation
<i>Mineral tenement and land tenure status</i>	<ul style="list-style-type: none"> • <i>Type, reference name/ number, location and ownership including agreements or material issues with third parties such as joint ventures, partnerships, overriding royalties, native title interests, historical sites, wilderness or national park and environmental settings.</i> • <i>The security of the tenure held at the time of reporting along with any known impediments to obtaining a licence to operate in the area.</i>
<i>Exploration done by other parties</i>	<ul style="list-style-type: none"> • <i>Acknowledgment and appraisal of exploration by other parties.</i>
<i>Geology</i>	<ul style="list-style-type: none"> • <i>Deposit type, geological setting and style of mineralisation.</i>
<i>Drill hole Information</i>	<ul style="list-style-type: none"> • <i>A summary of all information material to the understanding of the exploration results including a tabulation of the following information for all Material drill holes:</i> <ul style="list-style-type: none"> • <i>easting and northing of the drill hole collar</i> • <i>elevation or RL (Reduced Level – elevation above sea level in metres) of the drill hole collar</i> • <i>dip and azimuth of the hole</i> • <i>down hole length and interception depth</i> • <i>hole length.</i> • <i>If the exclusion of this information is justified on the basis that the information is not Material and this exclusion does not detract from the understanding of the report, the Competent Person should clearly explain why this is the case.</i>
<i>Data aggregation methods</i>	<ul style="list-style-type: none"> • <i>In reporting Exploration Results, weighting averaging techniques, maximum and/ or minimum grade truncations (eg cutting of high grades) and cut-off grades are usually Material and should be stated.</i> • <i>Where aggregate intercepts incorporate short lengths of high grade results and longer lengths of low grade results, the procedure used for such aggregation should be stated and some typical examples of such aggregations should be shown in detail.</i> • <i>The assumptions used for any reporting of metal equivalent values should be clearly stated.</i>
<i>Relationship between mineralisation widths and intercept lengths</i>	<ul style="list-style-type: none"> • <i>These relationships are particularly important in the reporting of Exploration Results.</i> • <i>If the geometry of the mineralisation with respect to the drill hole angle is known, its nature should be reported.</i> • <i>If it is not known and only the down hole lengths are reported, there should be a clear statement to this effect (eg ‘down hole length, true width not known’).</i>
<i>Diagrams</i>	<ul style="list-style-type: none"> • <i>Appropriate maps and sections (with scales) and tabulations of intercepts should be included for any significant discovery being reported These should include, but not be limited to a plan view of drill hole collar locations and appropriate sectional views.</i>
<i>Balanced reporting</i>	<ul style="list-style-type: none"> • <i>Where comprehensive reporting of all Exploration Results is not practicable, representative reporting of both low and high grades and/ or widths should be practiced to avoid misleading reporting of Exploration Results.</i>
<i>Other substantive exploration data</i>	<ul style="list-style-type: none"> • <i>Other exploration data, if meaningful and material, should be reported including (but not limited to): geological observations; geophysical survey results; geochemical survey results; bulk samples – size and method of treatment; metallurgical test results; bulk density, groundwater, geotechnical and rock characteristics; potential deleterious or contaminating substances.</i>
<i>Further work</i>	<ul style="list-style-type: none"> • <i>The nature and scale of planned further work (eg tests for lateral extensions or depth extensions or large-scale step-out drilling).</i> • <i>Diagrams clearly highlighting the areas of possible extensions, including the main geological interpretations and future drilling areas, provided this information is not commercially sensitive.</i>

Section 3 Estimation and Reporting of Mineral Resources

(Criteria listed in section 1, and where relevant in section 2, also apply to this section.)

Criteria	Explanation
<i>Database integrity</i>	<ul style="list-style-type: none"> • <i>Measures taken to ensure that data has not been corrupted by, for example, transcription or keying errors, between its initial collection and its use for Mineral Resource estimation purposes.</i> • <i>Data validation procedures used.</i>

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Criteria	Explanation
<i>Site visits</i>	<ul style="list-style-type: none"> • <i>Comment on any site visits undertaken by the Competent Person and the outcome of those visits.</i> • <i>If no site visits have been undertaken indicate why this is the case.</i>
<i>Geological interpretation</i>	<ul style="list-style-type: none"> • <i>Confidence in (or conversely, the uncertainty of) the geological interpretation of the mineral deposit.</i> • <i>Nature of the data used and of any assumptions made.</i> • <i>The effect, if any, of alternative interpretations on Mineral Resource estimation.</i> • <i>The use of geology in guiding and controlling Mineral Resource estimation.</i> • <i>The factors affecting continuity both of grade and geology.</i>
<i>Dimensions</i>	<ul style="list-style-type: none"> • <i>The extent and variability of the Mineral Resource expressed as length (along strike or otherwise), plan width, and depth below surface to the upper and lower limits of the Mineral Resource.</i>
<i>Estimation and modelling techniques</i>	<ul style="list-style-type: none"> • <i>The nature and appropriateness of the estimation technique(s) applied and key assumptions, including treatment of extreme grade values, domaining, interpolation parameters and maximum distance of extrapolation from data points. If a computer assisted estimation method was chosen include a description of computer software and parameters used.</i> • <i>The availability of check estimates, previous estimates and/or mine production records and whether the Mineral Resource estimate takes appropriate account of such data.</i> • <i>The assumptions made regarding recovery of by-products.</i> • <i>Estimation of deleterious elements or other non-grade variables of economic significance (eg sulphur for acid mine drainage characterisation).</i> • <i>In the case of block model interpolation, the block size in relation to the average sample spacing and the search employed.</i> • <i>Any assumptions behind modelling of selective mining units.</i> • <i>Any assumptions about correlation between variables.</i> • <i>Description of how the geological interpretation was used to control the resource estimates.</i> • <i>Discussion of basis for using or not using grade cutting or capping.</i> • <i>The process of validation, the checking process used, the comparison of model data to drill hole data, and use of reconciliation data if available.</i>
<i>Moisture</i>	<ul style="list-style-type: none"> • <i>Whether the tonnages are estimated on a dry basis or with natural moisture, and the method of determination of the moisture content.</i>
<i>Cut-off parameters</i>	<ul style="list-style-type: none"> • <i>The basis of the adopted cut-off grade(s) or quality parameters applied.</i>
<i>Mining factors or assumptions</i>	<ul style="list-style-type: none"> • <i>Assumptions made regarding possible mining methods, minimum mining dimensions and internal (or, if applicable, external) mining dilution. It is always necessary as part of the process of determining reasonable prospects for eventual economic extraction to consider potential mining methods, but the assumptions made regarding mining methods and parameters when estimating Mineral Resources may not always be rigorous. Where this is the case, this should be reported with an explanation of the basis of the mining assumptions made.</i>
<i>Metallurgical factors or assumptions</i>	<ul style="list-style-type: none"> • <i>The basis for assumptions or predictions regarding metallurgical amenability. It is always necessary as part of the process of determining reasonable prospects for eventual economic extraction to consider potential metallurgical methods, but the assumptions regarding metallurgical treatment processes and parameters made when reporting Mineral Resources may not always be rigorous. Where this is the case, this should be reported with an explanation of the basis of the metallurgical assumptions made.</i>
<i>Environmental factors or assumptions</i>	<ul style="list-style-type: none"> • <i>Assumptions made regarding possible waste and process residue disposal options. It is always necessary as part of the process of determining reasonable prospects for eventual economic extraction to consider the potential environmental impacts of the mining and processing operation. While at this stage the determination of potential environmental impacts, particularly for a greenfields project, may not always be well advanced, the status of early consideration of these potential environmental impacts should be reported. Where these aspects have not been considered this should be reported with an explanation of the environmental assumptions made.</i>
<i>Bulk density</i>	<ul style="list-style-type: none"> • <i>Whether assumed or determined. If assumed, the basis for the assumptions. If determined, the method used, whether wet or dry, the frequency of the measurements, the nature, size and representativeness of the samples.</i> • <i>The bulk density for bulk material must have been measured by methods that adequately account for void spaces (vugs, porosity, etc), moisture and differences between rock and alteration zones within the deposit.</i> • <i>Discuss assumptions for bulk density estimates used in the evaluation process of the different materials.</i>

