Creativity in consulting engineering:

How civil engineers talk about design

Marion Hayes

Thesis completed in partial fulfilment of
Master of Arts (Research)

Queensland University of Technology, Creative Industries
Research & Applications Centre, Brisbane

2005

Acknowledgments

I would like to thank Dr Judy Gregory for her immense and valuable support, guidance and friendship throughout this study. I thank the staff of Kellogg Brown & Root P/L (KBR) for their time, commitment and enthusiasm for the study, in particular to Mike Fordyce (the Company Study Leader) whose support was constant and exemplary. Not least I thank my husband Norman Cornwell for his patience, intelligence and understanding over the past two years. I would like to dedicate this work to my father, Patrick Joseph Hayes, who as a Master Builder and craftsman inspired my interest in the construction industry.

Statement of original authorship

This work has not been previously submitted for a degree or diploma at any other tertiary institution. To the best of my knowledge, this work contains no material previously published or written by another person except where due reference is made**.**

Signed: ________________________________

Date: __________________________________

Abstract

An appropriate civil infrastructure is vital to the wealth and wellbeing of cultures. Appropriateness is increasingly defined in terms of sustainability, aesthetics, innovation and cultural suitability. These expectations pose challenges for engineers to use their creativity, aesthetic appreciation, knowledge and character to predict and respond creatively with their designs. However, a treadmill of cost innovation in construction projects makes improved design challenging. This tends to reinforce the misconception that engineers are dull and uncreative, even though historically they have displayed considerable imagination and ingenuity.

This thesis is based on an in-depth study conducted at the Brisbane office of Kellogg Brown & Root P/L (a large consulting engineering firm). A contemporary qualitative approach is used to explore how creativity is manifested in an engineering design context, and how it relates to phenomena such as knowledge, innovation, project culture and organizational environment. In-depth interviews reveal the authentic meaning of design and creativity for engineers and other company staff. The study highlights an important distinction between design-based and cost-driven innovation and unveils multiple influences that can stifle or nurture personal and group creativity.

Keywords

Creativity; innovation; engineering design; aesthetics; sustainable building; organizational culture; project alliance; research and development (R&D); sustainability; eureka innovation; case study; qualitative research; tacit knowledge

Table of Contents

List of Figures

Chapter 1: Introduction

1.1 Creativity and engineering design

1.1.1 An introduction

Historically, engineers have produced an impressive ‘catalogue’ of structures, inventions and works of art that demonstrates a skilful and artful blend of foresight, knowledge, craft and reflection (Bernstein & Lemer, 1996; Ferguson, 1992; Gelernter,1998; Schon, 1991, 1983). Yet there are perceptions that engineers are dull and unimaginative (Bernstein & Lemer, 1996; Keegan & Turner, 2002) and creativity is not an important focal interest for engineering innovators (Chakrabarti, 2002, p.147; Kimbell, 2002; Powell, 1970). This has prompted this dissertation about engineering design, creativity and innovation, in the Brisbane office of a global consulting engineering firm.

Contrary to recent construction industry discussions that seem to imply that innovation in engineering is a recent phenomenon (see Ch. 1, pp. 10-11), the evidence of past and present creativity in engineering design is quite overwhelming, including icons such as: The Egyptian Pyramids, the Golden Gate Bridge, the Taj Mahal, the Eiffel Tower, the Hoover Dam, the Thames Tunnel, the Channel Tunnel and the Sydney Opera House (Gelernter, 1998; Ferguson, 1992; Parkyn, 2002). A recent example of creative collaborative design is London’s new high-rise office tower, 30 St. Mary Axe (also known as the Swiss Re Headquarters or the Norman Foster Tower - see Figure 1.1). Architecturally designed by Foster and Partners, it demonstrates creativity and innovation from multiple perspectives: Architectural and aesthetic, structural design, environmental sustainability, and innovative work spaces (Perinotto, 2003, p. 64).

Perinotto (2003) describes 30 Mary St. Axe as unusual and remarkable in appearance as it tapers in at the top and bottom like a giant cucumber or airship and stops passers-by in their tracks (p. 64). No floors are identical and the roof is unconventional. The building is a creative meeting of form and function designed to deliver an energy efficient building that is visually pleasing. The creative design is the result of collaboration and integrated planning and is proving an inspiration to structural engineers. 30 St. Mary Axe is thus a contemporary example of multiple facets of creativity in professional building design (Perinotto, 2003, p. 64):

- **Visual/aesthetic**: It is unusual and impressive in appearance and widely appreciated.
- **Environmental/experimental**: It represents a new benchmark in ‘green’ building design.
- **Human /social:** It demonstrates innovation in workspace design.
- **Risk-taking:** It is an example of the risk-taking required in creative design.
- **Challenging:** It is an example of the challenges involved in creative design and construction.
- **Collaborative design:** It is an example of successful collaborative and integrated design and planning.

Figure 1.1: 30 St. Mary Axe, London

This figure is not available online.
Please consult the hardcopy thesis
available from the QUT Library

(Source: Nigel Young/Foster and Partners, 2004).

Whilst many examples of engineering creativity can be found, creativity is not well discussed as part of the engineering design process. It is important that the creativity of engineers is recognized because the benefits of creativity are manifested at the personal, industry and cultural level (Amabile, 1999; Australian Construction Industry Forum (ACIF), 2002; Florida, 2002; Landry, 2001, pp. 1-4; Leonard & Swap, 2002).

> If we have a fuller understanding of the engineer as a creator and innovator, then with this knowledge we could create circumstances to encourage such performance. (Powell, 1970, pp. 2-3)

This thesis is an in-depth case study aimed at clarifying the meaning of creativity in an engineering business context, a context not adequately addressed in the literature. The thesis unveils sixteen important themes that help to explain how creativity is nurtured and stifled in a consulting engineering context. It highlights that creativity is complex, contextual and domain-specific. The company at the focus of the study is the Brisbane office of a large global consulting engineering company.

1.1.2 The creative practice of engineering design

"To design is to invent", says Ferguson (1992, p. 12). Invention and creativity are inherent in the professional title 'engineer' which has its origins in the 'one who uses ingenuity', 'to bring about or make manifest' and the Greek root '*techne*' meaning 'the arts of the mind' (Freeman-Bell & Balkwill, 1996, p. 1; Watts, 2001, p. 95). Engineering design is a part of the engineering practice which is most palpably and intrinsically creative. *The McGraw-Hill Encyclopedia of Science & Technology* (1997) describes a powerful artistry and ingenuity as engineers create the built environment:

> [Engineering is] the art of directing the great sources of power in nature for the use and convenience of humans. … Engineering therefore requires above all the creative imagination to innovate useful applications of natural phenomena. (p. 435)
>
> The process by which these goals are achieved is engineering design. (p. 439).

Engineering design as a creative practice is not widely assumed even though creativity is intrinsic to engineering design, being visually conceived and tested iteratively (Ferguson, 1992; Margolius, 2003). Instead, an emphasis on the rational and cognitive applications of scientific and analytical methods tends to overshadow the importance of art, intuition, iteration and aesthetics (Ferguson, 1992; Margolius, 2003; Schon, 1991, 1983).

That engineering and creativity are often disassociated could be due to a perception that functional is not always beautiful or aesthetically pleasing, and that engineers are actually responsible for environmental degradation and pollution (Gelernter, 1998, pp. 129-130; Martin & Schinzinger, 1996). It could also be due to the limited opportunities engineers have to be creative in competitive project cultures that frequently measure innovation in terms of savings in cost and time, rather than design or creativity-led innovation (Keegan & Turner, 2002). The perception may even relate to public perceptions that engineers and their work are dull and uninteresting (Bernstein & Lemer, 1996). It is likely that all of the above help to separate creativity from engineering design in the minds of innovators, the public, the construction community and engineers themselves.

1.1.3 Creativity and construction engineering innovation

The engineering education and construction management literature gives little attention to the relationships between creative conception, incubation and development of new engineering design ideas. This is evident in recent construction reports, where the critical linkages between engineering creativity and innovation remain silent or implicit (ACIF, 2002; Chakrabarti, 2002, p. 147; Committee for Economic Development of Australia [CEDA], 2004; Kimbell, 2002).

Given that the construction industry depends on innovation for global competitive survival, it is important for creativity to be associated with engineering design. It is therefore timely to investigate the role of creativity in engineering innovation for the following reasons:

- **Infrastructure & Progress**: Engineering infrastructure is foundational to western standards of living and quality of life because economic and social life depends directly or indirectly on it (ACIF, 2002; Martin & Schinzinger, 1996, pp. 1-5). Contemporary challenges involve creative solutions to complex problems (West & Farr, 1990).
- **Engineering influence**: Engineers are influential creators of the environment in which people work and live (Ferguson, 1992, pp. 1-2; Landry, 2001). Regulatory and professional charters offer engineers the opportunity to significantly influence the function, appearance and appreciation of the built, social and natural environment. Examples of this include: Flood mitigation schemes, residential sub-divisions, urban transport systems and international aid projects (Martin & Schinzinger, 1996, pp. 1-5).
- **Sustainable engineering**: The increasing complexity of real-world problems depends on creative engineering responses that exceed as well as keep pace with economic and societal expectations (ACIF, 2002; Bernstein & Lemer, 1996; West &

Farr, 1990). The need for sustainable design challenges engineers to use their creativity, aesthetic, scientific and ethical knowledge to predict and respond creatively through their design solutions (Martin & Schinzinger, 1998; Salmon, 1996). Sustainable approaches thus need to be creative, multi-disciplinary and integrated (Wiese & John, 2003, p. 35).

- **Global innovation imperative:** The construction industry is one of the most competitive of the world's global industries (ACIF, 2002, p. 3, Bernstein & Lemer, 1996; CEDA, 2004). Knowledge-based firms such as engineering consultancies believe that continuous innovation is imperative to securing long term competitive advantages (Boisot, 1998; Drucker, 1995). Whilst the construction industry endorses innovation, recent reports suggest a disproportionate focus on business rather than design innovation (ACIF, 2002; Gaynor, 2002; Shapiro, 2001; West & Farr, 1990).
- **Creativity and culture:** Innovation depends on encouraging people to develop and use their creative potential and knowledge (Flew, 2002; Florida, 2002). People will use their potential best when industries and organizations understand creativity and have the opportunity to develop it in its relevant context (Amabile, 1999; Mumford, 1996, 1981; Wheatley, 1999a).

The literature about creativity and innovation in construction engineering is highly fragmented. This is a strong indication that further research and learning are needed in the area (Chakrabarti, 2002, p. 147) thus providing convincing support for the current study.

1.2 The meaning of creativity and innovation: an introduction

1.2.1 Introduction to key concepts

The great variability in definitions of the creativity, innovation and engineering design, reflects the complexity of these terms. Figure 1.2 presents Bailey's (1978, pp. 39-40) clarification of popular creativity-related terms which are often used synonymously. Though it is impossible to define these tacit phenomena, Amabile (1988) suggests that working definitions are beneficial.

> [Creativity:] A product or idea is creative to the extent that it is both a novel and appropriate response to an open-ended task. [An open-ended task is one that does not have a clear and straightforward path to solution]. (Amabile, 1988, p. 147)

Innovation is the successful implementation of creative ideas about products or processes within an organization. … The products and processes can range from management ideas to manufacturing methods. (Amabile, 1988, pp. 145-146)

[Engineering design is] the conversion of an idea to an artefact, which engages both the designer and the maker, in a complex and subtle process that will always be far closer to art than to science. (Ferguson, 1992, p. 3)

[Design is] that combination of ability and motivation that transcends understanding and enables creative developments … [it] provides the gap between what is and what might be. (Kimbell, Stables & Green, 1996, p. 28)

Figure 1.2: Distinguishing creativity-related concepts

This figure is not available online.
Please consult the hardcopy thesis
available from the QUT Library

(Source: Bailey, 1978, pp. 39-40)

1.2.2 Creativity

The proliferation of definitions suggests a striking consensus that creativity is complex and manifested in various ways (Amabile, 1988; Nickerson, 1999; Polanyi, 1966). Collective discussions reveal that creativity has many facets including:

- **Novelty and usefulness**: Creativity is usually described as something ‘new’ and ‘useful’ to an individual or society (Amabile, 1988; Nemeth & Nemeth, 2001). Use or value is interpreted differently by different disciplines.

- **‘Big’ and ‘Small’ C:** It can pertain to outstanding achievements that cross disciplines and epochs, termed ‘Big C’ or ‘Breakthrough creativity’ (Csikszentmihalyi, 1999; Feldman, 1999). It can also manifest as everyday achievements of lesser magnitude at the individual level, sometimes referred to as ‘Small C’ (Basadur, 1993, 1987; Isaksen, 1988; Rickards & Moger, 2000; Weisberg, 1999).
- **Intrinsic and developmental:** ‘Big’ and ‘Small’ C can be developed to varying degrees and is agreed to involve short and long term investments in time, commitment and resources (Amabile, 1988; Feldman, 1999; Nickerson, 1999; Simonton, 1999; Weisberg, 1999). ‘Small’ C is an essential, intrinsic or natural inclination among people, encouraged by meaningful and whole work and life experiences (Isaksen, 1988; Mumford, 1996; Wheatley, 1999a).
- **Holistic and complex:** Creativity is holistic, multi-faceted and complex (Feldman, 1999; Landry, 2001, p. 11; Nickerson, 1999). It is also contextual because it is influenced by situational factors such as domain and environment (Feldman, 1999; Csikszentmihalyi, 1999; Isaksen, 1988). Holistic explanations about creativity highlight the inter-relatedness of the person, process, product and place (Amabile, 1999; Isaksen (1987, cited in Firestien, 1993, p. 262).
- **Domain-specificity:** Domain-specificity in creativity is widely accepted, e.g. creativity in engineering differs from other professions and practices (Amabile, 1999; 1988, 1983; Csikszentmihalyi, 1999; Weisberg, 1999).

This brief introduction to the nature of creativity is explored in greater depth in the coming chapters.

1.2.3 Defining innovation

Innovation is regarded as the managed gestation and manifestation of creative ideas and processes into tangible, often commercial outcomes (ACIF, 2002; Amabile, 1988; Landry, 2001, p. 15; West & Farr, 1990). Definitions of innovation suggest that it has the following features:

- **Novelty:** (Absolute or relative to the unit or organization) (Amabile, 1988).
- **Application:** An application component (e.g. ideas) (Amabile, 1988; Landry, 2001, p. 15).

- **Purposeful:** Intention of benefit or value, e.g. commercialisation of creative ideas (West & Farr, 1990, p. 9).
- **Managed or strategic**: A managed process (Gaynor, 2002; Shapiro, 2001).
- **Small and large scale:** Can be valued on a large or small scale (e.g. routine or radical). Incremental (or routine) and radical (or breakthrough) innovation are the main forms referred to in the literature (Gaynor, 2002, p. 29; Perry, 1973; West & Farr, 1990, p. 7).

Like creativity, innovation is experienced on various levels; big and small. Incremental or routine innovation is often associated with cumulative changes to existing rather than new products, but can also lead to breakthroughs over time (such as those resulting from research and development). Innovation achieved purely by lowering costs and profit margins, however, without increased productivity, is sometimes referred to as cost innovation and assumed to be unsustainable as a long term competitive innovation strategy (Gaynor, 2002; McLeish, 2004; Shapiro, 2001).

Radical innovation, in contrast, is associated with dramatic changes in investment, thinking, acting, communication and organizational structure and bears a strong similarity to breakthrough or 'Big' creativity (Gaynor, 2002, pp. 25-32; West & Farr, 1990, p. 7).

1.2.4 Creativity, innovation and engineering

The word innovation is favoured over the use of creativity in the literature (Amabile, 1988; Cavallucci, 2002; Kimbell, 2002; Sternberg, 1999; West & Farr, 1990). Many definitions suggest that innovation is more valuable, substantive and time-intensive (Landry, 2001; West & Farr, 1990). Innovation is often described as the value-adding stage of the creativity process, suggesting a higher sense of value for innovation.

> Creativity is the pre-condition from which innovations develop. An innovation is the realization of a new idea in practice, usually developed through creative thinking. An innovation exists when it passes the reality test; the creative idea on its own is not enough. (Landry, 2001, p. 15)

The limited attention to the intrinsic (e.g. experiential) and extrinsic (e.g. time-intensive) aspects of the creative process in innovation discussions is common in the construction innovation literature (Cavallucci, 2002; West & Farr, 1990), and partly explains its under-representation in engineering innovation discussions.

1.3 Engineering creativity in the knowledge economy

1.3.1 The knowledge economy

The term ‘knowledge economy’ is commonly used to refer to recent developments in a world economy that emphasizes the role of knowledge, talent, creativity and innovation in business survival (Boisot, 1998; Flew, 2002; Florida, 2002; Wiig, 1997). However, as history illustrates, innovation and engineering creativity are not new phenomena. Rather, they are part of an ongoing and historical process of technological, economic and cultural change (see Ch.1, p. 1, Ch.2, pp. 20-22). What is new, however, is a cycle of engineering invention and innovation that has rapidly shortened, creating a type of economic treadmill (or imperative) termed ‘continuous innovation’ (Boisot, 1998; Drucker, 2002). As explained in the following chapter (see Ch.2, pp. 51-53), this intensification of the innovation process principally relies on tighter delivery and cost schedules, conditions that in the creativity research literature are not considered to be supportive of creativity (see Ch.2, pp. 61-71). Since the search for ‘continuous innovation’ is a key characteristic of the engineering design and construction environment, it provides an appropriate context in which to investigate the implications for engineering creativity (Keegan & Turner, 2002; Kimbell, 2002; Porter, 2000).

1.3.2 The innovation imperative

To remain competitive, it is argued industries and organizations must continuously ‘invent’ new ways of differentiating themselves from their competitors (Keegan & Turner, 2002; Porter, 2000). Knowledge and creativity-based industries such as engineering, architecture, research and entertainment media cannot rely on information technology to create this competitive lead, because anything that can be captured, re-invented and quickly emulated using technology (such as information and business process ideas) is no longer of any competitive advantage (Porter, 2000).

In the knowledge economy, innovation is an imperative implicit in the commonly used term ‘continuous innovation’ (a self-propelling cycle of economic improvements which promise organizations a competitive edge (Boisot, 1998; Drucker, 2002; Wiig, 1997). The construction industry, say researchers and practitioners, must innovate or perish. Innovation is considered critical in what is described as one of the most fiercely competitive of all industry sectors (ACIF, 2002; Bernstein & Lemer, 1996).

1.3.3 Creative engineering design and the knowledge economy

The innovation imperative described above is an important consideration in engineering innovation. If innovation leads to economic advantage, and creativity is an important part of this process, an improved understanding of the creative process in engineering may assist engineering innovation efforts.

The construction industry may benefit from knowing how engineers contribute to innovation through their design creativity. This involves understanding the nature of design and creativity, the whole design practice and the total design environment (Kimbell, 2002; Powell, 1970; Tornkvist, 1998).

It is uncanny that over 30 years ago, the newly formed UK Committee on Creativity and Innovation made the following comment about the importance of creativity in engineering:

> In 1958, this country was richer, per capita, than any European country, with the exception of Luxembourg. Today our growth lags behind the rest of Europe; we are poorer than all but Italy … Recent research indicates that even in a company as highly rated as Rolls-Royce for its technological and innovative efforts … their job does not demand their full capacities as creative men. (Powell, 1970, pp. 2-3)

Powell (1970) suggests that creativity is important for two reasons. Firstly, creativity and innovation are necessary ingredients for economic growth. Secondly, creativity is a natural inclination, and work potentially gives people the opportunity to use their creative potential (pp. 2-3). The scenario described is remarkably similar to the innovation and creativity imperatives being discussed more than thirty years later, with the exception that the above description recognizes the intrinsic human need for creativity. Contemporary discussions concentrate on the business imperative (for examples of creativity as a business imperative see DeGraff & Lawrence, 2002, pp. 111-114; Florida, 2002; Kennedy, 2002, p. 65; Landry, 2001).

1.4 Engineering profession, industry and creativity

1.4.1 Engineering design education

One explanation for the relative emphasis on innovation compared with creativity in the engineering sector relates to 20th Century trends in engineering education (Schon, 1991, 1983). Since World War II engineering has increasingly been taught as an applied science, unlike its historical treatment as an intuitive blend of design art and scientific analysis (Ferguson, 1992; Schon, 1991, 1983). Several engineering educators suggest that the creative (or 'soft') issues in engineering design (such as aesthetics and cultural appropriateness), have become 'effete and marginal' and that engineers would rather be called scientists than artists or designers (Ferguson, 1992, p. 22; Gelernter, 1998, p. 10; Schon, 1991, 1983).

In contrast to the scientific rationalism prevalent in engineering education in the past 100 years, several authors emphasize that engineering design actually combines engineering science and design art. Ferguson (1992) says there are no single, unambiguous solutions independent of intuition, iteration and insight (p. 26). Designs are conceived as intangible or tacit images; scientific principles are used to iteratively analyze and test design concepts (Peters, 1998; Ferguson, 1992; Schon, 1991, 1983, 1983). Despite this, says Tornkvist (1998), engineering design is increasingly taught and experienced as an analytical science. This is significant because the way engineers learn design affects their ability to design creatively (Gelernter, 1998; Kimbell, 2002).

Kimbell (2002) suggests that engineering design can be taught with subtle changes to teaching curricula and methods to ensure that the creative aspects are nurtured and not excessively evaluated. Bailey (1978) demonstrated that engineers can be nurtured to design creatively. Engineers, according to Gelernter (1998), need to learn how to understand aesthetics, elegance and beauty in order to develop an appreciation of design aesthetics:

> Every technologist ought to study drawing, design, and art history … Some people are born with and some without an acute sense of beauty, but anyone's beauty sense can be improved by training. (Gelernter, 1998, pp. 129-130)

Thus, according to many engineering authors, developments in engineering education neither recognize nor demonstrate that creativity is an important part of engineering design (Ferguson, 1992; Gelernter, 1998; Kimbell, 2002; Schon, 1991, 1983; Tornkvist, 1998).

1.4.2 The construction industry and creativity

It is not surprising, given the trends in engineering education, that the consequences should be felt downstream in the construction industry. Engineers and managers seem unaware of the real extent to which their practice is creative (Ferguson, 1992; Schon, 1991, 1983). Hence, the latitude and considerations given to other palpably creative practices such as architecture and landscape design are not naturally considered a part of the engineering design environment (Gelernter, 1998; Schon, 1991, 1983).

In addition to the downstream effect, the construction industry has a culture that makes it difficult for consultants and clients to devote the necessary time and resources for activities associated elsewhere with creativity and innovation (Keegan & Turner, 2002). The construction industry is fiercely competitive and driven by cost criteria and related pressures (Keegan & Turner, 2002; Bernstein & Lemer, 1996). (See Appendix D: *A description of the construction industry: The relationship between industry culture and innovation and creativity*). The industry image described in the Appendix is not conducive to the type of innovation associated with long term benefits for industry and society; rather, it is overly focused on short term cost and efficiency gains (McLeish, 2004). Whilst occasional extrinsic or external pressures can spark creativity, they are widely believed to stifle creativity and innovation (Amabile, 1999, 1988, 1983; Basadur, 1993, 1987).

1.5 *The research study*

1.5.1 An introduction

No body of literature sufficiently highlights the link between creative engineering design and innovation in the construction industry (Chakrabarti, 2002, p. 147; Kimbell, 2002). The insufficient attention given to creative processes such as conception, development, incubation and testing of novel engineering design approaches is a serious gap in the general understanding about what contributes to breakthrough, as well as sustainable innovation in the construction industry (Chakrabarti, 2002, p. 147; Keegan & Turner, 2002). Engineers acknowledge that creativity is among the most neglected aspects of their daily work (Cavallucci, 2002; Powell, 1970, pp. 2-3). Similar statements have been echoed by engineering educators for almost a decade (Kimbell, 2002; Schon, 1991, 1983).

Some educators in engineering, design and technology have succeeded in raising awareness about the importance of creativity in design innovation (Bailey, 1978; Kimbell, 2002; Tornkvist, 1998). However, in its quest for innovation, construction engineering management has insufficiently invested in understanding the role of the engineering design and creative process in this scenario (ACIF, 2002; Bernstein & Lemer, 1996). For example, the ACIF (2002) report investigates innovation in the Australian building and construction industry. It focuses on a cross section of organizations, identifying industrial and organizational factors that are conducive to innovation. However, apart from paying lip-service to the importance of creative ideas, the report does not discuss the creative design process and its requirements.

1.5.2 The motivation for the study

I have been involved with the engineering profession for over 15 years. My involvement has been in assisting engineers and engineering managers to access the information they need to make good judgements. My involvement with corporate and business intelligence, and research support and training systems, prompted my interest in ‘tacit knowledge’ (the type of understanding which is difficult to explain) when it emerged in discussions about the knowledge economy (Nonaka & Takeuchi, 1995; Prusak, 2001; Von Krogh, 1998).

During my study of knowledge management (KM) I was aware of possible issues for the engineering profession. They related mainly to business process research (about process modelling and business process reengineering) which tries to measure, capture and preserve knowledge within company information technology (IT) systems. There seemed to be insufficient attention paid to the unique needs of professions such as engineering, architecture and law which involve high levels of intuitive knowledge, reflection and creativity.

I suspected that engineering creativity could become endangered by inauthentic attempts to capture knowledge and stimulate creativity using largely IT-based approaches. I became interested in engineering as a creative practice, prompting the question which later inspired my study - Is engineering design creative, how do we know and how can engineers reach their design potential?

1.5.3 The research objective

A chance meeting with a former colleague initiated a unique opportunity to revisit a former employer, a now global consulting engineering firm, and share this timely and mutual interest in engineering and creativity. Following visits and an invitation to a major global company innovation event, a mutual desire to investigate the topic culminated in the following research focus and research objectives:

> *How do civil engineers talk about their work and what does this reveal about their motivation to exercise creativity within a project consulting environment?*

- What is the meaning of creativity and innovation for participants?
- How do engineers describe engineering design?
- How does the organization's project environment influence engineering design?
- How does the organization support creativity and innovation?

The objectives of the study were as follows:

- To explore the nature of creativity and related phenomena in the lives of engineers in a global project consulting environment.

- To explore the nature of engineering design.
- To explore the influence of project managed engineering on engineering design and creativity.
- To explore the influence of organizational climate on engineering design and project engineering.
- To develop interpretive techniques that encourage authentic and reflective accounts, knowledge sharing and ethical research practices (see Lincoln, 2002; Herda, 1999; Schon, 1991, 1983).

1.5.4 Research methodology

The study develops a research approach that gives engineers within the consulting company the opportunity to 'tell their stories' about engineering design. By talking with engineers about their design work, the study attempts to reveal what is authentic about creativity in engineering design, and use it as the basis for exploring the personal, group and organizational factors that are central to manifesting creative potential in that profession (see Amabile, 1988, 1983; Herda, 1999; West & Farr, 1990).

An interpretive, qualitative research perspective underpinned the single case study of the Brisbane office of a global engineering firm. This was appropriate because of the contextual nature of creativity and engineering design, and because of the one-off opportunity to conduct the study in the contemporary context of the Company's 2002/03 focus on innovation and creativity. In-depth, semi-structured interviews allowed the study topic to be explored contextually, with the use of non-interview sources to increase the authenticity of the study methods and findings. Readers are invited to read the results of the single case and if they wish, draw inferences from their own knowledge and experience about other cases and the research phenomena.

1.6 Outline of the thesis

1.6.1 Chapter 1

Chapter 1 explains the reasons for the research study and the content of the five chapters. It also identifies the research focus (and objectives): How do civil engineers talk about their design work and what does this reveal about their motivation to exercise creativity within a project consulting environment?

The introductory chapter reveals the key study's themes, definitions and reasons for the research study. It introduces the notion that engineering design is a creative practice of considerable importance to the economy and society. It also identifies a fragmented literature that reflects a perception that creativity is less important than innovation. This lack of understanding about creativity in the industry, and its relationship to innovation, supports a strong need for further research as a foundation for improved understanding and action.

1.6.2 Chapter 2

Chapter 2 undertakes a detailed review of the relevant literature to inform the research focus. As the research literature about creativity, innovation and engineering design is fragmented and disparate, the aim of Chapter 2 is to progressively bring it into a common forum – the global construction industry. This is because the principal gaps in the literature relate more to its fragmentation than a dearth of specific and discipline-focused content. The literature review's key discussions correspond to recognized disciplines or bodies of knowledge: The knowledge economy, creativity research, engineering design and business management.

The literature uncovers a highly competitive construction industry driven by a restrictive traditional culture of low costs and profit margins, unrealistic deadlines, risk and conservative procurement cultures. The knowledge economy has intensified the continuous innovation cycle for the construction industry, leaving companies and engineers uncertain about how to achieve innovation in an already problematic environment.

The review highlights that the innovation imperative relies on understanding and nurturing people's potential such as creativity and knowledge in engineering design. This involves resources and other forms of industry and organizational support, investment and change. Paradoxically, the already troubled industry fears the investment needed to stimulate creativity and innovation.

Chapter 2 suggests that the engineering literature ascribes a singular role to creativity in engineering - idea generation – one which is facilitated by creative thinking. This definition is only a snap-shot of the potential role that creativity could play in design. The literature uncovers the rich holistic interpretation of creativity widely discussed in the general creativity and organizational literature. The chapter concludes with the suggestion that the innovation imperative (paradoxically) may be stifling the industry's ability to support creativity.

1.6.3 Chapter 3

Chapter 3 outlines the overall research perspective - a qualitative interpretive approach, and the research strategy (a single case study) used to collect, interpret and assess the quality of findings. The approach, strategy and methods evolved to suit the tacit and contextual study phenomena and the research objectives are discussed. A rationale for the single case study research strategy is given, along with a description of the case setting – the Brisbane office of a global consulting engineering company – the principal source of study information.

The chapter identifies appropriate methods for identifying, sourcing and managing field information, after which it provides guidelines for analyzing, interpreting, authenticating and reporting the study's findings. The methods used to source information are explained in detail: In-depth interviews, company documentation and participative observation. So too are the cycles of reading, analysis, interpretation and synthesis used to produce and validate the study findings.

1.6.4 Chapter 4

Chapter 4 gives a largely descriptive account, in the participants' words, of sixteen key themes that are important in explaining the relationship between creativity and engineering design innovation in the study organization. The themes are organized within four main categories, each illustrating a key research question. The themes explore the meaning of creativity and engineering for participants, the nature of engineering design according to participants, how participants say project environment and industry culture impacts on their design, and how they suggest that the study organization promotes and inhibits creativity in engineering design.

The chapter briefly explains the interpretive method used to uncover the study findings, and reminds that the interpretation is one of many possibilities, raised in credibility by the extensive used of participants’ words.

1.6.5 Chapter 5

The main purpose of Chapter 5 is to present what I learned from participants about the research study. It takes the themes and conclusions (in the participants’ words) from Chapter 4, and juxtaposes them among the related literature. The participants’ discussions are used to inform the literature and vice versa. Interpretation is taken beyond the descriptive and dialogical explanation of Chapter 4, to a higher level of analysis, synthesis and abstraction.

This synthesis and abstraction enables the themes of Chapter 4 to be abstracted to several key issues for the study organization. This abstraction leads to the introduction of a framework for understanding creativity in engineering design by proposing a reflective model. The chapter concludes with a summary of the study findings and questions for further reflection and research.

Chapter 2
Literature review

2.1 Introduction

2.1.1 Purpose of the literature review

Understanding creativity in the engineering design context is vital to knowing how innovation can be achieved in engineering design. Yet no single body of literature adequately discusses the holistic context in which the creative person, practice, product and place (Isaksen, 1987, cited in Firestien, 1993, p. 262) give rise to engineering design innovation.

This chapter integrates the disparate and fragmented literature about creativity, innovation and engineering design to inform the central question of this study: *How do engineers talk about their engineering design work and what does this reveal about creativity in a project consulting environment?* The review is divided into the following sections:

- Introduction
- The creativity research: Person, process, product, place
- Engineering design
- The construction industry: The context for engineering design
- Business management: Creativity and the organization
- Summary and conclusions

2.1.2 History of creativity

Creativity as an explicit term is less than 200 years old, but fascination with it has existed from Ancient times when creativity was perceived as a mystical or divinely-inspired power, gift or fortune, sometimes associated with madness or frenzied inspiration. Since the Middle Ages creativity has increasingly been associated with individual freedom, talent, genius, invention, originality, discovery and imagination, and no longer considered a supernatural force (Albert & Runco, 1999).

Fundamental changes in philosophy, science, religion and the arts accompanied the Renaissance and Age of Enlightenment (1500-1700) and had a profound impact on creativity research (Albert & Runco, 1999). The entrenchment of Scientific Rationalism, and the application of the measurable sciences to worldly phenomena to construct scientific and social meaning (Crotty, 1998), accompanied this Age of individual freedom. The latter entrenched a rationalist or positivistic notion that the world and its phenomena could be defined and measured, to form a universal (or objective) world view (Von Krogh, 1998; Nonaka & Takeuchi, 1995; Watts, 2001, p. 11).

Individuals were perceived as capable of freedom of thought and self expression; thus they were masters of their own creativity (Albert & Runco, 1999). Darwin's theory of evolution reinforced the view that in order to survive, people are innately creative. Freud perpetuated some traditional associations about creativity and pathology (e.g. emotional imbalance), when he suggested that creativity was a manifestation of unfulfilled (sexual) desire (Albert & Runco, 1999).

Scientific Rationalism dominated creativity research for almost 200 years. Until the mid 1970s, research psychologists identified and measured cognitive (thinking or mental) and personality (character and behavioural) traits that they associated with giftedness and exceptional creativity. Their focus was traits-based research about creative thinking and creativity training (CT) (techniques used to teach divergent or lateral thinking) (Rickards & Moger, 2000; Sternberg & Lubart, 1999).

By the mid 1970s, traits-related creativity research was less prominent (as explained by Feldman et al, 1994). The reason, they suggest, was the failure of the US Government to continue its generous funding previously aimed at attracting the gifted into space exploration, science and engineering. Whilst traits research has contributed valuable insights about the specific needs of creative people and environments, there is now a marked trend towards holistic and multi-faceted models (Feldman et al, 1994; Sternberg & Lubart, 1999).

The diverse creativity literature represents many lenses through which creativity has been viewed throughout history. Recent developments suggest that researchers are exploring multi-faceted, holistic and contextual approaches to this complex phenomenon. Further, they are using these theories to investigate the personal, group and organizational support believed to nurture creativity (see Amabile, 1999; Giugni, 2001; Sternberg & Lubart, 1999; Sutton, 2001).

2.1.3 The benefits of creativity

The business benefits of creativity have received considerable focus in the past 2-3 years (DeGraff & Lawrence, 2002; Flew, 2002; Florida, 2002; Kennedy, 2001), compared with its many intrinsic, personal and cultural benefits. Knowing about the whole creativity story (that is, the business, personal and cultural context) is important to help people, groups and societies understand the nature of the phenomenon, and thus enable them to have a positive influence on it (Basadur, 1993; Wheatley & Kellner-Rogers, 1996).

The value of creativity is supported by a wealth of literature (see Amabile, 1999, 1988; Basadur, 1993; Florida, 2002; Mumford, 1996, 1981; Nickerson, 1999; Wheatley & Kellner-Rogers, 1996). Being able to use one's creative potential, says Basadur (1993) brings considerable benefits (pp. 294-296):

- **Motivation:** When people are allowed to develop and use their creative potential, their inclination to explore this creativity further is increased.
- **Mastery:** Increases people's desire to master their environment.
- **Intrinsic value**: Provides needed challenge which can be intrinsically satisfying.
- **Breaks monotony:** Breaks the monotony of repetitive tasks, which can lead to fatigue and boredom and affect work satisfaction and performance.
- **Challenge:** Creativity can involve setting personal challenges which make work meaningful and enable personal and professional growth.
- **Work satisfaction**: Provides intrinsic rewards or satisfaction beyond those of salary, security and working conditions.
- **Problem solving:** Complements the human inclination to find and solve problems.
- **Goal setting:** Motivates people to set stimulating work goals and implement their own solutions.
- **Diversity:** Allows variety, diversity, autonomy, and responsibility often associated with environments that foster creativity.

Business creativity is considered to be an important catalyst for innovation in the knowledge economy. Allowing people to use their creative potential (in the right type of environment) can be extremely beneficial to organizations in the following ways.

- **Productivity:** Can enhance work satisfaction leading to higher productivity and creativity (Amabile, 1999; Mumford, 1996, 1981; Wheatley, 1999a).
- **Business process improvement:** Can lead to small, incremental improvements in work procedures (Gaynor, 2002, p. 24; West & Farr, 1990).
- **Company breakthroughs:** Can lead to larger, breakthrough improvements at the company level (Gaynor, 2002, p. 25; West & Farr, 1990).
- **Industry breakthroughs:** Can lead to breakthrough developments at the industry level (Gaynor, 2002, p. 26; Shapiro, 2001; West & Farr, 1990).
- **Differentiation:** Can help differentiate competitors (creativity as a marketing element) (DeGraff & Lawrence, 2002, p. 15; Florida, 2002).
- **New industries:** Can generate whole new industries, e.g. new media, public art (Flew, 2002; Florida, 2002).
- **Reform industries:** Can reform traditional industries, e.g. engineering, health, education (ACIF, 2002; Schon, 1991, 1983).
- **Commitment:** Can create an authentic working environment and commitment (Herda, 1999; Steiner, 2002).

Finally, allowing people to use and manifest their creative potential can be culturally, as well as economically and personally beneficial. Globalization is increasing the mobility of people, industries and cultures. The most ‘attractive’ cities will lure the most lucrative industries, employees and citizens (see Florida, 2002; Landry, 2001). Some of the cultural benefits include:

- **Creative places:** Cities that allow people to develop their creativity are becoming more attractive (Florida, 2002; Landry, 2001).
- **Diversity:** Cultural diversity and individual expression is associated with creativity (Florida, 2002).
- **Creative industries:** Cities with a high ‘creativity index’ attract business and industry (Florida, 2002).

- **Progressive education:** Educational systems that cater for creativity and diversity attract more people (Education Queensland, 2004).
- **Sustainability:** Environmental sustainability requires creative solutions (Martin & Schinzinger, 1996).
- **Cultural appreciation:** Appropriateness in urban planning, engineering and other practices requires creative solutions (Martin & Schinzinger, 1996).
- **Ethical solutions**: Environmental, business and other ethics are being noticed by voters as well as business shareholders; creativity is needed in the challenge to find ethical solutions to difficult issues (Salmon, 1996, p. 26).

The above illustrates the broad context in which creativity operates not only as a business imperative, but as a foundation for individual and cultural growth. It also highlights that understanding creativity is an effective weapon against singular and potentially counterproductive views about the phenomenon.

2.1.4 Researching creativity

Knowing how to research and understand creativity is challenging because it is different from other organizational phenomena such as information technology, finance, and marketing strategy. It is tacit, contextual and a whole practice or experience. According to Patton (1990), creativity cannot easily be broken into measurable variables (p. 130) and mapped into organizational routines, evaluation and benchmarking procedures (Wheatley, 1999b) because of its

- **Complexity:** It is complex, context-dependent, multi-dimensional and therefore difficult to define, measure and evaluate (Nickerson, 1999; Wheatley, 1999b; Woodman, Sawyer & Griffin, 1993).
- **Non-linearity:** It is non-linear in appearance, combining cognitive (thinking) and experiential practice (Court, 1998; Schon, 1991, 1983).
- **Holism:** Objectively oriented scientific test instruments (e.g. surveys) can detract from the holistic nature of creativity (Herda, 1999; Patton, 1990, p. 130).
- **Intrinsic motivation**: Environments and incentives which motivate other behaviours, such as efficiency, can stifle creativity. Excessive performance evaluation, undemocratic and unsupportive leadership are not generally associated with creativity (Amabile, 1999; Sutton, 2001; Wheatley, 1999b).

- **Authenticity:** It involves understanding the person, the creative process, the creative product and place in which the creativity is being manifested – the authenticity of the entire work experience or domain (Isaksen, 1987, in Firestien, 1993, p. 261; Steiner, 2002).
- **Domain-specificity**: Generic management prescriptions may not complement the domain-specific aspects of creativity relevant to the industry, practice or profession (Amabile, 1988; Schon, 1991, 1983).
- **Non-traditional perspectives:** It is not necessarily manifested by traditional and strategic approaches such as goal setting and rigid evaluation techniques (Amabile, 1999; Sutton, 2001).

Patton (1990) suggests that creativity might best be understood by observing what and how people do their work, thus allowing an authentic and holistic picture to emerge that is relevant to particular people and groups (p. 130). Thus creativity is different from other phenomena. Understanding its complexity attracts broad and multiple perspectives.

2.2 The creativity research: Person, process, product, place

2.2.1 Introduction

For almost 200 years until the early 1970s, research about creativity was focused on individual traits: Cognitive, personality, biological and other (Albert & Runco, 1999; Feldman et al, 1994). Confluence, multi-faceted and contextual perspectives about creativity have tended to absorb the former psychology-based research (Sternberg & Lubart, 1999).

The most widely cited of the multi-faceted perspectives is Amabile's (1988, 1987, 1983) intrinsic motivation theory, which states that people will be most creative when motivated by intrinsic satisfaction (relating to the activity itself), rather than extrinsic factors such as money and prestige. Amabile (1988, 1983) identified three critical influences on personal creativity.

- **Knowledge**: The importance of domain-specific knowledge and skill (usually around 7-10 years) because it increases proficiency in a domain (such as sculpture, science and engineering) and thus the likelihood of exceptional performance.

- **Creativity-related skills**: Creative and divergent thinking, problem solving, and related non-cognitive skills were also considered important in enabling people to develop their creative potential.
- **Motivation**: Whether or not people are motivated to use their creative potential is summed up in two well-known quotes by Amabile.

> The unifying theme in all my own research is that people will be most creative when they are motivated primarily by passionate interest in their work. (1987, p. 224)

> A person's creativity can be killed in an atmosphere fraught with evaluation pressures, reward systems, competition, restriction of choice and anything else that takes the focus off the intrinsic properties of the work itself. (1987, p. 252)

Woodman et al (1993) extend Amabile's model by synthesizing the literature about a variety of creativity variables and how they influence creativity at the personal, group and organizational level.

Isaksen (1987, cited in Firestien, 1993, p. 262) presents the Four Ps model of creativity, a multi-faceted and contextual explanation, in which creativity is inseparable from the people, processes, product and 'press' (or places) involved in the creative experience (see Figure 2.1). The model is a wide lens for viewing creativity and is used as a framework for structuring this section.

Figure 2.1: A holistic view of creativity: The Four Ps of Creativity

This figure is not available online.
Please consult the hardcopy thesis
available from the QUT Library

(Source: Isaksen, 1987, cited in Firestien, 1993, p. 262)

Another extension of Amabile's theory is the 'Investment theory of creativity' proposed by Sternberg, O'Hara and Lubart (1997) in which individual creativity is said to depend on knowledge, intellectual abilities, creative thinking and problem solving, thinking styles, personality, motivation and environment. According to this theory, creativity is personal and complex and people will be motivated to develop and use their creativity when their perceived chance of success is greater than the risk of failure (Sternberg et al, 1997).

Kimbell (2002), an engineering educator, synthesizes the creativity and design literature to identify important influences on creativity and design:

- **Personal traits**: Personal traits, character, knowledge and skill
- **Processes:** A person-process relationship involving task finding, spark generation, development and elaboration
- **Place:** A supportive environment (peers, teachers, physical and learning setting) that uses feedback rather than traditional evaluation.

Contextual explanations of creativity are relevant to engineering design because they highlight that creativity is not a single facet or trait such as creative thinking or spontaneous insights, but rather the confluence of numerous personal, practice-related and environmental influences. These influences are discussed below.

2.2.2 The creative person

2.2.2.1 Introduction

The personal experience of creativity is inseparable from the creative activity and environment (Csikszentmihalyi, 1994; Kimbell, 2002). While some aspects of creativity are domain-specific, certain facets (listed below) are common to most creative endeavours (Amabile, 1999, 1988, 1983; Sternberg et al, 1997).

- **Intelligence**: Rational and cognitive abilities needed to process a range of complex phenomena.
- **Knowledge**: Cumulative general or domain-specific understanding and skill.
- **Problem solving and creative thinking**: Cognitive, divergent and convergent mental skills associated with creative problem solving.
- **Personality:** Personal preferences and strengths relating to behavioural, work and other styles.
- **Motivation:** The desire to risk engaging in an experience or activity, and the environments which influence this.

2.2.2.2 Intelligence

Research indicates a positive relationship between creativity and intelligence up to a measured IQ of 120 points (Albert & Runco, 1999; Sternberg & Lubart 1999). McKinnon (1985, cited in Feldhusen, 1993, p. 35) found higher IQ scores among architects and inventors, reflecting the cognitive demands of science and mathematics. In general, however, motivation, environment and personality are said to have a greater influence on creativity than IQ (Amabile, 1999, 1988, 1983).

In engineering, authors suggest that an appropriate mix of intellectual and emotional skills may be required to master scientific and design engineering knowledge and to develop the social skills needed to appreciate the aesthetic, cultural and sustainability issues embedded in today's complex and collaborative global design environments (Court, 1998; Giugni, 2001; Wiese & John, 2003).

2.2.2.3 Knowledge

Knowledge and practice in a field (usually 7-10 years) lays the foundation for creativity in the field. Creativity is most likely to emerge with substantial knowledge and experience of a discipline. This is widely known as the 10-year rule (Amabile, 1988, 1983; Feldusen, 1993; Sternberg & Lubart, 1999; Weisberg, 1999). Too much knowledge, however, can breed conservatism and conformity which can impede creativity, so it is important to remain open to new perspectives (Giugni, 2001, p. 47; Nemeth & Nemeth, 2001; Sternberg et al, 1997; Sutton, 2001).

In engineering the mastery of scientific and design knowledge allows engineers to sense the limits of their domain, and engage in small and larger scale creativity (Amabile, 1988, 1983; Ferguson, 1992; Margolius, 2003; Sternberg et al, 1997; Weisberg, 1999). Life-long learning, knowledge sharing and personal reflection can help lay the foundational knowledge of engineering science and design associated with creativity (Ferguson, 1992; Kimbell, 2002; Schon, 1991, 1983).

2.2.2.4 Problem solving and creative thinking

Problem solving (finding, definition and resolution) and creative thinking (divergent and non-linear) are single facets of the creative experience which are widely recognized in creative endeavours (Amabile, 1988, 1983; Feldhusen, 1993; Nickerson, 1999; Sternberg & Lubart, 1999; Weisberg, 1999). Some authors, such as artificial intelligence (AI) specialists, consider the attributes to be cognitive, linear and easily simulated (Langley & Jones, 1988; Schank, 1988). Other authors view the attributes as a more complex, tacit and lateral interaction between linear (convergent) and non-linear (divergent) forms of thought (Amabile, 1988; Sternberg & Lubart, 1999; Weisberg, 1999).

Many authors believe these attributes can be learned by individual and group creativity training in brainstorming, lateral thinking and related techniques (preferably in real work contexts) but agree that the outcomes are difficult to measure (Amabile, 1988, 1983; Feldhusen, 1993, p. 42; Rickards & Moger, 2000; Sternberg et al, 1997; Talbot, 1993, pp. 211-212).

Individual and collaborative brainstorming constitutes the principal discussion about creativity in engineering (for examples see Bailey, 1978; Court, 1998; Eide, Jenison, Mashaw & Northup, 1998; Peters, 1998; Wiese & John, 2003). Court (1998) says that engineers need to know when to use divergent and convergent thinking (p. 145). This is because problem solving is not only analytical but intuitive and iterative (Ferguson, 1992; Schon, 1991, 1983).

For an outline of some popular techniques used to develop creative thinking and problem solving see Ch.2, pp. 39-41.

2.2.2.5 Personality

The intrigue surrounding the 'creativity personality' has spawned a long list of personality traits associated with creativity (Amabile, 1988, 1983; Nickerson, 1999; Torrance, 2003; Woodman et al, 1993). Traits research focused on giftedness and genius and used brief IQ-type tests and failed to capture the essence of creativity, or to predict long term creative performance (Amabile, 1983; Nickerson, 1999). The traits, however, can help organizations to understand the needs of the palpably creative, as well as the intrinsic needs of other employees (Nemeth & Nemeth, 2001; Giugni, 2001). Some of these traits include:

- Self confidence, aesthetic disposition, attraction to complexity, tolerance for ambiguity, risk taking, courage to overcome obstacles, freedom and spontaneity (Sternberg & Lubart, 1999, pp. 8-9).

- High ego strength, flexibility, independence, self confidence, openness to experience, intrinsic appreciation for the activity, non-conformity and persistence (Nemeth & Nemeth, 2001).

- Fluency, flexibility, originality, subjective responses, openness to alternatives, emotional expressiveness, synthesis or combination, unusual visualisation, extending the boundaries, humour, juxtaposition, richness of imagery, etc. (Torrance, 2003).

Engineers are sometimes perceived as dull and unimaginative (Bernstein & Lemer, 1996). This is refuted by Court (1998) who identifies desirable attributes of the engineering designer: Patience, concentration and will-power, as well as invention, creativity and communication (p. 144). Engineering educator, Kimbell (2002) prefers to focus on removing personal blocks to creativity in design-based work, which he sees possible through supportive environments. These blocks include fear of failure, frustration avoidance and fear of the unknown (p. 4). Kimbell (2002) also reinforces the distinction made in the literature between ‘adaptors’ and ‘innovators’. The ‘inventor’ produces designs that are revolutionary, impressive and attractive. The ‘adaptor’ delivers adequate, well crafted and useful designs. Both are integral to the design process (p. 4).

Personality and creativity are very broadly related, though specific traits tend to be associated with the exceptionally gifted (Torrance, 2003). An awareness of personality types can help people nurture environments which are conducive to creativity. This is increasingly believed to be more important than hiring ‘creative’ people (see Giugni, 2001; Sternberg et al, 1997).

2.2.2.6 Motivation

The relationship between domain-specific, creativity-related abilities and skills, and motivation towards the task, is widely cited in the literature (Amabile, 1999, 1988, 1983; Basadur, 1993). People, according to Amabile (1988), are most creative when intrinsically (internally) satisfied with what they are doing. The evidence that people are intrinsically motivated includes the following:

- They attain high levels of autonomy, self motivation and satisfaction (Giugni, 2001).
- They are motivated towards the task rather than to extrinsic (external) rewards (Amabile, 1987).
- They possess a considerable knowledge of their specialist field (Amabile, 1988, 1983; Weisberg, 1999).
- They appreciate an environment that supports risk-taking (Giugni, 2001; Sternberg et al, 1997).
- They have good social and interpersonal skills such as persuasion and suspension of premature judgement (Giugni, 2001; Nemeth & Nemeth, 2001).

- They have a supportive environment which includes appropriate resources, recognition and feedback (Amabile, 1999; Sutton, 2001)

What motivates people towards creativity has not been widely discussed in engineering. Relatively few engineering authors view engineering design as a total creative experience. However, some engineering authors (see Bailey, 1978; Kimbell, 2002; Tornkvist, 1998), present discussions about creativity which are quite consistent with the creativity research about holistic creativity (see Sternberg & Lubart, 1999).

2.2.3 The creative process

2.2.3.1 Introduction

The research about the creative process and product seems dwarfed by the scale and depth of research about the creative person and place (for examples of this see Albert & Runco, 1999; Giugni, 2001; Rickards & Moger, 2000; Sternberg & Lubart, 1999; Woodman et al, 1993). Furthermore, the creative process is often viewed in a cognitive or linear way such as in the cognitive models of artificial intelligence (AI) and the ‘incubation’ models of creativity and invention (for examples see Langley & Jones, 1988; Schank, 1988).

2.2.3.2 Cognitive models

The assumption behind cognitive process theories is that nothing is truly novel but based on prior thought and knowledge combinations (Weisberg, 1999). Creativity is thus a mental process (creative thought) able to be captured and simulated using artificial intelligence (AI) programs (e.g. jazz improvisation) (Sternberg & Lubart, 1999, p. 8). Personal creativity thus depends on a person’s knowledge, ‘indexing’ (or mental storage) system and the nature of the problem (Langley & Jones, 1988, p. 199). Cognitive perspectives are based on the following assumptions:

- Creative thinking is ordinary (linear) cognition (Weisberg, 1999)
- Cognition can be documented as a (linear) process (Langley & Jones, 1988)
- Computer programs can model the human cognitive process (Tomiyama, Yoshioka & Tsumaya, 2002, p. 67)

- AI programs can help understand human creativity by modelling it (Schank, 1988, p. 220)

Opponents of cognitive perspectives suggest that:

- Neither creativity nor creative thinking is ordinary cognition (Sternberg & Lubart, 1999).
- Some things are unknowable; some things are ‘tacit’ (Polanyi, 1966).
- Creativity is complex, contextual and heuristic (Amabile, 1988).
- Creativity is non-linear as well as linear (Peters, 1998).

.

Cognitive perspectives of creativity (based on linear thinking and artificial intelligence) have had considerable impact on engineering (see Langley & Jones, 1988; Schank, 1988). For example, Tomiyama et al (2002) propose that design is a combination of analysis and synthesis, and can be translated into ‘design protocols’ (rules) and computable design process models or simulators (p. 67). Cognitive models can be applicable to the scientific aspects of engineering design (analysis and testing) though many engineering authors recognize the importance of visual conception, iterative testing and intuitive problem solving (Ferguson, 1992; Kimbell, 2002; Schon, 1991, 1983).

Though many cognitive explanations of creativity are popular, it is widely recognized that creativity is neither linear nor cognitive (Amabile, 1988; Hausman, 1987).

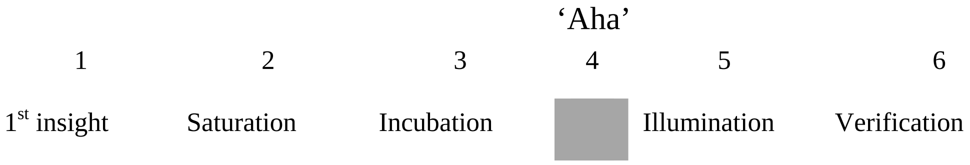
2.2.3.3 Incubation theories

Because of the association between creativity and scientific discovery, the incubation model of invention is often used to explain the creative process (see Rix, 1994, p. 161; Edwards, 1986, p. 222). One of many adaptations to the model is shown in Figure 2.2. It is a sequential representation of six linear and non-linear thought processes and related activities, thought to be involved in the invention process:

- **First insight:** An idea for exploration
- **Saturation and problem solving**: Information collection analysis and synthesis

- **Incubation:** Period of rest or diversion allowing further synthesis
- **Creative frustration**: Point of creative frustration (e.g. writer's block)
- **Illumination or discovery:** The 'Aha' or 'Eureka' stage or moment
- **Verification:** Testing and validation

Figure 2.2: The process of scientific invention



(Source: Adapted from Rix, 1994, p. 161).

The 'Aha' or 'Eureka' insight is the most publicized of many often lengthy gestation activities involved in invention, and by inference, creativity (Edwards, 1986, p. 222; Torrance, 2003). From this fixation has grown the 'Eureka' myth about creativity. Surprisingly common among engineers (see Perry, 1973, p. 8), it can perpetuate the misconception that breakthrough creativity results from sudden and spontaneous insights, short gestation periods and inconsequential investments (Edwards, 1986, p. 222; West & Farr, 1990). The myth can be damaging to research and development (R&D) budgets, and is evident in some construction industry discussions about multi-disciplinary collaboration, brainstorming techniques, and creative breakthroughs. Creativity researchers generally reinforce the importance of time (e.g. reflection) and investment (e.g. R&D) in breakthrough creativity (Amabile, 1999; 1988; Andriopoulos, 2001; Nonaka & Takeuchi, 1995; Weisberg, 1999).

Such models can help to identify certain stages in the design and creative process, particularly when heuristics (such as creative, iterative and reflective problem solving) are acknowledged (see Kimbell, 2002; Schon, 1991, 1983). Rather than mask the time and resources needed for creativity and innovation, the models can help people understand the nature of the creative process.

2.2.3.4 Big and Small Creativity

In Ch.1, pp. 7-8, a distinction was made between 'Big' and 'Small' C or creativity. 'Big', 'Exceptional' or 'Breakthrough' creativity refers to outstanding achievements that are widely acknowledged (see Csikszentmihalyi, 1999; Feldman, 1999). 'Small', ‘Everyday’ or ‘Intrinsic’ creativity represents smaller and more personal creative achievements (see Amabile, 1987; Rickards & Moger, 2000; Weisberg, 1999).

The importance of ‘Small C’, for its own value, and its incremental contribution to breakthrough creativity, is often under-recognized (see Amabile, 1988; Feldman et al, 1994; Sternberg & Lubart, 1999). In engineering, ‘Big C’ is often called breakthrough, radical or ‘Eureka’ innovation (CEDA, 2004; Gaynor, 2002), and tends to overshadow smaller but important creative contributions. This may be due to an emphasis in engineering on group creativity (for example, collaborative brainstorming, multi-disciplinary collaboration and project alliances). This emphasis on the group and end product of creativity can lead to the following oversights:

- An under-emphasis of the role of the engineer’s creativity, engineering process (and practice) and engineering environment (e.g. resources) in specific innovations (see Edwards, 1986; Powell, 1970).
- An under-emphasis of the time and creativity involved in identifying, developing, incubating, testing and implementing a given innovation (Edwards, 1986, p. 222; Perry, 1973; Rix, 1994, p. 161).

2.2.3.5 Summary

It is widely recognized that creativity as a process is both linear and non-linear (Amabile, 1988), even though linear process and cognitive models of creativity are common. In engineering, the creative process is described quite cognitively (e.g. problem solving) though recent literature acknowledges the role of iterative and intuitive practice, and creative problem solving (Eide, Jenison, Mashaw & Northup, 1998; Jones, 2002; Wiese & Jones, 2003).

2.2.4 The creative product

2.2.4.1 Introduction

The creative product receives little coverage in the creativity research, though as the precursor to innovation (see Amabile, 1988; Landry, 2001; West & Farr, 1990) its value is frequently discussed in the innovation literature.

2.2.4.2 Evaluating the creative product

As artefacts of the creative process, creative products provide a glimpse of the creative experience (see Besemer & O'Quin, 1993; Firestien, 1993; Kimbell, 2002). They are considered to be the end result of the creative process, for example an artist's painting, a building structure or product invention. Sometimes an emphasis on the creative end product can overshadow the time and creative efforts involved in the creative process (see the discussion about the 'Eureka myth' on pp. 34-35 of this chapter). Evaluating creative outcomes usually involves a combination of deliberate, unconscious and intuitive assessments (Amabile, 1988; Firestien, 1993; Nickerson, 1999). Evaluation can be difficult because of the complex and subjective nature of creativity, but it is generally agreed that a creative product or outcome is novel and useful to the individual, group or culture involved (Amabile, 1988; Csikszentmihalyi, 1999; Kimbell, 2002; Nickerson, 1999), suggesting that creativity can be appreciated on many levels.

Giving feedback about creative products is often the responsibility of educators and mentors. Creativity research strongly recommends that evaluation should encourage not stifle future creative efforts. Feedback and encouragement rather than rigorous criticism are considered to motivate creativity (Amabile, 1999, 1988; Wheatley, 1999b).

2.2.4.3 Evaluating the engineering product

The people and experts in a domain can usually develop an intuitive sense of what is creative and are thus able to assess the creative product (Amabile, 1988).

> There is no straightforward way to objectively measure how successfully a creative idea has been implemented. Nonetheless, it is reasonable to assume that, as with assessments of creativity, experts in a domain can agree to a satisfactory degree on the level of innovation exhibited. (Amabile, 1988, p. 146)

Based on this assumption, the engineering community can intuitively assess the novelty and usefulness of designs and completed structures. Firestien (1993) suggests that an adjunct to intuition is a set of carefully thought out guidelines. An example is the UK Highways Agency's (1996) publication titled, "*The appearance of bridges and other highway structures*", in which the importance of aesthetics in civil engineering design is given careful consideration. In consulting engineering, evaluation criteria are often determined by the industry culture and procurement process (Keegan & Turner, 2002). Proposals are evaluated using predetermined criteria such as, cost, delivery time, risk, innovation and safety; and sometimes sustainability and aesthetics (Queensland Government, 2004). In Queensland the weighting placed on cost and efficiency is about 75-95% in awarding contracts, compared with the weighting of 5-25% applied to non-cost criteria such as energy efficiency and aesthetics (see McLeish, 2004; Queensland Government, 2004). Internationally, and with larger projects, contracts are increasingly awarded on non-cost as well as cost criteria (Bernstein & Lemer, 1996; Tornkvist, 1998; UK Government, 2004).

2.2.4.4 Aesthetics and the creative product

Creativity in engineering is often associated with art, aesthetics and visual attractiveness (Ferguson, 1992; Gelernter, 1998). The UK Highways Agency (1996) underscores the importance of aesthetics (an intuitive and learned sense of appreciating phenomena) in engineering design. This is illustrated in the preface to one of their publications.

> As the Minister responsible for bridges I wish to impress upon all authorities the great importance of securing at the outset the best expert advice upon the design not merely from the standpoint of the stability and safety of the structure, but also of its proportions and appearance. (UK Highways Agency, 1996, p. 5)

Engineers are often criticized for insufficiently considering the aesthetics of structures (Ferguson, 1992; Gelernter, 1998; Tornkvist, 1998). Aesthetic understanding in engineering comes mainly from engineering practice and the development of an intuitive sense (Amabile, 1988; Gelernter, 1998; Schon, 1991, 1983). This intuitive sense, say Ferguson (1992) and Schon (1991), can be greatly enhanced by a substantive scientific and design knowledge. It can also be heightened by understanding cultural diversity and biodiversity (Gelernter, 1998).

Though aesthetics is perceptual and subjective, the design professions have developed a language (see below) that helps professionals talk about their designs (see Gelernter, 1998; Schon, 1991, 1983, p. 96; UK Highways Agency, 1996, pp, 10-15):

- **Function**: Safe, structurally sound, fulfils its purpose.
- **Form**: Balance of functions in the broadest sense, e.g. load carried.
- **Character and individuality**: A structure should be attractive to look at and have a natural and permanent appropriateness about it in relation to its setting.
- **Detail**: Detail is central to the social, scale, proportion and perceived beauty of the structure, often achieved by emulating the visual textures and patterns found in nature.
- **Scale:** Whether a structure appears to be large and imposing or small and intimate
- **Proportion:** Psychologically the brain perceives something as beautiful when the mathematical relationship is simple.
- **Environmental intrusion**: Structures can relate appropriately to the adjacent environment and cultural context.
- **Context and setting:** Whether the structure will be low key or bold, dramatic or mundane is often determined by the physical and cultural environment.

The cost innovation imperative in the construction industry makes it difficult for engineers to design creatively, because taking cultural, aesthetic and environmental appropriateness into account can require additional resources which can conflict with project budgets (Gelernter, 1998; Keegan & Turner, 2002). The pressure for change in the industry, is slowly shifting design benchmarks to include other factors (ACIF, 2002; Bernstein & Lemer, 1996). Changing construction industry culture may inspire and empower engineers to persuade clients about the value of design elements that involve creativity, and thus raise the standard of the engineering product.

2.2.5 The creative place

According to contextual explanations of creativity such as the Four Ps of creativity (see Isaksen, 1987, cited in Firestien, 1993, p. 262) creative people, processes and products exist inseparably in group, organizational and socio-cultural contexts (Amabile, 1988; Csikszentmihalyi, 1999; West & Farr, 1990). The final section in this chapter gives an in-depth coverage of how groups and organizations can affect creativity. I suggest that the discussion about creative place will be better understood after the following discussion about the engineering design practice and construction industry. This is because creativity is contextual and domain-specific (Amabile, 1988).

2.2.6 Creativity training (CT)

2.2.6.1 Introduction

Creativity training refers to largely cognitive techniques (such as brainstorming) used to improve idea generation and problem solving (Sternberg et al, 1997). There is a lack of consensus about the meaning, measurement and effectiveness of creativity training and its ability to enhance personal and group creativity (Nickerson, 1999; Sternberg et al, 1997). Despite this, CT has reappeared in cycles since the 1920s and continues to be the main context for creativity in many engineering organizations (Ferguson, 1992; Schon, 1991, 1983). It is particularly common as a facilitation tool in the ‘project alliance’ (a popular form of collaborative project procurement) (see pp. 54-56). Though cognitive creativity is the main context in which creativity is discussed in engineering (see Bailey, 1978; Eide et al, 1998), CT is one of multiple facets of the creative experience and environment (see Amabile, 1988; Bailey, 1978; Isaksen, 1987, cited in Firestien, 1993, p. 262).

Carefully selected and applied in the engineering context, however, CT can be beneficial to people, groups and organizations (Bailey, 1978, pp. 421-440; Rickards & Moger, 2000; Sternberg et al, 1997). Some popular and peer-reviewed techniques are outlined below.

2.2.6.2 Brainstorming

Brainstorming is widely used in non-traditional, collaborative project procurement methods such as project alliances. Its purpose is to improve design input in the early design stages, raising the chances of innovative solutions and reducing downstream construction issues (Bernstein, Kissinger & Kirksey, 1998). It is a popular and reputable technique used to explore multiple issues, look for synergies and develop outcomes. It is more successful when prejudice and premature judgement are delayed

(Giugni, 2001, p. 51; Michalko, 2001). Research suggests that smaller groups and fewer disciplines (such as 2 or 3 disciplines; 4 or 5 people) are more effective than larger groups in optimizing the benefits (Sethi et al, 2002, p. 18).

2.2.6.3 Lateral thinking

Many creative thinking tools are based on de Bono's writings about lateral, divergent and associative thinking. Exposure to disparate knowledge, talent and disciplines is considered to raise the likelihood of creative solutions (Michalko, 2001). There is a wide array of such tools, some of which are grounded in creativity traits research and pedagogy. Adaptations to de Bono's '*Six Thinking Hats*' approach can coax people to adopt different points of view. Multiple facets of issues are explored before conclusions are reached, arguably increasing the chances of creative solutions (Giugni, 2001, p. 51; Michalko, 2001).

2.2.6.4 Creativity games

Creativity games have gained in popularity. For example, van Oech developed the '*Creative WhackPack*' involving a 620 card pack, each card with one of four creative suits: Explorer, artist, judge, warrior, each a representing a different role in creative thinking. The cards are designed to 'whack' participants to remind them about habitual thought patterns and to stimulate different strategies (Giugni, 2001, pp. 51-52). This can encourage people to step outside their usual mindsets and consider other perspectives.

2.2.6.5 Scenario planning

Scenario planning is widely used in business as a CT and strategic planning tool. Four driving forces are assumed to be at the heart of most issues: Social, economic, political and technological. A scenario is proposed and participants use their imagination to understand the dynamics of each driving force.

> Scenario planning is possibly the ultimate creative game in that it helps us understand the uncertainties and what they mean, and allows us to rehearse our response to the possible futures. (Giugni, 2001, p. 53)

2.2.6.6 Mind mapping

Mind mapping is a whole-brain technique formalized by Buzan (in the 1970s) and increasing in popularity. It uses structured brainstorming and facilitates non-linear thought by the use of keywords, colours and conceptual veins to produce a visual map of a theme. It is based on the assumption that geniuses extend their associative boundaries widely and unusually (Michalko, 2001, p. 55).

2.2.6.7 Summary

Creativity training can help to improve creative thinking ability, which is associated with creativity (Amabile, 1988, 1983). The number and variation of tools, consultants and costs, however, makes it important to choose training methods and consultants that are peer reviewed and which can be incorporated into real work tasks (Kimbell, 2002; Rickards & Moger, 2000, p. 274; Sternberg et al, 1997).

Training in group or collaborative creative thinking and problem solving is regarded as important in engineering design innovation. Creative thinking training addresses one of the three facets that Amabile (1988) says is central to creativity in any domain. A highly comprehensive and context-specific tabulation of creative problem solving programs for engineering is given by Bailey (1978, pp. 421-440). He reminds readers, however, that CT is one of at least 26 facets of engineering creativity (see Figure 2.3, p. 44). It is also one of four central influences which Isaksen presents in his Four Ps model of creativity (1987, in Firestien, 1993, p. 262). There are clearly additional aspects to engineering creativity and ways of supporting it.

2.2.7 Summary

The creativity literature is rich and diverse, as revealed in the history of creativity and the discussions about personal attributes, creative process and product. Creativity is different from other human and business phenomena such as physiology and accounting, and thus invites a different treatment, using multiple and holistic perspectives.

2.3 Engineering design

2.3.1 Introduction

Engineering design is the part of engineering practice likely to reveal insights about creativity (Bailey, 1978; Court, 1998; Ferguson, 1992; Kimbell, 2002; Schon, 1991, 1983). Creativity is inherent in the title ‘engineer’ (Freeman-Bell & Balkwill, 1996, p. 1) and in the traditional engineering practice (which for over 500 years) saw engineers combine the design and art of architecture with the engineering sciences (physics and geometry) (Ferguson, 1992; Margolius, 2003; Schon, 1991, 1983). Several authors describe engineering design as an art and science:

> The engineering designer, who brings elements together in new combinations, is able to assemble and manipulate in his or her mind devices that as yet do not exist. (Ferguson, 1992, p. xi)

> The engineer combines an understanding of engineering science, knowledge of the behaviour of materials and structures, experience of construction process and his [sic] own successes and failures, thus bringing more into design than inevitability based on scientific laws. (Margolius, 2003, p. 13)

Civil and structural engineering continues to be practised (to varying degrees) as an intuitive art and science (a suggestion of its intrinsic nature). Since the 19th Century, however, engineering has increasingly been taught as a rational engineering science with increasingly less attention paid to the architectural, cultural, and other elements considered to be a natural part of project design (Ferguson, 1992; Gelernter, 1998, Schon, 1991, 1983). Consequently, many general engineering texts emphasize the scientific and linear aspects of the design process (Dym & Little, 2000; Eide et al, 1998; Peters, 1998; Wiese & John, 2003).

2.3.2 Recent views about engineering design

Despite the trends (in the past century and a half) towards teaching engineering as a design science, a number of engineering and educational authors have received increasing attention for their divergent views. These authors emphasize the need to teach and practise engineering as a creative design practice as well as a knowledge-based and analytical science (see Ferguson, 1992; Gelernter, 1998; Kimbell, 2002; Schon, 1991, 1982; Tornkvist, 1998). Ferguson (1992, p. 189) and Schon (1991), for example, describe engineering design as an iterative and reflective knowledge and design-based practice. This influential body of authors pays considerable attention to design elements such as visual thought, intuition, aesthetics, experimentation and creative problem solving, considering them to be fundamental to successful engineering solutions (Ferguson, 1992; Gelernter, 1998; Kimbell, 2002; Powell, 1970; Tornkvist, 1998). According to these authors, engineering design is comparable to palpably creative practices such as architecture and graphic design (see Ch.1, pp. 12-13). Potentially, it is a complete process, motivated by personal, business and other contexts (Bailey, 1978; Ferguson, 1992; Gelernter, 1998; Schon, 1991, 1983; Tornkvist, 1998).

There is thus an increasing trend for some authors to describe engineering design as linear and non-linear, intuitive and reflective, as well as an artistic blend of architectural design elements, and iterative interpretations of engineering science principles (Ferguson, 1992; Gelernter, 1998; Schon, 1991, 1983). Engineering design combines the rigour of scientific and rational knowledge with the less tangible aspects of visual conception (Ferguson, 1992), architectural and allied design (Margolius, 2003; Schon, 1991, 1983) and the social sciences and aesthetics (Gelernter, 1998). Visual conception is design, and scientific analysis allows the engineer to analyze and test the design concept (Ferguson, 1992).

Whilst the tendency to consider engineering design in this multi-faceted way is far from widespread, the trend towards combined linear and non-linear perspectives is encouraging, according to the above authors. These authors who speak about design as a linear and non-linear experience are concerned, however, about the tendency in engineering schools to view the artistic or ‘soft’ elements of their practice, as effeminate and useless (Ferguson, 1992, pp. 22-23; Gelernter, 1998). Examples of these so-called ‘soft’ but equally important elements of engineering are outlined below. The elements help to illustrate that engineering design is both creative and artistic.

- **Visual:** Design is visually conceived in the 'mind's eye' (Amabile, 1988, p. 151; Ferguson, 1992, p. xi).
- **Aesthetics:** Aesthetics is considered important when designing structures that will be appreciated (visually, functionally, culturally, etc.) (Gelernter, 1998; UK Highways Agency, 1996).
- **Experimentation:** Creativity is important in reaching appropriate cultural, social and ethical design solutions (Martin & Schinzinger, 1998).
- **Iterative:** Alternative solutions are formulated, analyzed and tested in an iterative way (Burghardt, 1999, p. 2).
- **Intuitive:** The intuitive, iterative and reflective nature of the design practice resembles the creative arts (Schon, 1991, 1983, pp. 171-172).
- **Artistic:** Engineering genius often combines scientific and artistic thinking and methods (Peters, 1998; Ferguson, 1992). The artistic aspects of design are clues that creativity is both present and important in engineering design (Schon, 1991, 1983).
- **Personal style**: The personal style of the designer is often embodied in the works of well-known engineers, e.g. Thomas Maillart, Thomas Edison (Ferguson, 1992, p. 26).
- **Linear and non-linear**: That engineering design has both linear as well as non-linear elements is implied in some recent explanations of the design process (see 2.3.2.1 to 2.3.2.3 (Ch.2, pp. 44-47).

The gradual tendency to view engineering design as a combined linear and non-linear process and experience is illustrated by the above and following explanations:

- Bailey's (1978) multi-faceted view about engineering design (see Figure 2.3).
- Kimbell, Stables and Green's (1996) model of the design process (see Figure 2.4).
- Weiss' (2002) Model of the innovation process at IDEO (see Figure 2.5).

2.3.2.1 Bailey's 'gem of creativity'

An example of a multi-faceted and multi-layered perspective about engineering design is Bailey's (1978) 'gem of creativity' (see Figure 2.3). Bailey describes engineering design as being part of a creative process. Design occurs in a context that has multiple and interrelated linear and non-linear aspects. The engineering process he describes is multi-faceted (it has at least 26 key influences) and multi-layered (it is influenced by personal and environmental factors (pp. 40-45). The relatively linear and sequential of these aspects appear easier for Bailey to explain. An example is the analyzing and testing of alternative engineering solutions (p. 40). There are, however, non-linear aspects that are highly contextual and more difficult to understand (such as aesthetics, ethics and culturally sensitive design). Such aspects are complex considerations because they involve the inter-relatedness of the engineer, the design practice and the engineering environment (pp. 40-45).

Whilst Bailey's illustrations of the engineering process can give an appearance that design is linear in nature, he consistently speaks about engineering as a practice involving creativity at every identifiable stage, and in almost every identifiable context - personal, group and organizational (pp. 40-45). The model is consistent with multi-faceted perspectives about creativity described in the creativity research (Amabile, 1999, 1988; Feldman et al, 1994; Firestien, 1993; Sternberg & Lubart, 1997; Sutton, 2001; Woodman et al, 1993).

Figure 2.3: The gem of creativity

This figure is not available online.
Please consult the hardcopy thesis
available from the QUT Library

(Source: Bailey, 1978, p. 41)

2.3.2.2 Kimbell et al model of the design process

Bailey's perspective about the engineering design process is similar to that of Kimbell et al (1996). Their model is intended to help teachers develop design skills among school students. Similar to Bailey, the design process is illustrated as a fairly logical step-by-step process (see Figure 2.4). However, the process by which one moves from one step to the next is described as involving numerous linear and non-linear influences. For Kimbell et al (1996) a good example of the non-linear nature of the design process is the role that student differences and school environmental factors play in promoting and inhibiting the designer's creativity, the design process and the design outcome.

Figure 2.4: Problem-solving process (after Schools Council Design and Craft Education Project, 1972)

This figure is not available online.
Please consult the hardcopy thesis
available from the QUT Library

(Source: Kimbell, Stables & Green, 1996, p. 30)

2.3.2.3 IDEO model of the innovation process

IDEO (a successful US product design and innovation company) believes that its ability to nurture creativity in its work environment, is the key to its success (see Kelley, 2001). Figure 2.5 is the Company's visual concept of its product innovation process. Similar to the previous explanations of the design process, IDEO illustrates the design innovation process as a largely step-by-step process in which the early creative phase is characterized by an iterative loop connecting what is called 'concept discovery' and 'concept design'. This apparent linearity is deceptive, however, because Kelley (2001) and Weiss (2001) clearly acknowledge the combined linear and non-linear nature of the process, in the text that accompanies their diagram.

Figure 2.5: Innovation from discovery to delivery

This figure is not available online.
Please consult the hardcopy thesis
available from the QUT Library

(Source: Weiss, 2002, p. 33)

An example of the contextual way in which IDEO says it tries to build linkages between the linear and non-linear aspects of creativity and innovation, is illustrated in the following IDEO principles (Kelley, 2001, pp. 6-7):

1. **The problem:** Understand the market, client, technology and perceived constraints of the problem.
2. **The people:** Observe people in real-life situations; their frustrations, their likes, dislikes and latent needs.
3. **The ideas:** Visualize and brainstorm new concepts and the customers likely to use them.
4. **The evaluation:** Evaluate and refine '3'. Reserve judgement and engage knowledgeable people outside the team about what works and what confuses people.
5. **The implementation**: Implement the concept; commercialize it. This is a long and challenging phase.

2.3.3 Cognitive models of the engineering design process

Though there are trends away from the view that engineering design is principally systematic, linear and cognitive, the influence of these perspectives still appears to be quite prominent, particularly in engineering text books (Ferguson, 1992; Schon, 1991). Though some recent text books discuss creativity (see Dym & Little, 2000; Wiese & John, 2003), they tend to refer to engineering design as a step-by-step problem solving process that can be augmented by creative thinking training (see Ch.2, pp. 39-41). Such interpretations of engineering design resemble the cognitive models of creativity and innovation (see Ch.2, pp. 32-33). Typical stages include: Identify problem, specify goals, develop solutions, optimize (test) solutions, build and verify, convince others (Court, 1998, pp. 144-145). Many authors try to accommodate the non-linear elements of engineering design by building iterative feedback loops and non-linear problem solving stages into their explanations of the design process (see Burghardt, 1999, p. 3; Eide et al, 1998; Wiese & John, 2003).

This recent focus on creative thinking and problem solving in the engineering literature, however, is a largely cognitive view of creativity (see Ch.2, pp. 32-33). In the creativity literature, there is a distinct trend away from purely cognitive models (see Amabile, 1999; Basadur, 1993). The implications for organizations that remain overly focused on cognitive theories, is that they could be prone to emphasizing the individual aptitudes and thinking capacities of the ‘creative person’ and underemphasizing the importance of the creative process, the creative product and the creative ‘press’ or place (see Ch.2, pp. 26-27 for a discussion about the Four Ps of creativity).