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Criteria	Explanation
<i>Classification</i>	<ul style="list-style-type: none"> • <i>The basis for the classification of the Mineral Resources into varying confidence categories.</i> • <i>Whether appropriate account has been taken of all relevant factors (ie relative confidence in tonnage/grade estimations, reliability of input data, confidence in continuity of geology and metal values, quality, quantity and distribution of the data).</i> • <i>Whether the result appropriately reflects the Competent Person's view of the deposit.</i>
<i>Audits or reviews.</i>	<ul style="list-style-type: none"> • <i>The results of any audits or reviews of Mineral Resource estimates.</i>
<i>Discussion of relative accuracy/ confidence</i>	<ul style="list-style-type: none"> • <i>Where appropriate a statement of the relative accuracy and confidence level in the Mineral Resource estimate using an approach or procedure deemed appropriate by the Competent Person. For example, the application of statistical or geostatistical procedures to quantify the relative accuracy of the resource within stated confidence limits, or, if such an approach is not deemed appropriate, a qualitative discussion of the factors that could affect the relative accuracy and confidence of the estimate.</i> • <i>The statement should specify whether it relates to global or local estimates, and, if local, state the relevant tonnages, which should be relevant to technical and economic evaluation. Documentation should include assumptions made and the procedures used.</i> • <i>These statements of relative accuracy and confidence of the estimate should be compared with production data, where available.</i>

Section 4 Estimation and Reporting of Ore Reserves

(Criteria listed in section 1, and where relevant in sections 2 and 3, also apply to this section.)

Criteria	Explanation
<i>Mineral Resource estimate for conversion to Ore Reserves</i>	<ul style="list-style-type: none"> • <i>Description of the Mineral Resource estimate used as a basis for the conversion to an Ore Reserve.</i> • <i>Clear statement as to whether the Mineral Resources are reported additional to, or inclusive of, the Ore Reserves.</i>
<i>Site visits</i>	<ul style="list-style-type: none"> • <i>Comment on any site visits undertaken by the Competent Person and the outcome of those visits.</i> • <i>If no site visits have been undertaken indicate why this is the case.</i>
<i>Study status</i>	<ul style="list-style-type: none"> • <i>The type and level of study undertaken to enable Mineral Resources to be converted to Ore Reserves.</i> • <i>The Code requires that a study to at least Pre-Feasibility Study level has been undertaken to convert Mineral Resources to Ore Reserves. Such studies will have been carried out and will have determined a mine plan that is technically achievable and economically viable, and that material Modifying Factors have been considered.</i>
<i>Cut-off parameters</i>	<ul style="list-style-type: none"> • <i>The basis of the cut-off grade(s) or quality parameters applied.</i>
<i>Mining factors or assumptions</i>	<ul style="list-style-type: none"> • <i>The method and assumptions used as reported in the Pre-Feasibility or Feasibility Study to convert the Mineral Resource to an Ore Reserve (i.e. either by application of appropriate factors by optimisation or by preliminary or detailed design).</i> • <i>The choice, nature and appropriateness of the selected mining method(s) and other mining parameters including associated design issues such as pre-strip, access, etc.</i> • <i>The assumptions made regarding geotechnical parameters (eg pit slopes, stope sizes, etc), grade control and pre-production drilling.</i> • <i>The major assumptions made and Mineral Resource model used for pit and stope optimisation (if appropriate).</i> • <i>The mining dilution factors used.</i> • <i>The mining recovery factors used.</i> • <i>Any minimum mining widths used.</i> • <i>The manner in which Inferred Mineral Resources are utilised in mining studies and the sensitivity of the outcome to their inclusion.</i> • <i>The infrastructure requirements of the selected mining methods.</i>