2.3.4 Engineering design education

2.3.4.1 Scientific design knowledge

Earlier in the chapter (see p. 29), the relationship between knowledge and creativity was highlighted by underscoring the 10-year knowledge rule from the creativity research. The rule cements the importance of knowledge and experience in enabling engineers to sense the limits of their domain, and increase their chance of producing small or large design breakthroughs (Margolius, 2003). Formal engineering knowledge involves an understanding and application of scientific principles, as well as ‘design-based’ knowledge which pertains to visual, perceptual and artistic aspects of technology and design (see Ferguson, 1992; Kimbell, 2002). Engineering science and mathematics are foundational to designing and testing workable and creative structures (Ferguson, 1992; Margolius, 2003, p. 14).

Contemporary authors such as Ferguson (1992) distinguish between scientific analysis and design.

> Structural analyses (indeed any engineering calculations) must be employed with caution and judgement, because mathematical models are always less complex than actual structures, processes and machines. (Ferguson, pp. 11-12)

Engineering science is used to analyze and test designs to ensure that they work, whereas designs (depending on the scope of the project) are often conceived visually (Court, 1998; Ferguson, 1992, pp. 9-11; Kimbell, 2002; Schon, 1991, 1983).

2.3.4.2 Artistic design knowledge

Design (or technical) knowledge is distinct from scientific knowledge and acquired through visual perception, learned design, aesthetic appreciation and contextual matters related to the natural, built, social and cultural environment (Kimbell, 2002; Tornkvist, 1998). These qualities allow engineers to consider cultural and environmental appropriateness and sustainability in their designs (Martin & Schinzinger, 1996). Kimbell (2002) refers to this as 'baseline knowledge and skills for design and technology' along with 'contextual (task-related) knowledge and skills' (p. 5). With knowledge, practice and experience, engineers develop informed judgement and intuition about structural design (Schon, 1991, 1983). Like scientific knowledge, the 10-year knowledge rule applies to design (see Amabile, 1988; Sternberg & Lubart, 1999).

2.3.4.3 Engineering education

Despite the obvious importance of design education, the concept of teaching an art or design, as well as science of engineering, has disappeared from engineering curricula (Ferguson, 1992; Schon, 1992, p. 172). There is some evidence of a resurgence of interest in design technology in the UK with the work of Kimbell (2002) and his colleagues who are challenging traditional beliefs that design cannot be taught (Court, 1998; Kimbell, 2002; Kimbell et al, 1996).

Contemporary perspectives about engineering design practice described by Ferguson (1992) and others do not represent the general interpretation in engineering schools (see Bailey, 1978; Ferguson, 1992; Gelernter, 1998; Kimbell, 2002; Schon, 1991, 1983; Tornkvist, 1998). Their concern is expressed by the following statement:

> The art of engineering has been orphaned in the engineering schools ... Paradoxically, in the schools of engineering the art of engineering has been largely neglected. The stress has been on analysis rather than synthesis, on the abstract rather than the messy alternatives of the real world. (Bailey, 1978, p. 19)

According to many educators, engineering education can be improved by the following:

- **Balance:** Redress the balance between design and other aspects of engineering education in universities (Gelernter, 1998; Schon, 1991, 1983).
- **Design language:** Improve the exposure of engineers to design-related languages used in allied areas such as architecture and urban design (Margolius, 2003; Schon, 1991, 1983).
- **Humanities:** Ensure that a basic education in art theory, the humanities, architecture and or design is offered to engineers (Gelernter, 1998).
- **Aesthetics:** Continue to develop guides to aesthetic design in engineering (UK Highways Agency, 1996).
- **Contextual:** Encourage holistic, contextual and team-based approaches to project design work (Court, 1998; Kimbell, 2002).
- **Awareness:** Improve awareness about the nature of the engineering design practice through formal and ongoing education and professional development (Schon, 1991, 1983).

2.3.5 Summary

How engineering practice is perceived underpins what engineering educators and employers think is necessary to develop engineering potential through formal and life-long education and learning (Tornkvist, 1998; Schon, 1991, 1983). It also affects the way that industry groups and organizations understand engineering creativity. It appears that there is a limited awareness about the domain-specific aspects of creativity, and how they contribute to small and breakthrough innovations in design (Chakrabarti, 2002, p. 147; Kimbell, 2002; Powell, 1970).

Creativity is given little attention within the engineering community. Innovation is discussed more often, the focus being cost innovation, business improvement and collaborative technologies, rather than on the design innovation process (for examples of this see Bower & Merna, 2002; Dozier, Cole, Manrique, Magee & Allen, 1996; Farrell & Watzke, 1997; Gilbert, 2000; Love & Gunasekaran, 1998). The engineering literature seldom discusses a broader context for creativity (such as the Four Ps of creativity, see Ch.2, pp. 26-27, see also Amabile, 1988; Csikszentmihalyi, 1999; West & Farr, 1990). Instead, the literature tends to focus on cognitive creativity (improving the problem solving skills of engineers through creative thinking techniques) (Burghardt, 1999; Eide et al, 1998; Wiese & John, 2003).

Thus the engineering literature does not by itself present the holistic view about creativity that is widely supported in the creativity and organizational literature (Amabile, 1988; Giugni, 2001; Nickerson, 1999; Sternberg & Lubart, 1999). In my opinion, the influence of a small but influential number of engineering authors is promising. They discuss the practice as a design art and science, recognizing the importance of teaching and practising design, like creativity, as a whole experience involving multiple personal, group and organizational facets (Ferguson, 1992; Gelernter, 1998; Kimbell, 2002).

2.4 The construction industry: The context for engineering design

2.4.1 Introduction

The construction industry culture has a powerful influence on creativity and innovation in engineering design, illustrated in the following themes:

- Global competition
- Cost and breakthrough innovation
- Procurement practices and regulatory environment
- Conservatism and risk avoidance
- Fostering an innovative industry culture

2.4.2 Global competition

The limited size of the Australian market, coupled with increased global competition, makes the market for construction procurement highly competitive (ACIF, 2002; CEDA, 2004). Engineering companies hence procure work in an industry where profit margins are unsustainably low (ACIF, 2004; Bernstein & Lemer, 1996; McLeish, 2004; UK Department of Trade and Industry, 2002). Engineers are pressured to deliver lower costs and price, faster delivery times, reduced risk and smarter and simpler designs, to provide them with a competitive edge (Bernstein & Lemer, 1996; Keegan & Turner, 2002; McLeish, 2004). Resources are scarce, limiting the ‘slack’ (free time and resources) for creativity-related activities such as reflection and experimentation, knowledge sharing and research and development (Keegan & Turner, 2002; Nonaka & Takeuchi, 1995). Somewhere in this scenario is an expectation that the time and resources will be found for innovation. The creativity research suggests that competitive conditions such as these limit the time and resources for creativity-related activities and are likely to stifle creativity (Amabile, 1999; Basadur, 1993; Keegan & Turner, 2002).

2.4.3 Cost innovation

The innovation response in the construction industry is dominated by a continuous cost innovation spiral (see Ch.1, pp. 10-13) which underpins competitive survival in the global knowledge economy. Cost innovation is a situation where companies achieve a competitive advantage by continually lowering their profit margins, or by implementing business improvement processes that improve administrative efficiency but not necessarily engineering design (see Shapiro, 2001). Cost innovation fits the category which Porter (2000) says offers a company little competitive advantage, because these practices are easily emulated by competitors.

Tilley (2004, cited in McLeish, 2004) states that cost innovation is no longer sustainable without fundamental changes in the procurement culture. Lowest cost bids, he says, lead designers to take short-cuts. Ninety-nine percent of Queensland projects suffer mild to serious design faults because of under-quoting on project tenders (McLeish, 2004). The condition has escalated with a Queensland government tradition of awarding work to the lowest bidder (a process which places a 75-95% weighting on cost criteria) (McLeish, 2004; Queensland Government, 2004). Research suggests that procurement practices which award on non-cost criteria such as sustainability and aesthetics, as well as cost criteria, are more sustainable and encourage competition based on design creativity and innovation (ACIF, 2002; Keegan & Turner, 2002; McLeish, 2004). Changes in government legislation are recommended as a partial solution to an unsustainable situation (McLeish, 2004).

Unrealistic cost and time pressures are transferred to the designer, who with insufficient time can make mistakes and take short-cuts which lead to design faults, delayed schedules and increased costs. Design problems are often found in the construction phase, causing further delays and cost. Frustrated by repetitions of this scenario, and with little 'slack' to find solutions, experienced and creative engineers leave an industry which they say is unsustainable (Tilley, 2004, cited in McLeish, 2004).

2.4.4 Breakthrough innovation

Incremental and breakthrough design innovation is distinct in its requirements from business process innovation (Gaynor, 2002; Shapiro, 2001; West & Farr, 1990). Unlike cost innovation, design innovation requires real improvements in design, methods, materials and project management to deliver sustainable advantages and innovation (ACIF, 2002; Bernstein & Lemer, 1996; UK Department of Trade and Industry, 2002).

Whilst some breakthroughs can appear to result from little effort, most result from sustained commitment and investments (Amabile, 1999; Nonaka & Takeuchi, 1995). The investment is preferably directed at domain-specific knowledge, R&D and experimental activities, than towards creativity skills alone (Ferguson, 1992). The creativity and business literature reinforces that strategic and informal investments and creativity-related activities are needed to sustain this type of innovation (Amabile, 1999; Nonaka & Takeuchi, 1995).

2.4.5 Procurement practices and regulatory environment

2.4.5.1 Traditional procurement

In Queensland, construction procurement is characterized by the following inhibitors to design innovation and creativity:

- Lump-sum or fixed fee contracts guarantee payment independent of performance thus discouraging creativity and innovation (ACIF, 2002; McLeish, 2004; UK Department of Trade and Industry, 2002).
- Tenders are awarded on cost rather than non-cost criteria such as innovation, aesthetics and sustainability (Queensland Government, 1994, p. 12).
- Cost and delivery cycles can lead to an over-reliance on tried-and-tested methods, use of short-cuts and risk-avoidance (Keegan & Turner, 2002).
- There is no 'slack' for creativity in cost-driven scenarios (Keegan & Turner, 2002).

- These conditions can lead to oversights in design and cost blow-outs when design and construction faults need correction (Bernstein & Lemer, 1996, p. 93; McLeash, 2004).
- Insufficient time and incentive for collaboration between the designer and builder can cause constructability issues and cost blow-outs downstream (McLeish, 2004).
- Creative approaches such as sustainable and environmental building design are often side-stepped because the needs of tenants and residents are insufficiently explored (see Perinotto, 2004, p. 63).

Traditional cost-driven environments thus tend to stifle creativity and innovation (Amabile, 1988; Keegan & Turner, 2002) whilst many non-traditional procurement options help to create the conditions that are often associated with creativity and innovation (Love & Gunasekaran, 1998).

2.4.5.2 Non-traditional procurement

Authors agree that the industry needs to change from traditional to alternative forms of project procurement, such as the project alliance (a formal collaborative tendering process), which are believed to foster creativity and innovation in engineering projects for the following reasons:

- Project fees are performance-dependent providing the incentive to improve all aspects of project design and delivery (Bernstein & Lemer, 1996).
- Multi-disciplinary collaboration is increased from the design to the construction stage. This often results in innovation because design oversights are reduced and breakthroughs are sometimes achieved through cross-fertilisation of ideas (Bernstein Kissinger & Kirksey, 1998).
- The high level of collaboration in project alliances can encourage mutual and reflective learning, a key to competitive solutions and successful customer relationships (Holt, Love & Heng, 2000).
- Project alliances encourage progressive management styles, teamwork and use of technology which can provide group support for innovation (Dozier et al, 1996).
- Project alliances can lead to better cultural relationships in global projects because collaboration makes the method more transparent (Farrell & Watzke, 1997; Kruglianskas & Thamhain, 2000).

- The above benefits can generate real time and cost savings in the short and long run (Bower & Merna, 2002).

2.4.6 Conservatism and risk avoidance

Project control systems such as project, risk and quality management, rules and procedures, tend to prioritise efficiency, time, cost and quality. In highly pressured environments, these demands result in inadequate time for the creative activities and R&D which are known to increase innovation (Bernstein & Lemer, 1996; Keegan & Turner, 2002). This tends to reinforce the stereotype of engineers as conservative and resistant to change and intensify other negative perceptions about engineering design as creating conservative, functional structures without regard for aesthetics and socially responsible principles (Bernstein & Lemer, 1996; Ferguson, 1992; Tornkvist, 1998).

Paradoxically, as the industry becomes more global and competitive, innovation is viewed as the only real competitive advantage. This innovation imperative carries an urgency which leads to a tightening of project controls, resources and technologies. These controls are impeding the motivation and risk-taking needed for creativity because they embed the following culture (Keegan & Turner, 2002; Bernstein & Lemer, 1996):

- **Conservatism:** Bespoke services are delivered to conservative clients.
- **Risk and rules**: Voluminous standards and risk mitigation systems discourage risk-taking such as investment in R&D and innovation.
- **Innovation:** Innovation is viewed as risky, costly, dangerous and often wasteful.
- **Innovation management**: Risk-minimisation prompts an emphasis on project management rather than design innovation, which tends to stifle design creativity and innovation.
- **Slack for creativity**: Innovation and ‘slack’ time and resources are often recognized in principle but not in action.
- **Innovation research**: Awareness about creativity and innovation is poor because of the disciplinary boundaries between innovation and project management research. The innovation research is also outcomes rather than process oriented.
- **Organizational structure:** The organic and democratic organizational forms (which foster information flow and innovation) are not common in the industry.

- **Project management**: Project control systems are water-tight and efficient, whereas innovation requires a loosening of control and allowance for 'slack'.

2.4.7 Fostering an innovative industry culture

The engineering innovation literature relies heavily on changes in procurement methods, information technology and collaboration and group brainstorming methods, as a means of achieving innovation (see Bernstein et al, 1998; Bower & Merna, 2002; Love & Gunasekaran, 1998; Nicoll, 1993; Reamer, 1997). Creativity is rarely discussed in construction innovation (Cavallucci, 2002; Chakrabarti, 2002, p. 147; Kimbell, 2002; Powell, 1970, pp. 2-3). This tends to draw attention away from design-related creativity and innovation activities such as R&D, thinking time, time for reflection and experiment, and investments in work environments considered to be critical to incremental and breakthrough innovation and creative expression (Amabile, 1999; Basadur, 1993; Giugni, 2001; Nonaka & Takeuchi, 1995).

Authors suggest the following ways to reverse the above situation:

- Improve existing engineering designs (Bernstein & Lemer, 1996).
- Simplify designs to reduce material costs (Bernstein & Lemer 1996).
- Develop new designs that combine methods or develop radically new approaches (see CEDA, 2004).
- Develop people-centred design for home and work (see Landry, 2001, pp. 3-4; Perinotto, 2003).
- Employ sustainable building practices and materials such as energy efficient building design (Kohler, 2003).
- Develop design solutions which are aesthetically pleasing (Gelernter, 1998; The UK Highways Agency, 1996).
- Change engineering education to include more about design practice (Schon, 1991, 1983). Teach design from primary school through to University (Kimbell, 2002; Kimbell et al, 1996).
- Reduce investment risk through government investment in innovation as well as tax, capital and other incentives to encourage creativity and innovation-related projects (ACIF, 2002, p. 3; CEDA, 2004).
- Modify procurement procedures to genuinely encourage non-cost as well as cost criteria in the award of tenders.

- Simplify or combine the multitude of regulatory codes to increase the flexibility needed to encourage innovative alternatives (ACIF, 2002, p. 38; Bernstein & Lemer, 1996, p. 87; CEDA, 2004)
- Develop internal organizational resource approaches which support creative endeavours (ACIF, 2002, p. 4)

2.4.8 Summary

The construction industry has many features which affect the willingness of companies to invest in longer term creativity and innovation-related activities. Fierce competition tends to fuel cost innovation and business process improvement as distinct from design innovation. The regulatory environments also inhibit creativity and innovation because they encourage traditional methods, multiple rules and procedures and a regressive long term innovation policy (Bernstein & Lemer, 1996). Many suggestions were provided as to how these inhibitors might be altered to provide a better industry context for design innovation.

2.5 Creativity and the organization

2.5.1 Introduction

Many researchers agree that organizational culture is an important influence on workplace creativity by influencing employee satisfaction and motivation at the group and organizational level (Amabile, 1999; Basadur, 1993; Giugni, 2001, p. 48; Nickerson, 1999). The following section returns to Isaken's (1987, cited in Firestien, 1993, p. 262) Four Ps of creativity (see Ch. 2, pp. 26-27). In addition to the person, process and product involved in the creative experience, the 'press' (place or context) is widely believed to enable or discourage the motivation to use one's full potential. In engineering, the project group and organization are two important contexts for engineering design (and hence creativity).

2.5.2 Group environment and creativity

2.5.2.1 Introduction

Engineering design is practised in project teams formed for specific projects. An understanding of the role of groups in creativity is important because engineering design is largely experienced within the group dynamic (see Amabile, 1999; King &

Anderson, 1990; Rickards & Moger; 2000). Creative group environments can provide psychological safety, tolerance for diversity and other support necessary for the developing new perspectives, innovation and change (Andriopoulos, 2001; Marshall, 1995; Sutton, 2001; West & Farr, 1990). The literature highlights five aspects of group work which are important in laying the foundations for creativity:

- Leadership
- Cohesiveness
- Longevity
- Team selection and diversity
- Knowledge transfer

2.5.2.2 Leadership

Group leadership, cohesiveness, longevity, composition and structure are central to group innovation (King & Anderson, 1990). Research suggests that group innovation is supported by democratic collaborative management styles, whilst over-controlled and hierarchical forms can inhibit it (Amabile, 1999, 1988; King & Anderson, 1990; Nonaka & Takeuchi, 1994). For example, democratic leadership is often associated with higher levels of trust, freedom and autonomy, factors associated with intrinsic motivation and creativity (see Amabile, 1999; Keegan & Turner, 2002).

Leaders can promote innovation by providing expert facilitation. Facilitation can help to improve problem solving by encouraging the use of brainstorming and other creativity training techniques (Amabile, 1999; Guigni, 2001; Rickards & Moger 2000, p. 74). Good leadership also encourages members to value and contribute to developing different perspectives (Sethi, Smith & Whan, 2002; Rickards & Moger, 2000).

2.5.2.3 Cohesiveness

When members of a team work together with a mutual sense of purpose and enthusiasm, they build cohesiveness or connectedness (Andriopoulos, 2001, pp. 837-838). This common sense of purpose helps people feel empowered, supported and psychologically safe enough to take risks. The willingness to take risk is associated with creativity and innovation (Andriopoulos, 2001, p. 837; Sternberg & Lubart, 1999). Cohesiveness also means working without unnecessary conflict which can cause stress, deflect from the central design task, and inhibit creativity (see Amabile, 1999). Gossip, politics and cliques (behaviours which tend to reduce cohesiveness) can create poor morale, fear, mistrust and a negative attitude towards the work and colleagues (Andriopoulos, 2001, p. 837).

Many authors also suggest that too much consensus may not be associated with innovation because it encourages people to maintain the status quo (King & Anderson, 1990; Nemeth & Nemeth, 2001; Sternberg et al, 1997). Conflict is common to innovation, however, and may be an important factor when assembling and leading innovative teams, but it is important to know how to manage conflict when it arises (Rickards & Moger, 2000; West, 2001, p. 46). The occasional use of a devil's advocate and well organized brainstorming can help steer groups away from overly consensual views (Nemeth & Nemeth, 2001; Rickards & Moger, 2000).

2.5.2.4 Longevity

Longevity refers to the life of the project as experienced by team members. Whilst not conclusive, some research suggests that engineers may be more creative if not assigned to permanent groups. This is related to some research about group cohesiveness which suggests that a culture of consensus and conservative thinking can entrench itself and stifle innovation (King & Anderson, 1990).

2.5.2.5 Team selection and diversity

Diversity refers to a multiplicity of people, perspectives, knowledge and talent. In selecting innovative teams, diversity is widely considered important. Amabile (1999) states that "of all the things managers can do to stimulate creativity, perhaps the most efficacious is the deceptively simple task of matching people with the right assignments" (p. 81).

Diverse teams are usually capable of developing a strong knowledge base, necessary in achieving creative solutions (Amabile, 1999; Sutton, 2001). Diversity can encourage people to incorporate multiple disciplinary perspectives, which can lead to the cross-fertilisation and association of disparate ideas, to form new combinations and unforeseen solutions (Michalko, 2001; Sethi et al, 2002, p. 18).

Team selection is important in defining the mood of the group and working environment, because groups that enjoy and celebrate their work are generally more creative (Andriopoulos, 2001).

Too much diversity, however (such as too many disciplines), can stifle creativity and innovation through information overload and by challenging problem solving. Sethi et al (2002) consider that an optimum number of different disciplines for workable teams may be as low as two (p. 18). This questions a type of determinism present in the literature that multi-disciplinary collaboration automatically leads to innovation (for papers about collaborative engineering technologies see Eriksson, Lillieskold & Jonsson, 2002; Gilbert, 2000; Jones & De Vreede, 2002; Maliniak, 2001; Paton, 2002).

2.5.2.6 Knowledge transfer

The contextual nature of much knowledge makes it difficult to easily capture in words or routines (Fahey & Prusak, 1998; Nonaka & Takeuchi, 1995). Hence the collaborative exchange of knowledge occurs in a largely informal and social manner (Fahey & Prusak, 1998; Schon, 1991, 1983). Since knowledge is strongly related to creativity (see Amabile, 1988; Sternberg & Lubart, 1999), environments that support the development and exchange of knowledge are more likely to inspire creativity among its members. The group factors discussed above are important in creating a safe and productive exchange of ideas and experience.

The collaborative nature of engineering design makes group design (and creativity) a natural phenomenon for engineers. Knowledge (important for creativity) is immediately shared and well managed project teams share stories about successes and failures in a safe and trusting environment (Bernstein et al, 1998; Bower & Merna, 2002; Dozier et al, 1996; Ferguson, 1992). The opportunity for engineers to be involved in many different projects throughout their careers provides diverse opportunities for accumulated learning and knowledge transfer (Keegan & Turner, 2002).

2.5.2.7 Summary

Group composition is critical to creativity and innovation. When managers are assembling project teams, they need to have a thorough and intuitive understanding of the diverse knowledge, skills, talent and personalities of their potential team members. The opportunity to manage diverse projects and collaborations over relatively short time spans, allows project leaders to learn quickly about the diverse needs of projects and people, thus improving their leadership (Bernstein & Lemer, 1996). Managers have the opportunity, therefore, to assemble and lead teams that are motivated towards improvement and innovation.

2.5.3 Business management: Creativity and the organization

2.5.3.1 Introduction

Organizational climate as a context for creativity has attracted increasing attention since the late 1980s. Amabile (1999, 1988) established the relationship between intrinsic motivation and creativity, and the influence of organizational setting (pp. 139-142):

- Organizational climate or culture (including attitudes towards innovation, risk-taking, organizational structure, evaluation systems, communication channels and reward systems).
- Leadership style and its influence on creativity at the organizational and project level.
- Resources (including materials, money, people and time) and their influence on creativity.

Similar influences were found by Simonton (1999) after studying different cultures over several years. These are:

- Cultural diversity
- Role models
- Resources and financial support

Diversity brings different values, perspectives, ideas and traits together, often resulting in creativity. Mentors, leaders and supervisors can motivate people to develop their intrinsic creative potential through their inspiration, direct support and creative actions (Simonton, 1999). However, many organizational conditions known to support creativity are considered insufficient without the necessary resources and financial support (see Amabile, 1988; Simonton, 1999; Sternberg & Lubart, 1999, p. 9).

An overview of the creativity literature suggests that organizations with high levels of creativity have the following features which are discussed below:

- Supportive organizational structure and leadership
- Supportive organizational culture
- Understanding about creativity
- Knowledge and learning priorities
- Investment in creativity-related activities
- Appropriate rewards and feedback

2.5.3.2 Supportive organizational structure and leadership

Supportive senior leadership is widely associated with creativity and innovation (Amabile, 1999; Basadur, 1993; Giugni, 2001; Kennedy, 2001). Leaders who support creativity often exhibit the following characteristics:

- **Theory and practice:** They show their support for creativity and innovation by practising what they preach. Examples of this, says Kennedy (2001), are IDEO, Skandia and Sun Microsystems (p. 68).
- **Unofficial and official support:** They condone an employee practice called ‘bootlegging’ (a situation where workers are allowed to work on renegade or unofficial efforts to improve the company’s products and services). The practice is used at IBM and General Electric (GE) and is considered a sign of innovation health (Amabile, 1987, p. 252).
- **Nurture creative work environments:** They create physical and social work environments that assist people to propose and champion new ideas, e.g. General Electric, Disney Animation, IDEO (Kennedy, 2001, p. 76).

- **Accept failure:** They accept a high failure rate when encouraging and investing in creative ideas and environments. Sutton (2001) believes that a high failure rate is necessary to achieve a high rate of creativity. Mistakes and failures are believed to be part of the lifelong engagement characteristic of palpably creative people (Michalko, 2001).
- **Multiple perspectives about innovation**: Unlike traditional leadership, creative leaders often focus on breakthrough innovation as well as innovation driven by linear thinking (Sutton, 2001, p. 96).

A good example of an organization with this structure and leadership is IDEO, the successful US product design company. It has no organization charts or titles (Sternberg et al, 1997, p. 19) and IDEO, says its founder Kelley (2001), lives and breathes innovation.

Organizational structure is a company's framework for decision making and communication. Democratic and less-hierarchical structures tend to create flexible, open communication channels and supportive leadership; this tends to support creativity and innovation (Amabile, 1999; Basadur, 1993; Nonaka & Takeuchi, 1995).

Top-down or hierarchical structures tend to be less participative, resulting in a lack of autonomy which can impede creativity (Amabile, 1999; Basadur, 1993, 1987; Seely-Brown & Duguid, 2000). Hierarchical structures also tend to maintain the status quo by encouraging conformity and consensus (Amabile, 1988; Giugni, 2001; Keegan & Turner, 2002, p. 368; Nemeth & Nemeth, 2002).

2.5.3.3 Supportive organizational cultures

Organizational culture refers to "the system of shared beliefs and values that develops with an organization and guides the behaviour of its members" (Schermerhorn, Hunt & Osborn, 1991, pp. 340-341). The following cultural features are frequently associated with creative organizations:

- **Appreciation for diversity:** Diverse people, beliefs, talent and perspectives within an organization bring a depth of knowledge, character, thinking styles and preferences, which under the appropriate leadership can support creativity and innovation (Sutton, 2001).

- **Democratic goal setting:** Invites choice, autonomy, empowerment, involvement and ownership of the work or task. Work tends to be more meaningful and authentic, producing feelings which are more likely to motivate creativity (Nickerson, 1999, p. 416; Wheatley, 1999a).
- **Mutual respect**: Trust, cooperation, sharing and learning create environments that tend to motivate people to be creative from intrinsic desire rather than for purely external or extrinsic reward (Amabile, 1988, 1983; Giugni, 2001; Isaksen, 1988, p. 192)
- **Senior leadership support**: Supportive leadership tends to accept the need for 'slack' time, effort and investments, which in research are associated with creativity (Amabile, 1999, 1988; Keegan & Turner, 2002; Nonaka & Takeuchi, 1995; Simonton, 1999).
- **Work is playful and fun:** People are more creative when they enjoy their task. As Sternberg et al (1997) state, "Probably the single most important thing a manager can do to encourage creativity on a project is to make it fun to work on that project" (p. 17).

As organizations and leaders start to reflect upon the conditions that nurture people's knowledge and ideas (Florida, 2002; Wheatley, 1999a), they are starting to focus on aspects of their organization which are likely to stifle creativity (Amabile, 1999; Kennedy, 2001; Sutton, 2001; Wheatley, 1999a). These include:

- **Cult-like or artificially engineered models of organizational culture** which are common in the US and discourage independent or divergent (hence creative) thinking (see Kennedy, 2001). They can stifle creativity by fostering conformity and encouraging an intolerance of the unconventional and are identifiable by practices such as (Nemeth & Nemeth, 2001, p. 101):
    - Recruiting people who fit their culture
    - Socialising new recruits into this culture
    - Developing mottoes, slogans and special language to increase conformity and cohesion
    - Discouraging divergence from the culture

- **An over reliance on business improvement processes** such as quality and workflow modelling as the vehicle for innovation, says Shapiro (2001), can stifle creativity in a number of ways (pp. 9, 67):
    - Inflexible embedded best practice routines make innovation more difficult.
    - Cost innovation is favoured over technical, design innovation and creativity.
    - The linkages or synergies among organizational systems can be underemphasized hindering creativity and innovation.
    - Endless processions of new business fashions can frustrate and disappoint as their relative successes and failures discourage motivation and creativity (Giugni, 2001; Wheatley, 1999a).
- **Project management control cultures** can stifle innovation and creativity by favouring procedures, risk, quality and cost over creativity and innovation. Investment in creativity and innovation is often perceived as risky, costly, wasteful and dangerous (Keegan & Turner, 2002).
- **Excessive evaluation and criticism of work performance**. Rigid and excessive personal performance evaluation can stifle creativity, particularly if unsupportive supervisory relationships are common. Constructive feedback, latitude for error and the opportunity to try and fail are associated with creativity (Amabile, 1999, 1988; Basadur, 1993; Wheatley, 1999b).

Creative cultures tend to have certain features in common. The more palpably creative the industry, the more this is evident. For example, IDEO (US product design company) hires archaeologists and psychologists as well as main-stream design people. It encourages idea generation and championing through daily brainstorming. By fostering a playful work atmosphere and attitude it supports creativity (Kelley, 2001).

2.5.3.4 Understanding about creativity

Organizations that support creativity tend to have a better understanding of what it is and how it can be supported (see Giugni, 2001; Isaksen, 1988, p. 191). Research suggests that organizations which have a deeper understanding about creativity acknowledge that:

- **Creativity is innate** and capable of being nurtured by learning, knowledge of one's discipline and multi-disciplinary collaboration (see Nickerson, 1999, p. 415; Sternberg & Lubart, 1999).
- **Creativity is domain-specific** and influenced by different knowledge and skills bases and work practices (see Amabile, 1988, 1983; Schon, 1991, 1983).
- **Creativity is a whole and complex work or life experience** which occurs in a context involving people, processes (practices), products (end results) and places (environments) ((Isaksen, 1987, cited in Firestien, 1993, p. 262).
- **Creativity is perceived as a life-long endeavour** involving hard work and investment in time and resources, rather than a single 'Eureka' moment. As Nickerson (1999) reminds, "Few creative products of lasting value have been produced quickly and with little effort" (p. 416).
- **Creativity is difficult to measure** using metrics such as work competencies and rigorous evaluation (Wheatley & Kellner-Rogers, 1996).

In organizations, says Giugni (2001), creativity is increasingly understood as a whole experience rather than a business input or output (p. 50). New scientific management perspectives that recognize that complexity, chaos and uncertainty are inherent in nature and human organization are providing alternative contexts for understanding complex phenomena such creativity (Mumford, 1996; Wheatley, 1999a).

2.5.3.5 Knowledge and learning priorities

The importance of knowledge in creativity was demonstrated earlier in this chapter (see pp. 31). Organizations that support the development and sharing of knowledge often exhibit the following features:

- **Diversity** in knowledge, talent, skill and emotional intelligence because it creates a climate for learning and creativity. As Giugni (2001) states, "The ideal innovative organization utilises the full range of skills and talents (IQ) of all staff and generates innovation through their successful collaboration and interaction (EQ)" (p. 55).
- **Multi-disciplinary collaboration** which enables the cross-fertilisation of ideas and experience resulting in novel solutions (Michalko, 2001, p. 113). For example, in 1843 Sir Marc Brunel (a famous 19th Century engineer) observed how the pipe worm (a sea mollusc) drilled through the river's silt. Combining this observation with his mechanical knowledge, he invented the human-driven tunnelling shield (Peters, 1998, pp. 48-9).

- **Well organized information** about past projects and possible new methods which is indexed, accessed and shared using interpersonal means, intranets, online discussion forums, conferences, virtual library sources and other means (see Eriksson et al, 2002; Standards Australia, 2001).
- **Balance between interpersonal and virtual** communication. “Although IT is a wonderful facilitator of data and information transmission and distribution, it can never substitute for the rich interactivity, communication and learning that is inherent in dialogue” (Fahey & Prusak, 1998, p. 273).
- **Recognize the tacit nature of knowledge** and the conditions (such as trust and autonomy) that encourage knowledge sharing and learning in a way that is authentic to the person, group and profession (Herda, 1999; Nonaka & Takeuchi, 1995; Schon, 1991, 1983).
- **Recognize the value of group brainstorming** to encourage people with different knowledge, talent and expertise to interact and contribute to novel solutions (Rickards & Moger, 2000)
- **Use technologies** to encourage real-time exchange of information within projects, e.g. collaborative publishing systems, document management systems and computer assisted design and drawing packages (Gilbert, 2000; Maliniak, 2001; Paton, 2002; Standards Australia, 2001, pp. 23-24).
- **Information technology (IT**) **is an important enabler** or learning ‘host’ but an insufficient substitute for a wide range of traditional and contemporary learning methods such as training, mentoring and conference attendance (see Fahey & Prusak, 1998, p. 273).
- **Practice succession planning** in their knowledge development and sharing activities to reduce the reliance on clinical and short-sighted exit methods for preserving the company’s intellectual capital (see Standards Australia, 2001, pp. 23-24).

In engineering the main avenues for developing knowledge include life-long education such as formal education, training, professional development, mentoring, practice and project opportunities (Amabile, 1999; Basadur, 1993; Schon, 1991, 1983). They also include the use of collaboration, informal discussion and group brainstorming to develop and exchange knowledge and ideas within projects (Wiese & John, 2003).

Because knowledge of a domain is a prerequisite for creativity, organizations need to value learning. They can do this by guiding knowledge development in ways that are meaningful and workable for people and professions (see Amabile, 1999, 1983; Weisberg, 1999).

2.5.3.6 Investments in creativity-related activities

By making short and long term investments in creativity, an organization can support 'small' and 'big' creativity as well as breakthrough and incremental innovation (see Edwards, 1986, p. 222; Gaynor, 2002; Shapiro, 2001; West & Farr, 1990). Many authors say that steady, incremental innovation and small creativity are as important for competitive success as breakthrough creativity and innovation (Edwards, 1986, p. 222; Gaynor, 2002; Shapiro, 2001; West & Farr, 1990). An organization that is investing in both types of creativity might exhibit the following features:

- **People have adequate time to correctly define** project problems, experiment with and test alternative solutions, complete assigned tasks and reflect on past and future successes and failures (Amabile, 1999; Basadur, 1993; Schon, 1991, 1983)
- **People have time, resources and skills** to brainstorm new ideas and the time and resources to work on pet projects and provide the autonomy associated with motivation and creativity (Amabile, 1999). For example, IDEO, IBM and 3M trust employees to spend up to 15% of their time on pet projects (Giugni, 2001; Sutton, 2001).
- **People have time to reflect**. There is evidence that taking a break from a demanding task can allow the time for ideas to incubate and manifest in creative solutions (Amabile, 1999; Edwards, 1986, p. 222; Nickerson, 1999, p. 418).
- **The organization has a research and development (R&D)** and innovation strategy which allows acceptable failure rates and 'redundancy' (see Keegan & Turner, 2002; Nonaka & Takeuchi, 1995; Shapiro, 2001)
- **The organization gives appropriate rewards**, awards, bonuses and recognition for successful innovation, e.g. PriceWaterHouseCoopers offers prizes up to $US100,000 (Giugni, 2001).
- **Workplaces are designed to inspire creativity**. Kennedy (2001) gives examples of corporate creativity centres such as 'Chaos' zones, 'Zen' rooms and 'Touchdown' bars, designed to cater for different stages of the creativity process such as brainstorming, incubation and implementation (see Kennedy, 2001, pp. 63-76).

However, such investment may reflect management support for creativity without necessarily encouraging creativity.

The literature suggests that few organizations are investing adequately in the above activities. A recent study revealed that innovation is the number one issue for the Australian construction industry (ACIF, 2002, p. 5). However, organizations are reluctant to invest the 'slack' (additional resources and time) and redundancy (investment in activities that may not generate immediate profit) that the industry requires for innovation (ACIF, 2002; Keegan & Turner, 2002). The ACIF report identifies three significant inhibitors to construction innovation investment in Australia (2002, p. 6):

- Internal company resource pressures
- Perceived lack of capital and finance to champion new ideas
- Perceived excessive commercialisation risks

Research suggests that in Australia and elsewhere, the level of investment in construction industry innovation may be inadequate to meet the needs of an economy and society that is knowledge and innovation-dependent (see Ch.1, pp. 10-11 and Drucker, 2002; Flew, 2002; Porter, 2000; Wheatley, 1999a). This is because economic growth and innovation that relies on knowledge and talent (for example, engineering design), requires higher than the current levels of investment in knowledge-based activities such as research and development (R&D), professional development and training, and organizational support for knowledge, learning and creativity (see Ch.1, pp. 10-11 where the relationship between construction innovation and the knowledge economy is explained; see also Ch.2, pp. 61-74).

The evidence that knowledge-based investments are currently inadequate for construction industry innovation (particularly design innovation), is as follows:

- It is agreed that resources are needed for experimentation but insufficient resources are allocated in that area (Keegan & Turner, 2002; Nonaka & Takeuchi, 1995).
- It is believed that intense industry competition reduces the incentive to invest scarce company resources in innovation and R&D (Bernstein & Lemer, 1996).

- It is feared that investments in R&D and innovation may be wrongly targeted or unsuccessful (Keegan & Turner, 2002).
- It is agreed that investment is needed but the inaccessibility of finance and government incentives is a disincentive (ACIF, 2002, p. 5).
- It is agreed that the risk of commercialisation of R&D and innovation make investments prohibitive (ACIF, 2002, p. 5; CEDA, 2004).
- Investment in innovation and R&D has declined at an industry level, though the knowledge economy calls for increased investment (Bernstein & Lemer, 1996).
- Because of lowering profit margins, adequate time and resources are unavailable for existing projects let alone innovation efforts (Keegan & Turner, 2002).
- Adequate time and resources are not being devoted to creativity and innovation as time, cost, risk and other pressures mount in the industry (Keegan & Turner, 2002).

Investment in creativity-related activities is associated with incremental and breakthrough innovation. However, cost innovation and other pressures in the global economy deter companies from investing in innovation, even though they believe it to be important. According to the research reviewed, this is likely to have a negative impact on creativity (Basadur, 1993; Keegan & Turner, 2002).

2.5.3.7 Hiring for diversity

Diversity in hiring is important to organizational creativity because a wide range of talent, skill, knowledge and personality increases the depth of an organization's knowledge and capacity to adapt to uncertain external environments (Giugni, 2001; Nonaka & Takeuchi, 1995). Organizational diversity also enables people to see things in new ways by exposing them to different perspectives and opinions (Sutton, 2001, p. 96; Sternberg et al, 1997, p. 18).

Organizations that support creativity tend to believe that organizational diversity:

- **Broadens** the organizational knowledge and ideas base (associated with creativity) (Amabile, 1999; Giugni, 2001) allowing the cross-fertilisation of ideas and the possibility of novel combinations (Edwards, 1986; Ferguson, 1992, p. 23; Michalko, 2001, pp. 55, 137)
- **Gives access** to people skilled in various stages of the innovation process such as idea generators, incubators and implementers (Sternberg et al, 1997). Sternberg et al

(1997) call these skills different thinking preferences: Synthetic – can identify problems or ideas; analytical – are able to evaluate ideas; and practical – are able to sell ideas (p. 7)

- **Provides creative people** needed for R&D and palpably creative activities such as product design (see Kennedy, 2001)
- **Recognizes the special needs** of the palpably creative in companies such as IDEO and Disney Animation (see Kennedy, 2001) by dispelling the myth that the palpably creative are unwise, oddballs or misfits (Nemeth & Nemeth, 2001; Sternberg et al, 1997). This is important because intolerance and mistrust are known to stifle creativity (Nemeth & Nemeth, 2001).
- **Requires flexibility** to cater for individual and varied working styles such as flexible working hours, work roles, training requirements and general work conditions (Giugni, 2001; Isaksen, 1988)

Encouraging organizational diversity is not just a matter of hiring for diversity but knowing how to develop and manage diverse abilities (Sutton, 2001).

2.5.3.8 Appropriate rewards and feedback

Extrinsic rewards and punishments are commonly used to monitor work performance yet research confirms these methods are not supportive of intrinsic motivation (associated with creativity) (Amabile, 1999; Andriopoulos, 2001; Handy 1999, cited in Kennedy, 2001, pp. 132-3; Nickerson, 1999; Sutton, 2001; Wheatley & Kellner-Rogers, 1996).

Rewards and punishments can be intrinsic or extrinsic. Amabile (1988) found that intrinsic rewards such as engagement in stimulating work are associated with motivation and organizational creativity, and less influenced by extrinsic rewards such as material or monetary gain. Creativity is also negatively influenced by extrinsic pressures such as unreasonable deadlines and a shortage of resources (p. 154). Extrinsic rewards that are tailored to individual needs tend to motivate creativity (Amabile, 1988; Giugni, 2001; Kimbell, 2002). The most widely cited rewards and incentives for creativity are as follows:

- **Material rewards**: Amabile (1999) and Basadur (1993) say that extrinsic rewards (such as salary, job security and working conditions) are ultimately less important to people than intrinsic ones, provided that the extrinsic rewards are fair and reasonable.
- **Recognition**: Examples of intrinsic rewards include constructive feedback, peer recognition, competitions, awards, better working environments, opportunities, equipment and resources (Giugni, 2001; Sutton, 2001, p. 42).
- **Stimulating work**: Meaningful and challenging work is known to engage creativity (Basadur, 1993; Mumford, 1996). To motivate creativity, work can be modified by the redesign or removal of boring, repetitive and energy-depleting tasks and job rotation (Basadur, 1993, p. 295).
- **Autonomy and self direction**: Japanese experience has shown the positive influence of autonomy on team work, commitment, employee involvement and job satisfaction, which in turn is believed to motivate creativity (Basadur, 1993, p. 298; Nonaka & Takeuchi, 1995).
- **Risk-taking**: Generally some latitude (among supervisors) for risk-taking is associated with creativity because it allows people to feel safe about spending time on ideas they believe are promising (Amabile, 1988; Sternberg & Lubart, 1999; Van Gundy, 1987).
- **Playfulness and fun**: A work philosophy and environment that is fun and playful can generate intrinsic motivation and creativity, fostering freedom, exploration, risk-taking and interaction, often associated with creativity (Basadur, 1993, p. 296; Giugni, 2001, pp. 35, 41; Sternberg et al, 1997, p. 7).
- **Empowerment**: Having the necessary knowledge, skills and resources to engage in challenging work is important in empowering and giving people the confidence to use their creativity (see Amabile, 1999).
- **Adversity**: As an incentive for creativity this is a contentious one. Kennedy (2001) presents examples of ‘the garage legend’ – the situation where well-known successful companies originated in cramped, workplaces, e.g. IDEO, Hewlett Packard, and Yahoo (pp. 71-77). Too much adversity, however, is known to stifle creativity (Amabile, 1999).

2.5.3.9 Punitive measures, evaluation and creativity

Widely cited effects of evaluation and punishment on creativity are summarized below:

- **External pressure**: Authors agree that some external pressure is helpful in motivating creativity because it provides focus, challenge and the motivation to complete a task (Amabile, 1999). However, too much stress, unreasonable deadlines, insufficient work resources and repetitive and mundane work, can reduce satisfaction, motivation and creativity (Amabile, 1999, 1988; Basadur, 1993).
- **Punishment**: Rigid and inflexible punishment norms can stifle the motivation to be creative (Amabile, 1999). Anderson et al (1992, cited in Andriopoulos, 2001) state that people will only risk being creative if the fear of criticism and punishment is removed. Thus a tolerance among management for mistakes, failure and error is needed for creativity (p. 836).
- **Rigorous evaluation**: Whilst creativity is encouraged by genuine and supportive feedback and trust, it is discouraged by excessive or overly rigorous evaluation such as personal performance reviews and assessment (Amabile, 1988; Basadur, 1993; Kimbell, 2002; Wheatley, 1999b). Excessive performance evaluation also tends to maintain the status-quo because performance criteria are relatively prescriptive, outcomes and control-oriented (Wheatley, 1999b).
- **Feedback**: Feedback rather than evaluation is recommended for supervisors wanting to support creativity. Feedback provides an opportunity for personal, contextual, adaptive and meaningful exchanges about work (Wheatley, 1999b).
- **Role mismatch**: A mismatch of roles, task and opportunities can cause people to become bored, stressed and dissatisfied at work, reducing motivation and creativity (Amabile, 1999, p. 80). Even a correct match can have similar results if the opportunity for challenging work and to develop one's potential is not available (see Amabile, 1999, p. 81; Basadur, 1993).
- **Resources, time and money**: Providing resources for creativity is challenging for organizations in the competitive knowledge economy (Amabile, 1999; Giugni, 2001). Handy (1999, cited in Kennedy, 2001, p. 132) recognizes that today's organizations can have efficiency as well as creativity.

A variety of appropriate intrinsic and extrinsic rewards, incentives and feedback are believed to motivate creativity in organizational settings (Amabile, 1999; Basadur, 1993; Nickerson, 1999; Sutton, 2001).

2.5.3.10 Summary

Organizations can understand or misunderstand creativity. If they misunderstand it, they may knowingly or unknowingly stifle creativity (Wheatley, 1999a). If they understand creativity, they have a greater chance of knowing what motivates people to use their potential, and the organizational conditions that support rather than inhibit it (Amabile, 1999; Mumford, 1996). The creativity research widely supports the view that democratic organizations with supportive leadership can have a positive influence on creativity by providing people with the appropriate latitude, feedback, resources and other support to develop their full potential (Amabile, 1999; Basadur, 1993; Giugni, 2001; Simonton, 1999)

2.6 Conclusions

In this chapter, I reviewed the literature needed to inform the question: *How do engineers talk about their engineering design work and what does this reveal about creativity in a project consulting environment?* I surveyed the fragmented literature which spans the creativity, engineering, construction and business literature, attempting to draw key phenomena such as engineering design, creativity and innovation into the same discussion.

I reviewed several contexts in which engineering design and creativity occur: The global construction consulting industry, the engineering profession, the project group and the organization, explaining how each can support and stifle creativity. Organizations in this industry are highly competitive, featuring ever-lowering profit margins and a treadmill of cost innovation. Whilst breakthrough and incremental innovation are a potential break from this cycle, companies are reluctant to allow the slack needed for investing in creativity.

A review of the creativity and engineering design research revealed an intrinsically creative practice which combined applied science with artistic practice. The internal and external investments needed to manifest this intrinsic creativity, however, are discouraged by out-dated industry rules and constraints and a traditional cost-focused construction culture. Concern was also expressed over the lack of holism in the education and practice of engineering design. The creativity research illuminated possible solutions to this problem by unveiling creativity as a complex experience involving inseparable relationships between people, processes, products and places (Amabile, 1999; Isaksen 1987, cited in Firestien, 1993; Kimbell, 2002).

The literature review revealed numerous gaps in the general understanding about engineering design and creativity:

- Engineering design is not generally discussed as a creative practice. Further research may be needed to establish the nature of design and the conditions that support creative approaches to it.
- The relationship between creativity and innovation is not explicit in the general literature. Further research may be needed to avoid misconceptions such as the 'Eureka' myth.
- Finally, there is considerable scope (within the creativity literature) to explore the holistic and contextual aspects of creativity in specific work environments.

There is a demonstrated lack of holistic studies about creativity and innovation in a construction engineering context. The case study of the Brisbane office of a global engineering firm addresses the need for research about construction innovation which explores creativity as a central study phenomenon.

Chapter 3: Methodology

3.1 Introduction

The importance of creativity and innovation in a sustainable and competitive engineering industry provides a rationale for a case study of the Brisbane office of a large consulting engineering firm. This chapter is organized into the following sections which outline how the research study was conducted, and the research strategy used to source, interpret and authenticate the study findings:

- Introduction
- The philosophical perspective and assumptions
- The research strategy: A single case study rationale
- The case setting: How it evolved
- Research methods: Identifying and sourcing data and information
- Research Methods: Analysis and interpretation
- Reporting the study findings
- Evaluating the study, method and findings
- Conclusions

The evolution of the research focus and study was consistent with inductive research (Herda, 1999; Marshall & Rossman, 1999; Patton, 1990; Yin, 1994).

- **Personal interest and potential study setting**: It evolved from a personal interest and negotiation with a potential study setting, about a contemporary issue – creativity – and its timely and not-to-be repeated opportunity to be researched in the context of the company's 2002/03 global focus on innovation.
- **Refinement of research interest and focus** following a review of the related research. The study was proposed after a preliminary review of current research revealed a fragmented understanding about creativity, innovation and engineering design.

This, and a mutual negotiation with the prospective study organization, led to the following research focus, questions and objectives (which guided the study): *How do engineers talk about their engineering design work and what does this reveal about creativity in a project consulting environment?*

- What is the meaning of creativity and innovation for participants?
- How do engineers describe engineering design?
- How does the organization's project environment influence engineering design?
- How does the organization support creativity and innovation?

Though many flow charts of the research process can give an impression that research is linear and sequential, it is quite iterative; the researcher moves back-and-forth through different stages of research, to clarify the research question, methods and findings in the light of new evidence (Creswell, 2002, p. 9; Marshall & Rossman, 1999, pp. 26-27; Yin, 1994).

The study's objectives were:

- To explore the nature of creativity and innovation in engineering design.
- To explore the influence of project management on engineering design and creativity.
- To explore the influence of organizational climate on engineering design and creativity.
- To develop a holistic approach for understanding creativity and design.
- To report study findings to a variety of audiences (academic and business).

3.2 The philosophical perspective and assumptions

3.2.1 The research phenomena

The key research phenomena, creativity and engineering design, are complex, context-dependent, intrinsic (personal) and social (shared) (Nonaka & Takeuchi, 1995; Polanyi, 1966; von Krogh, 1998; Schwandt, 2000; Steiner, 2002, 1995; Wheatley, 1999a). Objective survey instruments are of limited assistance in understanding creativity in a design practice such as engineering, because they can strip the context (and meaning) from creativity as it is experienced and supported by people in a particular organization (Patton, 1990). According to Patton (1990), understanding how to support creativity may be achieved by looking at how people do their work, rather than at how to evaluate it (p. 130).

This study uses a holistic approach to the study of complex phenomena (such as knowledge, design and creativity) and relies on philosophical interpretation (instead of objective measurement and definition), an approach supported by contemporary research methodologists (Creswell, 1998; Herda, 1999; Patton, 1990; Schon, 1991, 1983).

3.2.2 Research perspective

My research perspective was influenced by the German Existentialist philosopher, Heidegger. Heidegger (1962) distinguishes between objective or scientific meaning and 'authentic' meaning, in his discussions about two key terms. He uses the term 'b*eing'* to discuss the objective pieces of the world – simplified measurements or constructions (pp. 39, 95-97). Heidegger (1962) uses the term '*Being'* to interpret the whole and authentic experience of life, a phenomenon that is all-encompassing and difficult to measure (pp. 22-23, 29). According to Frede (1993) and Watts (2001, p. 14), authentic meaning for Heidegger is complex because of the simultaneous and potential relationships among all things, and one's need to understand these relationships. Thus, according to Heidegger (1962, p. 29), an understanding of *'being'* partly, but never completely, captures the completeness or authenticity of '*Being.*' On this premise, Heidegger (1962) cautions readers about the limits of scientific research (when used to interpret authentic meaning), by stating that it only "accomplishes, roughly and naively, the demarcation and initial fixing of the areas of subject-matter (p. 29).

According to this philosophy, it is natural for people to seek an authentic, personal and complex understanding of the world, which can be achieved contextually. This possibility of going through life, progressively and simultaneously discovering one's unique understanding of the relationship between *'Being'* and *'being'*, is expressed in the concept of the 'Hermeneutical Circle' (see Heidegger, 1962, pp. 23-26; Watts, 2001, p. 43). The Circle raises the possibility that phenomena such as creativity and design can be simultaneously understood within their complete contexts.

> A continuous dialectical tacking between the most local of local detail and the most global of global structure in such a way as to bring both into view simultaneously … hopping back and forth between the whole and the parts conceived through the whole. (Geertz, cited in Schwandt, 2000, p. 193)

Whilst this simultaneous comprehension is an ideal, it provided a reflective reminder during the study to reflect back-and-forth the parts of the engineering creativity, and the whole, complex environments in which it is experienced. Schon (1991) recognized the importance of reflection in the development of informed and educated intuition in the knowledge and design professions.

In my opinion, the views of Heidegger influenced the current study because understanding the complex phenomena of design and creativity, is in many ways similar to exploring the essence of '*Being*''. The current study explores the engineers' experience of creativity by attempting to understand the complex relationships among the engineers, the engineering design practice and their design environment or context.

After reviewing the research methodology literature and reflecting about its relevance to the study, I used multiple perspectives as a reflective guide to develop, conduct and evaluate the research study (see Figure 3.1). The value of tailoring the research approach to the needs of the researcher, phenomena and participants is supported by many authors (Creswell, 1998; Herda, 1999; Lincoln, 1998; Patton, 1990; Schon, 1991, 1983).

Figure 3.1: A perspective for investigating creativity in engineering design

Perspective	*Description*
Reflective	Philosophical and thoughtful (Schon, 1991, 1983)
Authentic	Meaningful, genuine and appropriate to variant interests (Lincoln, 1998)
Multi-disciplinary	Cross-disciplinary, participative, interactive and collaborative (Herda, 1999)
Holistic	Contextual and situational (Watts, 2001, p. 414)
Naturalistic	Researcher tries not to manipulate the research setting (Patton, 1990, p. 39)
Iterative	Ongoing, heuristic learning in action (Denzin, 1994, p. 500)
Interpretive	Inductive, intuitive (Denzin, 2002, 1994)
Creative	Imaginative, innovative, design as research (Herda, 1999; Patton, 1990)
Pragmatic	Practical, workable and feasible (Patton, 1990)
Ethical	Appreciates a diversity of value systems and assumptions about human nature (Lincoln & Guba, 1998)

3.2.3 Researcher's stance

Creswell (1998) describes the role of the researcher in qualitative research which I subscribe to in the study:

> We represent our data, partly based on participants' perspectives and partly based on our own interpretation, never clearly escaping our own personal stamp on a study. (p. 20)

My stance was also influenced by what Patton (1990) calls 'empathic neutrality' (pp. 56-59). Empathy favours a non-judgemental and open stance, allowing a researcher to care about the study participants and phenomena. A neutral or non-judgemental attitude towards people's responses, according to Patton (1990, p. 58), is more appropriate than aspiring to complete objectivity or pure subjectivity, which is unachievable (p. 41). Furthermore, interpretive qualitative inquiry requires an intense interest in the study phenomena in order to develop rich descriptions and authentic meaning (Herda, 1999; Patton, 1990; Watts, 2001). Uncovering authentic meaning requires understanding one's biases, not escaping from them (Schwandt, 2000, p. 195).

3.2.4 Assumptions about people

My stance about human nature (which influenced my research approach) is summed up by Wheatley and Kellner-Rogers (1996), "people are intelligent, creative, adaptive, and meaning-seeking" (p. 3). In the pursuit for authentic meaning people prefer situations where they can think and act holistically (see Patton, 1990, p. 130; Steiner, 2002). I therefore invited participants to discuss their whole experience of engineering design, rather than isolated fragments of it. People also prefer to share their experiences and learning naturally, so I developed the study collaboratively, sharing the results in an ongoing way (see Herda, 1999).

After reflecting on qualitative research and related perspectives, I assumed that people inherently prefer: Autonomy, authenticity, reflection, complexity, holistic appreciation, mutual learning and interaction, creativity and self mastery, pragmatism and an ethical stance (see Amabile, 1988; Herda, 1999; Mumford, 1996; Steiner, 2002; Wheatley, 1999a; Schon, 1991, 1983). Based on this assumption, people tend to contribute practically towards a complex and meaningful world, by searching for 'authenticity'. The search is possible without the need for simplified and abstract concepts and, if trusted, people will generally do this in a cooperative and democratic way (Crotty, 1998; Mumford, 1996; Schwandt, 2000; Steiner, 2002; Wheatley & Kellner-Rogers, 1996).

3.2.5 Qualitative research vs. quantitative research

3.2.5.1 Introduction

The study was qualitative and interpretive. Qualitative research suits in-depth investigations of research phenomena that are social, contextual and ill-defined (Patton, 1990, p. 13; Yin, 1994), whilst quantitative approaches generally use scientific methods to understand objective phenomena (such as variables, factors and hypotheses) (see Crotty, 1998, p. 15; Leedy & Ormrod, 2001; Marshall & Rossman, 1999, p. 56).

Ideally, qualitative research is a creative practice in which multiple perspectives and methods are combined to suit the research questions, phenomena and participants (Herda, 1999; Patton, 1990, pp. 432-433). It therefore allows the flexibility needed to explore and obtain rich descriptions of complex phenomena (such as design and creativity) (Crotty, 1998, p. 13; Herda, 1999; Patton, 1990, pp. 14, 64-91).

3.2.5.2 Strengths of qualitative research

An interpretive qualitative approach was appropriate for the study because of the need for a holistic understanding of participants' experiences of complex matters (such as creativity, engineering design and innovation) in their natural context (consulting engineering). The value of contextual research is articulated by many authors (Denzin, 2002, 1994; Herda, 1999; Patton 1990, p. 59; Yin, 1994).

The rationale for adopting a qualitative perspective in this study is similar to that used to justify a case study research strategy. To avoid unnecessary repetition I have included the rationale with the case study section in this chapter (see pp. 86-88).

3.2.5.3 Weaknesses of qualitative research

The following weaknesses of qualitative research question the subjectivity of the researcher (Guba & Lincoln, 1998, p. 197; Patton, 1990, p. 14). However, many authors question whether research can be completely objective (Crotty, 1998, p. 27; Patton, 1990; Schwandt, 2000). The weaknesses can be minimized by effective research design (Yin, 1990) and a balance between systematic and creative data collection and interpretation (Patton, 1990, pp. 432-433).

- **The researcher**: The quality of findings relies on the skill, competence and rigour of the research investigator (Patton, 1990, p. 14; Yin, 1994).
- **Research rigour**: The possibility of a poorly planned and executed research study can be minimized by a sound research strategy (Yin, 1994, pp. 9-10).
- **Objectivity of research**: Mood, personal bias, and attributes of the researcher can reduce the objectivity of the research findings (Miles & Huberman, 1994; Patton, 1990; Yin, 1994, p. 10).
- **Scientific generalization**: Single case strategies cannot offer the scientific generalization possible with other approaches (Yin, 1994, p. 10). They can, however, be generalized to concepts and theories, and informally compared to other contexts by readers of the study findings (Patton, 1990).
- **Research efficiency:** Case studies are time consuming and resource-intensive. Considerable time savings can result from good research strategy and research information management (Miles & Huberman, 1994; Yin, 1994, p. 10).
- **Quality of findings:** The study can fail to meet quality criteria such as validity, credibility, transferability, dependability and confirmability (Marshall & Rossman, 1999, p. 192) and emergent criteria such as: Authenticity, fairness and mutual learning (Creswell, 1998; Herda, 1999; Lincoln & Guba, 2002; Herda, 1999). These are common to all research (Patton, 1990).

Despite an ongoing debate between qualitative and quantitative researchers, Creswell (1998) states unequivocally that:

> Qualitative inquiry represents a legitimate mode of social and human science exploration **without apology** or comparisons to quantitative research. Good models of qualitative inquiry demonstrate the rigour, difficulty, and time-consuming nature of the approach. (Creswell, 1998, p. 9)

3.3 The research strategy: The case study

3.3.1 Introduction

To justify a case study strategy, researchers often discuss why a case study context is appropriate for fulfilling the objectives of the research study and are expected to offer additional reasons for pursuing the strategy (see Marshall & Rossman, 1999, p. 63; Yin, 1998, 1994, pp. 38-44).

The case study is a roadmap or overall plan that allows a researcher to systematically explore their phenomena of interest (Marshall & Rossman, 1999, p. 62). According to Yin (1995):

> A case study is an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between the phenomenon and context are not clearly evident. (Yin, 1994, p. 13)

Design-based practices such as architecture and engineering are good examples of such contexts (Schon, 1991, 1983). According to Yin (1994), the case study strategy is suitable for investigating contemporary design responses and outcomes because it can accommodate real-life contextual conditions. Its suitability for studying creativity, in particular, is made explicit by Patton (1990):

> A program that was attempting to make students or clients more creative might do better to document in detail the activities, behaviours, thoughts, feelings, and creations of participants rather than to administer some standardized instrument. (p. 130)

3.3.2 Case study rationale

The reasons for adopting a case study strategy are summarized below, and overlap with the reasons for using a qualitative approach.

- **Phenomena:** To explore contemporary issues in a real-life or natural context, e.g. sustainable design practices (Yin, 1994).
- **Setting:** To explore issues and context where boundaries and definitions are unclear, e.g. fostering creativity in design (Yin, 1998, 1994).
- **Richness:** To explore and describe the richness and diversity about research phenomena (Marshall & Rossman, 1999, p. 61), e.g. organizational conditions for innovation.

- **Variables:** To understand phenomena, issues and context for which there are many more data points than areas of interest, e.g. incentives for using sustainable design practices (Yin, 1994).
- **Multiple sources**: Where rich, multiple and diverse perspectives are sought by using multiple sources of evidence, e.g. interviews, focus groups, documents, artefacts and surveys (Yin, 1994).
- **Flexibility**: Case studies allow the research purpose and phenomena to guide the research design as the study progresses (see Marshall & Rossman, 1999).
- **Meaning and purpose**: To understand the meaning behind phenomena as distinct from strategies that might strip context and deeper understanding (Guba & Lincolm, 1998, pp. 197-198).
- **Evaluation**: Case studies can be used to link program or policy implementation and effects in real life situations too complex for quantitative or survey techniques (Yin, 1994, p. 15**)**.

3.3.3 Weaknesses of the case study strategy

Case studies are sometimes questioned for a perceived lack of 'external validity' and 'reliability' (Yin, 1994, p. 33) but these so-called weaknesses can be minimized by planning and conducting a well organized and systematic research strategy:

- **External validity**: Because of their uniqueness, case study findings cannot be replicated across multiple external cases. Therefore this criterion is only relevant to people who choose to make the transfer, not to the original researcher (see Patton, 1990).
- **Reliability:** The dependability and credibility of a case study's findings can be raised by a good research design or protocol, the type recommended by Miles and Huberman (1994).

3.3.4 Rationale for the single case study strategy

Stake (2000) believes that the single study can be undertaken purely for the intrinsic value of the case and its uniqueness and phenomena (p. 437). Yin

(1994) identifies four additional situations for which a single case study strategy can be ideal:

- **Critical case**: Useful in testing and extending well-established theory, e.g. a single community may challenge a proposition that low-income suburbs only consider cost when buying or building a new home (p. 38).
- **Extreme or unique case**: Certain behaviours are so rare that even one case is worth investigating in depth (1994, p. 39). A company, for example, may have a unique innovation culture which has enabled it to spawn inventions where similar companies have failed. A single case study would allow this phenomenon to be explored in depth.
- **Revelatory case**: A researcher may have a never-to-be-repeated opportunity to investigate a contemporary event within a company context (1994, p. 40), e.g. a once-off company investment in a contemporary topic such as design innovation.
- **Exploratory or pilot**: Sometimes a single case study is justified as a testing ground for a multiple or cross sectional study. Yin (1994) argues that the single case study can be legitimately used by itself (p. 41).

The research case, topic and phenomena were of intrinsic interest to the Brisbane office and to the researcher. The study is revelatory because it represents a one-off opportunity to explore the nature and relationship of three contemporary phenomena (design, creativity and innovation) in a contemporary global and company context: A global company innovation focus for 2002/03.

3.4 The case study setting

3.4.1 Background

A chance meeting with a former colleague alerted me to the Company's global innovation initiative (I was formerly employed by the company and knew many of the senior engineers). After meeting with a former senior colleague and discussing the one-off opportunity to explore engineering design creativity within the Company's 2002/03 innovation focus, I accepted an invitation to conduct the confidential study at their Brisbane office. The company's innovation focus, my rapport with former engineering and management staff and the contextual appropriateness of the Brisbane office made the organization an ideal study setting.

3.4.2 A description of the case setting

3.4.2.1 Introduction

The single organizational case study was set in the Brisbane office of a global, multidisciplinary engineering consulting company. To maintain the anonymity of the case organization and participants, the description of the case setting (which would otherwise be more detailed) is brief and general.

The Brisbane office is one of a large number of offices which the parent company has in over 50 countries. It has approximately 200 staff, two thirds of whom are engineers and other professionals and about one-third who comprise general management and project support personnel. The number of the Company's regional and global technical experts based in Brisbane represents a critical mass of highly experienced engineers and well regarded leaders committed to innovation within the company.

The core office business comprises civil and structural infrastructure engineering projects. Projects are becoming cross-disciplinary, geographically spread and more diversified. Though the company is global, the organizational structure is relatively flat (contains few management layers) because the company has tried to avoid the bureaucratic tendencies characteristic of other large companies.

The Company has a formal and documented commitment to developing and enabling engineering potential and innovation. The office work space, general facilities and information and telecommunications infrastructure, suggest a progressive global consulting organization.

3.4.2.2 Innovation

Each year, the global company focuses on a core area for attention or change which is adopted and modified to reflect local and regional needs. The key business focus for 2002/03 was innovation and a timely opportunity for the study of engineering creativity. The senior and general commitment to the 200/03 focus was reflected in the resource-rich global road-show called the Innovation Fair, used by the US Head Office to launch the company's global innovation focus.

3.4.3 Negotiating the study: The 'study package'

The study package, which formed the research contract and protocol (see Appendices A and B) was developed in conjunction with the study company and endorsed by the QUT Research Ethics Committee. The package proposed an in-depth, interpretive single case study, using multiple information sources (with in-depth interviews the focal contextual source). It was aligned with:

- **The research focus:** Research topic, description and purpose
- **The research benefits:** Benefits to the organization
- **The research strategy:** Methods used to source information (table summary)
- **The consent forms:** General consent form for non-specific participation
- **The interview protocol:** Interview guide and consent form for interviewees
- **The special requirements:** Such as privacy, confidentiality, treatment of recording and transcripts.

The package made the study transparent to participants, and provided an efficient way for the Company Study Leader to share information about the project among participants. The study leader was critical to the study because of his expert role as facilitator and ongoing point of contact. His senior leadership and formal innovation role, as well as good rapport with staff, helped to give the study a serious profile among participants.

3.4.4 The participants

The Brisbane office employees selected for in-depth participation included a multi-disciplinary engineering project team (of seven members) and a mixed group of managers, engineers and project support staff involved in the company's innovation initiative (eight staff). The two groups of participants and the extent of their participation are outlined in Figure 3.2 (see pp. 95). About 100 employees were indirectly involved through their participation in the office innovation meetings that I attended. Almost half of those interviewed were senior managers and leaders and the generosity of their time suggested a sound commitment to the study and innovation-related issues.

3.4.5 The pilot study

Yin (1994) suggests that the pilot study is an important stage of the case study preparation. It is used to gather preliminary information which can be used to assess the appropriateness of the case setting and to help develop and test the proposed data collection instruments (Miles & Huberman, 1994; Yin, 1994, pp. 74-75). Its conduct can be based on convenience, accessibility and congeniality of the location and participants (Yin, 1994, p. 74) such as with the Brisbane study where the three pilot interviewees were engineering friends, only one of whom worked for the company.

3.5 Research methods: Identifying and sourcing data and information

3.5.1 Introduction

3.5.1.1 Interviews and storytelling

In-depth, semi-structured interviews and conversations were the principal source of contextual information, and multiple methods were used to raise the quality and authenticity of the study findings (Patton, 1990; Stake, 2000; Yin, 1994).

I assumed (see Herda, 1999) that conversation would tease out authentic descriptions about creativity in engineering practice. To understand creativity holistically in an engineering design, it seemed appropriate to engage participants in conversations about what and how they did their design, rather than abstract discussions about the criteria they would use to assess design creativity in the workplace (see Patton, 1990, p. 130).

Many authors support the value of language and text in qualitative studies (Creswell, 1998; Grondin, 2002). Their value is illustrated by Gadamer (cited in Grondin, 2002):

> Limited and ambiguous as language may be, every process of understanding strives to ground itself in language, even though not everything that can be understood can be put into words. (pp. 41-42)

Storytelling is increasingly appreciated as a medium for sharing understandings, personal and social issues (such as design and creativity) in a safe environment. Creswell (1998) describes this process:

> Throughout the slow process of collecting data and analyzing them, we shape our narrative …We tell a story …We talk about our experiences in conducting the study. We let the voices of the informants speak and carry the story through dialogue. (p. 20)

Narrative is commonly used in organizational research and practice to encourage knowledge sharing and to inspire action (Creswell, 1998, p. 14; Herda, 1999; Simmons, 1999).

> A well-told story has the power to permeate the mind, body, and emotion of a listener. It can sneak past resistance, engage the right brain's powers and imagination, and anchor an abstract point to any of a thousand connections including past experiences as well as visual, auditory, and even through

imagination, kinaesthetic and olfactory sensory reference points. (Simmons, 1999, p. 170)

3.5.2 Multiple sources and corroboration

It is quite legitimate to use a principal data collection source such as in-depth interviews, and to use other sources to corroborate facts, themes and findings. I considered the following data collection methods appropriate for exploring creativity and design in their natural setting. (For guidelines on their correct use see Bouma, 2002; Marshall & Rossman, 1999; pp. 108-116; Patton, 1990, pp. 277-368; Robson, 2002, pp. 267-291; Yin, 1994, pp. 84-86):

- **Interviews:** In-depth, semi-structured interviews with relatively open-ended guide questions
- **Observation**: Participative but relatively unobtrusive observation in company events (e.g. innovation workshops and events, other meetings)
- **Documentation:** Company strategic plans, Minutes of Meetings, the Intranet, marketing brochures
- **Participation:** Active participation, e.g. giving study presentations, reports and feedback

According to Yin (1994, pp. 80, 90-98) using multiple sources assists with the following:

- **Verification**: Corroboration across different sources
- **Authenticity**: The more sources, the more likely that findings will be representative of the group or individuals being studied
- **Accuracy:** Increasing the overall accuracy of study findings
- **Triangulation**: Corroboration of sources against each other to strengthen findings and maintain a ‘chain of evidence’

For the Brisbane Study the use of multiple methods had the following benefits:

- **Revelatory insight:** A three-day study of the company Intranet revealed information about creativity as a human resource competency that enabled the interview guide to be modified slightly to allow discussion of salient issues.
- **Historical context:** The company Intranet and informal conversations uncovered information about past and planned company and project activities. This information created a broader context for viewing innovation and creativity within the company.
- **Case setting:** The Intranet provided information about company strategy and procedures, engineering projects, professional development programs, information and knowledge systems and other details that enabled an informative description of the case setting.
- **Verification:** Clarifying factual information about people, roles, programs and systems was important for the authenticity of the study, e.g. the correct name of the company's performance review system.
- **Innovation champion meetings**: Attendance at 'Innovation champion meetings' demonstrated knowledge transfer in action as engineers and colleagues gave presentations about innovative designs and work practices and revealed an unmitigated willingness to share their ideas and expertise..
- **My research presentations**: During my research results presentations, numerous questions were asked which altered the way study information was interpreted and reported, for example, 'How do you measure the return on company investments in creativity training?'

3.5.3 Data collection matrix

Appendix B summarizes the study's key information sources, access and management procedures and outlines how each source addressed the study's research questions. Tying research questions to sources helped to streamline information sourcing and maintain research focus. The tabular summary (see Appendix B) was part of the 'study package' (but omitted in Appendix A). The matrix and study package can assist other researchers to develop a similar approach to exploring similar phenomena.

3.5.4 Semi-structured interviews

3.5.4.1 Rationale

According to many authors, the essence of lived experiences is vitally important for qualitative research and can be progressively unveiled through conversation and language (Creswell, 1998, p. 37; Denzin, 2002, p. 354; Herda, 1999; Schwandt, 2000). Lived experiences about work can be communicated (at least in part), by language and conversation (Herda, 1999, p. 14). Interviews provide an opportunity for participants to speak about their work practice in a meaningful way (in context), particularly when they are asked 'How' (or practice-based) questions (Patton, 1990; Yin, 1994). Yin (1994) considers the interview to be one of the most important sources of case study evidence (p. 84). In the study, in-depth semi-structured interviews were a foundational part of the study, the principal vehicle towards rich, personal and contextual insights about lived experiences (project-based engineering design and creativity) of complex phenomena. Fifteen semi-structured guided interviews were conducted and transcribed.

3.5.4.2 Types of interviews

Many authors give comprehensive advice about how to conduct successful interviews (Marshall & Rossman, 1999; pp. 108-116; Patton, 1990, pp. 277-368; Robson, 2002, pp. 267-291; Yin, 1994, pp. 84-86). They consider it important to develop a technique that fits the study's purpose.

Interview structures can vary, according to Patton (1990), from informal and conversational, to closed, fixed response interviews (pp. 281-290). He outlines four types of interview (the second approach was used for the study):

- **Informal conversational:** These are casual meetings in which questions emerge from the immediate context. The key strength is the opportunity for the conversation to develop according to the relevance of the research. Its weakness is the different information collected from different people, and the approach can be less systematic and comprehensive (Patton, 1990, p. 289).

- **Interview guide approach:** The approach was used in the Brisbane study; research topics, issues and guide questions (open-ended) were specified in advance. Changing the sequence and wording of questions is allowed in this technique. The approach allowed the study interviews to remain conversational and situational, whilst collecting comprehensive responses in a systematic way, a strength highlighted by Patton (1990). A potential weakness (failing to explore other salient issues) was lessened by the careful use of prompts and sub-questions (see Patton, 1990, p. 289).
- **Standardized open-ended**: Questions are open-ended but determined in advance and their sequence and wording is the same for all participants. This gives comparability of responses, reduced interviewer bias and more systematic analysis of responses. However, it provides limited flexibility for catering for individual preferences and salient issues (Patton, 1990, pp. 288-289).
- **Closed, fixed response**: Similar to a survey, questions and response categories are fixed and predetermined by the researcher, allowing for little variation. It is an efficient method for obtaining and analyzing simple responses (Patton, 1990, p. 289), but inappropriate for the Brisbane study because of the nature of exploration required.

3.5.4.3 Choosing interview participants

There are no rules for the size of sample in qualitative research, says Patton (1990). It depends on the study's purpose, what is likely to be useful and credible, and the time and resources available. The purposeful sampling used in the Brisbane study (sampling with the intent of the study in mind), is based on the following criteria (Creswell, 1998, pp. 118-119; Miles & Huberman, 1994, cited in Creswell, 1994, p. 119; Patton, 1990, pp. 182-183):

- **Maximum variation:** Purpose: To obtain a wide range of perspectives
- **Critical case**: Purpose: What's true of this case may also be true of other cases
- **Intensity**: Purpose: Information-rich but not necessarily extreme
- **Theory-based:** Purpose: Use of the research literature to help select cases
- **Critical and disconfirming cases**: Purpose: Actively seek variation
- **Snowball or chain**: Purpose: Ask people who know potentially information-rich cases.

Using the above criteria, the following guidelines were used to assist the company study leader to select interview participants:

- **Project group:** Using the following criteria, eight people were selected to explore the nature and meaning of 'engineering design' and creativity in its natural context – project group:
    - **Depth:** Wide range of engineering experience
    - **Equity:** Female and male representation
    - **Disciplines:** At least one discipline external to civil engineering
    - **Project status:** A work in progress
    - **Diversity:** A diversity of opinion and experience
- **Innovation champions**: Using the following criteria, eight people were selected to explore the meaning of creativity and innovation in a broader organizational context:
    - **Leadership:** Key leadership roles, e.g. human resources, operations and general management, engineering excellence
    - **Innovation:** Involvement with company innovation initiative
    - **Equity:** Female and male representation
    - **Operational role:** Operational and human resource roles
    - **Political:** Politically important cases.

The interview participants were as follows. To protect their anonymity only general information is given about their roles.

Figure 3.2: Interview record: The participants

Table 1: Project Group Members

Pseudo	Work Role
Emily	Graduate Structural Engineer & Innovation Champion
Roger	Senior Designer Drafter
Maree	Project Administration Officer
Sean	Graduate Structural Engineer
James	Project Manager & Civil Engineer
Frank	Senior Structural Engineer
Kevin	Senior Structural Engineer

Table 2: Innovation Champions

Pseudo	Work Role
Terry	Senior Structural Engineer & Innovation Champion
Brian	Project Manager, Engineer, General Operations Manager
Roz	Project Administration Officer & Innovation Champion
Christine	General Operations Manager
Lloyd	Project Manager & Civil Engineer
Greg	Senior Civil Engineer
Ian	Senior Structural Engineer & Innovation Champion
Ellie	Non-engineering Professional & Innovation Champion

3.5.4.4 The interview guide

To understand the complex study phenomena in depth and in context it was important to create a context in which participants could express their understandings in their own terms (Patton, 1990, p. 290). To optimize the benefits of the technique, I developed an interview guide or protocol that included the following features (see also Appendix A). Many authors support this approach (Creswell, 1998, pp. 123-124; Marshall & Rossman, 1999, pp. 108-111; Yin, 1994, pp. 63-66, 84-86):

- **Study package**: An interview guide was included in the participants' study package (see Appendix A) which was endorsed by QUT and the company.
- **Alignment**: Guide questions aligned to the study's research questions.
- **In-depth:** In-depth, semi-structured 60 minute interviews with 5-6 focused, open-ended guide questions.
- **Questions**: 'How' questions about whole work experiences aimed at increasing contextual meaning (and authenticity).
- **Opportunistic:** Purposeful exploration of tacit phenomena using a flexible protocol. Wording and sequence of questions was not critical.
- **Advanced notice:** The study package and guide questions were presented in advance for transparency and trust.
- **Researcher & rapport**: Professional, punctual and friendly.

- **Field notes**: Field notes were made before and after each interview.
- **Confidentiality**: Anonymity of interviewees was maintained by the use of pseudonyms.
- **Audio-taping**: Interviews were audio-taped and transcribed professionally.
- **Transcription**: Verbatim transcriptions were signed off by participants.
- **Pilot:** Pilot testing of interview guide enabled refinements to protocols.
- **Ethical clearance**: Endorsed by QUT Ethics Committee.

3.5.4.5 Interview questions and authenticity

Asking engineers to talk about how they did their design work focused on doing, experience and feelings. The question, "How do you go about doing your design work?" allowed people to talk comfortably about their design (in context), without struggling with abstract terms such as creativity. By contrast, 'what' questions such as "What is creative about engineering design" were avoided. In my view, this minimized response bias, because it was of little use for participants to prepare responses prior to the interview. 'What' questions can be abstract, requiring people to define complex phenomena like creativity, a task which can evoke confusion and frustration (see Patton, 1990, p. 130), and result in cognitive rather than experiential responses.