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Criteria	Explanation
<i>Metallurgical factors or assumptions</i>	<ul style="list-style-type: none"> • <i>The metallurgical process proposed and the appropriateness of that process to the style of mineralisation.</i> • <i>Whether the metallurgical process is well-tested technology or novel in nature.</i> • <i>The nature, amount and representativeness of metallurgical test work undertaken, the nature of the metallurgical domaining applied and the corresponding metallurgical recovery factors applied.</i> • <i>Any assumptions or allowances made for deleterious elements.</i> • <i>The existence of any bulk sample or pilot scale test work and the degree to which such samples are considered representative of the orebody as a whole.</i> • <i>For minerals that are defined by a specification, has the ore reserve estimation been based on the appropriate mineralogy to meet the specifications?</i>
<i>Environmental</i>	<ul style="list-style-type: none"> • <i>The status of studies of potential environmental impacts of the mining and processing operation. Details of waste rock characterisation and the consideration of potential sites, status of design options considered and, where applicable, the status of approvals for process residue storage and waste dumps should be reported.</i>
<i>Infrastructure</i>	<ul style="list-style-type: none"> • <i>The existence of appropriate infrastructure: availability of land for plant development, power, water, transportation (particularly for bulk commodities), labour, accommodation; or the ease with which the infrastructure can be provided, or accessed.</i>
<i>Costs</i>	<ul style="list-style-type: none"> • <i>The derivation of, or assumptions made, regarding projected capital costs in the study.</i> • <i>The methodology used to estimate operating costs.</i> • <i>Allowances made for the content of deleterious elements.</i> • <i>The source of exchange rates used in the study.</i> • <i>Derivation of transportation charges.</i> • <i>The basis for forecasting or source of treatment and refining charges, penalties for failure to meet specification, etc.</i> • <i>The allowances made for royalties payable, both Government and private.</i>
<i>Revenue factors</i>	<ul style="list-style-type: none"> • <i>The derivation of, or assumptions made regarding revenue factors including head grade, metal or commodity price(s) exchange rates, transportation and treatment charges, penalties, net smelter returns, etc.</i> • <i>The derivation of assumptions made of metal or commodity price(s), for the principal metals, minerals and co-products.</i>
<i>Market assessment</i>	<ul style="list-style-type: none"> • <i>The demand, supply and stock situation for the particular commodity, consumption trends and factors likely to affect supply and demand into the future.</i> • <i>A customer and competitor analysis along with the identification of likely market windows for the product.</i> • <i>Price and volume forecasts and the basis for these forecasts.</i> • <i>For industrial minerals the customer specification, testing and acceptance requirements prior to a supply contract.</i>
<i>Economic</i>	<ul style="list-style-type: none"> • <i>The inputs to the economic analysis to produce the net present value (NPV) in the study, the source and confidence of these economic inputs including estimated inflation, discount rate, etc.</i> • <i>NPV ranges and sensitivity to variations in the significant assumptions and inputs.</i>
<i>Social</i>	<ul style="list-style-type: none"> • <i>The status of agreements with key stakeholders and matters leading to social licence to operate.</i>
<i>Other</i>	<ul style="list-style-type: none"> • <i>To the extent relevant, the impact of the following on the project and/or on the estimation and classification of the Ore Reserves:</i> • <i>Any identified material naturally occurring risks.</i> • <i>The status of material legal agreements and marketing arrangements.</i> • <i>The status of governmental agreements and approvals critical to the viability of the project, such as mineral tenement status, and government and statutory approvals. There must be reasonable grounds to expect that all necessary Government approvals will be received within the timeframes anticipated in the Pre-Feasibility or Feasibility study. Highlight and discuss the materiality of any unresolved matter that is dependent on a third party on which extraction of the reserve is contingent.</i>
<i>Classification</i>	<ul style="list-style-type: none"> • <i>The basis for the classification of the Ore Reserves into varying confidence categories.</i> • <i>Whether the result appropriately reflects the Competent Person's view of the deposit.</i> • <i>The proportion of Probable Ore Reserves that have been derived from Measured Mineral Resources (if any).</i>
<i>Audits or reviews</i>	<ul style="list-style-type: none"> • <i>The results of any audits or reviews of Ore Reserve estimates.</i>

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Criteria	Explanation
<i>Discussion of relative accuracy/confidence</i>	<ul style="list-style-type: none"> • <i>Where appropriate a statement of the relative accuracy and confidence level in the Ore Reserve estimate using an approach or procedure deemed appropriate by the Competent Person. For example, the application of statistical or geostatistical procedures to quantify the relative accuracy of the reserve within stated confidence limits, or, if such an approach is not deemed appropriate, a qualitative discussion of the factors which could affect the relative accuracy and confidence of the estimate.</i> • <i>The statement should specify whether it relates to global or local estimates, and, if local, state the relevant tonnages, which should be relevant to technical and economic evaluation. Documentation should include assumptions made and the procedures used.</i> • <i>Accuracy and confidence discussions should extend to specific discussions of any applied Modifying Factors that may have a material impact on Ore Reserve viability, or for which there are remaining areas of uncertainty at the current study stage.</i> • <i>It is recognised that this may not be possible or appropriate in all circumstances. These statements of relative accuracy and confidence of the estimate should be compared with production data, where available.</i>

Section 5 Estimation and Reporting of Diamonds and Other Gemstones

(Criteria listed in other relevant sections also apply to this section. Additional guidelines are available in the 'Guidelines for the Reporting of Diamond Exploration Results' issued by the Diamond Exploration Best Practices Committee established by the Canadian Institute of Mining, Metallurgy and Petroleum.)

Criteria	Explanation
<i>Indicator minerals</i>	<ul style="list-style-type: none"> • <i>Reports of indicator minerals, such as chemically/physically distinctive garnet, ilmenite, chrome spinel and chrome diopside, should be prepared by a suitably qualified laboratory.</i>
<i>Source of diamonds</i>	<ul style="list-style-type: none"> • <i>Details of the form, shape, size and colour of the diamonds and the nature of the source of diamonds (primary or secondary) including the rock type and geological environment.</i>
<i>Sample collection</i>	<ul style="list-style-type: none"> • <i>Type of sample, whether outcrop, boulders, drill core, reverse circulation drill cuttings, gravel, stream sediment or soil, and purpose (eg large diameter drilling to establish stones per unit of volume or bulk samples to establish stone size distribution).</i> • <i>Sample size, distribution and representivity.</i>
<i>Sample treatment</i>	<ul style="list-style-type: none"> • <i>Type of facility, treatment rate, and accreditation.</i> • <i>Sample size reduction. Bottom screen size, top screen size and re-crush.</i> • <i>Processes (dense media separation, grease, X-ray, hand-sorting, etc).</i> • <i>Process efficiency, tailings auditing and granulometry.</i> • <i>Laboratory used, type of process for micro diamonds and accreditation.</i>
<i>Carat</i>	<ul style="list-style-type: none"> • <i>One fifth (0.2) of a gram (often defined as a metric carat or MC).</i>
<i>Sample grade</i>	<ul style="list-style-type: none"> • <i>Sample grade in this section of Table 1 is used in the context of carats per units of mass, area or volume.</i> • <i>The sample grade above the specified lower cut-off sieve size should be reported as carats per dry metric tonne and/or carats per 100 dry metric tonnes. For alluvial deposits, sample grades quoted in carats per square metre or carats per cubic metre are acceptable if accompanied by a volume to weight basis for calculation.</i> • <i>In addition to general requirements to assess volume and density there is a need to relate stone frequency (stones per cubic metre or tonne) to stone size (carats per stone) to derive sample grade (carats per tonne).</i>
<i>Reporting of Exploration Results</i>	<ul style="list-style-type: none"> • <i>Complete set of sieve data using a standard progression of sieve sizes per facies. Bulk sampling results, global sample grade per facies. Spatial structure analysis and grade distribution. Stone size and number distribution. Sample head feed and tailings particle granulometry.</i> • <i>Sample density determination.</i> • <i>Per cent concentrate and undersize per sample.</i> • <i>Sample grade with change in bottom cut-off screen size.</i> • <i>Adjustments made to size distribution for sample plant performance and performance on a commercial scale.</i> • <i>If appropriate or employed, geostatistical techniques applied to model stone size, distribution or frequency from size distribution of exploration diamond samples.</i> • <i>The weight of diamonds may only be omitted from the report when the diamonds are considered too small to be of commercial significance. This lower cut-off size should be stated.</i>