According to Heidegger's reasoning (cited in Watts, 2001, p. 103) 'How' questions are likely to reveal authentic responses, because they take participants closer to what they are familiar with. Amabile (1988) used 'How' and 'Why' questions to explore experiential creativity within organizational settings (1988, 1983). Patton (1990) recommends a similar approach, in contrast to objective, criteria-oriented instruments which in his opinion are less helpful in understanding creativity (p. 130).

Purposeful, expert, exploratory and opportunistic interviewing techniques are encouraged by many authors (Creswell, 1998; Patton, 1990). Some questions were discussed with both groups, whilst other questions were directed at the particular group. The project interviews were intended to uncover a personal and group context for creativity, whilst innovation champions were interviewed to help provide an organizational context for creativity.

3.6 Research methods: Analysis and interpretation

3.6.1 Introduction

No consensus exists for the analysis of qualitative information (Creswell, 1998, p. 140; Yin, 1994, p. 102) so researchers have developed a variety of analytic and interpretive methods. These range from 'quasi-statistical' and objective methods (e.g. computerised content analysis) to interpretation through complete immersion (e.g. ethnography) (Crabtree & Miller, 1992, cited in Marshall & Rossman, 1999, p. 151; Robson, 2002). The continuum is illustrated in Figure 3.3. Immersion is an unstructured and often creative approach used to study complex topics, whilst the quasi-statistical approach lends itself to relatively well-defined topics and phenomena. The interpretive approach used in the Brisbane study tended towards the 'emergent intuitive' rather than the 'prefigured technical', which seems appropriate for complex and contextual concepts.

Figure 3.3: A Continuum of Analysis Strategies

This figure is not available online.
Please consult the hardcopy thesis
available from the QUT Library

(Source: Crabtree & Miller, 1992, cited in Marshall & Rossman, 1999, p. 151)

The process of analysis and interpretation developed during the Brisbane study closely approximated the 'Data analysis spiral' described by Creswell (1998, pp. 142-143) – see Figure 3.4. Qualitative analysis evolves in 'analytic circles' or spirals, rather than in a linear fashion as suggested in the following description of the process (p. 143):

- Data collection and managing (files, database)
- Reading and ‘memoing’ (reflecting, writing notes, questions)
- Describing and classifying (context and categories)
- Interpretation (comparisons)
- Representing and visualizing (Propositions, theories, conceptual diagrams)

Field notes and transcripts are often read and annotated, and analyzed and interpreted with the aid of coded themes or classifications. Understanding usually evolves in iterative cycles where the researcher moves from data to abstraction (or representation) (Creswell, 1998, pp. 142-143).

Figure 3.4: The Data Analysis Spiral

This figure is not available online.
Please consult the hardcopy thesis
available from the QUT Library

(Source: Creswell, 1998, p. 143)

3.6.2 The Brisbane study

The following outlines the evolutionary nature of analysis and interpretation in the Brisbane study. The approach is an amalgam of general analytic strategies posed by several authors (Creswell, 1998, pp. 142-143; Marshall & Rossman, 1999, pp. 150-157; Yin, 1994, pp. 102-103):

- **Information management***:* Manual and computer files of raw field information (such as field notes, transcripts and annotated documents) formed the study's original database. A second database was created into which coded or annotated field information was placed, enabling the distinction between original and analyzed materials and providing evidence of the interpretive process.
- **First reading – 'Reading and memoing'**. 'Raw' field information was reviewed, creating annotated interview transcripts, field notes and company documents (see Creswell, 1998, p. 143).
- **Thematic coding and categories**. During the second reading I developed a nested coding table of themes and sub-themes using terminology from the creativity literature (an analytical technique endorsed by Creswell, 1998, p. 142). The coding able provided a conceptual reference throughout the analysis (see '\Analysis\Analysis_Codes.doc on the research data CD).
- **Computerised coding:** After finding the NU*IST and NVivo content analysis software time-consuming and unsuited to the study's key concepts (creativity and design), I developed the codes manually.
- **Second reading: Coded annotation**. During this complete reading, I analyzed transcripts and field notes again. I used the thematic coding table to annotate the materials, moving between transcripts, field notes, and coding table, cutting and pasting codes, and adding notes where needed. Within transcripts, I underscored quotes which might potentially be used in reporting the study findings. As analysis and interpretation proceeded, a progressive 'winnowing' and 'discarding' of themes occurred. About 10% of the themes included in the coding table were used for illuminating the study findings. This process is natural and recommended, according to Wolcott (1994, cited in Creswell 1998, p. 141).
- **Third reading: Case summaries**. Readings one and two largely involved description and classification using coding and note-taking (see Creswell, 1998, p. 143). The third reading involved summarizing transcripts and field notes. For each interview participant, I compiled a ½ page summary. This was useful in uncovering individual 'stories', even though they were less useful than expected in writing up the study findings.
- **Advanced interpretation 1***:* The advanced interpretation stages were simultaneous with the production of Chapter 4: The study findings, and Chapter 5: The study conclusions. These activities were intuitive, reflective as well as iterative,

in contrast to earlier stages. The process involved re-reading field note and transcript annotations, revisiting and reflecting upon the research questions and emerging themes.

- **Advanced interpretation 2***:* The principal difference between this and the previous stage was the importance that was placed on reduction, summary and abstraction. Reflection (in my view) was the most important feature of this stage.
- **Participation and feedback***:* There were ongoing opportunities for mutual learning through feedback during the interpretation stage. Providing participants with drafts of the findings gave them the opportunity for feedback and mutual learning.

3.7 Reporting the study's findings

3.7.1 Introduction

Authors discuss a variety of presentation styles for reporting qualitative research including oral, written, descriptive, narrative and analytical (Creswell, 1998, pp. 168, 186; Yin, 1994, p. 127). Descriptions or narratives (used in the study) are, as Marshall and Rossman (1999) stated, "Detailed descriptions or stories, punctuated with the social or other significance of the events uncovered" (p. 158). Descriptions can range from 'thick' to 'thin', and decisions are made about the desirable balance between description and analysis, and interpretation and assertion (Creswell, 1998, pp. 184, 186; Patton, 1990, pp. 429-430).

3.7.2 The Brisbane Study

The study results were delivered progressively, by oral presentation, and officially as an academic thesis. Feedback was solicited and unsolicited. My objective was to report the study's results, whilst providing appropriate opportunities for knowledge sharing, learning and feedback (recommended by Herda, 1999; Lincoln, 2002; Maxwell, 1996). Below I outline how the study results were delivered.

3.7.2.1 Reporting methods

To cater for a diversity of audiences (such as academic, business and engineering) the study findings were delivered in these ways:

- **Academic thesis**: The academic thesis was the formal method for reporting and publishing the study findings. I attempted to make the document cross-disciplinary, friendly and free of unnecessary jargon (see Creswell, 1998, p. 170).
- **Oral presentations:** Power point presentations helped to maintain interest in the study whilst pitching the delivery at the correct audience (see Creswell, 1998, p. 168; Yin, 1994, pp.129-130). This technique also encouraged knowledge sharing and mutual learning (see Lincoln & Guba, 2002).

3.8 Evaluating the study, method and findings

3.8.1 Introduction

Traditional criteria for evaluating qualitative research are based on many positivistic assumptions about scientific knowledge with its logical conclusions, grounded in irrefutable data. This assumption has been largely abandoned by philosophers and methodologists (Maxwell, 1996, p. 86). This has led to ongoing attempts to develop contemporary and emergent criteria for qualitative studies (Herda, 1999; Lincoln, 1995; Lincoln & Guba, 2002, pp. 207-208).

3.8.2 The Brisbane Study: Research quality

In this section I comment on how research quality was maintained for the Brisbane study.

3.8.2.1 Validity

Validity is relates to the applicability of the research strategy to the study objectives and phenomena (see Maxwell, 1996, p. 86; Yin, 1994, p. 33). The development and reporting mechanisms (research strategy, data collection and interpretation processes) of the Brisbane study demonstrate the seriousness with which validity was treated. For example:

- **Construct validity**: Construct validity (appropriateness of data collection instruments and analysis) is taken seriously in the Brisbane study as indicated by the use of multiple data sources, triangulation and inviting participants to review the case study report (Yin, 1994, p. 33).
- **Internal validity**: Internal validity (the suitability of data collection and analysis techniques to the study objectives) is demonstrated by ongoing attempts to develop a research strategy appropriate to engineering design creativity in context. I tried to achieve this goal by being systematic about data analysis and by contextualising interpretation, rather than by extracting and measuring criteria about creativity (Yin, 1994, p. 33).

3.8.2.2 External validity

External validity or transferability is the capacity of the case to be generalized or compared with external cases, a criterion often confused with statistical sampling (Yin, 1994, p. 33). In my view, the criteria for justifying a single case study strategy (see Ch.3, pp. 85-86) refutes the argument that the purpose of a case study is to position it on a statistical distribution or probability curve. The Brisbane study was intended to enable readers to compare the findings to themes, theories and cases within or external to the study and thus allow an intuitive assessment of the study's 'validity' (relevance) (Yin, 1994, p. 36). This is consistent with Stake's (2000) view that the reader is the ultimate assessor of the qualitative case study.

3.8.2.3 Reliability

Reliability is the ability of a researcher to use a similar approach and achieve similar results (Yin, 1994, p. 33). Exact replication is logically impossible, and arguably inappropriate. The Brisbane study was reliable and replicable to the extent that the research and reporting process was documented consistently and comprehensively. The documented strategy may produce quite different results under the guidance of a different researcher in a different context (see Creswell, 1998, p. 143; Yin, 1994, pp. 33-38).

3.8.2.4 Credibility

Credibility is the extent to which the study's conclusions engender confidence in the methods and the 'wholeness' or completeness of the study (p. 198). According to Marshall and Rossman (1999), credibility is reflected in the richness and authenticity of descriptions of study phenomena (pp. 192-193). These rich descriptions, according to Lincoln and Guba (1985, cited in Creswell, 1998, p. 203), allow the reader to decide how meaningful and transferable the study results are.

The Brisbane study is credible to the extent that the conceptualisation, conduct and documentation of the study and its strategy raise the chances that its findings will be perceived as meaningful by participants and readers.

3.8.2.5 Transferability

Transferability in a single case study relates to the ability of the researcher, participants and reader to reflect on the study findings internal and external to the case (Stake, 2000). The evidence of this is the possibility that readers (through rich case descriptions and interpretation) will be inclined to relate the study findings to themes and theories inherent in the case report, as well as their knowledge and experience of cases external to the study (Marshall & Rossman, 1999, p. 193). This is not the responsibility of the researcher.

I suggest that the in-depth and contextual study about engineering creativity in the Brisbane office, and its documentation and self-checking processes, has the possibility to convey a degree of authenticity which might inspire readers to reflect beyond the study to other cases and experiences.

3.8.2.6 Dependability

Dependability is often assumed to refer to a study's reliability and replication. The Brisbane study was exploratory, thus an invitation to be opportunistic. In my view, the study's dependability relies on properly documented evidence of exploration rather than *a priori* assumptions and definitions (see Patton, 1990)..

The dependability of the study relies on the reader's judgement (see Herda, 1999; Stake, 2000), which relies on the extent to which the opportunistic methods used for sourcing and interpreting information were conducted and documented reliably and explicitly (see Miles & Huberman, 1994).

3.8.2.7 Confirmability

How can the researcher and reader verify the truth (see Creswell, 1998, p. 193), authenticity and accuracy of the study findings? (Marshall and Rossman (1999, p. 192). The Brisbane study provided a safe (confidential) environment for authentic conversations. The way the researcher reported the findings, by necessity, reflected the bias of participants and researcher, as well as the reader, which is inevitable and necessary (Stake, 2000; Patton, 1990). Because the study explored the participants' descriptions of engineering design practice and creativity, the accuracy of the findings depended (in my view) on facilitating a setting for communication that would encourage people to reflect their bias, and therefore their honesty.

3.8.2.8 Authenticity

Authenticity is a relative term dependent upon the meaningfulness of the research experience to participants, and how genuine the research report appears to readers. Holistic research, practices and experiences can reflect a sense of completeness, relevance and participation among the people involved in conducting, reporting and reading the study results (Herda, 1999). This extends to the study's conduct and reporting and the way descriptions and inferences are delivered. The importance of authenticity and other emergent criteria is discussed by many authors (Creswell, 1998; Herda, 1999; Lincoln & Guba, 2002).

3.8.2.9 Ethical considerations (Fairness, mutual learning)

The philosophical assumptions of the study (see Ch.3, pp. 77-81) acknowledge that people prefer to engage in activities in which they are permitted:

- **Autonomy** - freedom, choice, responsibility
- **Reflection**:**-** ability to contemplate past, present and future actions
- **Authenticity** - meaningful and genuine experiences such as whole work practices
- **Holistic approaches** - contextual, whole life and work experiences
- **Complexity** - whole authentic meaning in preference to simplified objective measures
- **Mutual learning & interaction** - social interaction, participation, mutual learning and action
- **Fairness** - trust, transparency, equal treatment, equal opportunity for action, acceptance of diversity

The above are increasingly recognized as important in research and business practice (Herda, 1999; Lincoln & Guba, 2002; Mumford, 1996, 1981; Steiner, 2002; Wheatley, 1999a. There are formal and informal ethical matters that needed addressing in the study. The formal issues were largely managed by the QUT ethical clearance process, in which the study's proposed strategy and related procedures were granted ethical clearance.

3.8.3 Evaluating the Brisbane study

Creswell (1998, pp. 195-203, pp. 213-214), Marshall and Rossman (1999, pp. 196-201) and Maxwell (1996, pp. 92-96) provide practical check-lists which I used reflectively throughout the study, and use below to demonstrate how I attempted to produce high quality results.

- **Perspective:** Interpretive qualitative research felt like an authentic way of exploring engineering creativity in its natural setting. The philosophical assumptions about participants were validated by the approach used (Creswell, 1998; Patton, 1990; Yin, 1994)

- **Strategy:** A sound rationale was presented for the single case study strategy and this strategy was clearly documented. The contextual strategy for data collection and analysis felt appropriate for the research questions and ill-defined and contextual phenomena (Patton, 1990; Stake, 2000; Yin, 1994).
- **Methods:** The data collection methods (principally semi-structured interviews) permitted a holistic and contextual approach. The level of responsiveness and the holistic nature of responses suggests that the methods were appropriate for the research objectives (Patton, 1990; Robson, 2002; Yin, 1994)
- **Evaluation:** I explained how the study met a range of traditional, contemporary and emergent research evaluation criteria (Ch.3, pp. 102-106). The research information was collected, stored, analyzed and reported according to accepted norms as well as emergent opinion (Lincoln & Guba, 2002; Creswell, 1998; Marshall & Rossman, 1999)
- **Information management:** The study demonstrates that interpretive holistic studies can be verified by sound documentation, allowing others to use it as a guide for their own studies, and as a way of assessing its credibility. Original tapes, transcripts, field notes and company documents, were stored electronically or in hard copy for ease of access (Miles & Huberman, 1994; Yin, 1994).
- **Reporting**: The study results were reported in an ongoing way to share and receive feedback from participants.
- **Knowledge sharing**: The importance of knowledge sharing was reflected in the range of opportunities provided in the study organization for participation in the research study, such as: Formal research interviews, email and telephone communication, questions posed at innovation workshops, discussions at research presentations and invitations to read and give feedback about the study report.
- **Ethical practices**: Confidentiality, privacy, academic honesty, mutual learning and appropriate methods for the research question are some of the ethical issues adhered to.
- **Participants' voice**: The importance of participants' words and experiences was reflected in the main data collection method (interviews) and in the abundant use of interview quotes in reporting the findings (see Herda, 1999).

- **Subjectivity:** An empathic and interested (rather than disinterested) attitude was adopted towards participants (Patton, 1990). Similarly, an interested but critical subjectivity or self-awareness with regards to phenomena and participants was adopted (Creswell, 1998, p. 196).
- **Comprehensiveness:** The documentation of the study's strategy suggests that the study explored the research phenomena comprehensively and in-depth. As Stake (2000) informs us that the researcher inevitably decides what is included in the final report. The researcher's perceptions about what is important will influence the final story told, suggesting that with in-depth, contextual studies, there are many possible interpretations (Patton, 1990). The authenticity and accuracy of this account will vary from reader to reader.

3.9 Conclusions

This chapter explained the assumptions behind and the methods use to conduct an interpretive qualitative case study about engineering creativity in the Brisbane office of a large global consulting engineering firm. 'Tacit' or intangible human experiences are different from objective phenomena (for example budgeting) because they are personal, contextual, complex and ill-defined. Their exploration and description usually requires researchers to move beyond objective methods and unhelpful simplifications (such as variables and measurements), towards contextual and holistic research perspectives (see Patton, 1990, p. 130).

The philosophical approach described in this chapter, is holistic, flexible and interpretive. People are assumed to prefer whole (contextual) and meaningful (authentic) work and life experiences, in preference to abstract and simplified ones (see Watts, 2001, p. 14). The research perspective and strategy was tailored to explore the authentic meaning of engineering design for participants, and the implicit meaning of creativity in that practice.

The case study research strategy was also discussed as the context in which information and understanding was sought, interpreted and authenticated. I suggested that the principal data source, in-depth, semi-structured interviews, would allow people to talk about their design work in a meaningful context, and allow comparisons to be made with other palpably creative practices such as architecture and urban design.

The chapter discussed how field or case information was identified, sourced and managed, and how the research findings were analyzed, interpreted, authenticated and reported. The mode of interpretation was described as a series of analytic and reflective cycles, which allowed the participants’ responses to be interpreted in their personal, group and organizational context. The methods and considerations involved in reporting the study findings were discussed, after which the research study was assessed using a range of traditional, contemporary and emergent criteria for gauging the value of qualitative studies.

Chapter 4: Study findings: Engineering innovation and creativity: Person and process; Product and place

4.1 Presenting the findings

4.1.1 The structure

This chapter gives a descriptive and dialogical account of sixteen key themes that unveil the relationship between creativity and engineering design innovation in the study organization. It uses extracts from interview transcripts to allow the themes to speak through the words of participants. To maintain focus on the participants, the discussion also uses minimum critical interpretation and references to the literature (which is deferred to Chapter 5). The sixteen themes are organized around the study's focal questions (listed below) which help to structure the discussion and give it context.

- What is the meaning of creativity and innovation for participants?
- How do engineers describe engineering design?
- How does the organization's project environment influence engineering design?
- How does the organization support creativity and innovation?

Whilst the process of uncovering the themes was as organized and contemplative as possible, and whilst I attempted to increase authenticity by using participants' words, I recognize that the interpretation is one of many possibilities.

4.1.2 The participants

The themes refer substantively to in-depth interviews conducted with engineers, managers and innovation champions, and is supported by other sources such as attendance at company events, the minutes of innovation meetings, the company Intranet and other company information.

In quoting from transcripts, I avoid unnecessary repetition of participants' work roles by summarizing information about the participants in Figure 4.1. Exact titles are avoided to protect the participant's anonymity. The usual format for participant's quotes is as follows:

> I might add I don't like the word innovation [Kevin:3]

('[Kevin:3]' refers to page 3 of the annotated transcript of Kevin's interview).

Figure 4.1: Interview Record: The participants

Table 1: Project Group Members

Pseudo	Position
Emily	Graduate Structural Engineer & Innovation Champion
Roger	Senior Designer Drafter
Maree	Project Administration Officer
Sean	Graduate Structural Engineer
James	Project Manager & Civil Engineer
Frank	Senior Structural Engineer
Kevin	Senior Structural Engineer

Table 2: Innovation Champions

Pseudo	Position
Terry	Senior Structural Engineer & Innovation Champion
Brian	Project Manager, Engineer, General Operations Manager
Roz	Project Administration Officer & Innovation Champion
Christine	General Operations Manager
Lloyd	Project Manager & Civil Engineer
Greg	Senior Civil Engineer
Ian	Senior Structural Engineer & Innovation Champion
Ellie	Non-engineering Professional & Innovation Champion

4.2 What is the meaning of creativity and innovation for participants?

4.2.1 Introduction

As explained in Section 4.1.1, p. 110, the study's sixteen key themes are organized around the study's four research questions. The first of these questions addresses how participants understand creativity and innovation. Their understanding about the phenomena can influence their approach to engineering design by affecting the way they interact with their design environment. A fragmented understanding can lead to design environments that discourage or stifle creativity and innovation, whilst a more complete understanding can do the opposite. Though the words 'innovation' and 'creativity' were used together or interchangeably among participants, and though 'innovation' was used more frequently, it was usually possible to distinguish between them by studying their context.

4.2.2 Theme 1: Innovation receives more explicit attention than creativity

Innovation received more explicit attention than creativity, even though participants were concerned about the negative effects of industry culture on their creativity, and even though they intuitively described engineering design as a creative practice.

I suggest that this is probably because participants found it easier to define and describe innovation than they did creativity. Their conversations indicated that it was easier to express their understanding about creativity when discussing their design practice than when they talked about creativity as a company performance criterion. It may also be (as Ellie suggests) due to the association of creativity with 'soft' and recreational rather than work-related practices.

> You can easily quantify how you have contributed to the innovation program ... but it's much harder to show how you've been creative I think … people are creative in different ways. [Ellie:10]

> Once you've got something down … on paper [creativity is] probably hard to define or show the steps that you went through in getting to that idea. [Ellie:10]

> If someone says…you're creative, it may be they're thinking that you're a bit … laid back and relaxed … maybe people think that if they're described as creative they're a bit soft or something … more than being creative in terms of making something tangible. [Ellie:10-11]

Though creativity is not often explicitly mentioned, it is generally perceived as complex, natural and beneficial, and connected with 'breakthroughs', historic invention and innovation (consistent with 'Small C' and 'Big C' in the literature - see Ch.2, pp. 34-35) even though breakthrough creativity was more likely to be called innovation.

> You go to university to learn engineering … but … you're always going to want to try new things. Whether you're an engineer, a PA or cleaner, you're going to want to try to do it better. [Maree:13]

> [Creativity] gets the imagination of engineers who whilst they have to be logical and ordered … they have to be creative too. [Brian:6]

> We win jobs on…creativity and that innovation … we've got to be producing very sensible methodologies that are smart and innovative. [Lloyd:6]

Despite a tendency to associate creativity and breakthrough innovation with spontaneous and serendipitous events, there was a suggestion that creativity involved a type of process involving time and effort. This was corroborated in discussions about the impact of project time and cost constraints on creativity in engineering design.

> Other people … could come up with some crazy idea … [about how to] produce some instrument that's going to save a hundred lives … that's creative as well

> because they've had to … think and go through a process to get to that point and produce it. [Ellie:10]

> What … stifles … creativity and innovation, is you don't have enough time to do a job properly in our game. [James:6]

When participants discussed creativity outside of their engineering design and project management context, they described it in abstract and fragmented ways rather than as a complete experience. This occurred less often when engineers talked about creativity in a meaningful context such as their design work, rather than as abstract and cognitive traits (such as creative or divergent thinking performance measures).

Innovation, on the other hand, was described as less personal than creativity, often associated with groups and collaboration, and linked to discussions about strategic, tangible and often quantitative initiatives and outcomes, such as winning a major project bid or the number of new ideas generated. Among project managers it was frequently associated with the words 'breakthrough', 'paradigm shift' and 'cultural change' even when it appeared that they were talking about 'Big' or 'breakthrough' creativity.

> We've either got to do it cheaper than someone else or we've got to do it better. … We've got to bring something to it and if we can, do things a bit differently. [Ian:7]

> Colleagues in other companies [are] going through the same thing [3] … We need to be coming up with ideas all the time. [Christine:6]

Innovation thus received markedly more attention throughout the study. According to participants, innovation occurs either as breakthrough changes (which managers tended to emphasize) or smaller, incremental improvements in office and work procedures (often discussed by staff in general and innovation champions). The value of small or incremental innovation is expressed by a senior manager.

> It can be something very simple…just make their life easier and makes everybody life easier; … it doesn't need to be engineering. [Ian:8]

In contrast, project managers describe a need for breakthroughs at the project level, particularly the stage at which work is procured. They often discuss a new form of project delivery called the 'project alliance' and the way it employs collaboration, expert facilitation and creative brainstorming, to achieve breakthroughs that managers hope will help them procure more work.

From reflecting on participants' conversations about the innovation strategy, I suggest that creativity receives not only less attention but a considerably narrower focus than innovation. This focus is not echoed to the same extent in participants' conversations about their design work and creative performance.

4.2.3 Theme 2: There is a broad-scale support for innovation

Though the proprietary nature of the innovation strategy limits what I can disclose, there is sufficient documentary and conversational evidence to describe the global company commitment to innovation. Innovation is not a choice but an imperative:

> Our industry is possibly one of the most competitive in Australia ...with our dropping multipliers [hence profit margins]…from 3 ... to … 2.2. [Lloyd:6]

> We've either got to do [the work] cheaper than someone else or we've got to do it better. [Ian:7]

> The company's got to do things differently. … If you … keep doing the same thing that you've been doing … you're not going to survive … because your competitors are going to get a jump ahead of you. … A lot of the work we do is

> … straightforward engineering that anybody can do. ... If we can do things a bit differently … that puts us a jump ahead of other people. [Ian:8]

> If we don't show that we're trying to be innovative and have that sort of culture, then [we're] not going to win the jobs because that's what the client's asking for. [Ellie:3]

> [Innovation's] one of the key things that people look for when deciding whether or not they want to go to a particular service provider. [Brian:1]

Innovation was identified as one of five key company focus areas (and market differentiators) for 2002 and reinforced in corporate, operational and marketing strategies, as well as personal performance competence measures in the human resources (HR) system.

> [Innovation]: Fostering a culture that promotes ideas to differentiate us from the competition [Company brochure 2002]

> [Creativity]: Forms new and unique solutions to issues and problems by seeing patterns and connections others do not recognize [The HR System, The Intranet]

The paradigmatic nature of innovation in the company was demonstrated by the resource-rich global road-show called the Innovation Fair used to launch the company's innovation focus in late 2002. Several weeks of related activities (some of which I attended) were involved.

- Inter-active displays about innovative company projects
- Inter-active displays about creative thinking techniques
- Slides showing a formal global framework for innovation including the mechanisms for generating, evaluating and championing new ideas
- Informal discussion among staff and visitors from the industry

At the time of the study, the innovation focus was on idea generation (using brainstorming techniques) and administrative (or business) process, rather than engineering and design. Though office improvements and project management tended to dominate innovation workshops, the engineers say they would like to see more attention paid to engineering design

> [Innovation] doesn't need to be engineering; … it can be our admin people… secretarial people, admin people, planners, engineers. [Ian:10]

> I'd like to see the innovation initiative carried through more to the design work; … it's one thing to … make the office run more smoothly. It's another to fundamentally change the approach that people have to project work. [Sean:9]

Within innovation discussions, the principal reference to creativity was creative thinking and training (see Ch.2, pp. 39-41). Managers hoped that creative thinking training would improve problem solving and lead to breakthroughs. The treatment of creativity as learned thinking or as a human resource competency (see Ch.2, pp. 65-66), suggests that the company's formal systems viewed creativity in a limited way.

> Our people should be using creativity techniques just as second nature when they're working on the job. So … there'd be a reduction in cost because you'd be doing things smarter and better. [Ian:10]

> [Mind mapping] makes you become a bit more creative. … I'm a … a regimental person. … I … like lists and numbers. … I don't find that that really leads to many new ideas. Whereas a mind map … leads you to come up with things … [you] wouldn't have otherwise considered. [Emily:11]

> I … then … implement a process called breakthrough focus; … that's all about setting targets that are beyond the … best outcomes that you would get for a normal project. … Then the team is facilitated to think outside the square … to achieve those targets. [Brian: 2]

> People have different ways of thinking; they've got different backgrounds and training. Ideas develop when you do get people brainstorming … [one] idea sprouts another idea and you go from there. [Ian:11]

With the initial global financial investment in innovation over, ongoing support relies on informal, voluntary and largely under-funded innovation activities.

> I call [the innovation champions] the volunteer movement; … there's no specific allocation of resources been given. … Fortunately … [the innovation champion idea] is also an attractive thing; … I think people are gaining from it themselves … [and] they're improving their career … and … improving the standard in the company. [Greg:8]

> To keep innovation going, we're running monthly innovation workshops and training sessions. [Ian:10]

To compensate for resource deficiencies, managers are keen and innovation champions willing to learn and transfer a diversity of knowledge and innovative techniques at the project level.

> [Project alliance and creative thinking techniques promote] cultural characteristics that are very attractive to apply throughout the organization. [Brian: 6]

> A lot of [money's] being spent on [innovation]; … you don't want to waste what you've learnt. [Ellie:3]

The participants' conversations and high attendance rates at lunch-time innovation meetings suggests a high level of commitment to innovation. However, time and resources available for the initiative are scarce, and it is not surprising that participants are starting to reflect on how the previous momentum can be sustained.

> A lot of [innovation-related activity] is being done in people's own time; my fear is that ideas will be generated and … without a clear signal … [that] there is a chance of getting some of these implemented it may be that people don't want to invest a lot of their own time for no reward at the end. [Sean:9]

> The big danger with all this is … we encourage people to submit ideas and then you just don't get back to them. [Greg:5-6]

> Keeping the momentum up … not having too much of it at once … Give different initiatives a chance to work and get settled so that it's part of our culture … like health and safety. … Eventually I would like to see innovation and creativity as part of our every day thinking. [Christine:6-7]

> They've highlighted innovation as a high priority. … They've had the fair, they've got the website … but they don't give you the time; … it's all in your lunch hour. … Why couldn't we have a budget for two people for an hour a month to prepare … a talk? [Roz:7-8]

> At the end of the day people are constrained to put the time against a project. [Ian:13]

> A lot of the training that we do … [and the innovation meetings] … [are] in [our] lunch hour and it does become a problem after a while … you don't have a job [number to charge it to]. [Ellie:7-8]

The study evidence suggested a considerable formal and informal support for innovation which is summarized below.

- A global innovation strategy with formal and informal mechanisms.
- A strategy that includes the whole business: General business processes (administration), project management (procurement, project management) and engineering design.
- A company and marketing focus on innovation in 2002/03.
- A global 'Innovation Fair' (road-show) to launch the innovation strategy.

- An official avenue (framework, structure) to channel, discuss, champion and implement innovative ideas.
- A national innovation champion (Asia Pacific) and regional and national innovation meetings.
- A global and regional innovation portal (website).
- A global creativity training program.
- An informal structure including: innovation champion in each project group, innovation moments, innovation awards, monthly innovation workshops, innovation presentations, transfer of creativity techniques.

4.2.4 Summary

Creativity was given considerably less explicit attention than discussions about innovation. The focus on cognitive attributes of creativity such as creative thinking and training and the personal creativity competence criterion, suggests that outside of the engineering design context, creativity is discussed in a limited way. Participants also struggled when talking about creativity out of context, but their descriptions reflected the complexity of the phenomenon. By contrast, innovation is discussed more often and more easily and the company's strategy reflects a proportionately greater emphasis on innovation activities than creativity-related investments.

4.3 How do engineers describe engineering design?

4.3.1 Introduction

The language used by participants to describe their design work bore a strong resemblance to that often used to discuss other creative practices such as architecture, product design, urban planning (see Ch.2, pp. 42-44). The following themes help to describe the practice of engineering design and the roles played by creativity and innovation.

4.3.2 Theme 3: Engineers are creative

The degree to which people practising as engineers express their creative potential is reflected in the participants' discussions about themselves, the engineering profession and their engineering design work. Senior engineers such as Brian, Kevin and George suggest that the public perception of engineers is not entirely favourable:

> Oh we've got a huge problem in terms of public perception of the career; the engineering industry. [Brian:10]

Kevin suggests that a possible reason for this poor image is that cost pressures cause engineers to compromise on the aesthetic aspects of their design.

> The problem with Queensland is they always take the lowest cost, irrespective of what they say, which means aesthetics … is well down the list of important priorities. [Kevin:9]

For George, a negative public perception could be related to the perceived poor quality of engineering designs (which he suspects could be related to an inferior design education).

> Universities teach analysis for design poorly.… Firstly design is hard to teach; … the second reason is most lecturers have done very little design. The average experience … might be one, two or three years; … something they're very weak in … but maybe that's not a problem. Maybe you learn it on the job. [George:4]

According to Terry, some people perceive engineering work as dull, whereas it is really quite uninteresting and varied.

> There are some other professions where people are interesting … not quite the right word but more outgoing. The analysis part of engineering can be dull. There are dull parts of engineering; truly mind boggling dull. [Terry: 6]

> It's quite fun designing things. I suppose I did that as a child as well, draw things up and try to build then. [Terry:6]

> A couple of years ago I was ready to chuck it in and why I didn't is because there's always something different … something interesting … you can make of it what you want. [Ian:1]

> It's the variety. No two projects will ever, ever be the same … It doesn't matter if it's a thing that you've built twenty times …You won't have the same team in a job … [in] every project you're going to learn something new. [Marie:14]

Any suggestion that exceptionally creative or gifted engineers do not exist is also disputed by many study participants. Many are aware of the palpably creative or gifted engineer, viewing them as an asset rather than a liability.

> I don't know whether it's the people working on the project or if it's engineers in general, but some of the people on the project do tend to be quite creative. ... I also think it's got a bit to do with [Frank's] nature; … I think he's quite creative. [Emily: 4]

In the following comment by Greg, a senior manager, there is an appreciation of the need to encourage the exceptionally talented who are sometimes perceived in negative terms.

> [Recognizing creative performance is] giving encouragement to those … that are palpably creative; … mostly doing new and creative things. ... They're a bit brighter in the sun, even if they have other foibles. [Greg:10]

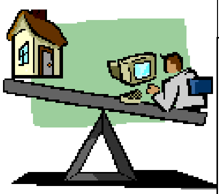
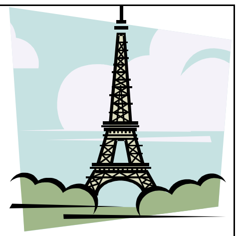
Even though the public perception of engineers is sometimes poor and inaccurate, there is agreement among participants that engineers are creative and sometimes exceptionally so. Understanding how engineers actually do their design work unveils further insights about the role of creativity in the engineering profession.

4.3.3 Theme 4: Engineering design is a creative practice

My expectation that ‘engineering design’ would be the activity most likely to engage discussions about creativity in engineering was confirmed. The descriptions of engineering design given by participating engineers were similar to descriptions of other palpably creative professional practices (see Ch.2, pp. 42-44).

By reflecting on the literature and listening to engineers’ conversations, I was able to identify words and phrases used by participants which helped to describe aspects of engineering design work which appeared to be palpably creative. I was also able to divide these words into two categories, which though inseparable in the design practice, were helpful when discussing creativity in engineering design (see Figure 4.2). In Figure 4.2, the column headed ‘Scientific/ Analysis’ includes the words used to describe the definable and organized aspects of engineering design; the other called ‘Design/Creative’ describes the more intangible and heuristic aspects that participants spoke about. Though the categories appear to represent opposing forces, the way that participants used the language suggested that there was a synchrony between them.

Figure 4.2: Engineering design: Opposing elements working together

	**Scientific/Analysis**	**Design/Creative**	
	Scientific	Artistic, visual	
	Physics & geometry	Applied technology	
	Analysis	Design	
	Linear, convergent	Non-linear, divergent	
	Problem solving	Problem finding	
	Cognitive, thinking	Intuitive, design practice	
	Knowledge	Technology	
	Exact	Iterative, experimental	
	Function	Aesthetics, ethics	

To varying degrees every project is unique, a suggestion that there is novelty and creative potential in every new design:

> A lot [about engineering design and creativity] is to do with the physical parameters you're given on each project. They're never the same, such as ground conditions, units of site that you have to work within. [Kevin:5]

Engineering design is also intrinsically creative in the way it is first conceived as a visual or mental image. Once inspired, it is communicated through drawing, modelling and analysis. This non-linear aspect to design runs counter to impressions outside engineering that design is a sequential and exact science.

> The engineer has got to be able to visualise the structure in his [sic] mind … and you work all that out without using any numbers at all. … Once that's sorted out you can then analyze the structure; … the creativity part is in that initial, up front design. [Ian: 2]

> You go to another bridge and you [think]; … what did they do there, because the person that designed it really didn't stop to think ahead and visualise what he [sic] was designing.[Ian:3]

> What science will help you do is to analyze the thing once you've thought of it. [Terry:3]

The intrinsic quality to creativity is expressed by Kevin, who was strongly opposed to taking 'creativity' out of context and using it as a measure of personal competence.

> I might add I don't like the word innovation. … I … object to putting it into a little box; … I just regard that as part of my job. [Kevin:3]

Though analysis is described as a more concrete stage in engineering design (originating in scientific laws and principles), it is frequently spoken about as experimental and iterative.

> [Iterative] means you guess the answer and then you analyze it and then you adjust the answer if you like, and analyze it again and fiddle with it; … analysis is simply checking that it'll function the way you think it's going to function. [Terry:3]

> Design isn't a linear process. It's very much an iterative one. … I think to a certain extent design involves an element of trial and error. ... You have to come up with an idea, test it and see if it will work. [Sean:1-2]

> It's not an exact science, pavement design. … There's a lot of theory in it but at the end of the day it boils down a lot to trial and error. [James:3]

Design may be visually conceived and tested iteratively, but it is by no means random or chaotic. Its order is sometimes revealed as a more linear sequence of stages and sometimes as a heuristic evolving out of knowledge and experience.

> That's what engineering's about … first to find the problem. … Once you define what you're trying to do … you … go through the process of [defining the objectives of] what [you're] trying to do. Then you gather all the facts together; … then you start looking at solutions. [Ian:7]

> Design tasks have probably got a lot of common elements … regardless of how different they might be in a physical sense … there are probably … common elements that will come back time and time again with each project. [Sean:5]

> [The systems approach to engineering is] a way of looking at problems. … It can be summarized as … objectives, criteria, alternatives and analysis. [Terry:1]

Some aspects of the design process have more potential for creativity than others. The engineers described how they could benefit from applying creative thinking tools to the problem finding and solving stages of design.

> It would be good to start trying to factor in time into projects for innovation because we want to encourage people. [Ellie:8]

> I doubt [whether] there's too much de Bono or word association … that's being used. … [The challenge is] how to get that next step. [Brian:6].

The nature of the problem finding and solving process also suggests another important property of engineering design; it is a reflective practice (see Ch.2, pp. 42-44):

> Engineering is [about] looking for solutions to problems. … However, if you just step back and think for a moment there's always more than one solution and usually there's a simple solution. … Defining the problem is always the thing. [Ian:6]

> You can make a lot of headway … saying … what is the real problem here? … A classic example of where that wasn't done … was the Concord. … It's very fast but it's also very expensive; … a 747 … is half the speed or less … [and] … a lot cheaper. [Terry:1]

Most engineers and managers described how creative problem solving techniques such as lateral thinking, mind-mapping and brainstorming can help them to think more divergently.

> [The objectives stage is] when … [you] make sure you're actually quite clear on what it is you really want … that's where you'd use previous experience and some innovation tools [e.g. brainstorming]. [Terry:1]

> It would be good to start trying to factor in time into projects for innovation because we want to encourage people to use the innovative … and … creative tools. [Ellie:8]

What engineers say is a creative or innovative design tends to be cost efficient, that is, the lowest cost alternative. Even though the design discussed by Frank was cheaper, it was considered innovative because it was functionally superior to competing bids.

> The best design in this case was the lowest price [Frank:2] -- Was it the best because it was the lowest price? [Marion:2] -- We met the functional requirements at the lowest cost; … we just did it a different way to the others. … We probably had a third of the concrete that the other two had … and [that was] a big component of the costs. We had a more time effective design. [Frank:2]

4.3.4 Theme 5: Knowledge and collaboration are related to design creativity and innovation

Project engineers and managers support the view that creativity in design is developmental and knowledge dependent. Continued learning and practise increases the range of possible solutions and is therefore foundational to creative design (see Ch.2, pp. 29, 60-61, 66-70).

> Engineers are definitely made not born. [Creativity in engineering design is] … an accumulation of knowledge over a long time to know all the different ways you can do a certain thing. … then … you think … we could combine this one and this one together to get something new. [Terry:6]

> People who are good at design and who are very experienced … tend to have an idea of what the important aspects will be before they start. There's a certain element of that lacking with me … because I won't necessarily have an instinct for what would be … critical factors. [Sean:4]

Documentary evidence and conversations with Terry, Sean, Ellie and Greg support the view that continuing professional development (CPD), such as the following, is vital to acquiring the foundational knowledge needed for improved design.

- A global excellence in engineering program, e.g. regional networks of experts (Source: Intranet; Ian and Greg).

- A global training program aligned to strategic and personal performance objectives (Source: Intranet, Terry).
- A global mentoring program tailored to all experience levels (Source: Intranet – HR; Terry, Ellie and Sean).
- A knowledge sharing culture which encourages conference attendance and professional networking (Source: Terry and Greg).
- A professional development culture, e.g. Institution of Engineers, Australia, Universities (Source: Intranet, Terry, Greg).

The company's global Excellence in Engineering Program has a high company profile. Its high priority for ensuring regional expertise and networking reflects the importance of knowledge development and transfer. A leader in this area discusses his regional networking role:

> I've established a global network map of chief engineers across the three regions; … various technical gurus in each area [using me as a contact point]; … it's a networking … role I have to play. [Greg:5]

The company's support for conference attendance reflects the value its places on acquiring external knowledge.

> [The company's] very keen that you do attend conferences; … you find out … where the industry is heading. You meet a lot of people; … most innovations are … a small step from a vast body of knowledge. [George:3]

Multi-disciplinary collaboration was considered by managers and engineers to be an important means of combining old, new and diverse knowledge and talent, because novel combinations often result from the interaction of different disciplines and skills.

> The ideal innovation is using … those old heads and young heads with the new technology to get a solution to jobs. [Lloyd:3]

> I think a lot of [design creativity] is experience as much as anything else. We'd adapted things that were used in other constructions before. [Frank:2]

> We have a couple of our senior project directors from [the] industrial section running a waste water job … using … the more stringent and process driven thinking of an industrial engineer in the waste [area]. [Lloyd:3]

> Don't reinvent the wheel. People in this place have done probably most things … so why waste time struggling over the basics of the problem. … People in this place … are really willing to share their experience and knowledge. [Emily:12]

Participants indicated that knowledge, experience and collaboration influenced their creativity. They described the following formal and informal knowledge sharing practices common throughout the company.

- Informal collaboration, e.g. small group or one-to-one exchanges.
- Formal collaboration, e.g. meetings, facilitated project alliances.
- Monthly innovation meetings, e.g. presentations about new design or other work methods.
- Project team brainstorming, e.g. project start-ups and idea-intensive parts of design and problem solving.
- Good communication, e.g. face-to-face as well as electronic.
- Access to past design records, e.g. document management system (DMS), office reference library, corporate Intranet.
- Access to external designs, e.g. Intranet, library, journals, conferences, professional and other networks.
- Knowledge sharing, e.g. regional networking, communities-of-practice, video and teleconferencing.
- Diversity in team selection, e.g. to improve collaboration, broaden knowledge and skills bases.
- Project leadership, e.g. formal and informal sharing of expertise, team briefings.

4.3.5 Theme 6: Engineering design involves aesthetic appreciation

The conversations with engineers suggest that design aesthetics (appreciation of) is not overlooked in engineering.

> Aesthetics are important; … I believe the structural engineer has to be part of the team early. … Most … [architects] are keen to get the engineer involved early. [Ian:1-2]

The subjective quality of aesthetics is reflected in the language used to describe the way that structures are appreciated: Beauty, simplicity, proportion, function, visual attractiveness, art and appreciation.

> The most beautiful structures are the ones that are simple and obvious. [Ian:2]

> [Aesthetics is] subjective … but … in a lot of structures you do get a feeling for proportion. [Kevin:10]

> Structural form is the key to the bridge working; … you don't put any other embellishments on it. [Frank:6]

> We can also build things that don't look out of proportion and [a] blight on the landscape within the cost. [Greg:10]

> I think [aesthetics is] very important; … that doesn't mean it has to be … beautiful … [just] … the way that it's appreciated. [Greg:15]

Engineers tend to have an intuitive sense of aesthetics in structures.

> Some structures you look at and say … that looks heavy. You haven't done any calculations. … It just looks bulky for what it's doing and it looks out of proportion. [Kevin:10]

> You can look at a bridge and say … that bridge is nice. You can see the lines of it and … how it works. [Ian:2-3]

> The Merivale Bridge is naturally attractive I think. [Frank:6]

Aesthetics is related to cultural and environmental appropriateness as much as to artistic and visual appeal.

> [Aesthetics is about] getting to understand what the local environment is; … you've got to make the thing fit to where it is … to be sustainable. [Ian:3-4]

> Highways that have more greenery and plants … [are] an enormous advantage for the people who use the highway and … for engineering as a profession. [Greg:14]

> You could incorporate things into the landscaping that you wouldn't necessarily see, … things like grassing things instead of concreting … to allow a bit more filtration. [Ellie:5]

Aesthetic appreciation is often visual, but function plays an important role in design.

> I think [the structure/object] is creative in the fact that people don't notice that they use things that are so functional. … If you could pin them down … about how it was actually done, they would probably find it quite creative and amazing. [Emily:7]

> [Referring to the Harley Davidson motorcycle] there's not much on the motor bike that is purely decorative. … It's a pretty functional machine. … What's happened is something that works well has acquired a beauty of its own; … if it works really well people think oh that's nice. [Terry:7]

Knowledge about design aesthetics is an important marketing tool among bidders in competitive tendering.

> One of the other tenderer[s]… actually went into great pages of aesthetics in their tender [Frank:7] -- So it's an example of how you can woo people with words sometimes? [Marion:7] -- Yeah, that's what he tried to do, but they didn't win it though of course. [Frank:7]

The engineers' conversations suggested that they have a sound understanding of the language used in discussing design aesthetics, as well as its relevance to engineering.

4.3.6 Theme 7: Design aesthetics competes with budgetary pressures

Engineers and managers were explicit about the effects of competitive cost and time pressures on their ability to deliver aesthetically appropriate designs.

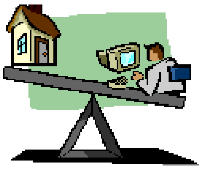
> I'd say that Queensland … builds some of the worst looking bridges in Australia. … They always take the lowest cost … which means aesthetics … is well down the list of important priorities. [Kevin:9]

> In building a minimum cost structure, I still don't think it has to be ugly. … For a very small outlay of the cost you can make something look a little bit different. [Kevin:10]

> Sometimes you have to spend a bit more to … [make it look] good … but you probably don't have … the [opportunity] to do that. [Greg:15]

Though aesthetics is subjective, after reflecting on participants' conversations, I identified the following design elements (see Figure 4.3) that they say represents good aesthetic design and those elements that they say compete against it. It is evident that cost, completion time and other budgetary and industry factors compete with a wide range of aesthetic design elements.

Figure 4.3: Engineering design and aesthetics: a 'creative tension'

	**Complementary to aesthetics** Structural integrity; Function; Art form; Balance; Proportion; Simplicity; Beautiful; Appreciated; Cultural sensitivity; Environmental appropriateness; 'Striking'; Visual appeal; Different; Functional beauty; Natural; Nice lines; Proportion; Different
	**Competing with aesthetics** Lowest cost; Function; Completion (time); Risk (liability) Conflict with architects; Quality; Safety; Over-designing

4.3.7 Theme 8: Computer technology is an aid, not a substitute, for creativity

The way participants discussed computer design tools suggested that they viewed computing technology as an aid, rather than a replacement for design. They made no suggestion that computer software was making their design or creativity obsolete.

> All technology is really doing is helping you in the analysis part, not in the design part. [Terry:5]

> All that's happened is that a person using a CAD [computer assisted drawing] system does it on a computer now but [the original design is] … still off a sketch. [Terry:5-6]

The role of computer technology is not amplified in conversations. This could indicate that technology has become embedded in the routines and practices of engineering design. Technical engineering software, however, plays an important role and is being used creatively on a small and large scale within the company.

> If things can be done to make [design] easier and remove the drudgery … your mind can handle [the] … real issues and solve things better [Ian:8]

On a larger scale, the company's global engineering excellence in technology program is a high level and strategic part of the company's attempt to promote innovative and high standards in engineering design through the creative use of technical engineering software.

> The other side of … technology is what we call execution technology. … We try to improve the way we execute things [for example] … flood studies and better models … to do it better, either … more efficiently or … for less cost or better results … [or] better design outcome[s]. [Greg:4]

Locally, there is evidence that engineers are adapting their engineering software tools in creative and useful ways. For Roger, a designer drafter, the complexity and scope of three (3D) and four-dimensional (4D) modelling software creates unlimited opportunities for using his knowledge, experience and imagination. Technology has not made creativity redundant.

> [There're] any number of ways that [the drawing can be done]. … The only limit is … time. … There's ample opportunity in the way that we employ these tools. … 3D modelling software is … quite complex; … [there're] limitless opportunities to use that in … clever and new ways. [Roger:4]

Technology has also helped to make engineering design fun, interesting and enjoyable by making the analytical design stage more flexible, and by removing tedious tasks. Some participants associate this with creativity.

> Things that used to take a month you can do in a day and they're tedious things. [Terry:5]

> [The] 3-dimensional conceptual design package … allows us to look at different plan arrangements [and] to optimise those arrangements according to different parameters; … it helps people sit there and play. [Brian:8]

4.3.8 Summary

The study's multiple information sources support the view that engineering design is a creative practice. Engineers paint their design practice as visual, thoughtful, knowledgeable, scientific, artistic and creative. They paint it as an organized process with some straightforward aspects. There are also divergent, iterative and intuitive aspects that they associate with creativity and innovation. Engineering design is enhanced by high levels of individual and shared knowledge, technical engineering software and opportunities to develop their creativity, through knowledge development, time for reflection and time for using creative thinking and brainstorming.

Though engineers described their work as innately creative, most participants were seriously concerned about the negative impact that the competitive rigours of their industry (such as dead-lines and cost) are having on the quality and creativity of their designs. Those interviewed said that profit margins were very low, dead-lines tight and there was insufficient time to do their jobs properly, let alone to be creative.

The industry thus places limits on the engineers' opportunity to exercise their creativity. They no longer have the time to think and reflect on old and new designs and there is overwhelming evidence from the above discussion that conditions in the construction consulting industry are stifling creativity and innovation in engineering design.

4.4 How does the organization's project environment influence engineering design?

4.4.1 Introduction

Participants discussed many ways that the project consulting industry is influencing their design work and creativity. They also discussed some imaginative responses to these challenges.

4.4.2 Theme 9: Creativity is stifled by budgetary constraints

The engineers and managers said that industry pressures required them to deliver improved solutions in ever-shortening cost and delivery cycles. They said that they wanted to be more creative with their designs, but that economic realities made this increasingly difficult. The resulting adversity was viewed differently among participants, depending on their role.

> We've either got to do [the work] cheaper than someone else or we've got to do it better. … We've got to bring something to it and if we can, do things a bit differently. [Ian:7]

> Time pressure and the cost pressure … to a lesser extent is … [one of] the biggest changes I've seen in engineering. … I don't think the times we set ourselves … [are] realistic [for] the problem. [Kevin:2]

> We're never provided with what you might call ample time. Everything is always very much time constrained but … [but] nobody said that you had to do [the design in a particular way]. [Roger:2]

> One of my biggest worries when I'm project managing a job, is not only do you have to produce a quality product but you have to make your financial return for the company. [James:7]

According to project managers many adverse conditions are attributable to government procurement cultures that perpetuate lowest cost bidding practices.

> In Queensland … the government's Main Roads [Department] … will always take the lowest cost and therefore you have to produce the lowest minimum cost structure. [Kevin:10]

> Our industry is possibly one of the most competitive in Australia; … it's our industry that is probably stifling innovation and creativity. …We no longer have the luxury of dollars to spend on … searching … more creative solutions; … we just don't have the time or the money left on jobs now to do that. [Lloyd:6]

> I think [change] has to start [in] the public sector … because they're the ones that … drive a lot of our work. … [In] a lot of cases you produce a time chart … of your project … but you know you … have little hope of doing the project … [in] that period of time. The client knows it too but [it's] … what he [sic] wants to hear and everyone goes along with it. [Kevin:2]

Some managers and engineers said that adversity motivated creativity and innovation, possibly even breakthroughs. However, the argument is a truism, with no suggestion of how the adverse conditions led to creativity and innovation.

> Through breakdown comes breakthrough; … through adversity or challenge comes major change. … Time pressures are one of those [adverse things]. [Brian:9]

Other participants argued the benefits of balancing creativity with business objectives but generally agreed that too much adversity stifled their creativity. Also apparent was that some of the purported creative responses to adversity were (no less important but) small scale manifestations such as efficient work practices and 'creative' interpretations of standards and specifications, rather than creative breakthroughs.

> Innovation has to be tempered to some extent, because we work in an industry where there are some tried and true design rules. [Lloyd:3]

> I … see [innovation in projects] having to be a combination [of] using all of the best of our attributes to get the answer. [Lloyd:3]

> I think [adversity] encourages you to work as hard as you can to get things done in the shortest time. But it can stifle creativity; … you can't go and totally reinvent the wheel. …. You have to … adopt … an efficient or effective way of doing things if you want to make money on jobs. [Sean:8]

> Everything is always … time constrained but there [is] no limit on the way you [can] approach something, within the constraints that you were given. … You were certainly at liberty to apply the design standards and the design brief in any number of combinations. [Roger:2]

Generally, however, engineers and managers agreed that too much adversity (such as cost constraints, risk and liability) restricted the opportunity or motivation to be creative. Of all the conditions that create adversity, the one emphasized most was lack of time.

> Sometimes you have to spend a bit more to make it look [good] … but you probably … don't have the ability to do that. [Greg:15]

> Cost and time constraints plus the litigation is going to increase … and you can spend more and more time defending yourself. [Kevin:15]

> There's risk … because no one's done it that way before and we're still solving the problems, but at least we have enough fat in the price that we … cover the price of the problems that we didn't foresee. [Frank:9]

4.4.3 Theme 10: Engineers need time to produce creative designs

Of all constraints, insufficient time for design and development was emphasized the most. With less time to think, the processes necessary for thoughtful and creative design are inhibited.

> The issue that you've said [regarding] time is really important and something I'm intrigued about … it's been the biggest issue. … Time availability or being able to do things with less time is becoming more and more important. [Greg:7]

> The time pressures stop you. … If you've got time pressures you have less chance to think. That's certainly the case. [Frank:10]

A tight rein on project costs meant insufficient time for engineers to engage in activities associated with creativity and innovation (such as time to reflect on and pursue a different approach). This tended to encourage the use of tried and tested methods and to compromise design quality and creativity.

> I think mainly cost and time constraints would often lead you towards … given results, as opposed to … looking down another road. [Sean:2]

> You're heavily constrained by time, and … you continue with something that you really think could perhaps have been a little bit different; … you're not exactly sure, but it would've been a better result at the end of the day. [Roger:4]

Time constraints on projects also reduce the opportunity to learn, practise and share new knowledge and ideas.

> You … need to allow some time in your project to enable you to have a start up meeting where you can do a bit of a brainstorm or a mind map and … get … those ideas out there. [Ellie:8]

Participants were generally concerned about the impact that shortage of time and resources had on their opportunity to:

- Reflect on past and existing solutions
- Think about possible new designs
- Practise creative thinking techniques
- Engage in group brainstorming and creative problem solving
- Learn smart ways to use existing and new technology
- Consider aesthetic and cultural aspects of design
- Do their job properly

Though the above appears grim, participants suggested partial solutions to the time shortage. Increased research and development (R&D) was one proposition, but managers generally considered it to be a government or construction industry responsibility.

> [The level of R&D in] our industry … is probably stifling innovation and creativity because we are no longer spending dollars. [Lloyd:6]

> [The company] talked about doing [R&D] with academics. It hasn't really come to very much. ... [The industry has] to put serious money into innovation and research in Australia. [Terry:9]

> We used to have a research and development section. … [Those in Head Office] … don't seem to be able to come up with the money to actually employ a group of people … and it's expensive. … They do put serious money into [R&D] in Head Office but they mainly research into [other areas besides civil engineering]. [Terry:9]

On a smaller scale, some project managers recommended building 'slack' time for creativity into project fee structures.

> I haven't tried to [under-quote on my fees] …because I want my fee to be robust … [so that] I can have proper reviews and do the job properly. [James:6]

> You tell the client that [you're] planning on having weekly meetings with [your] staff and. … He [sic] thinks it's … proactive … because he's getting a collaborative approach among the people. [James:6]

According to participants, time, cost and other constraints will continue to pose challenges for engineers who attempt to meet project requirements, and design creatively at the same time. There is a suggestion that under adverse project conditions, creativity and innovation may manifest as smaller, day-to-day, routine and incremental improvements such as cost reductions, smarter work procedures and re-use or combination of previous designs, rather than the needed 'breakthroughs' talked about by managers.

4.4.4 Theme 11: Traditional project management stifles creativity

Participants said that traditional procurement methods with their lowest cost and guaranteed payment methods stifle creativity and innovation. The methods also discourage collaboration and communication, which has a similar effect.

> I'm a critic of traditional lump sum contracting in that it forces you to an outcome without necessarily applying all of the smarts that you can bring to the table. [Brian:4]

> We as a company would certainly prefer to work in … alliance situations than the old traditional [approaches] where people don't always communicate in the best way. [Lloyd:5]

Traditional procurement cultures provide little incentive for innovation and creativity, because they discourage realistic time estimates for completing jobs. This is in contrast to newer forms of delivery such as the 'project alliance' where fees are performance-dependent and project teams have an incentive to be more innovative.

> [Speaking about non-traditional project delivery methods] Having struck those targets at the outset we're judged by those at the end and our fee is adjusted according to how we perform against them. [Brian:3]

> [One or two large projects use newer methods] which [are] different to the other 456 jobs that we do … [in the] year. [Brian:6]

According to project managers the lack of collaboration from the design to construction phase tends to cause 'constructability issues' downstream which lengthens the delivery process as well as increasing costs.

> [With traditional procurement] a lot of times designers miss out on the constructability issues. [James:4]

> [As often the case with traditional project methods] engineers can no longer just walk into a room and say, this is the problem … this is how it's going to be fixed. In every other sphere of our society now we debate all of these issues. [Lloyd:5]

Radical change at the industry level, say project managers and senior engineers, is needed to reverse the above situation.

> I think [change] has to start from the public sector rather than the private sector because they're the ones that in particular, drive a lot of our work. [Kevin:2]

4.4.5 Theme 12: Project alliance principles encourage innovation

Participants generally accuse governments and traditional project methods of stifling creativity and innovation in project work. A popular alternative discussed by managers was the 'project alliance'.

> [The project alliance is] a structured process … with a bunch of engineers and constructors… [the team emerges] … [with a] target cost estimate for the total project. … [The team then goes and builds the job for that or less]. … [I then] …

> implement a process called breakthrough focus … (that's all about setting targets that are beyond the … best outcomes that you would get for a normal project). … Then the team is facilitated to think outside the square; … to achieve those targets. [Brian: 2]

> [The project alliance] I think is absolutely fantastic … you can allow for all those decent type of deliverables where you can do your job properly … The outcomes are all really good, solid and I think all the major clients are realizing that this is the way to go; … they've been burnt in the past with taking [lowest bids]. James:6]

> There are other ways … that do allow for a certain amount of creativity, but I have to say the [alliance] process is the one that sits right at the front; … they definitely have innovation in all of them. [Brian:4]

Participants were enthusiastic about the principles behind the project alliance for several reasons. The project delivery method explicitly encourages innovation and factors in time and cost ('slack') for group and individual activities that are associated with creativity such as brainstorming, reflection and mind-mapping (a creative thinking technique). Alliances thus greatly improve communication, which tends to promote new ideas and approaches.

> That model does lend itself to have more time and money for [creativity, brainstorming and meetings]. [James:7]

> [With project alliances] the innovation may be in the design process or it may be in the delivery process of how it's contracted; … [alliances] all push heavily on innovation and that's why they are successful. [Brian:6]

> It's been proven that [project alliances are] the way to go … [they] engender … open and honest … discussion. … They definitely have innovation in all of them. [Lloyd:5]

When discussing new 'project alliances,' managers suggested that breakthrough innovation is achievable through collaborative techniques such as multi-disciplinary collaboration, facilitation and group brainstorming. This amounts to a type of collaborative creativity which does not necessarily cater for the extra time engineers said they needed to reflect on existing and develop new approaches.

A strong proponent of the method recognized that project alliances may not be the sole answer to cultural change in the industry. The method is a realistic option for about 2 of the 450 annual office projects because to qualify and/or warrant use of the expensive method of project facilitation, the projects must be large, complex and have fees in excess of $20m.

> With an outside consultant … it costs … $50 to $100,000 to [facilitate the alliance]; … some of them cost a hell of a lot more. … They have to be a sizable job with a sizable fee with a … very good chance of us winning … before we'll consider pursuing it. [Brian:5]

> I don't know that [the alliance is] … going to become more commonplace. … I think [there're] two alliances out for tender at this moment …We're not tendering either of them. … [Alliances are really only affordable for the $20 million plus project]. [Brian:6]

However, other managers and engineers suggested that whilst the formal method may be inaccessible in many cases, the principles of project alliances can be transferred to the remaining 450 office projects.

> [The project alliance] … brings with it certain cultural characteristics that are very attractive to apply throughout the organization. … [They] include [the] breakthrough approach that would be a huge benefit to us … in terms of the cultural side … and getting team alignment, leadership commitment … [etc]. There are workshopping and [other] approaches in [alliances] that are very applicable across the board. [Brian:6]

Multiple study sources suggested that the following transfer of alliance and related principles was already underway within the organization. This trend represents an accessible and economical means of building otherwise costly principles and techniques into all projects.

- Projects appoint an innovation champion [Ian, Ellie].
- An 'innovation moment' (reminder) is incorporated into project meetings, e.g. a safety reminder [Roz, Ellie].
- Innovation champions learn and train others in creative thinking techniques [Ian, Brian, Maree, Roz].
- Team selection, facilitation and leadership to achieve strong alignment with project resources and briefs [James, Lloyd].
- Time is allocated for creativity-related reflection and other activities [James, Ellie].
- Multi-disciplinary teams and collaboration are encouraged [Lloyd, James].
- Constructability issues are identified by collaborating with the construction contractor [James, Terry].
- Formal and informal project collaboration techniques become part of the project design culture [Sean, James, Lloyd, Ellie].
- Innovation champions learn, use and train other project members in facilitation and project alliance skills [Roz, Ellie, Ian].
- Smaller projects build time into project work for group and individual creativity [Ellie, James].
- Presentation skills used in project alliances are shared with other colleagues [James, Lloyd].
- Project managers learn to build 'slack' for creativity through negotiation with clients [James, Frank].

4.4.6 Theme 13: Project teams affect creativity

Careful team selection, appropriate leadership style and good collaboration and communication are emphasized by project managers and senior engineers.

> The ideal innovation is using … those old heads and young heads with the new technology to get a solution to jobs. [Lloyd:3]

> We need our young guys combining their good ideas with some proven methodologies of the older guys right back at the bid stage to win us jobs. [Lloyd:6]

Even traditional project styles can be successful when good project management skills, personal style and inter-personal communication skill are used. Nor must the leader be from the project's predominant discipline (suggesting the opportunity to cross-fertilise knowledge and ideas).

> I wouldn't say that the style of contract is the only way … to get creativity and innovation. … It's better assisted with [the project alliance and other methods] but … if you use good project management skills within a normal [traditional] type of delivery it can still be achieved. [James:7]

> We are now attempting to get a lot of our project directors and project supervisors being inter-disciplinary. [Lloyd:3]

> We're … talking about … project managers who are generalists perhaps, but who see the big picture, being put on project teams to … level out … [the] more technically focussed people. [Lloyd:4]

Leaders need to be able to select teams (and cater for each individual differently) so that the varied strengths and personalities can work well together and provide a suitable environment for creativity and innovation. Team selection is not a random process.

> You've got to structure teams together … everybody is different … you've got to talk to everybody very differently and everybody has got different needs and different ways of doing things. … What we should do … is structure people's strengths … to create a better bonding of people, … rather than just saying … who's available at the time and [then] throw them together. [James:9-14]

> We … go to a lot of trouble to create a project team environment; … moving people around our Brisbane office into a section that we're going to dedicate to a particular project; … [generally] breaking down of some of the old silos between branch offices and discipline groups. [Lloyd:3]

Leadership, mentoring, feedback and encouragement (such as the opportunity to learn from their mistakes and a tolerance for reasonable error, and rewarding them in appropriate ways) were valued among participants.

> I always encourage people to have a go at something in the first instance and to come up with an idea themselves. … If you've never made a mistake you've never done anything. Getting things wrong is part of it. [Roger:6-7]

> I think that there's a lot of latitude given to graduates to … make a few mistakes and take a bit longer. [Sean:8]

After conversations with participants and attending company events, it was obvious that the company was making many efforts at the project group level to encourage creativity and innovation by:

- Allocating time for individual and group brainstorming, reflection, and the use of creativity techniques [Ian, James, Ellie, Frank, Kevin].
- Employing communication with a human touch (inter-personal as well as virtual) [Lloyd, James, Greg, Ian, Brian, Maree].
- Selecting teams for diversity in character, expertise and discipline [Lloyd, James, Greg].
- Creating a team work environment that supports collaboration, 'breaking down silos' [Lloyd, Brian, James].
- Transferring knowledge about project alliance principles [Brian, Maree, Ellie, Roz].
- Developing leadership that supports latitude and independent thinking [Roger, James, Sean].
- Developing an overall team culture where people can work, share and celebrate work and social aspects [Greg, James].

- Allowing reasonable considerations for aesthetic and other design improvements in project costing [Kevin, Greg, James, Frank].

The above discussions about diversity and team selection suggest that managers do not expect individuals to change fundamentally. The real task in team selection is to bring differences together through the right mix of talent, experience, inexperience and personality for the given project.

4.4.7 Conclusion

Whilst the industry sets parameters beyond the control of engineers and their managers, the discussion reveals numerous adaptive and creative responses to sometimes quite adverse conditions. Whilst participants generally believe that adversely competitive and cost-focused requirements stifle creativity, their conversations suggest that they are also proactive, pragmatic and philosophical.

4.5 How does the organization support creativity?

4.5.1 Introduction

If the culture of the construction industry is stifling creativity and innovation in engineering design (as strongly indicated by participants), how is the Brisbane office responding to this?

4.5.2 Theme 14: The local culture supports creativity

After reflecting on participants' conversations, there is evidence that the managers, engineers and their colleagues welcome, but also challenge and adapt new ideas and changes, to suit their local office culture. This opportunity to mould their local environment seems very important to the Brisbane office and appears to influence their commitment to innovation.

Several participants recognized that the Brisbane office staff is able to mould external ideas to fit the local culture rather than naively accept or conform to them.

> There was talk of bringing in … [the] SAP [management information system]. … We were … told [by head office] that everyone was going [on to the system] … [but the Australian office scrutinised the system and] found that the [engineering consulting nature of the business] didn't fit [with SAP, so the system wasn't introduced in Australia]. [Roz:11-12]

> The Americans are very gung ho. … Our programs have been running for 13 … year[s]. … The US and the UK … only had their programs for about 2 years, but [it] almost [seemed] like … [there] was … pressure [for] us to change; … we've resisted. [Ellie:12-13]

Participants also demonstrated a pragmatic response to the types of adversity often associated with change. For example, they expressed an ability to 'work around' formal obstacles (such as budgets) in order to sustain support for innovation and creativity.

> We did the [creativity] training workshops. … We decided as a group, that we would … run lunch time sessions to get the information out and try and get people to start using the tools. [Ellie:1]

> There is always money available when you really need it, so [there is] an innovations budget as such. [Ian:10]

> [There are training budgets administered by resource groups]. … If there is something that relates to innovation … then people in that resource group can tackle the resource group leader. [Ian:12]

> [Creativity is] a thing that … people have done all the time but never thought of it in a particular box … but it's something you're always looking for as a manager. … You start to wonder … which is the better assessment … the gut feel one or not. [Greg:10]

Similarly, a tendency among managers and engineers to view project work in a holistic, intuitive and inter-personal manner suggests an ability to adopt broad and contextual rather than narrow and criteria-based perspectives.

> The best [selection criteria for some of these overseas projects] is based on people's personality]. … That would not always [place a high priority on] creativity. … I think it's personality; it's nature … sincerity and being able to work overseas and respect the people you're working with. [Greg:8-9]

> You … need people … [who] have personalities … have personal traits that are desirable in order to win work … do work and get on with each other and celebrate; so it's a whole mixture of things that are absolutely essential. [Greg:14]

Participants value an authentic culture. The Brisbane office is inclusive, caters for individual differences, invites genuine feedback and provides genuine and appropriate forms of acknowledgement. The topic of rewarding innovation was taken very seriously and was discussed formally and informally giving consideration to different tastes and preferences (Source: Minutes of Innovation Meetings).

> [The innovation initiative is not an exclusive thing]. Once everybody in the firm is an innovation champion then we will have achieved the objective. [Ian:13]

> There's a bright idea of the month [award for innovative] … [for] project work [Roz:7].

Compared with other offices in the region, Brisbane has a critical mass of managers and technical experts who have global and regional leadership roles. This broad-based and critical support is considered by Roz to play a significant role in the participants' commitment to creativity and innovation. It also influences the access that the office has to resources for innovation-related activities.

> We’re lucky … having [a company leader] … in Brisbane because it gives us that little bit of a boost along [support and resources]. … [The Brisbane office also has a strong technical leadership in many important infrastructure disciplines]. [Roz:15]

Conversations and other evidence suggest that the local culture allows people to:

- Remain open to new ideas.
- Challenge and adapt new ideas to suit local culture.
- Maintain a pragmatic approach to strategic limitations (e.g. budget).
- Value an holistic and reflective view of work culture and creativity.
- Nurture an authentic office culture, e.g. rewards, diversity, inclusiveness.
- Encourage the type of leadership that supports creativity and innovation.

The office culture described by participants accommodates creativity and innovation. The participants are allowed to challenge and adapt new ideas and are therefore able to develop and sustain an authentic and meaningful local culture.

4.5.3 Theme 15: Resources for creativity are very limited

Study conversations and attendance at innovation workshops suggested that relatively more attention is being given to business improvement than to engineering and design innovation and creativity. Improvements in administrative efficiency can free up time and resources and help to make life easier, but they do not automatically lead to engineering innovation.

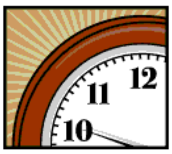
> It can be something very simple; … just make their life easier and makes everybody’s life easier; … it doesn’t need to be engineering. [Ian:8]

> I’d like to see the innovation initiative carried through more to the design work. [Sean:9]

I don’t think we’re quite there yet; … the challenge for us now is how to get [innovation] into the projects … those other 456 projects. [Brian:6]

Figure 4.4 summarizes practices and policies (which I gleaned from conversations with participants and supporting evidence) that were considered to be potentially unsupportive of creativity. Whilst the Brisbane office strongly and explicitly supports innovation, it provides considerably less formal support (resources, time and R&D) for creativity. Though the informal support for creativity is implicit in the engineers’ conversations about their design work, engineers repeatedly express their need for additional time and resources to help them pursue and develop their creative potential.

Figure 4.4: Company practices that are unsupportive of creativity



Company practices that are unsupportive of creativity

- Limited resources for creativity – to reflect on past projects
- Limited resources for creativity – to develop new approaches
- Limited resources for creativity – to consider aesthetics
- Limited R&D and design-focused investments
- ‘Eureka’ or ‘Aha’ myths about creativity and innovation
- Argument that adversity stimulates creativity
- Emphasis on business innovation to detriment of design
- Knowledge silos, remote site isolation, the tried-and-true
- Creativity as single competence - tick in a box, out of context
- Innovation strategy – informal aspects done in own time

Source: Interviews, workshops, Intranet, company documents

4.5.4 Theme 16: Creativity is more than a personal performance measure

It was surprising to the participants and to me that numerous measures of creative personal performance were embedded in the company’s human resource system, as shown in this exchange between Frank and me.

> I've noticed that creativity and innovation has … made its way into the performance evaluation criteria [Marion] -- How did you know that? [Frank] -- I saw it … in the HR … competencies [Marion] -- But how does it get measured? [Frank] -- Do you think that creativity should be a core competence? [Marion] -- [Yes and no], you can't easily transfer it; it's really there as experience. [Frank:11]

Managers and engineers consider creativity to be complex, personal and difficult to measure. Even so, they generally support the idea of encouraging and giving feedback about creative performance:

> If he's [sic] doing that work well that should be reflected in his [sic] performance review, whatever you might call that thing he's [sic] doing. … It should be [a competence]…but not as a separate little box out on the side that's called innovation. [Kevin:11]

> [Recognizing creative performance is] giving encouragement to those … that are palpably creative; … mostly doing new and creative things; ... they're a bit brighter in the sun, even if they have other foibles. [Greg:10]

> I think it's good that [creative competencies are] in there because it's saying that the firm believes this is important; … recognizing it for survival. [Ian:7]

Many who were interviewed recognized the difficulty of assessing a phenomenon which they describe as subjective.

> You can easily quantify how you have contributed to the innovation program ... but it's much harder to show how you've been creative I think; … people are creative in different ways. [Ellie:10]

> Once you've got something [e.g. an idea] down … on paper, it's probably hard to define or show the steps that you went through in getting to that idea. [Ellie:10]

Many participants explained how they would attempt to demonstrate or assess creativity. Their responses revealed holistic, reflective and sensitive discussions which suggested that creativity was more than a human resource criterion.

> [How to demonstrate creativity is difficult] … you could do it by demonstrating that you're applying [creative thinking tools to your work]. [Ellie:10]

> I'd see how they'd done and what they'd done that's been different. Have they come up with better solutions? [Ian:7-8]

> [Creativity's something] that … people have [probably] done all the time but never thought of … in a particular box. [Greg:10]

> You've got to try and be creative. Whether you are, always can be, able to be is a different matter though, because you can't just be creative. Some people will never be creative. You know, it's an intuitive sense. [Frank:8]

> I don't like the word innovation … because I think it's just a fancy sort of box we've … created for what we've always done. [Kevin:3]

Criteria-based evaluation can also be open to misuse. For example, the right person for a particular role might get overlooked in favour of someone who is creative at promoting themselves or who knows someone close to the action.

> People who are close to the senior people might get priority over others who aren't … and there might be some very good people who aren't known, who don't get contacted - wrong place, wrong time. [Greg:13]

> Some people can be very creative about the way they [write] … [criteria based assessments]. … Sometimes the best advice isn't straight down the line, it's someone in the ranks if you like, who you know but respect and you get good advice from. [Greg:13]

Rather than criteria and assessment-based feedback, some participants suggested that informal and genuine feedback and recognition might be a more authentic way of encouraging and rewarding creativity.

> What you really like to hear is someone who you respect saying to you … "Mary Jones is really bright", and … I'd value that more than a tabulated list of someone's creativity and innovation. [Greg:12].

> [The reward for a previous US initiative to reduce bureaucracy was that] … everyone who submitted … got a wooden plaque which said 'congratulations.'… [A colleague reacted by saying] … instead of a plaque I'd rather they give me something else to give to the people. [Greg:6]

Participants suggested a range of non-monetary awards/rewards that might be appropriate, none of which involved explicit recommendations for salary-related rewards:

- Serious consideration and support given for their ideas
- Supervision that offers latitude with supportive feedback
- Genuine acknowledgement in the annual performance review
- Project time allocated for reflection and thinking
- Free time for innovation-related activities
- Consider R&D design initiatives
- Conference attendance and training
- Monthly innovation awards – symbols of recognition
- Flexible working hours to meet individual needs

The study evidence demonstrates that participants are more interested in encouraging creativity and providing feedback and acknowledgement in a variety of informal, genuine, practical and non-monetary ways.

4.6 Conclusions

Chapter 4 presented what the participants said about creativity, their work and the role played by their industry, group and organizational environments. They painted engineering design as an intrinsically creative practice and project management as the principal design setting. The way that the design setting supports and stifles engineering design and creativity is discussed by engineers and managers. There appears to be a focus on cost rather than design innovation, though the participants seemed to recognize that this cost-fixation has negative effects on their creativity. It is also obvious from participants' conversations that their organization plays a significant role in supporting and inhibiting creativity, particularly in the way it allows an authentic informal culture to be sustained.

Chapter 5: Study conclusions: Resolving the creative tension in engineering design practice

5.1 Introduction

In this chapter I present the conclusions to the research study and central research focus: *How do engineers talk about their engineering design work and what does this reveal about their creativity in a project consulting environment?* To achieve this, I:

- Synthesize what participants say are the important creativity-related issues for them and how this compares with the literature
- Summarize the overall contribution of the study to research
- Propose questions for further reflection and discussion

To do this I reflect on the study's four research questions:

- What is the meaning of creativity and innovation for participants?
- How do engineers describe engineering design?
- How does the organization's project environment influence engineering design?
- How does the organization support creativity and innovation?

The discussion is divided into the following sections:

- Introduction
- The study findings: Integrating the participants' understanding and the related literature
- A framework for understanding creativity in engineering design: Overall conclusions
- Conclusion

5.2 The study findings: The participants and the literature

According to this study and related research, organizations with a diverse and domain-specific understanding about creativity are more likely to support intrinsic (innate) and learned creativity, as well as 'Big' (breakthrough) and 'Small' (everyday) creativity and innovation (Amabile, 1999; Basadur, 1993; Giugni, 2001). The study underscores the creativity research by suggesting that engineers need time, resources and supportive environments to incubate and develop small and large breakthroughs in engineering design (Amabile, 1999; Keegan & Turner, 2002; Kimbell, 2002).

By reflecting on the first two of the study guide questions 'What is the meaning of creativity and innovation for participants?' And, 'How do engineers describe engineering design?' it was possible to answer the question '*Is engineering design a creative practice?'* It was therefore possible to better understand what is creative about engineering design and what engineers, groups, organizations and the industry can do to help develop engineering design potential.

5.3 Is engineering design a creative practice?

5.3.1 Describing creativity in engineering design

At the Brisbane office of the study organization an onlooker might observe mindfully engaged professionals with their heads down, in a sea of differential equations, flipping back-and-forth between their design tools, sketches and short conversations with colleagues. Without saying a word to the engineer, you might suspect that engineering design is a step-by-step and logical routine based on a science and practice that is analytical and exact, a view surprisingly common in the engineering literature, but erroneous according to a small group of increasingly cited engineering authors (Ferguson, 1992; Kimbell, 2002; Gelernter, 1998; Schon, 1991, 1983; Tornkvist, 1998).

But when I spoke to the office engineers about how they conceived of and developed their designs, there was little mention of tools and calculations, mathematics or analysis. Their design is inspired up-front in the mind's eye and reflected upon with notes, pencil sketches and rule-of-thumb calculations. At a point where a design has some authenticity, engineers subject it to the test of engineering science – analysis, testing and modelling – a process which is iterative and intuitive rather than an exact. This is the practice described by many authors (Bailey, 1978; Ferguson, 1992; Kimbell, 2002; Schon, 1991, 1983).