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Criteria	Explanation
<i>Grade estimation for reporting Mineral Resources and Ore Reserves</i>	<ul style="list-style-type: none"> • <i>Description of the sample type and the spatial arrangement of drilling or sampling designed for grade estimation.</i> • <i>The sample crush size and its relationship to that achievable in a commercial treatment plant.</i> • <i>Total number of diamonds greater than the specified and reported lower cut-off sieve size.</i> • <i>Total weight of diamonds greater than the specified and reported lower cut-off sieve size.</i> • <i>The sample grade above the specified lower cut-off sieve size.</i>
<i>Value estimation</i>	<ul style="list-style-type: none"> • <i>Valuations should not be reported for samples of diamonds processed using total liberation method, which is commonly used for processing exploration samples.</i> • <i>To the extent that such information is not deemed commercially sensitive, Public Reports should include:</i> <ul style="list-style-type: none"> • <i>diamonds quantities by appropriate screen size per facies or depth.</i> • <i>details of parcel valued.</i> • <i>number of stones, carats, lower size cut-off per facies or depth.</i> • <i>The average \$/carat and \$/tonne value at the selected bottom cut-off should be reported in US Dollars. The value per carat is of critical importance in demonstrating project value.</i> • <i>The basis for the price (eg dealer buying price, dealer selling price, etc).</i> • <i>An assessment of diamond breakage.</i>
<i>Security and integrity</i>	<ul style="list-style-type: none"> • <i>Accredited process audit.</i> • <i>Whether samples were sealed after excavation.</i> • <i>Valuer location, escort, delivery, cleaning losses, reconciliation with recorded sample carats and number of stones.</i> • <i>Core samples washed prior to treatment for micro diamonds.</i> • <i>Audit samples treated at alternative facility.</i> • <i>Results of tailings checks.</i> • <i>Recovery of tracer monitors used in sampling and treatment.</i> • <i>Geophysical (logged) density and particle density.</i> • <i>Cross validation of sample weights, wet and dry, with hole volume and density, moisture factor.</i>
<i>Classification</i>	<ul style="list-style-type: none"> • <i>In addition to general requirements to assess volume and density there is a need to relate stone frequency (stones per cubic metre or tonne) to stone size (carats per stone) to derive grade (carats per tonne). The elements of uncertainty in these estimates should be considered, and classification developed accordingly.</i>

Appendix 1 Generic Terms and Equivalents

Throughout the Code, certain words are used in a general sense when a more specific meaning might be attached to them by particular commodity groups within the industry. In order to avoid unnecessary duplication, a non-exclusive list of generic terms is tabulated below together with other terms that may be regarded as synonymous for the purposes of this document.

Generic Term	Synonyms and similar terms	Intended generalised meaning
<i>assumption</i>	<i>value judgements</i>	<i>The Competent Person in general makes value judgements when making assumptions regarding information not fully supported by test work.</i>
<i>Competent Person</i>	<i>Qualified Person (Canada), Qualified Competent Person (Chile)</i>	<i>Refer to the Clause 11 of the Code for the definition of a Competent Person. Any reference in the Code to the singular (a Competent Person) includes a reference to the plural (Competent Persons). It is noted that reporting in accordance with the Code is commonly a team effort.</i>
<i>cut-off grade</i>	<i>product specifications</i>	<i>The lowest grade, or quality, of mineralised material that qualifies as economically mineable and available in a given deposit. May be defined on the basis of economic evaluation, or on physical or chemical attributes that define an acceptable product specification.</i>
<i>grade</i>	<i>quality, assay, analysis (that is value returned by the analysis)</i>	<i>Any physical or chemical measurement of the characteristics of the material of interest in samples or product. Note that the term quality has special meaning for diamonds and other gemstones. The units of measurement should be stated when figures are reported.</i>
<i>metallurgy</i>	<i>processing, beneficiation, preparation, concentration</i>	<i>Physical and/or chemical separation of constituents of interest from a larger mass of material. Methods employed to prepare a final marketable product from material as mined. Examples include screening, flotation, magnetic separation, leaching, washing, roasting, etc. <i>Processing is generally regarded as broader than metallurgy and may apply to non-metallic materials where the term metallurgy would be inappropriate.</i></i>
<i>mineralisation</i>	<i>type of deposit, orebody, style of mineralisation.</i>	<i>Any single mineral or combination of minerals occurring in a mass, or deposit, of economic interest. The term is intended to cover all forms in which mineralisation might occur, whether by class of deposit, mode of occurrence, genesis or composition.</i>
<i>mining</i>	<i>quarrying</i>	<i>All activities related to extraction of metals, minerals and gemstones from the earth whether surface or underground, and by any method (eg quarries, open cast, open cut, solution mining, dredging, etc)</i>
<i>Ore Reserves</i>	<i>Mineral Reserves</i>	<i>'Ore Reserves' is preferred under the JORC Code but 'Mineral Reserves' is in common use in other countries and is generally accepted. Other descriptors can be used to clarify the meaning (eg Coal Reserves, Diamond Reserves, etc).</i>
<i>recovery</i>	<i>yield</i>	<i>The percentage of material of interest that is extracted during mining and/or processing. A measure of mining or processing efficiency.</i>
<i>significant project</i>	<i>material project</i>	<i>An exploration or mineral development project that has or could have a significant influence on the market value or operations of the listed company, and/or has specific prominence in Public Reports and announcements.</i>
<i>tonnage</i>	<i>quantity, volume</i>	<i>An expression of the amount of material of interest irrespective of the units of measurement (which should be stated when figures are reported).</i>

Appendix 2 Competent Person's Consent Form

Companies reporting Exploration Targets, Exploration Results, Mineral Resources or Ore Reserves are reminded that while a public report is the responsibility of the company acting through its Board of Directors, Clause 9 requires that any such report 'must be based on, and fairly reflect the information and supporting documentation prepared by a Competent Person or Persons'. Clause 9 also requires that the 'report shall be issued with the prior written consent of the Competent Person or Persons as to the form and context in which it appears'.

In order to assist Competent Persons and companies to comply with these requirements, and to emphasise the need for companies to obtain the prior written consent of each Competent Person for their material to be included in the form and context in which it appears in the public report, ASX, together with JORC, have developed a Competent Person's Consent Form that incorporates the requirements of the JORC Code.

The completion of a consent form, whether in the format provided or in an equivalent form, is recommended as good practice and provides readily available evidence that the required prior written consent has been obtained.

Having the consent form witnessed by a peer professional society member is considered leading practice and is strongly encouraged.

The Competent Person's Consent Form(s), or other evidence of the Competent Person's written consent, should be retained by the company and the Competent Person to ensure that the written consent can be promptly provided if required.