Engineering design is by no means synonymous with science for the Brisbane engineers, who suggested by their descriptions that the rigour might come less from science, and more from art – the iterative combination of reflective and intuitive practices grounded in, but not superseded by, the laws and principles of physics and geometry. Their discussion about aesthetics and sustainability, and the perceived need for time to reflect on and incubate new ideas, cements my impression that design (for these engineers) is unequivocally and intrinsically a potentially creative practice. (This creative practice is characterised by the many features summarized in Appendix C: *A description of the engineering design practice, as reflected in conversations with engineers from the study organization*.

The participants' accounts are typical descriptions of engineering design in the study organization, and dispute some public and engineering perceptions that engineering is rigorously scientific, exact and unimaginative (Bernstein & Lemer, 1996; Keegan & Turner, 2002; Schon, 1991, 1983). The finding is revelatory, in my view, because apart from a small, frequently cited section of the engineering education literature, design is not described in ways that resemble creative tasks, nor is the word creativity explicitly used in discussions about design innovation (Chakrabarti, 2002, p. 147; Gelernter, 1998; Kimbell, 2002; Powell, 1970; Schon, 1991, 1983; Tornkvist, 1998).

5.3.2 Creativity and the importance of design context

It is unsurprising that outside of their design practice, study participants struggled to express their wide-ranging views about a phenomenon (creativity) which according to creativity research is complex, multifaceted and intrinsic (Amabile, 1988; Nickerson, 1999; Sternberg & Lubart, 1999). This was noticeable when creativity was discussed as a personal performance competency and understandable given the research that highlights the negative effects of being overly critical about creativity (Amabile, 1988, 1987; Basadur, 1993).

No similar struggle was apparent when the study engineers talked about their design work, where design was implicitly discussed in ways that authors describe palpably creative design practices such as architecture, landscape design and urban planning (see Gelernter, 1998; Landry, 2001; Schon, 1991, 1983). In the design context, the study engineers portrayed design as a whole creative practice influenced by personal, group, organizational and industrial factors. This is highly consistent with the literature that describes creativity as holistic and multi-faceted (Bailey, 1978; Isaksen, 1987, cited in Firestien, 1993, p. 262; Sternberg & Lubart, 1999), and the construction research suggesting that unsustainable cost, conservative procurement practices and other pressures are impeding engineering innovation and creativity (ACIF, 2003; CEDA, 2004; McLeish, 2004; UK Dept. of Trade & Industry, 2002; UK Government, 2004).

I suggest that the authentic practice and experience of creativity in engineering design is unveiled at the design face, the point at which engineers and colleagues are engaged in the act of doing the design. In my perception, the study engineers' discussions about their design work revealed an authentic and complex account of the creative experience for them. This is because they described design and creativity in a familiar and meaningful context, that is, authentic, genuine and less abstract for them. This context enabled them to intuitively understand creativity without having to explain it in words. In my view, when engineers discussed their design work in this way, they illuminated what creativity meant for them and the myriad of potential influences upon it.

The engineers' message is endorsed by recent holistic research about organizational creativity (Amabile, 1999; Andriopoulos, 2001; Giugni, 2001; Sutton, 2001). Organizations that perceive creativity as a whole experience are more likely to recognize the multiple and diverse influences on creative potential (Csikszentmihalyi, 1999; Giugni, 2001; Sternberg & Lubart, 1999; Sutton, 2001; Wheatley & Kellner-Rogers, 1996). They are thus more likely to develop meaningful (and authentic) work environments in which creativity and innovation are nurtured (Basadur, 1993; Herda, 1999; Wheatley, 1999a). Despite growing research evidence, however, holistic explanations of creativity are uncommon in the engineering literature (Bailey, 1978; Kimbell, 2002; Schon, 1991, 1983). Where creativity is discussed in engineering, the focus is on the cognitive elements of creative problem finding and solving (Court, 1998; Eide et al, 1998).

5.3.3 The relationship between design innovation, creativity and 'slack' resources

In their stories about design, the study engineers described mainly small, personal and incremental developments in design, enabled by technology and motivated by the constant pressure to deliver within constrained budgets and ever-shortening time-frames. There is little suggestion that breakthroughs manifest as flashes of inspiration without time and investment and sustained work commitment (see Ch.2, pp. 33-35 for a discussion about the 'Eureka' myth). The need for reflective time and experiment is repeatedly emphasized but not experienced by many engineers; something that they suggest inhibits their opportunity to investigate better, more aesthetic and innovative design solutions, and leads them towards tried-and-tested methods. In the creativity research, the lack of time for reflection, learning and R&D, is considered to be one of the most significant impediments to creativity (Amabile, 1999, 1987; Basadur, 1993; Giugni, 2001):

> The pressure created by time restrictions may be more immediate in its effects on creativity than any other extrinsic constraints. With strong implicit or explicit deadlines, people may be paralysed from working at all. (Amabile, 1987, p. 244)

This is further supported by the R&D literature in which creativity is associated with longer term inventions and breakthroughs (Keegan & Turner, 2002; Nonaka & Takeuchi, 1995; Shapiro, 2001), recognized in the construction literature (ACIF, 2002; CEDA, 2004; Martin, 2000), but currently inhibited by endemic disincentives in the construction industry (see Appendix D). Hence the industry condones a type of treadmill imperative towards cost innovation (cost reduction) allowing little room for the incubation and experimentation historically associated with sustained, breakthrough innovation and invention (see Ch.2, pp. 51-52).

5.3.4 The study's contribution to understanding creativity in engineering design

The study engineers' representation of design as creative, reflective, holistic and contextual, is in my opinion surprising and revelatory, because what they say is consistent with a relatively small and increasingly cited section of engineering research that describes engineering design as more than a cognitive and linear science (Ferguson, 1992; Gelernter, 1998; Martin & Schinzinger, 1996; Schon, 1991, 1983; Tornkvist, 1998). The study could provide a critical case for these authors because it reinforces a story about engineering design which is uncommon, that design is a whole creative endeavour combining artistic sensibility and scientific understanding (Kimbell, 2002; Schon, 1991, 1983).

Construction industry research focuses on collaborative and cognitive creativity and innovation driven by project alliances (Court, 1998; Eide et al, 1998; Wiese & John, 2003). The Brisbane study extends this understanding, by reinforcing the importance of time and resource-related activities that support creativity-inspired (as opposed to cost or business process-driven) innovation. The relationship between creativity, innovation and R&D is more widely acknowledged in the general research about creativity and R&D literature (Amabile, 1999, 1987; Basadur, 1993; Giugni, 2001; Weisberg, 1999).

For the Brisbane organization, it might be good news to know that engineering design is intuitively experienced as a creative practice by engineers and managers. It may also be welcome news that the study engineers are committed to and constantly searching for opportunities to use their potential. The news that this might require company and project investment in 'slack' time and resources may be less welcome, but nevertheless an opportunity to engage in reflection and creative thinking at the leadership level and design face, to address how this 'slack' might be built into the project design experience.

5.4 How does the organization's project environment influence engineering design?

5.4.1 Project environment, industry culture and design innovation

The study's third guide question was given serious consideration within the Brisbane office: *How does the study organization's project environment influence engineering design*? The study engineers suggest unequivocally that the construction industry is the most direct influence on their work. After all, it is where work is procured, specified and where the industry culture is adopted by default. The highly competitive, cost-focused and traditional procurement environment provides limited opportunity for the Brisbane engineers to exercise creativity. It also limits the ability of managers to invest time and resources in creativity-related design issues (such as aesthetics, culture, sustainability and energy efficiency). Time, for engineers and managers, is the most critical factor in design creativity and innovation, as well as a luxury which seems outside their control. Amabile (1987) states that time is the most critical factor in organizational creativity.

Recent construction research describes a similar industry culture, one that reduces the incentive for engineers to be creative in design. Appendix D: *A* *description of the construction industry: The relationship between industry culture and innovation and creativity,* summarizes these features and implicitly spells out wide-ranging needs for change. Recent construction research reveals an awareness of the endemic disincentives towards creativity in the industry and possible bases for change (ACIF, 2002; CEDA, 2004; McLeish, 2004; UK Dept. of Trade & Industry, 2002; UK Government, 2004). These solutions promise solid and inclusive, flexible and long-term foundations for creating a supportive global environment and culture of creativity and innovation in construction (ACIF, 2002; Martin, 2000; UK Government, 2004).

The Brisbane office engineers are aware that innovation is an imperative in the industry, but for engineers who are busy at the design face, innovation can mean anything that promises a competitive lead – small or big, creativity or cost-inspired. Currently within the Brisbane office, industry-driven cost innovation and business process innovation are receiving disproportionate attention, compared to engineering design innovation. In the innovation literature, investment in incremental, breakthrough and business process innovation is considered an important part of innovation strategy (Edwards, 1986, p. 222; Gaynor, 2002; Keegan & Turner, 2002; McLeish, 2004; Shapiro, 2001; West & Farr, 1990). However, cost and business process improvements or innovation are easily emulated by competitors (Porter, 2000; Shapiro, 2001; West & Farr, 1990). A focus on cost innovation, for example, at the expense of creativity-inspired or technology-driven innovation, can encourage a short-sighted interpretation of invention, innovation, creativity and the breakthrough process (Drucker, 2002; Edwards, 1986; West & Farr, 1990).

Research demonstrates that idea generation, business process improvement and collaborative creativity alone are insufficient catalysts for long-term design improvements (Kimbell, 2002; West & Farr, 1990). Focused and flexible R&D is associated in research with novel, valuable and longer term breakthrough changes, capable of impressing themselves upon the profession and the industry and cementing ‘real’ competitive advantages (Drucker, 2002; Nonaka & Takeuchi, 1995; Shapiro, 2001).

The company’s innovation strategy and informal initiatives reflect the Brisbane office’s serious attempts to understand and promote innovation by covering all bases. This and the recent surge of community interest in construction industry change (UK Dept. of Trade & Industry, 2002; UK Government, 2004) and creativity-inspired innovation (Kimbell, 2002; Tornkvist, 1998) could be a timely opportunity for the Brisbane office to direct some of its grass-roots energy and senior leadership commitment to discussions about how to achieve innovation in engineering design (perspectives, methods and materials). The awareness of Brisbane office staff about design creativity, coupled with the critical mass of senior leadership support and grass-roots support, provides an invaluable reflective base to formulate a new role for company R&D and similar activities, which might inspire creativity-led, rather than cost or business process-driven innovation (see Nonaka & Takeuchi, 1995; Shapiro, 2001; West & Farr, 1990).

5.4.2 Project design and ‘Eureka’ innovation

The study engineers appeared most directly affected by time-related creativity issues. However, even engineers and project managers involved in better funded project alliances seem attracted towards a type of ‘collaborative creativity’ highlighting design facilitation, multidisciplinary collaboration and group brainstorming. This focus on ‘collaborative’ and cognitive creativity among project managers might be expected given its emphasis in construction innovation research (Bower & Merna, 2002; Burghardt, 1999; Cavallucci, 2002; Court, 1998; Dozier et al, 1996; Eide et al, 1998; Wiese & John, 2003).

The expectation that multidisciplinary environments will generate spontaneous, automatic or serendipitous breakthroughs is common in the construction literature, particularly in discussions about project alliances and collaborative technologies (Bower & Merna, 2002; Court, 1998; Dozier et al, 1996; Farrell &

Watzke, 1997; Love & Gunasekaran, 1998; Wiese & Jones, 2003). However, the research about collaborative technologies, project alliances and group creativity is not explicit about the process relationships between collaboration, creativity and design innovation (Maliniak, 2001; Paton, 2002). This could be a misplaced suggestion (in the study and the construction literature), that 'collaborative creativity' and project alliances, by themselves, are able to generate 'Eureka' style breakthroughs in innovation. This interpretation, according to the creativity literature, would down-play the value of the individual creative process, person, practice and related creativity investments and environments, necessary for innovation (Amabile, 1988; Edwards, 1986, p. 222).

It is not surprising, then, that creativity goes largely unnoticed in engineering innovation research and practice (Chakrabarti, 2002, p. 147; Kimbell, 2002; Powell, 1970). An interesting question for reflection by the Brisbane Office engineers and Innovation Champions might be: *To what extent is design innovation associated with spontaneous bursts of genius and inspiration, rather than focused, time and resource-intensive personal input?* (for a detailed discussion about the 'Eureka' myth see Edwards, 1986, p. 222).

5.4.3 Collaboration, design innovation and the project alliance

The study's project managers are optimistic about the potential for new project procurement methods (such as the project alliance) and transferring their principles to smaller projects. However, the myriad of creativity-related benefits ascribed by the study's managers (and the construction literature) to the project alliance method are inaccessible to the majority of small to medium sized projects unable to afford the costly facilitated tendering process involved.

Whilst some empirical research about project alliances suggests that creativity and innovation are encouraged by collaboration and slack for brainstorming (Bailey, 1978; Court, 1998; Wiese & Jones, 2003), there is little evidence that alliances by themselves increase the levels of creativity-related investments associated with the development and incubation of innovative solutions (Keegan

& Turner, 2002; Nonaka & Takeuchi, 1995). It is understandable with the complexity of modern engineering, and the emphasis on efficiency in industry, that collaborative techniques would be viewed by many authors as a cost effective substitute for R&D and other creativity-related activities (see discussions by Bower & Merna, 2002; Court, 1998; Dozier et al, 1996; Farrell & Watzke, 1997; Love & Gunasekaran, 1998; Wiese & John, 2003).

5.4.4 The engineers' response to construction culture

The participants suggest that a consequence of the prevailing industry culture is that engineers manifest their creativity as smaller improvements in work process and technologies, and the over-use of tried-and-tested methods, rather than new or breakthrough approaches associated in the literature with purposeful investment and time for reflection (ACIF, 2002; Gaynor, 2002; Keegan & Turner, 2002; Nonaka & Takeuchi, 1995). Conversations with the study's senior managers suggest that they are implicitly seeking breakthroughs in the design process as well as improvements in business processes (the latter are less related to creativity) (Bernstein & Lemer, 1996; Gaynor, 2002).

The engineering industry literature focuses on business process, cost and information technology (IT) innovation (such as collaborative design, publishing and project management) (see Adhikary, 2001; Maliniak, 2001). This is quite distinct from creativity-led design innovation (see Bower & Merna, 2002; Dozier et al, 1996; Farrell & Watzke, 1997). The creativity and business literature widely supports the view that creativity-related investments are associated with innovation (Edwards, 1986, p. 222; Gaynor, 2002; Shapiro, 2001; West & Farr, 1990).

Chapter 4 outlined the variety of ways in which the Brisbane engineers and project managers respond to industry adversity, suggesting pragmatism, flexibility and tenacity. But the engineers generally accept the status quo. A few engineers and managers reflected beyond the organization, however, to suggest that industry culture and related government policies need changing. The literature endorses this view and provides an inspiration for the Brisbane office to continue to think about ways they can lobby for change and create conditions, opportunities and incentives for creativity and innovation (ACIF, 2002; McLeish, 2004; UK Dept. of Trade & Industry, 2002; UK Government, 2004)

Though the construction literature is fragmented about the paths towards change, recent research shows a general consensus about the need for change, the type of changes required and the vehicles towards achieving this. These discussions may be encouraging to the Brisbane engineers (ACIF, 2002; CEDA, 2004; McLeish, 2004; UK Dept. of Trade & Industry, 2002; UK Government, 2004).

5.4.5 The study's contribution to understanding creativity in the project environment

The study participants, and recent construction innovation research, have progressively informed my understanding that engineering design innovation is more than 'collaborative creativity' and 'Eureka' moments, though collaboration and group creativity no doubt contribute to engineering innovation (Bernstein & Lemer, 1996; Rickards & Moger, 2000; Wiese & John, 2003; West & Farr, 1990). Design innovation (according to participants and recent industry discussions) depends on more than the project alliance, creativity training for groups, improvements in business processes and other valuable expressions of high level commitment to innovation and excellence (see ACIF, 2002; UK Dept. of Trade & Industry, 2002; UK Government, 2004). Creativity-led innovation appears to involve big and small scale creativity, involving efforts at the individual, group, company and industry level (Csikszentmihalyi, 1999; Gaynor, 2002; Keegan & Turner, 2002). It also appears to require an appropriate blend of traditional and contemporary R&D and related investments, tailored to the needs of creative work (such as engineering design) (Basadur, 1993; Nonaka & Takeuchi, 1995; Shapiro, 2001).

The Brisbane study suggests that industry pressures to continually lower costs without the aid of research and creativity-inspired innovation tend to inhibit creativity by motivating people to work faster and develop time-efficient work procedures, thus motivating smaller, personal levels of creativity important to help them survive. Reliance on collaborative creativity tends to rely on 'Eureka' type moments, which the literature does not recommend as a basis for company investments in long term, creativity-led innovation (Edwards, 1986; Gaynor, 2002; Nonaka & Takeuchi, 1995). Larger scale, breakthrough or industry-significant innovation requires strategic and purposeful investments and risk-taking (Gaynor, 2002; Nonaka & Takeuchi, 1995; Shapiro, 2001).

5.5 How does the organization support creativity and innovation?

5.5.1 Democratic and supportive leadership

The Brisbane study is an example of the powerful influence that meaningful project and organizational leadership can have on people working in demanding, competitive and sometimes adverse industry cultures. The study's fourth guide question is important in uncovering the ways in which the Brisbane office supports creativity and design innovation: *How does the study organization support creativity and innovation?*

The consultative, democratic and appreciative culture of the Brisbane office gels the staff's commitment and morale, particularly at times when resources are scarce, and innovation is voluntary. The value of this culture is reinforced by conversations with project and senior managers and participants, and widely associated in creativity and management research, with innovation and creativity (Amabile, 1999; Basadur, 1993; Nonaka & Takeuchi, 1995; Rickards & Moger, 2000).

Describing how they lead, managers reveal an approach to leadership, team alignment and personal performance which allows them to embrace complex issues (such as industry adversity, resource scarcity, engineering excellence and innovation) in holistic, reflective, diverse and pragmatic ways. Democratic communication is valued above bureaucratic control systems, and the diverse needs of individuals above formalised systems and strategies (such as performance review). Balancing individual autonomy with latitude and leadership is embedded in their skill and intuitive understanding about diverse and successful teams – a surprising emphasis on the 'soft' or people issues. Their intuitive understanding of the relationship between knowledge, diversity and creativity is associated (in the creativity literature) with organizations that support creativity and innovation (Amabile, 1988; Simonton, 1999; Weisberg, 1999; West & Farr, 1990). The study findings about project leadership and creativity are consistent with research about group creativity (Amabile, 1999; Rickards & Moger, 2000; Sutton, 2001; West & Farr, 1990) and organizational creativity (Amabile, 1999; Basadur, 1993; Giugni, 2001; Sutton, 2001).

The most serious leadership challenge the Brisbane managers face is not the commitment of their team members, which is widespread, but their ability to source the 'slack' time and resources which contribute to innovation. Faced with adversity and ambiguity (such as the need to lead innovation with undefined budgets), they use their expertise, skill, intuition and emotional intelligence to access resources for creativity, a practice which in the literature is demonstrative of meaningful support for creativity (see Giugni, 2001; Simonton, 1999).

The Brisbane office appears to have a critical mass of highly experienced leaders who engage leadership qualities increasingly recognized by new management science (Drucker, 2002, 1995; Kennedy, 2001; Mumford, 1996; Wheatley, 1999a), the ability to respond appropriately to complex and ambiguous situations. The critical mass is more than technical excellence and life-long learning. The leadership appears to have an intangible quality – philosophical, adaptive, intuitive and authentic – a type of leadership that reflects a simultaneous understanding of the local people's needs, and the wider needs of the company's global project consulting business (see Schon, 1991, 1983; Wheatley, 1999a).

In the Brisbane study, project and senior leadership is thus the type which in the traditional and contemporary literature is associated with organizations that support creativity and innovation (Amabile, 1999; Basadur, 1993; Giugni, 2001; Herda, 1999; Sutton, 2001; Wheatley, 1999b). This description of leadership (strongly associated with research about organizational creativity) is potentially informative for engineers and managers, because the pressure to perform, excessive restrictions on personal autonomy and an extrinsic basis to motivating and rewarding creativity are all known to stifle creativity (Amabile, 1988; Basadur, 1993).

5.5.2 Authentic local culture

The supportive (intelligent, reflective, intuitive and creative) leadership demonstrated in Brisbane's critical mass of senior Brisbane managers and technical leaders is (according to the study's findings) a critical feature of the organizational context for design creativity and innovation. In a resource-stretched project culture with insufficient 'slack' for developmental activities, participants value an authentic and supportive local office culture which they have the opportunity to help mould to meet their diverse and authentic needs (see Ch.4, pp. 146-149). The company innovation initiative and its ever-present and demonstrated commitment by senior leadership is an indication of a serious commitment to improving the office and design environment, even though engineers would like to see engineering design innovation given more emphasis. This culture of genuine support and appreciation among senior leadership for the authentic needs of the Brisbane individuals, is (I suggest) an explanation for the high levels of unconditional and voluntary commitment to innovation-related activities, a commitment which is not taken for granted, however. Managers and engineers increasingly discuss how they can secure time, resources and developmental funding (Amabile, 1988; Nonaka & Takeuchi, 1995; Shapiro, 2001) which they know is needed to sustain the current involvement, and which the R&D literature states is fundamental to innovation (Drucker, 1995; Nonaka & Takeuchi, 1995; Shapiro, 2001).

After reflecting on the creativity issues for the Brisbane office, I suggest that the informal culture, support and practices have a profound influence on the morale, motivation and satisfaction of engineers and other staff. Even though most of the formal identifiers of large and progressive organizations are evident in Brisbane, (vision, strategy, procedures, performance, benchmarking and innovation), the informal support, practices and intrinsic factors seem to be valued as much (if not more) by engineers and their colleagues. This is exemplified in the participants' opportunity to challenge, test and adapt new ideas (no matter how faddish) to suit their local cultural needs. For a reflective organization, this may be the most important means of sustaining grass-roots commitment towards company initiatives. This is highly consistent with the new management literature which reinforces the foundational importance of authentic and meaningful work cultures, where people can have their need for autonomy, valued contribution and work satisfaction taken seriously (Handy, 1999, cited in Kennedy, 2001; Herda, 1999; Mumford, 1996; Steiner, 2002; Watts, 2001; Wheatley, 1999b).

5.5.3 Resources, knowledge and creativity

The Brisbane office mostly supports and sometimes inhibits design creativity. However, its culture of investing in learning and excellence, collaboration, diversity and people-orientation, and design and information technology excellence, reflects a genuine understanding of the role of knowledge and learning. Even though creativity tends to be more explicitly associated with creative thinking (CT) training and brainstorming (see Ch.2, pp. 39-41), it may be of value to the Brisbane office to know that the creativity literature generally considers life-long knowledge and learning to be more important than training in creativity thinking, particularly in knowledge-intensive domains such as engineering and architecture (Amabile, 1999; Weisberg, 1999; see also Ch.2, pp. 29, 48-49, 66-68). Without engineering and related domain knowledge, it is doubtful whether creativity techniques and brainstorming would support short and long term domain-specific creativity (Amabile, 1988; Margolius, 2003; Weisberg, 1999).

There is general agreement within the office of the importance of time and resources for creativity and innovation, which in the literature is widely associated with breakthrough or creativity-inspired innovation (Edwards, 1986, p. 222; Gaynor, 2002; Keegan & Turner, 2002; Kimbell, 2002; West & Farr, 1990). The difference between this type of innovation and cost and business process innovation has been well established in this study.

5.5.4 Understanding the role of creativity in design innovation

The study's evidence shows that the participants understand engineering creativity best in the design context, and least in abstract discussions about creativity definitions and performance competencies. The study also suggests that Brisbane office staff intuitively understand the time and resources needed to help them turn their individual and group potential into innovation. The qualitative research literature supports the applicability of the study's approach to creativity (Creswell, 1998; Herda, 1999; Patton, 1990) and provides evidence to participants that their intuitive and implicit understandings about creativity in their engineering practice are of considerable value in sensing the meaning of this complex phenomenon. Being able to sense meaning in this way is an important step towards being able to understand the personal, group and organizational practices that support creativity and other desirable work experiences (Herda, 1999; Steiner, 2002; Watts, 2001).

The Brisbane response to the complex issue was diverse and appropriate for the complex phenomenon (creativity), which the literature suggests is impossible to reduce to single, abstract and simplified criteria or measures (Nickerson, 1999; Patton, 1990; Watts, 2001). Participants are thus open to reflective and holistic ways of understanding and providing feedback about creativity and related complex phenomena. This is significant, because the Brisbane managers supervise by encouraging the development of the whole person and their potential, rather than by focusing on a few criteria listed in the human resource system. This failure to over-evaluate creativity is highly consistent with organizational cultures which support the intrinsic motivation towards creativity and work satisfaction (Amabile, 1998, 1987; Basadur, 1993; Kimbell, 2002; Wheatley, 1999b).

5.6 Reflections about creativity in engineering design: The research study

5.6.1 The research context

The study revealed a potentially valuable, holistic and meaningful context for understanding creativity (one not widely used), and its contribution to innovation in engineering design (for a discussion about holistic methods for studying creativity see Patton, 1990, p. 130). In unveiling engineering design as a rich contextual mix of science, art and intuition, the study participants uncovered numerous intrinsic and creative elements of the practice, many which were inadequately expressed in words, definitions and abstract measures. The methodology used in this study maintained a focus on participants, how they did their design work and the environmental influences on it, doing this largely through conversation. The study engaged people in aspects of their design and leadership work which represent the act of doing (rather than thinking). Thinking is more abstract and arguably less appropriate for representing the essence of the design and leadership experience. The study conversations and involvement in company activities appeared to be an appropriate way of uncovering the meaning of creativity in the context of engineering design.

The concept of design as a creative practice and as research (experiment and learning) is increasingly supported in the literature (Herda, 1999; Patton, 1990; Schon, 1991, 1983). Creativity is domain-related and contextual and understood intuitively (often insufficiently in words) (Amabile, 1988; Patton, 1990). Objective survey instruments are of limited assistance in understanding creativity in a design practice such as engineering, because they can strip context from creativity, leaving a set of definitions, traits and criteria (see Patton, 1990, p. 130). The study shows how creativity can be uncovered by understanding the whole professional and work practice, rather than singular aspects of it, such as divergent thinking. The value of allowing people to talk about their design experiences cannot be underestimated in conceiving, developing and sharing design ideas and innovations.

5.6.2 The research content

The study developed new knowledge about engineering creativity by bringing existing but disparate ideas together, creating new possibilities for describing and interpreting the complex creativity phenomenon in the engineering design consulting context. The study drew together complex concepts (such as creativity, innovation, design and knowledge) from multiple disciplines. This helped to lay foundations for an authentic description of engineering design, (hence engineering creativity), for the study organization. Prior to and throughout the Brisbane study, I had uncovered only two references in which contextual case studies were the preferred approach for studying the meaning (rather than measured value) of creativity in science-based design practices (see Amabile, 1988; Patton, 1990, p. 130). The Brisbane study extended the work of these authors by exploring engineering creativity at the personal, professional, group and organizational levels. By placing the study in the context of the global knowledge economy, it also provided a contemporary interpretation.

Issues which seemed under-represented in the construction innovation discussions earlier in the study were receiving limited clarification in the literature by the study's completion (see CEDA, 2004; McLeish, 2004; UK Government, 2004). These issues include the need (in my view) to distinguish between cost and design innovation, and the need to understand the 'Eureka' myth about innovation (see Ch.2, pp. 33-35).

The knowledge contribution made by the study (in my view) is as follows:

- **Research methodology**: The importance of emerging qualitative case study approaches in understanding complex phenomena such as creativity and design.

- **Engineering design**: The complex, creative and contextual nature of engineering design.
- **Engineering design**: The creative, reflective and intuitive aspects of the engineering design practice.
- **Investment in learning**: The importance of investing in knowledge and learning-related activities that support engineering design creativity and innovation.
- **Creativity**: The importance of understanding the myth of 'Eureka' creativity and innovation and its possible role in recent R&D investment behaviour in the construction industry.
- **Innovation:** The importance of creativity-led as distinct from cost or business process innovation, in sustainable innovation and breakthroughs.
- **Human resources**: The importance of individual development as well as collaborative practices and activities in motivating creativity-inspired innovation.
- **Construction industry**: The importance of grass-roots change in the construction industry culture.
- **Leadership**: The importance of sustained, sincere and supportive senior leadership in motivating people to develop their potential.
- **Local culture**: The importance of an authentic and adaptable local office culture
- **Value to the study organization**: The knowledge and insights gained by the study participants about creativity, its relevance to engineering design practice and the ways in which individuals, groups and the organization can motivate rather than inhibit creativity.

5.6.3 Research reflection

Schon (1991) emphasizes the importance of personal and professional reflection in the ongoing development of professional knowledge. The value of professional reflection was evident among managers and engineers in the study, with an unexpected importance placed on individual and collaborative reflection about past designs and future possibilities. The study raises a number of possible questions for reflection (outlined below) about issues for creativity in the industry.

5.6.3.1 Question 1: How can engineers help change industry culture?

The Brisbane study confirmed what is found in recent construction industry literature, that an out-dated and cost-fixated industry culture is stifling creativity and innovation in engineering. A question of possible interest to the company's engineers and managers is: What can the company do individually or collectively with others in the industry to lobby for changes in the industry; changes that are likely to motivate engineers, companies, clients and governments to use their creative potential, as well as to appreciate the investments and conditions that support creativity and innovation in the industry? The U.K. Government Sustainability Website mediates a forum in which members of the construction industry contribute their views about construction industry change (UK Government, 2004; http://www.sustainable-development.gov.uk/consult/construction/response/7.htm). The forum is an opportunity for professionals worldwide to contribute to and learn about salient construction industry issues such as sustainable change, creativity and innovation.

5.6.3.2 Question 2: How can the Brisbane office invest in creativity and design-inspired innovation?

The study also confirmed construction industry discussions that members of the engineering industry are extremely reluctant to make investments in activities that the creativity research suggests are conducive to breakthrough creativity and innovation. It also confirms that there is a preoccupation with cost innovation (as distinct from engineering design innovation). The company's engineers and managers may wish to consider this question: With the overwhelming focus on cost in the industry, how can engineers and managers help to turn the emphasis towards investments in time, resources and approaches which encourage design and creativity-inspired innovation (and possible breakthroughs in engineering design)? In competitive terms, how is creativity-inspired innovation preferable to a fixation on cost and business process innovation? These are significant questions, because in the knowledge and creativity literature higher rates of

R&D are associated with breakthrough innovation and long term competitiveness (Keegan & Turner, 2002; Nonaka & Takeuchi, 1995).

5.6.3.3 Question 3: How can engineering educators teach engineering design as a creative practice?

The concern expressed in the engineering literature about the inadequacies of engineering design education, and the lack of awareness about the intrinsically creative aspects of the engineering practice (see Ferguson, 1992; Gelernter, 1998; Kimbell, 2002; Tornkvist, 1998; Schon, 1991, 1983), was not reflected in the Brisbane study. Engineers at the company may wish to consider this issue and contemplate the question: What changes can be made to formal and continuing education to allow engineering design to be perceived and practised as an intrinsically creative practice similar to architecture and urban design? What is a suitable context for studying and understanding creativity in design-based practices such as engineering? How can engineers continue to learn about creativity and its role in engineering design and innovation? If changes are needed in engineering education, then the contribution of practising engineering professionals is vital.

5.6.3.4 Question 4: What role does creative thinking training play in creativity-inspired engineering design?

Both the construction literature and the study participants placed more emphasis on creative thinking and training than any other facet of creativity. Yet the study revealed multiple aspects of the creative experience that are likely to influence design creativity and innovation. These include the people involved and their attributes and preferences, the nature of the creative process, the aspects of creative product and the group, organizational and industry environments, which simultaneously influence the way engineering practice is carried out. The current western global attention on creativity as a business and cultural imperative (see Florida, 2002; Kennedy, 2001; Landry, 2001) has caused a resurgence of interest in old and new creative thinking techniques. The managers at the Brisbane office also expressed interest in creativity training investments and outcomes. A question of possible relevance for the engineers and managers is: What potential role does creativity thinking and training play in engineering design education? What other investments are likely to affect engineering design innovation and creativity? How can these investments be prioritised? These questions are potentially important ones, because there is a proliferation of creativity training techniques (varying in cost and credibility) (see Sternberg et al, 1997), and companies may need to decide on the following:

- What are the ways a company can support creativity?
- How important is creativity training in this support?
- What are credible and peer-reviewed techniques for improving creative thinking ability?
- Is the investment in creativity training disproportionate to other widely recognized foundations for domain creativity such as knowledge and learning, and intrinsic and extrinsic motivational factors?

5.7 Conclusion

5.7.1 The study

The study topic evolved out of a twenty year understanding about engineering consulting and my observation that creativity was rarely mentioned in the construction innovation literature. A timely opportunity to research the topic in a global consulting engineering firm led to an in-depth study about the nature of creativity in engineering design and the project and company cultures that influence it. The central focus was the question: *How do civil engineers talk about their design work and what does this reveal about their motivation to exercise creativity within a project consulting environment?*

5.7.2 The focus

The literature revealed an abundance of research about creativity and innovation in the education, psychology and management disciplines. Only a small group of engineering educational authors linked engineering design to creativity; even fewer linked creativity to design innovation. The largest gap in the literature about the research topic was uncovered in the construction industry literature, where creativity was hardly discussed except for references to brainstorming. In this research, engineering design was neither discussed as a creative process, nor was it linked to discussions about construction or engineering design innovation. A review of creativity, engineering and management research (see Chapter 2) allowed a conceptual framework to be established for the single case study.

5.7.3 The case study

The single case study strategy and its philosophical assumptions were detailed in Chapter 3. The chapter identified appropriate methods for identifying, sourcing and managing field information, after which it provided guidelines for analyzing, interpreting, authenticating and reporting the study's findings. The nature of creativity and design, being complex, contextual and ill-defined, favoured an interpretive qualitative study as an appropriate way of exploring the authentic meaning of the phenomena for the study participants. In-depth conversations, participation in company events, and reviewing company documents and systems allowed a holistic and developmental approach to uncovering meaning. The multiple sources also assisted in authenticating (or corroborating) the research findings. The numerous interpretive cycles (of reading, analysis, annotation and interpretation) allowed the progressive unveiling and synthesis of themes. The most revelatory aspect of the study (in my view) was the finding that engineers revealed most about engineering creativity by simply talking about how they did their design work. This was pivotal in uncovering their experiences of design and creativity, free from limiting definitions and concepts.

5.7.4 The findings

The study's findings and conclusions were presented in Chapters 4 and 5. Chapter 4 was a mainly descriptive account of the important phenomena, themes and issues for the study participants. Their words were used frequently to raise the authenticity of the account. In Chapter 5 the findings were interpreted further by corroborating them against the relevant literature, and by proposing a possible framework for investigating creativity in a consulting engineering context.

The study explored what is creative about engineering design, concluding that it is a creative, intuitive and reflective practice. These practices are also whole (complete) and not easy to define, but possible to understand in an appropriate and authentic context. It also concluded that engineers are creative by nature, and that this creativity can be supported by appropriate individual, group and organizational attributes, experiences and environments. Some of the more powerful influences on creativity that were revealed included:

- A realisation that engineering design is a creative practice
- A realisation that time, effort and resources are associated with creativity and long term and breakthrough innovation
- An industry culture that runs counter to creativity and innovation, but that is slowly changing
- A company culture which allows authentic local cultures to develop
- A supportive and democratic senior leadership

.

The reflective questions posed in this chapter provide an opportunity for this discussion to continue informally and formally. It is currently inspiring that the construction industry is showing serious signs of embracing the need for change, and how it can be achieved.

5.7.5 Further research

An in-depth, exploratory study is limited in the extent to which it can address questions which arise unanswered from the research. I suggest that the principal achievement of this study was in clarifying the nature of creativity and engineering design and their possible relationships to industry and organizational influences. Whilst clarifying the nature of engineering creativity, the study raised many issues and questions which researchers may wish to investigate further. They include:

- **Investments in creativity:** What creativity-related investments are likely to contribute to engineering creativity and engineering design innovation? How can organizations justify, fund and support these investments? How can the benefits of such investments be demonstrated? How can business objectives be managed whilst respecting the intrinsic needs of human creativity?
- **The relationship between creativity and innovation:** The actual relationship between creativity and innovation is not made explicit in the literature or in the Brisbane study. To avoid possible misconceptions such as the 'Eureka' myth, researchers may wish to investigate how creativity (as a whole and time-intensive experience) can be nurtured to contribute to innovation in general, and engineering design in particular.
- **Construction engineering innovation:** The recognition in the construction industry literature that industry culture may be impeding creativity in engineering design is not widely expressed. Innovation maintains a disproportionate focus whilst creativity remains largely silent. Further research may be needed to identify what aspects of construction culture are affecting creativity and how they are doing so.
- **Engineering education:** The engineering education literature emphasizes the analytical and applied engineering sciences, rather than aspects of design such as visual conception, intuition, heuristics and aesthetics. Further research may be needed to investigate how well formal and ongoing education is preparing engineers for the complex, cross-disciplinary issues arising from contemporary themes such as 'sustainability' and 'globalization'. How can engineering education prepare graduates for the complexity of issues related to the cultural, environmental, moral and other appropriateness of engineering design solutions?
- **Engineering case studies:** The contextual treatment of engineering creativity in business organizations is relatively new. The value of the in-depth single case study for understanding context is explained in Chapter 3. There is scope for further case studies to explore the holistic and contextual aspects of creativity in specific work environments. There is also potential for cross-industry comparisons using multiple case studies of engineering and allied design practices such as architecture, urban planning and landscape design.

References

1. Adhikary, A. (2001). Export of engineering services and information technology. *Export of Engineering Services and Information Technology, 15*(5), PIII. Retrieved August 12, 2003, from EBSCO host electronic database.

2. Albert, R. S., & Runco, M. A. (1999). A history of research on creativity. In R. J. Sternberg (Ed.), *Handbook of creativity* (pp. 16-31). Cambridge: Cambridge University Press.

3. Amabile, T. M. (1983). *The social psychology of creativity*. New York: Springer-Verlag.

4. Amabile, T. M. (1987). The motivation to be creative. In S. G. Isaksen, (Ed.), *Frontiers of creativity research: Beyond the basics* (pp. 223-254). Buffalo, NJ: Bearly Ltd.

5. Amabile, T. M. (1988). From individual creativity to organizational innovation. In K. Gronhaug, K. & G. Kaufmann (Eds.), *Innovation: A cross-disciplinary perspective* (pp. 139-166). London: Norwegian University Press.

6. Amabile, T. M. (1999). How to kill creativity: Keep doing what you're doing. Or, if you want to spark innovation, rethink how you motivate, reward and assign work to people. *Harvard Business Review, 76*(5), 76-87. Retrieved June 28, 2003, from EBSCO host electronic database.

7. Andriopoulos, C. (2001). Determinants of organizational creativity: A literature review. *Management Decision, 39*(10), 834-840. Retrieved March 5, 2003, from EBSCO host electronic database.

8. Australian Construction Industry Foundation (ACIF). (2002). *Innovation in the Australian building and construction industry: A study report*. Retrieved April 19, 2004, from http://www.acea.aust.com/issues/ACIFsurvey.pdf

9. Bailey, R. L. (1978). *Disciplined creativity for engineers*. Collingwood, MI: Ann Arbor Science Publishers.

10. Basadur, M. (1987). Needed research in creativity for business and industrial applications. In S. G. Isaksen (Ed.), *Frontiers of creativity research: Beyond the basics* (pp. 390-416). Buffalo, NJ: Bearly Ltd.