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[Letterhead of Competent Person or Competent Person's employer]

Competent Person's Consent Form

Pursuant to the requirements of ASX Listing Rules 5.6, 5.22 and 5.24 and Clause 9 of the JORC Code 2012 Edition (Written Consent Statement)

Report name

(Insert name or heading of Report to be publicly released) ('Report')

(Insert name of company releasing the Report)

(Insert name of the deposit to which the Report refers)

If there is insufficient space, complete the following sheet and sign it in the same manner as this original sheet.

(Date of Report)

JORC Code, 2012 Edition
Statement

I/We,

(Insert full name(s))

confirm that I am the Competent Person for the Report and:

- I have read and understood the requirements of the 2012 Edition of the Australasian Code for Reporting of Exploration Results, Mineral Resources and Ore Reserves (JORC Code, 2012 Edition).
- I am a Competent Person as defined by the JORC Code, 2012 Edition, having five years experience that is relevant to the style of mineralisation and type of deposit described in the Report, and to the activity for which I am accepting responsibility.
- I am a Member or Fellow of *The Australasian Institute of Mining and Metallurgy* or the *Australian Institute of Geoscientists* or a 'Recognised Professional Organisation' (RPO) included in a list promulgated by ASX from time to time.
- I have reviewed the Report to which this Consent Statement applies.

I am a full time employee of

(Insert company name)

Or

I/We am a consultant working for

(Insert company name)

and have been engaged by

(Insert company name)

to prepare the documentation for

(Insert deposit name)

on which the Report is based, for the period ended

(Insert date of Resource/Reserve statement)

I have disclosed to the reporting company the full nature of the relationship between myself and the company, including any issue that could be perceived by investors as a conflict of interest.

I verify that the Report is based on and fairly and accurately reflects in the form and context in which it appears, the information in my supporting documentation relating to Exploration Targets, Exploration Results, Mineral Resources and/or Ore Reserves *(select as appropriate)*.

JORC Code, 2012 Edition
Consent

I consent to the release of the Report and this Consent Statement by the directors of:

(Insert reporting company name)

Signature of Competent Person:

Date:

Professional Membership:
(insert organisation name)

Membership Number:

Signature of Witness:

Print Witness Name and Residence:
(eg town/suburb)

JORC Code, 2012 Edition

Additional deposits covered by the Report for which the Competent Person signing this form is accepting responsibility:

Additional Reports related to the deposit for which the Competent Person signing this form is accepting responsibility:

Signature of Competent Person:

Date:

Professional Membership:
(insert organisation name)

Membership Number:

Signature of Witness:

Print Witness Name and Residence:
(eg town/suburb)

Appendix 3 Compliance Statements

Appropriate forms of compliance statements should be as follows (delete bullet points which do not apply).

For Public Reports of Exploration Targets, initial or materially changed reports of Exploration Results, Mineral Resources or Ore Reserves or company annual reports:

- *If the required information is in the report:
‘The information in this report that relates to Exploration Targets, Exploration Results, Mineral Resources or Ore Reserves is based on information compiled by (insert name of Competent Person), a Competent Person who is a Member or Fellow of The Australasian Institute of Mining and Metallurgy or the Australian Institute of Geoscientists or a ‘Recognised Professional Organisation’ (RPO) included in a list that is posted on the ASX website from time to time (select as appropriate and insert the name of the professional organisation of which the Competent Person is a member and the Competent Person’s grade of membership).’*
- *If the required information is included in an attached statement:
‘The information in the report to which this statement is attached that relates to Exploration Targets, Exploration Results, Mineral Resources or Ore Reserves is based on information compiled by (insert name of Competent Person), a Competent Person who is a Member or Fellow of The Australasian Institute of Mining and Metallurgy or the Australian Institute of Geoscientists or a ‘Recognised Professional Organisation’ (RPO) included in a list posted on the ASX website from time to time (select as appropriate and insert the name of the professional organisation of which the Competent Person is a member and the Competent Person’s grade of membership).’*
- *If the Competent Person is a full-time employee of the company:
‘(Insert name of Competent Person) is a full-time employee of the company.’*
- *If the Competent Person is not a full-time employee of the company:
‘(Insert name of Competent Person) is employed by (insert name of Competent Person’s employer).’*
- *The full nature of the relationship between the Competent Person and the reporting Company must be declared together with the Competent Person’s details. This declaration must outline and clarify any issue that could be perceived by investors as a conflict of interest.*
- *For all reports:
‘(Insert name of Competent Person) has sufficient experience that is relevant to the style of mineralisation and type of deposit under consideration and to the activity being undertaken to qualify as a Competent Person as defined in the 2012 Edition of the ‘Australasian Code for Reporting of Exploration Results, Mineral Resources and Ore Reserves’. (Insert name of Competent Person) consents to the inclusion in the report of the matters based on his (or her) information in the form and context in which it appears.’*

For any subsequent Public Report based on a previously issued Public Report that refers to those Exploration Results or estimates of Mineral Resources or Ore Reserves:

Where a Competent Person has previously issued the written consent to the inclusion of their findings in a report, a company re-issuing that information to the Public whether in the form of a presentation or a subsequent announcement must, state the report name, date and reference the location of the original source Public Report for public access.

- *‘The information is extracted from the report entitled (name report) created on (date) and is available to view on (website name). The company confirms that it is not aware of any new information or data that materially affects the information included in the original market announcement and, in the case of estimates of Mineral Resources or Ore Reserves, that all material assumptions and technical parameters underpinning the estimates in the relevant market announcement continue to apply and have not materially changed. The company confirms that the form and context in which the Competent Person’s findings are presented have not been materially modified from the original market announcement.’*

Companies should be aware this exemption does not apply to subsequent reporting of information in the company annual report.

Appendix 4 List of Acronyms

AIG	Australian Institute of Geoscientists
ASX	Australian Securities Exchange
CIM	Canadian Institute of Mining, Metallurgy and Petroleum
CMMI.....	Council of Mining and Metallurgical Institutions
CRIRSCO.....	Committee for Mineral Reserves International Reporting Standards
ICMM.....	International Council on Mining and Metals
JORC.....	Joint Ore Reserves Committee
JORC Code	Australasian Code for Reporting of Exploration Results, Mineral Resources and Ore Reserves
NAEN.....	The Russian Society of Subsoil Use Experts
NPV.....	Net Present Value
NROs	National Reporting Organisations
NZX	New Zealand Stock Exchange
UN-ECE.....	United Nations Economic Commission for Europe
UNFC	United Nations Framework Classification
PERC	Pan-European Reserves & Resources Reporting Committee
RPO.....	Recognised Professional Organisation
SAMCODES	South African Mineral Codes
SME.....	Society for Mining, Metallurgy & Exploration (USA)
The AusIMM.....	The Australasian Institute of Mining and Metallurgy
VALMIN Code	Code and Guidelines for Technical Assessment and/or Valuation of Mineral and Petroleum Assets and Mineral and Petroleum Securities for Independent Expert Reports

APPENDIX 2
STRONG STRUCTURATION FOCUS QUESTIONS
(after Greenhalgh & Stones, 2010)

Macro Level Questions in Relation to an Unfolding Program

Mapping the network-in-focus

1. What is the prevailing political, economic, technological and institutional context within which the technology is being introduced locally or nationally?
2. What is the socio-technical network of this project or programme? Which agents and technologies are represented, and what are their position-practices?
3. What are the key-relationships (agent-agent, technology-technology, agent-technology) in the network and how are they changing over time?
4. To what extent has stability of the network been achieved – and why?

Micro Level Questions Focussed on Specific Conjunctures within the Unfolding Process

Mapping the relevant part of the network ('network-in-focus')

1. Who are the key human agent(s) involved in this conjuncture?
2. What are the key technologies involved in this conjuncture?
3. What technological, financial and organisational infrastructure is needed to support the conjuncture?

Actant's internal structures relevant to the conjunctural situation

1. Human agent's general dispositions (e.g. socio-cultural schemas, hierarchies of values, virtues, cognitive capability, embodied skills, past experience)
2. Relevant technology's material properties and inscribed socio-economic structures
3. Human agent's conjuncture-specific knowledge (perhaps imperfect): of relevant external structures (the strategic terrain), technology-in-focus's material properties and inscribed socio-cultural structures ; and of technology-in-focus's range of functionality relevant to the immediate situation

Active Agency

1. What does the human agent do – i.e. how does s/he reflexively relate to, and draw on, general dispositions, conjuncture-specific knowledge, and technological properties (actant's internal structures) in an unfolding sequence of action?
2. How do the social structures (e.g. norms, duties, physical and cognitive demands, rights, rewards/sanctions) inscribed deliberately or inadvertently, in the technology-in-focus enable, influence, or constrain the active agency and strategic orientations of agents?

Outcomes

1. What are the immediate consequences of specific actions (intended and unintended)?
2. How do these consequences feedback on the position-practices in the network and wider external structures?
3. What significance – both positive and negative – do these consequences have for others in the network in terms of power, legitimacy, and other factors?
4. What role has the technology-in-focus played in the production of these positive and negative consequences?

Policy/political implications

1. How modifiable are the inscribed technological features that have contributed to negative consequences? By whom are they modifiable, over what timescale and at what cost?
2. Addressing1 ('how modifiable?') should be linked to lessons learned from analysis of prior negotiations about standards, codes, fields, access privileges, interoperability, and other 'technical' questions (e.g. who were the players in these negotiations, who 'won' and why?)

APPENDIX 3
SUMMARY OF INFORMAL WORKPLACE LEARNING
RESEARCH

Table A Summary of quantitative research

Author(s)	Empirical collection	data	Sample	Analytical process	Industry	Limitation
(Kyndt, et al., 2009)	Survey		1,162 employees in 31 different organisations	explorative factor analysis, ANOVA	Not specified	Not presented, assumed limited by not knowing the organisational contexts
(Berg & Chyung, 2008)	Anonymous on-line survey		Email solicited 125 workplace learning and performance improvement professionals	ANOVA	HRD professionals	Results framed from a HRD implementation perspective
(Hicks, et al., 2007)	Combination of surveys,	of	Telephonic and email solicited (prize draw for entrants) 143 accountants in 9 offices	MANOVA	Accountancy, within Halifax Regional Municipality, Nova Scotia, Saint John and Fredericton, New Brunswick Canada	Highly localised sample; profile of accountants willing to engage as respondents?
(Karkoulian, et al., 2008)	Surveys		499 employees from 10 Lebanese banks	Pearson correlation	Lebanese banks	Highly localised sample and context

Table B Summary of qualitative research

Author(s)	Empirical data collection	Sample	Analytical process	Industry	Limitation
(Ellinger, 2005)	Case study	13 employees Pilot interview, main interview study; critical incident technique and semi-structured in-depth interviews	Coding, Content analysis, Narrative portrait	Consumer-focussed manufacturing, eastern region USA	Not able to generalise findings, low number of incidents and analyses based on recall
(Gola, 2009)	Narrative interview	30 in-service social workers in a cross-section of working contexts	Content analysis and narrative structure in grounded theory approach	Social workers	Not able to generalise findings
(Jubas & Butterwick, 2008)	Interviews	75 women, Vancouver, Victoria and Toronto (Canada)	Feminist epistemology linked to results from USA and UK	IT	Not able to generalise findings
(Poell, et al., 2003)	Interviews	20 HRD professionals	Coding and analysis of clusters	Dutch HRD professionals	Not able to generalise findings
(Collin, 2006)	Interviews and observations	18 interviews, 5 to 6 week observations in each of four companies	Phenomenographic and narrative analysis, ethnographic analysis	Finnish: two high-tech companies, supplier of industrial workstations, electronics manufacturing services	Not able to generalise findings
(Paloniemi, 2006)	Group and individual interviews	16 semi-structured interviews (43 employees) from six SMEs	Phenomenological analysis, contextual analysis,	Finnish SMEs (bank, pharmacy, horticultural nursery, IT)	Not able to generalise findings
(Styhre, 2006)	Group and individual interviews	50 semi-structured interviews from six construction companies	Coding, content analysis	Swedish construction industry	Not able to generalise findings
(Cho, et al., 2005)	Longitudinal survey	31 distributed learners	Social Network Analysis	Computer supporter collaborative learning community – aerospace design	Not able to generalise findings
(Del Campo, et al., 2008)	Questionnaire, interview	175 completed questionnaires from 209 qualifying participants	Exploratory Social Network Analysis	Spanish High-tech company	Not able to generalise findings

Table C Summary of empirical studies

Factor	Author(s)	Research question	Methodology	Most significant finding(s)
Organisational contextual factors	(Ellinger, 2005)	What are the organisational context factors and how do these influence informal workplace learning?	Action learning theory, Qualitative case study	Positive factors: committed leadership, learning culture, resources and social networks Negative factors: lack of above, structural inhibitors, lack of time, too much change too fast, not learning from learning
Organisational contextual factors	(Ellinger & Cseh, 2007)	How do employees facilitate others' learning and what are the contextual factors that influence this facilitation?	Action learning theory, Qualitative case study	Positive factors: The role of learning-committed leadership is a powerful contextual factor, an internal culture committed to learning Negative factors: reverse of positive factors listed above, lack of time/workload, fast pace of change, negative attitudes
Characteristics of organisation	(Kyndt, et al., 2009)	Does the type and/or size of organisation influence informal workplace learning?	Quantitative: Survey, Factor analysis, ANOVA	Informal workplace learning styles vary according to both industry and organisational size
Characteristics of organisation	(Doornbos, et al., 2008)	Is there a relationship between workplace characteristic and types of workplace learning?	Descriptive survey	The results from the study presents a learning profile for Dutch police that may be different to other contexts. Study has limited transferability.
Organisational context and employees' gender, age and education	(Berg & Chyung, 2008)	Influence of organisation's learning culture? Influences of gender, age, level of education? Factors influencing informal workplace learning?	Qualitative analysis of on-line survey	No link between organisational culture and informal learning engagement. No difference in informal workplace learning for gender and level of education. Older employees have higher degree of informal learning (older employees engage more with independent learning). Factor influencing informal workplace learning with highest response was "interest in current field" and "monetary rewards" is least effective in engaging workplace learning.
Gender	(Jubas & Butterwick, 2008)	Whether alternative career pathways and informally acquired skills and knowledge and operation of gender are acknowledged by workplace actors	Qualitative feminist approach to interviewing 75 women	Binary constructs are persistent and tenuous within Canadian IT
Gender, age and education	(Kyndt, et al., 2009)	Do gender, age and/or level of education influence informal workplace learning?	Quantitative: Survey, Factor analysis, ANOVA	1. Styles of workplace learning vary for genders; 2. Younger employees have more access to coaching; 3. Differences in informal workplace learning according to level of education
Professional characteristics	(Kyndt, et al., 2009)	Does seniority influence informal workplace learning?	Quantitative: Survey, Factor analysis, ANOVA	Difference in workplace learning factors according to seniority
Learner and managers' perceptions of learning	(F. van der Krogt, J. & Vermulst, 2000)	Determine the dimensions in people's perceptions of workplace learning and associated stable profiles	Learning Theory; survey with quantitative analyses	Dimensions of perceptions include: managers and workers have different perceptions of learning. Learning action theory provides perspective for studying and improving learning in the workplace.
Learning strategies, facilitators and barriers	(Hicks, et al., 2007)	What are the workplace learning strategies, facilitators and barriers?	Survey with quantitative analysis (MANOVA)	Informal learning is most favoured of a wide variety of workplace learning strategies used. Greatest impact from: completing new tasks, learning from experience, working with others. Social relationships are a significant factor, especially for entry-level Internal professional development programs are less favoured
Individual and social processes;	(Collin, 2006)	Design engineers' conceptions of learning? Role of previous work	Qualitative Ethnographic methods	Importance of former education and experience, Shared, situated and contextualised through multidisciplinary teams

previous experience		experience on workplace learning? Learning through shared practice of design and development?	(phenomenographic, narrative and ethnographic analysis)	
Processes of learning	(Gola, 2009)	Investigate the processes and constructs present in non-intentional and non-structured learning	Qualitative narrative approach interviewing 30 in-service social workers	The process of informal learning appears random with change and development result from reflection and awareness
Temporal influences on peer learning	(Styhre, 2006)	Investigates temporal aspects of organisational and workplace learning using Henri Bergson's notion of virtuality	Qualitative interviews	Interactions between peers within construction projects with multi-disciplinary teams are based on an integration of past, present and future experiences, aspirations and practicality.

APPENDIX 4

COMPARISON OF LEARNING THEORIES

	Activity Theory	Structuration Theory	Actor-Network Theory	Learning Network Theory	
Activity Theory	Learning and knowing are products of activity/experience. Situated within an organisation/society with a community/rules and norms/ division of labour. Expansive Network Theory -> extended to connect multiple relationships through mediating artefacts.	AT: learning occurs using mediating artefacts - no such requirement for Structuration Theory; in Structuration Theory, structure is dynamic whereas AT structure is the foundation which frames activity	ANT incorporates non-human nodes in addition to human nodes in the network; ANT focuses on incorporation of machines, while this is generalised into mediating artefacts for AT. ANT appears more ad hoc in learning objectives, while AT is pinned to learning objectives, which connect bounded systems	Learning Network Theory does not explicitly reference mediating artefacts, which are central to knowledge accumulation in AT; Learning Network Theory is more explicit regarding structure and processes	Differences between theories
Structuration Theory	Situated within an organisational/societal context with defined norms/roles; learning/development occurs through social action; action leads to change	Social structures and social practice are inter-dependently renewed. Organisations change through social practice, which is itself conditional to the structure within which socialisation takes place. There is a continual renewal of the structural norms through social activity.	Structuration Theory allows the structure to update as society develops, while ANT focuses on emerging social networks without reference back to the implications for the organisation. ANT places objects within the structure, while Structuration Theory makes no direct reference to objects as such. AT links bounded systems at mediating artefacts, while ANT links systems at the learner	Structuration Theory, structures are adaptive, while in Learning Network Theory structures provide a reflection of the learning relationships	
Actor-Network Theory	Meaning occurs through activity; mediating artefacts are present in AT as useful to the process. Mediating artefacts are present in ANT as actants in the same way that humans are. Both theories operated within a static structure. Appear to have the same Vygotskian basis of " -> subject/learner->mediating artefact->object/knowing->" compared with "-> agency->machines->knowledge->"	social relationships change when knowledge is acquired	Relationships are created between actants (human and non-human). When meaning is translated between actants, the connection in the network is sustained. New entities can be incorporated. Social performance is described by the strength of the relationships between actants (human and non-human). Learning processes: Connectivism (incorporates both instructionism and constructivism and extends control to the individual)	Learning Network Theory has more formalised disclosure regarding processes and structures, while ANT allows more flexibility in process and mechanisms; ANT includes non-human objects within the network while Learning Network Theory restricts the network to those social actions related to learning	
Learning Network Theory	Use of networks. Assumption of workplace structure implicit in Learning Network Theory and explicit in AT; both include reference to connectivity between organisations (bounded systems)	formalisation of influences of processes and structures	Network described the social links through which learning occurs	Learning processes and structures mirror work processes and structures. Links within the learning networks can be categorised for work/learning as liberal/entrepreneurial; horizontal/adhocratic; vertical/bureaucratic and external/professional.	
	Similarities between theories				

APPENDIX 5
REASONING ASSESSMENT AND JORC TABLE 1
CRITERIA

Highlighted questions indicate the aspect of JORC Table 1 to which the question refers.

Extract from JORC Code Table 1		JORC Reasoning Assessment Question Number											
Criteria	Explanation	1	2	3	4	5	6	7	8	9	10	11	12
Sampling techniques and data													
Sampling techniques	+ Nature and quality of sampling (eg. cut channels, random chips etc.) and measures taken to ensure sample representivity.			*		*							
Drilling techniques	+ Drill type (eg. core, reverse circulation, open-hole hammer, rotary air blast, auger, Bangka etc.) and details (eg. core diameter, triple or standard tube, depth of diamond tails, face-sampling bit or other type, whether core is oriented and if so, by what method, etc.).			*		*	*						
Drill sample recovery	+ Whether core and chip sample recoveries have been properly recorded and results assessed.			*		*	*						
	+ Measures taken to maximise sample recovery and ensure representative nature of the samples.			*		*	*						
	+ Whether a relationship exists between sample recovery and grade and whether sample bias may have occurred due to preferential loss/gain of fine/coarse material.			*		*	*						
Logging	+ Whether core and chip samples have been logged to a level of detail to support appropriate Mineral Resource estimation, mining studies and metallurgical studies.		*			*							
	+ Whether logging is qualitative or quantitative in nature. Core (or costean, channel etc.) photography.		*			*							
Sub-sampling techniques and sample preparation	+ If core, whether cut or sawn and whether quarter, half or all core taken.			*		*							
	+ If non-core, whether riffled, tube sampled, rotary split etc. and whether sampled wet or dry.	*		*		*							
	+ For all sample types, the nature, quality and appropriateness of the sample preparation technique.	*				*							
	+ Quality control procedures adopted for all sub-sampling stages to maximise representivity of samples.	*				*							
	+ Measures taken to ensure that the sampling is representative of the in situ material collected.	*		*		*							
	+ Whether sample sizes are appropriate to the grainsize of the material being sampled					*							
Quality of assay data and laboratory tests	+ The nature, quality and appropriateness of the assaying and laboratory procedures used and whether the technique is considered partial or total.	*											
	+ Nature of quality control procedures adopted (eg. standards, blanks, duplicates, external laboratory checks) and whether acceptable levels of accuracy (ie. lack of bias) and precision have been established	*											
Verification of sampling and assaying	+ The verification of significant intersections by either independent or alternative company personnel.			*			*						
	+ The use of twinned holes.	*		*									

	+ If it is not known and only the down-hole lengths are reported, there should be a clear statement to this effect (eg. 'downhole length, true width not known').					*	*								
Diagrams	+ Where possible, maps and sections (with scales) and tabulations of intercepts should be included for any material discovery being reported if such diagrams significantly clarify the report.		*			*					*				
Balanced reporting	+ Where comprehensive reporting of all Exploration Results is not practicable, representative reporting of both low and high grades and/or widths should be practiced to avoid misleading reporting of Exploration Results.						*								
Other substantive exploration data	+ Other exploration data, if meaningful and material, should be reported including (but not limited to): geological observations; geophysical survey results; geochemical survey results; bulk samples - size and method of treatment; metallurgical test results; bulk density, groundwater, geotechnical and rock characteristics; potential deleterious or contaminating substances.					*									
Further work	+ The nature and scale of planned further work (eg. tests for lateral extensions or depth extensions or large-scale step-out drilling).						*								
Estimation and reporting of Mineral Resources															
Database integrity	+ Measures taken to ensure that data has not been corrupted by, for example, transcription or keying errors, between its initial collection and its use for Mineral Resource estimation purposes.	*								*					
	+ Data validation procedures used	*								*					
Geological interpretation	+ Confidence in (or conversely, the uncertainty of) the geological interpretation of the mineral deposit.		*	*	*	*	*			*	*				
	+ Nature of the data used and of any assumptions made.		*	*		*	*				*				
	+ The effect, if any, of alternative interpretations on Mineral Resource estimation.		*		*	*	*			*	*				
	+ The use of geology in guiding and controlling Mineral Resource estimation.		*	*	*	*	*			*	*				
	+ The factors affecting continuity both of grade and geology.		*	*	*	*	*			*	*				
Dimensions	+ The extent and variability of the Mineral Resource expressed as length (along strike or otherwise), plan width, and depth below surface to the upper and lower limits of the Mineral Resource			*	*	*	*			*	*				
Estimation and modelling techniques	+ The nature and appropriateness of the estimation technique(s) applied and key assumptions, including treatment of extreme grade values, domaining, interpolation parameters, maximum distance of extrapolation from data points.				*	*				*	*				
	+ The availability of check estimates, previous estimates and/or mine production records and whether the Mineral Resource estimate takes appropriate account of such data.									*	*				
	+ The assumptions made regarding recovery of by-products.					*					*				

	+ Estimation of deleterious elements or other non-grade variables of economic significance (e.g. sulphur for acid mine drainage characterisation)					*			*	*										
	+ In the case of block model interpolation, the block size in relation to the average sample spacing and the search employed.					*	*		*	*										
	+ Any assumptions behind modelling of selective mining units.					*	*		*	*										
	+ Any assumptions about correlation between variables.	*				*	*		*	*										
	+ The process of validation, the checking process used, the comparison of model data to drillhole data, and use of reconciliation data if available.					*	*		*	*								*		
Moisture	+ Whether the tonnages are estimated on a dry basis or with natural moisture, and the method of determination of the moisture content.						*			*										
Cut-off parameters	+ The basis of the adopted cut-off grade(s) or quality parameters applied.																			*
Mining factors or assumptions	+ Assumptions made regarding possible mining methods, minimum mining dimensions and internal (or, if applicable, external) mining dilution. It may not always be possible to make assumptions regarding mining methods and parameters when estimating Mineral Resources. Where no assumptions have been made, this should be reported.		*			*			*	*										*
Metallurgical factors or assumptions	+ The basis for assumptions or predictions regarding metallurgical amenability. It may not always be possible to make assumptions regarding metallurgical treatment processes and parameters when reporting Mineral Resources. Where no assumptions have been made, this should be reported.		*						*	*										*
Bulk density	+ Whether assumed or determined. If assumed, the basis for the assumptions. If determined, the method used, whether wet or dry, the frequency of the measurements, the nature, size and representativeness of the samples.						*			*										
Classification	+ The basis for the classification of the Mineral Resources into varying confidence categories.					*	*												*	
	+ Whether appropriate account has been taken of all relevant factors. i.e. relative confidence in tonnage/grade computations, confidence in continuity of geology and metal values, quality, quantity and distribution of the data.					*	*												*	
	+ Whether the result appropriately reflects the Competent Person(s)' view of the deposit.					*													*	
	+ Whether it is appropriate to classify resources on a local or global basis.						*				*	*								
Audits or reviews	+ The results of any audits or reviews of Mineral Resource estimates.										*									

<p>Discussion of relative accuracy/confidence</p>	<p>+ Where appropriate a statement of the relative accuracy and/or confidence in the Mineral Resource estimate using an approach or procedure deemed appropriate by the Competent Person. For example, the application of statistical or geostatistical procedures to quantify the relative accuracy of the resource within stated confidence limits, or, if such an approach is not deemed appropriate, a qualitative discussion of the factors which could affect the relative accuracy and confidence of the estimate.</p>	<p>*</p>						<p>*</p>				
	<p>+ The statement should specify whether it relates to global or local estimates, and, if local, state the relevant tonnages or volumes, which should be relevant to technical and economic evaluation. Documentation should include assumptions made and the procedures used.</p>							<p>*</p>				
	<p>+ These statements of relative accuracy and confidence of the estimate should be compared with production data, where available.</p>							<p>*</p>				