11. Basadur, M. (1993). Impacts and outcomes of creativity in organizational settings. In S. G. Isaksen, M. C. Murdock, R. L. Firestien, & D. J. Treffinger (Eds.), *Nurturing and developing creativity: The emergence of a discipline* (pp. 278-313). Norwood, NJ: Alex Publishing Corporation.

12. Bernstein, H. M., Kissinger, J. P., & Kirksey, W. (1998). Moving innovation into practice. *Proceedings of the 1st International Civil*

Engineering Conference, February 19-20, 1998, Manila, Philippines, 250-259.

13. Bernstein, H. M., & Lemer, A. C. (1996). *Solving the innovation puzzle: Challenges facing the US design & construction industry*. New York: American Society of Civil Engineers (ASCE).

14. Besemer, S. P., & O'Quin, K. (1993). Assessing creative products: Progress and potential. In S. G. Isaksen, M. C. Murdock, R. L. Firestien & D. J. Treffinger (Eds.), *Nurturing and developing creativity: The emergence of a discipline* (pp. 331-349). Norwood, NJ: Alex Publishing Corporation.

15. Boisot, M. H. (1998). *Knowledge assets: Securing competitive advantage in the information economy*. New York: Oxford University Press.

16. Bouma, G. D. (2001). *The research process* (4th ed.). New York: Oxford University Press.

17. Bower, D., & Merna, A. (2002). Finding the optimal contractual arrangement for projects on process job sites. *Journal of Management in Engineering, 18*(1), 17-20. Retrieved September 10, 2003, from EBSCO host electronic database.

18. Burghardt, M. D. (1999). *Introduction to engineering design and problem solving*. London: McHraw-Hill.

19. Cavallucci, D. (2002). TRIZ, the Altshullerian approach to solving innovation problems. In Chakrabarti, A. (Ed.), *Engineering design synthesis: Understanding, approaches and tools* (pp. 131-149). London: Springer.

20. Chakrabarti, A. (Ed.). (2002). *Engineering design synthesis: Understanding, approaches and tools*. New York: Springer.

21. Committee for Economic Development of Australia (CEDA). (2004, April). *Innovating Australia*: Committee for Economic Development of Australia (CEDA). Retrieved April 24, 2004, from http://www.ceda.com.au/ResearchNew/Publications/Growth/Innovation%20Policy%20Statement.pdf

22. Court, A. W. (1998). Improving creativity in engineering design education. *European Society for Engineering Education, 23*(2), 141-155. Retrieved June 10, 2003, from EBSCO host electronic database.

23. Creswell, J. W. (1998). *Qualitative inquiry and research design: Choosing among five traditions*. London: Sage Publications.

24. Creswell, J. W. (2002). *Educational research: Planning, conducting, and evaluating quantitative and qualitative research*. Columbus, OH: Merrill Prentice Hall.

25. Crotty, M. (1998). *The foundations of social research: Meaning and perspective in the research process*. London: Sage Publications.

26. Csikszentmihalyi, M. (1999). Implications of a systems perspective for the study of creativity. In R. J. Sternberg (Ed.), *Handbook of creativity* (pp. 313-335). Cambridge, England: Cambridge University Press.

27. DeGraff, J., & Lawrence, K. A. (2002). *Creativity at work: Developing the right practices to make innovation happen*. San Francisco, CA.: Jossey-Bass; Wiley.

28. Denzin, N. K. (2002). The interpretive process. In A. M. Huberman & M. B. Miles (Eds.), *The qualitative researcher's companion* (pp. 349-366). London: Sage Publications.

29. Dozier, G. C., Manrique, J., Magee, R., & Allen, R. (1996). Creative management for continuous economic growth: Lost Hills Alliance, Kern County, California. *Proceedings of the SPE Annual Technical Conference and Exhibition*, 27-34.

30. Drucker, P. F. (1995). *Managing in a time of great change* (Reprinted 1998 ed.). Oxford: Butterworth Heinemann.

31. Drucker, P. F. (2002). *Managing in the next society*. New York: Truman Talley Books.

32. Dym, C. L., & Little, P. (2000). *Engineering design: A project-based introduction*. Brisbane, Qld: John Wiley & Sons.

33. Education Queensland. (2004). *[Education Queensland home page]*. Retrieved June 10, 2004, from http://education.qld.gov.au/

34. Edwards, B. (1986). *Drawing on the artist within: A guide to innovation, invention, imagination and creativity*. New York: Simon and Schuster.

35. Eide, A. R., Jenison, R. D., Mashaw, L. H., & Northup, L. L. (1998). *Introduction to engineering design & problem solving* (2nd ed.). Sydney, NSW: McGraw Hill.

36. Eriksson, M., Lillieskold, J., & Jonsson, N. (2002). How to manage complex, multinational R&D projects successfully. *Engineering Management Journal, 14*(2), 53-60. Retrieved March 15, 2003, from EBSCO host electronic database.

37. Fahey, L., & Prusak, L. (1998). The eleven deadliest sins of knowledge management. *California Management Review, 40*(3), 265-276. Retrieved May 20, 2002, from EBSCO host electronic database.

38. Farrell, S., & Watzke, J. (1997). International alliances: Closing the cultural gap. *29th Annual Offshore Technology Conference Proceedings, May 5-8, 1997, Houston TX, 2*, 8367-8371.

39. Feldhusen, J. F. (1993). A conception of creative thinking and creativity training. In S. G. Isaksen, M. C. Murdock, R. L. Firestien & D. J. Treffinger (Eds.), *Nurturing and developing creativity: The emergence of a discipline* (pp. 31-50). Norwood, NJ: Alex Publishing Corporation.

40. Feldman, D. H. (1999). The development of creativity. In R. J. Sternberg (Ed.), *Handbook of creativity* (pp. 169-186). Cambridge, England: Cambridge University Press.

41. Feldman, D. H., Csikszentmihalyi, M., & Gardner, H. (1994). A framework for the study of creativity. In D. H. Feldman, M. Csikszentmihalyi, *& H.* Gardner (Eds.), *Changing the world: A framework for the study of creativity* (pp. 1-45). Westport, CT: Praeger.

42. Ferguson, E. S. (1992). *Engineering and the mind's eye*. London: MIT Press.

43. Firestien, R. L. (1993). The power of product. In S. G. Isaksen, M. C. Murdock, R. L. Firestien & D. J. Treffinger (Eds.), *Nurturing and developing creativity: The emergence of a discipline* (pp. 261-277). Norwood, NJ: Alex Publishing Corporation.

44. Flew, T. (2002). *New media: An introduction*. Oxford: Oxford University Press.

45. Florida, R. (2002). *The rise of the creative class: And how it's transforming work, leisure, community and everyday life.* New York: Basic Books.

46. Frede, D. (1993). The question of being: Heidegger's project. In C. Guignon (Ed.), *The Cambridge companion to Heidegger* (pp. 42-69). New York: Cambridge University Press.

47. Freeman-Bell, G., & Balkwill, J. (1996). *Management in engineering: Principles and practice* (2nd ed.). New York: Prentice Hall.

48. Gardner, H. (1988). Creative lives and creative works: A synthetic scientific approach. In *From individual creativity to organizational innovation* (pp. 298-321). London: Norwegian University Press.

49. Gaynor, G. H. (2002). *Innovation by design: What it takes to keep your company on the cutting edge*. New York: American Management Association (AMACOM).

50. Gelernter, D. (1998). *Machine beauty: Elegance and the heart of technology.* New York: Basic Books.

51. Gilbert, A. (2000). Online collaboration tools help simplify product design. *Informationweek.com*, 131-136. Retrieved September 12, 2002, from EBSCO host electronic database.

52. Giugni, S. (2001). Nurturing imagination: Introducing creativity to organizational environments. In B. Hamilton (Ed.), *Innovation and imagination at work* (pp. 35-59). Roseville, NSW: McGraw-Hill.

53. Grondin, J. (2002). Gadamer's basic understanding of understanding. In R. J. Dostal (Ed.), *The Cambridge companion to Gadamer* (pp. 36-51). Cambridge, England: Cambridge University Press.

54. Guba, E. G., & Lincoln, Y. S. (1998). Competing paradigms in qualitative research. In N. K. Denzin & Y. S. Lincoln (Eds.), *The landscape of qualitative research: Theories and issues* (pp. 195-220). London: Sage Publications.

55. Guignon, C. (1993). Introduction. In *The Cambridge companion to Heidegger* (pp. 1-41). New York: Cambridge University Press.

56. Hausman, C. R. (1987). Philosophical perspectives on the study of creativity. In S. G. Isaksen (Ed.), *Frontiers of creativity research: Beyond the basics* (pp. 380-389). Buffalo, NJ: Bearly Ltd.

57. Heidegger, M. (1962). *Being and time* (J. Macquarrie & E. Robinson, Trans.). New York: Harper & Row Publishers. (Original work published in 1927).

58. Herda, E. A. (1999). *Research conversations and narrative: A critical hermeneutic orientation in participatory inquiry*. London: Praeger.

59. Holt, G. D., Love, P. E. D., & Heng, L. (2000). Learning organization: Toward a paradigm for mutually beneficial strategic construction alliances. *International Journal of Project Management, 18*(6), 415-421. Retrieved May 12, 2003, from EBSCO host electronic database.

60. Hubka, V., & Eder, W. E. (2002). Theory of technical systems and engineering synthesis. In *Engineering design synthesis: Understanding, approaches and tools* (pp. 49-66). New York: Springer.

61. Isaksen, S. G. (1988). Educational implications of creativity research: An updated rationale for creative learning. In K. Gronhaug & G. Kaufmann (Eds.), *Innovation: A cross-disciplinary perspective* (pp. 167-168). London: Norwegian University Press.

62. Jones, J. C. (1992). *Design methods* (2nd ed.). New York: John Wiley.

63. Jones, N., & De Vreede, G.-J. (2000). Using collaborative technology in environmental strategy development. *Local Environment, 5*(2), 2111-2216. Retrieved June 2, 2002, from EBSCO host electronic database.

64. Keegan, A., & Turner, R. J. (2002). The management of innovation in project-based firms. *Long Range Planning, 35*, 367-388. Retrieved August 10, 2003, from EBSCO host electronic database.

65. Kelley, T. (2001). *The art of innovation: Lessons in creativity from IDEO, America's leading design firm*. New York: Doubleday.

66. Kennedy, C. (2001). *The next big idea: The big ideas for business in the 21st Century*. London: Random House.

67. Kimbell, R. (2002). *Assessing design innovation*. London: Engineering Council (UK). Retrieved May 1, 2003, from www.engc.org.uk/publications/pdf/design_innovation.pdf

68. Kimbell, R., Stables, K., & Green, R. (1996). *Understanding practice in design and technology*. Buckingham, PA: Open University Press.

69. King, N., & Anderson, N. (1990). Innovation in working groups. In A. M. West & J. L. Farr (Eds.), *Innovation and creativity at work: Psychological and organizational strategies*. New York: John Wiley & Sons.

70. Kohler, N. (2003). Cultural issues for a sustainable built environment. In R. J. Cole & R. Lorch (Eds.), *Buildings, culture and environment: Informing local and global practices* (pp. 83-108). Oxford: Blackwell Publishing.

71. Kruglianskas, I., & Thamhain, H. J. (2000). Managing technology-based projects in multinational environments. *HPAC Heating, Piping, Air Conditioning, 72*(2), 55-64.

72. Landry, C. (2001). *The creative city: A toolkit for urban innovators*. London: Earthscan Publications.

73. Langley, P., & Jones, R. (1988). A computational model of scientific insight. In R. J. Sternberg (Ed.), *The nature of creativity: Contemporary psychological perspectives* (pp. 177-201). New York: Cambridge University Press.

74. Leedy, P. D., & Ormrod, J. E. (2001). *Practical research: Planning and design* (7th ed.). Upper Saddle River, NJ: Merrill Prentice Hall.

75. Leonard, D., & Swap, W. (2002). How managers can spark creativity. In F. Hesselbein & R. Johnston (Eds.), *On creativity, innovation, and renewal: A leader to leader guide* (pp. 55-65). San Francisco, CA: Jossey-Bass [Wiley].

76. Lincoln, Y. S. (1995). Emerging criteria for quality in qualitative and interpretive research. *Qualitative Inquiry, 1*, 275-289.

77. Lincoln, Y. S., & Guba, E. G. (2002). Judging the quality of case study reports. In *The qualitative researcher's companion* (pp. 205-215). London: Sage Publications.

78. Love, P. E. D., & Gunasekaran, A. (1998). Concurrent engineering: A strategy for procuring. *International Journal of Project Management, 16*(6), 375-384. Retrieved June 28, 2003, from EBSCO host electronic database.

79. *McGraw-Hill encyclopedia of science & technology*. (8th ed.). (1997). New York: McGraw-Hill.

80. McLeish, K. (2004, April 2). Demolition job. In *Stateline*. Brisbane, Qld: Australian Broadcasting Corporation. Retrieved June 16, 2004, from http://www.abc.net.au/stateline/qld/content/2004/s1080142.htm

81. Maliniak, D. (2001). Design teams collaborate using internet fast track. *Electronic Design Automation* (21 May), 69-75. Retrieved August 10, 2003, from EBSCO host electronic database.

82. Margolius, I. E. (Ed.). (2003). *Art + architecture*. Chichester, England: Wiley-Academy.

83. Marshall, C., & Rossman, G. B. (1999). *Designing qualitative research* (3rd ed.). London: Sage Publications.

84. Marshall, E. M. (1995). *Transforming the way we work: The power of the collaborative workplace*. New York: American Management Association.

85. Martin, M. W., & Schinzinger, R. (1996). *Ethics in engineering* (3rd ed.). New York: McGraw-Hill.

86. Martin, M. J. C. (2000, May 18). *Construction industry [Westminster Hall, Parliamentary Sitting, Thursday 18 May 2000]*. Retrieved April 24, 2004, from http://www.parliament.the-stationery-office-office.co.uk/pa/cm199900/cmhansard/vol000518/haltext/0051h01.htm

87. Maxwell, J. A. (1996). *Qualitative research design: An interactive approach*. London: Sage Publications.

88. Michalko, M. (2001). *Cracking creativity: The secrets of creative genius*. Berkeley, CA: Ten Speed Press.

89. Miles, M. B., & Huberman, A. M. (1994). *Qualitative data analysis: An expanded sourcebook* (2nd ed.). London: Sage Publications.

90. Mumford, E. (1981). *Values, technology and work*. London: Martinus Nijhoff Publishers.

91. Mumford, E. (1996). *Systems design: Ethical tools for ethical change*. London: Macmillan.

92. Nemeth, C. J., & Nemeth, L. (2001). Understanding the creative process: Management of the knowledge worker. In I. Nonaka & D. J. Teece (Eds.), *Managing industrial knowledge: Creation, transfer and utilization* (pp. 91-105). London: Sage Publications.

93. Nickerson, R. S. (1999). Enhancing creativity. In R. J. Sternberg (Ed.), *Handbook of creativity* (pp. 392-426). Cambridge, England: Cambridge University Press.

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

95. *Oxford Reference Online.* (2004). London: Oxford University Press. Retrieved February 20, 2004, from http://www.oxfordreference.com/

96. Parkyn, N. (Ed.). (2002). *The seventy architectural wonders of our world*. London: Thames & Hudson.

97. Paton, J. (2002). *Collaboration in the civil engineering market: Breaking down the barriers to success*. Retrieved August 10, 2002, from http://www.ice.org.uk

98. Patton, M. Q. (1990). *Qualitative evaluation and research methods* (2nd ed.). London: Sage Publications.

99. Perinotto, T. (2004, May 11). Design builds the bottom line. *The Australian Financial Review (AFR),* p. 63.

100. Perinotto, T. (2003, September 2). The 'erotic' gherkin' breaks new ground. *The Australian Financial Review),* p. 64.

101. Perry, R. J. (1973). *Survey of engineering creativity*. London: Institution of Mechanical Engineers.

102. Peters, T. F. (1998). How creative engineers think. *Civil Engineering, 68*(3), 48-52. Retrieved March 12, 2003, from EBSCO host electronic database.

103. Polanyi, M. (1966). The tacit dimension. In L. Prusak (Ed.), *Knowledge in organizations* (pp. 135-144). Oxford: Butterworth-Heinemann.

104. Porter, M. E. (2000). Location, competition and economic development: Local clusters in a global economy. *Economic Development Quarterly, 14*(1), 16-34. Retrieved April 5, 2002, from EBSCO host electronic database.

105. Powell, R. W. (1970). *Creativity in engineering: A profile of researches*. London: Institution of Mechanical Engineers.

106. Prusak, L. (2001). Where did knowledge management come from? *IBM Systems Journal, 40*(4), 1002-1007.

107. Queensland Government. (2004). *Building industry contractor: Tendering and selection process*. Brisbane, Qld: Queensland Government, State Supply Commission. Retrieved June 4, 2004, from http://www.build.qld.gov.au/industry/BiDocs/PQCserviceriskassessment.pdf

108. Reamer, D. (1997). How to identify the key elements of successful industry alliances. *Oil and Gas Journal, 95*(14), 25-27.

109. Rickards, T., & Moger, S. (2000). Creative leadership processes in project team development: An alternative to Tuckman's Stage Model. *British Journal of Management, 11*, 273-283. Retrieved January 20, 2003, from EBSCO host electronic database.

110. Rix, S. (1994). *Superworking: How to achieve peak performance without stress*. Sydney, NSW: Simon & Schuster.

111. Robson, C. (2002). *Real world research* (2nd ed.). Oxford: Blackwell Publishers.

112. Salmon, R. (1996). *The future of management: All roads lead to man*. Oxford: Blackwell Business.

113. Schank, R. C. (1988). Creativity as a mechanical process. In R. J. Sternberg (Ed.), *The nature of creativity: Contemporary psychological perspectives* (pp. 220-238). New York: Cambridge University Press.

114. Schermerhorn, J. R., Hunt, J. G., & Osborn, R. N. (1991). *Managing organizational behavior* (4th ed.). New York: John Wiley & Sons.

115. Schon, D. A. (1991). *The reflective practitioner: How professionals think in action* (2nd ed.). London: Ashgate Publishing.

116. Schon, D. A. (1983). *The reflective practitioner: How professionals think in action* (1st ed.). London: Ashgate Publishing.

117. Schwandt, T. A. (2000). Three epistemological stances for qualitative inquiry: Interpretivism, hermeneutics, and social constructionism. In N. K. Denzin & Y. S. Lincoln (Eds.), *Handbook of qualitative research* (2nd ed., pp. 189-213). London: Sage Publications.

118. Seely-Brown, J., & Duguid, P. (2000). Balancing act: How to capture knowledge without killing it. *Harvard Business Review* (May-June), 73-80.

119. Sethi, R., Smith, D. C., & Whan, P. C. (2002). How to kill a team's creativity. *Harvard Business Review, 80*(8), 16-19. Retrieved December 12, 2002, from EBSCO host electronic database.

120. Shapiro, S. M. (2001). *24/7 innovation: A blueprint for surviving and thriving in an age of change*. New York: McGraw-Hill.

121. Simmons, A. (1999). *A safe place for dangerous truths: Using dialogue to overcome fear & distrust at work*. New York: AMACOM.

122. Simonton, D. K. (1999). Creativity from a historiometric perspective. In R. J. Sternberg (Ed.), *Handbook of creativity* (pp. 116-133). Cambridge, England: Cambridge University Press.

123. Stake, R. E. (2000). Case studies. In N. K. Denzin & Y. S. Lincoln (Eds.), *Handbook of qualitative research* (2nd ed., pp. 435-454). London: Sage Publications.

124. Standards Australia. (2001). *Knowledge management: A framework for succeeding in the knowledge era*. Sydney, NSW: Standards Australia.

125. Steiner, C. J. (2002). The technicity paradigm and scientism in qualitative research. *The Qualitative Report, 7*(2), 1-19. Retrieved August 2, 2003, from www.jitter.com.au/PUBLISH/HTML/QualitativeResearch.pdf

126. Sternberg, R. J., & Lubart, T. I. (1999). The concept of creativity: Prospects and paradigms. In R. J. Sternberg (Ed.), *Handbook of creativity* (pp. 3-15). Cambridge, England: Cambridge University Press.

127. Sternberg, R. J., O'Hara, L. A., & Lubart, T. I. (1997). Creativity as investment. *California Management Review, 40*(1), 8-16.

128. Sutton, R. I. (2001). The weird rules of creativity. *Harvard Business Review, Sept*, 94-103. Retrieved June 28, 2003, from EBSCO host electronic database.

129. Talbot, R., J. (1993). Creativity in the organizational context: Implications for training. In S. G. Isaksen, M. C. Murdock, R. L. Firestien & D. J. Treffinger (Eds.), *Nurturing and developing creativity: The emergence of a discipline* (pp. 177-214). Norwood, NJ: Alex Publishing Corporation.

130. Tomiyama, T., Yoshioka, M., & Tsumaya, A. (2002). A knowledge operation model of synthesis. In A. Chakrabarti (Ed.), *Engineering design synthesis: Understanding, approaches and tools* (pp. 67-90). New York: Springer.

131. Tornkvist, S. (1998). Creativity: Can it be taught? The case of engineering education. *European Journal of Engineering Education, 23*(1), 5-13. December 12, 2002, from EBSCO host electronic database.

132. Torrance, E. P. (2003). Reflection on emerging insights on the educational psychology of creativity. In J. C. Houtz (Ed.), *The educational psychology of creativity* (pp. 273-287). Cresskill, NJ: Hampton Press.

133. UK Department of Trade and Industry. (2002, March 15). *Rethinking construction innovation and research: "The Fairclough Report"*. Retrieved April 20, 2004, from http://www.dti.gov.uk/construction/cmptence.html

134. UK Government. (2004, April 26). *Sustainable development the UK Government's approach: Could Industry do more of its own volition?* Retrieved June 23, 2001, from http://www.sustainable-development.gov.uk/consult/construction/response/7.htm

135. UK Highways Agency. (1996). *The appearance of bridges and other highway structures*. London.: HMSO

136. Van Gundy, A. (1987). Organizational creativity and innovation. In S. G. Isaksen (Ed.), *Frontiers of creativity research: Beyond the basics* (pp. 358-379). Buffalo, NY: Bearly Ltd.

137. Von Krogh, G. (1998). Care in knowledge creation. *California Management Review, 40*(3), 133-149. Retrieved April 5, 2002, from EBSCO host electronic database.

138. Watts, M. (2001). *Heidegger: A beginner's guide*. London: Hodder & Stoughton.

139. Weisberg, R. W. (1999). Creativity and knowledge: A challenge to theories. In R. J. Sternberg (Ed.), *Handbook of creativity* (pp. 226-250). Cambridge, England: Cambridge University Press.

140. Weiss, L. (2002). Developing tangible strategies. *Design management journal, 13*(1), 33-38.

141. West, A. M., & Farr, J. L. (1990). Innovation at work. In *Innovation and creativity at work: Psychological and organizational strategies* (pp. 3-13). New York: John Wiley & Sons.

142. West, M. (2001). How to promote creativity in a team. *People Management*, *7*(5), 46-49. Retrieved August 25, 2003, from EBSCO host electronic database.

143. Wheatley, M. J. (1999a). *Leadership and the new science* (2nd ed.). San Francisco, CA.: Berret-Koehler Publishers.

144. Wheatley, M. J. (1999b). *What do we measure and why? Questions about the uses of measurement*. Retrieved June 12, 2003, from http://www.margaretwheatley.com/articles/whymeasure.html

145. Wheatley, M. J., & Kellner-Rogers, M. (1996). *A simpler way*. San Francisco, CA: Berrett-Koehler Publishers.

146. Wiese, P. R., & John, P. (2003). *Engineering design in the multi-discipline era: A systems approach*. London: Professional Engineering Publishing Ltd.

147. Wiig, K. M. (1997). Knowledge management: Where did it come from and where will it go. *Expert Systems With Applications*, *13*(1), 1-14. Retrieved March 29, 2002, from EBSCO host electronic database.

148. Woodman, R. W., Sawyer, J. E., & Griffin, R. W. (1993). Toward a theory of organizational creativity. *Academy of Management Review*, *18*(2), 3-32. Retrieved April 15, 2003, from EBSCO host electronic database.

149. Yin, R. K. (1994). Case study research: design and methods. In (2nd ed.). London: SAGE Publications.

150. Yin, R. K. (1998). The abridged version of case study research: Design and method. In L. Bickman & D. Rog, J. (Eds.), *Handbook of applied social research methods* (pp. 229-259). London: Sage Publications.

APPENDIX A: The study package

Queensland University of Technology

Master of Arts (Research) Project

Creativity in consulting engineering: How civil engineers talk about design

COVER SHEET

This project is being conducted as part of Marion Hayes' Master of Arts (Research) Thesis. Marion is a research student with the QUT Creative Industries Research & Applications Centre (CIRAC).

Names and contact details for the research team

Researcher

Supervisor

Company
Contact

Introduction

Attached is a Company Information study package, which will be mailed to the COMPANY X study leader. The package is detailed and intended for the study leader, to spare other staff detail they will probably not need. The package consists of the following. Participants will be provided with an abridged guide:

a) A detailed description of the study and basic research protocols.
b) An abridged study guide for study participants.
c) A consent form for the Company Study leader (principal contact person in the study organization) to sign. This can also be used for participants other than interviewees (who will be provided with a specific form.
d) A data collection guide.
e) Interview questions – Group 1 (Project team members)
f) Interview questions – Group 2 (Innovation champions)
g) An interview consent form and guide

Queensland University of Technology

Master of Arts (Research) Project

Creativity in consulting engineering: How civil engineers talk about design

COMPANY INFORMATION PACKAGE

This project is being conducted as part of Marion Hayes' Master of Arts (Research) Thesis. Marion is a research student with the QUT Creative Industries Research & Applications Centre (CIRAC). Please Note: The "COMPANY X innovation study: interview consent form" and guide is for use by participants in the interviews (which comprise a substantive part of the case study).

Names and contact details for the research team

Researcher

Supervisor

Company Contact

About the Study

Excellence in engineering design underlies the company philosophy of (COMPANY X). It has a reputation in civil, structural and hydrologic design, and is increasingly integrating environmental science and engineering, urban planning, quality and risk management, into its sustainable design initiatives. To support the philosophy of excellence in engineering design, COMPANY X has embarked on a strategic global company initiative "Excellence through innovation", recognizing the importance of innovation for being competitive in the knowledge economy. Part of this strategic initiative, is to develop creative thinking and related skills among engineering and project staff, and to provide avenues through which the company and its individuals can achieve their creative potential.

This global strategic initiative of COMPANY X for 2002-3, paralleled by the current interest about innovation in management and engineering research, provides a unique opportunity to conduct a case study about creativity and innovation within one of the world's largest consulting engineering firms. The chance to conduct the study within the context of the "Excellence through Innovation" 2002-3 is therefore opportune.

The proposed case study will explore organizational creativity and innovation in engineering design. Within research, organizational creativity and innovation has so far been dealt with in a fragmented way; management theory has rarely discussed the link between creativity and innovation, paying disproportionate attention to knowledge, information and technology management. The engineering discipline has focused on creativity in engineering education rather than on organizational creativity. Psychological research has focused on traits and measurable variables in creativity and innovation. The case study is a unique opportunity to bring the research from these disciplines together, to develop a better understanding of organizational creativity and innovation in engineering design organizations.

The descriptive and exploratory study will explore the COMPANY X experience of creativity and innovation. It will use multiple data sources (principally interviews) to understand (1) How engineers design and develop their design expertise; (2) How engineers make the transition from formal education to design practice; (3) How COMPANY X is helping its individuals and teams to realize their innovative potential. The investigation will corroborate findings from observation, interviews and document analysis. For more detail about data collection procedures, see the attached document: COMPANY X innovation study:

Expected Benefits:

Through interaction with the researcher as an independent observer, and a final report, the following benefits to COMPANY X are envisaged:

- Learning how creativity facilitates innovation within its organization.
- Understanding the way in which its work environment is supporting creativity and innovation.
- Learning about the theories that underpin innovation and creativity.
- Learning the way creativity is developed among its professional staff.
- Learning the conditions that allow individuals and groups to reach their creative potential.
- Discovering possible relationships between project collaboration, innovation and creativity.
- Moreover COMPANY X will have the opportunity to share current research knowledge and to promote its image as an innovator, through jointly published conference and journal papers.

Wider benefits for research and practice:

- The proposed project will advance scholarly knowledge about the link between creativity and innovation in the engineering profession.
- The project will improve the understanding of the creative and related phenomena (and processes) that are involved in creative engineering design.
- The project setting may advance knowledge of the role of collaboration in creativity and innovation within knowledge intensive industries such as civil engineering design.
- The project will assist engineering firms to understand the importance of creativity in design innovation, and the ways in which individual, group and organizational creativity can be facilitated.

Commencement Date

An intensive review of the related literature has been completed and is ongoing. Preliminary investigation is currently underway with permission granted to attend a number of company innovation events. The proposed interviews will commence in mid-late January 2003, depending on staff availability, and be completed in early April. It is anticipated that the final research results and final draft of the thesis, will be available in August 2004.

Risks

No risks have been identified that will affect individuals participating in the project. Anonymity of the company and participants will be maintained throughout the study. Pseudonyms will replace personal, project and other names.

Confidentiality

Confidentiality will be ensured in that (1) only the research team will have access to primary data; and (2) participants' anonymity and confidentiality will be safeguarded in any publication of the results of this research, through the use of pseudonyms.

Voluntary participation

The project has been approved by the Company Study Leader of COMPANY X. However, individuals' decisions whether to participate in this project is voluntary, and they may withdraw at any time without comment. Both this 'package' and the consent form for interviews (attached) will be used to gain participant's consent and to inform them about the study.

Questions / further information

For additional information about the project, or to have questions answered, participants can contact the members of the research team or the Company study leader (COMPANY X).

Concerns / complaints

In case of any concerns or complaints about the ethical conduct of the project, participants should contact Gary Allen, Secretary of the University Human Research Ethics Committee on: 3864 2902

Feedback

Outcomes of the field study will be communicated to COMPANY X through presentations, workshops and reports, or other means negotiated with COMPANY X. Transcripts of recorded sources (interviews, observations), will be presented to participants for signing off, and COMPANY X will receive a copy of the final research thesis.

Approval by participating organizations

The project has been approved by the Senior Project Engineer, COMPANY X, Company study leader.

Queensland University of Technology

Master of Arts (Research) Project

Creativity in consulting engineering: How civil engineers talk about design

This project is being conducted as part of Marion Hayes' Master of Arts (Research) Thesis. Marion is a research student with the QUT Creative Industries Research & Applications Centre (CIRAC).

Purpose of this guide: This is an **abridged** study guide for general participants. There is a special consent form and guide for those participating in the interviews. If further detail is needed, please contact Company study leader or myself (Ph: 3864 1163 / 0405 029 536).

Guide to COMPANY X Innovation Study: Background Information for Participants

Purpose of the Study

The COMPANY X Innovation Study will explore the COMPANY X experience of creativity and innovation. Organizational creativity and innovation has been dealt with in research, in a fragmented way, for example:

- Insufficient attention has been paid to the role of individual and group creativity in innovation.
- The engineering discipline (if it does value creativity), does so with regard to engineering education.
- Psychological research has focused on traits and genius. Research suggests that everyone has some creative potential which can be developed.
- There is recent, but minimal focus on organizational creativity in the engineering profession.

The Study Method

The descriptive and exploratory case study is a unique opportunity to bring the research from many related disciplines together, in order to understand how creativity works in the world of project engineering, and how organizations can provide the environment (resources, culture, etc) to support this important factor in innovation.

Multiple sources of information will be accessed to help answer questions such as: (1) How do engineers and design practitioners actually design, and how do they develop their design expertise; (2) How do engineers and design practitioners make the transition from formal education to design practice; (3) How does COMPANY X help its individuals and teams to realize their innovative potential.

Data Collection Matrix

[A table cross-referencing the research aims with the intended data collection methods was included in the original package but omitted here because I have included it separately in Appendix B - see pp. 219-222].

Expected Benefits:

Through interaction with the researcher as an independent observer, and a final report, the following benefits to COMPANY X are envisaged:

- Learning how creativity facilitates innovation within its organization.
- Understanding the way in which its work environment is supporting creativity and innovation.
- Learning about the theories that underpin innovation and creativity.
- Learning the way creativity is developed among its professional staff.
- Learning the conditions that allow individuals and groups to reach their creative potential.
- Discovering possible relationships between project collaboration, innovation and creativity.
- Moreover COMPANY X will have the opportunity to share the current relevant research knowledge and to promote its image as an innovator, through jointly published conference and journal papers.

Confidentiality

Confidentiality will be ensured in that (1) only the research team will have access to primary data; and (2) participants' anonymity and confidentiality will be safeguarded in any publication of the results of this research, through the use of pseudonyms.

Voluntary participation

The project has been approved by COMPANY X (the Company Study Leader). However, individuals' decisions whether to participate in this project is voluntary, and they may withdraw at any time without comment. Both this 'package' and the consent form for interviews (attached) will be used to gain participant's consent and to inform them about the study.

Questions / further information

For additional information about the project, or to have questions answered, participants can contact the members of the research team or Company study leader (COMPANY X), or myself: Marion Hayes, on 3864 1163 / 0405 029 536, or by Email: m4.hayes@student.qut.edu.au.

Consent Forms

These are available from Company study leader. There is a special form and guide for interview participation and another for general participation (e.g. observation, meetings, etc).

Queensland University of Technology

Master of Arts (Research) Project

Creativity in consulting engineering: How civil engineers talk about design

GENERAL CONSENT FORM (See separate form for interviewees)

This project is being conducted as part of Marion Hayes' Master of Arts (Research) Thesis. Marion is a research student with the QUT Creative Industries Research & Applications Centre (CIRAC).

Names and contact details for the research team

Researcher

Supervisor

Company Contact

Statement of consent

By signing below, you are indicating that you:

- have read and understood the information sheet about this project
- have had any questions answered to your satisfaction
- understand that if you have any additional questions you can contact the research team
- understand that you are free to withdraw at any time, without comment or penalty
- understand that you can contact the research team if you have any questions about the project, or the Secretary of the University Human Research Ethics Committee on 3864 2902 if they have concerns about the ethical conduct of the project; and
- understand that my conversations with members of the research team will be audio-recorded. Audio recordings will be transcribed verbatim. Storage and retention of sound storage media and transcripts will be handled in compliance with the QUT Code of Conduct for Research
- agree to participate in the project.

Name ____________________

Signature ____________________

Date _______ / _______ / _______

.

Purpose of this form: *Please read the following and attached information about the COMPANY X Innovation study and interview questions, and give your consent by signing in the space provided.*

COMPANY X Innovation Study: Interview Consent Form

Thank you for agreeing to take part in the case study about innovation and creativity at COMPANY X.

This interview is part of a **Masters Research** project being conducted by me (Marion Hayes from the QUT Creative Industries Faculty). Through this research, I hope to learn more about how engineers develop their design expertise, and how COMPANY X is helping individuals and groups to design in creative and innovative ways.

Your participation in this interview is entirely **voluntary** but immensely appreciated. You are free to discontinue at any time without explanation.

The interview will last for approximately 45-60 minutes, and you will be asked to informally **discuss your experiences** in reaching your current level of design expertise. You will be asked to recall any experiences where you considered your approach to be creative.

Neither you nor COMPANY X is being evaluated or tested in any way during this interview. There is no 'right' answer to any question. I am interested in your opinions, perceptions, memories and experiences. This is important, because yours' and the COMPANY X experience of creative design and innovation is unique, and evaluations or comparisons would not achieve the aims of this study.

All information provided by you will be treated as **strictly confidential**. No identifying information about you or any other participant will be discussed or published. In published work about the interview, I will refer to you, your projects, and company by pseudonym(s). The interview will normally be recorded using audiotape. During the interview, I may also take some notes. The audiotapes, notes and eventual transcripts, will be kept in a locked filing cabinet which will be accessible only to me, and managed to comply with the QUT research ethics requirements.

Shortly after the interview, I will send you a copy of the interview transcript for you to **check for accuracy**.

If you would like **more information** about the research and what is required of participants, please contact me (Marion Hayes) in B505 at Gardens Point Campus, by phone on 3864 1163 / 0405 029 536, or by email at m4.hayes@student.qut.edu.au.

If you have any concerns about ethical issues relating to this research, please contact the Secretary of the University's Research Ethics Committee on 3864 2902.
Thank you very much for your involvement in this research

Please sign below to give your consent to this interview

I confirm that:

- I have read the information provided about this interview
- I agree voluntarily to participate in this interview

Signed: ____ Date: ___/___/_

Interview Questions – Group 1: Project Group

The following questions (or slight variations when the pilot study is complete), are intended for the semi-structured interviews. The questions are appended to the consent form to be signed by each participant. The questions will be given at least one week in advance.

Group 1: Multidisciplinary project team

Q1: In what way(s) did your tertiary education prepare you for engineering project design work?

- *Purpose: to explore the ways in which formal education has inspired (or otherwise) creative approaches to engineering design (e.g. creative thinking, problem solving, brainstorming, team work, project work, etc.)*

Q2: I'd like to understand more about the actual process involved in engineering design. Think about a project where your design work made a substantial or significant contribution. Think about how you went about completing the design. I'd like you to describe the design process to me, assuming that my technical knowledge of engineering is limited.

- *Purpose: To explore the engineer's workplace engineering design experience. The engineer will be invited to talk freely about the process, techniques and other ways they physically go about their design work. Purpose: to explore the process, product, person and context involved in project engineering design.*

Q3: Think about an occasion where you thought of a significantly different way of designing something, but decided against it. Tell me a little about the project/circumstance, etc., and why you didn't go ahead with your different approach.

- *Purpose: to explore some of the personal and contextual factors that affect a person's desire to try new ways.*

Q4: Think about an occasion where you had the inclination or opportunity to try something which you consider to be quite innovative and where you decided to try the different method/technique/idea. Tell me about this project/circumstance, etc., what it was that you chose to do differently and why.

- *Purpose: to explore some of the personal and contextual factors that affect a person's desire to try new ways.*

Q5: What is your experience of being part of your current project team? Could you tell me about the ways that being part of a team has made your design work easier or in some cases more difficult? Do you think that being part of a project motivates you to be creative and innovative?

- *Purpose: to explore the ways in which personal and group creativity and innovation is enhanced or inhibited at the group level.*

Q6: How does COMPANY X try to create a work environment that makes it easier for people and groups to do things in creative or innovative ways?

- *<u>Purpose</u>: to explore the ways that COMPANY X fosters an environment that is conducive to creativity and innovation.*

Interview Questions - Group 2: Innovation Champions

Note: Engineers who are also ICs may be asked some of the Project Group questions.

Q1: How did you come to be involved in the innovation initiative? I'd like to know about the ways in which you are involved in the current and planned innovation activities and programs.

- *<u>Purpose</u>: to describe the innovation and creativity-related initiatives, programs and activities which the staff and company are involved with. Conversations will probably reveal the meaning of creativity and innovation for innovation champions.*

Q2: [If the innovation champion is an engineer this question can be asked] I'd like to understand more about the actual process involved in engineering design. Think about a project where your design work made a substantial or significant contribution. Please describe the design process to me, assuming that I am not an engineer.

- *<u>Purpose</u>: To explore the engineer's workplace engineering design experience. The engineer will be invited to talk freely about the process, techniques and other ways they physically go about their design work. The question explores the process, product, person and context involved in project engineering design.*

Q3: [Ask this question regardless of professional discipline or role] Think about an occasion where you thought of a significantly different way of designing something, but decided against it. Tell me a little about the project/circumstance, etc., and why you didn't go ahead with your different approach.

- *<u>Purpose</u>: to explore some of the personal and contextual factors that affect a person's desire to try new ways.*

Q4: Think about an occasion where you had the inclination or opportunity to try something which you consider to be quite innovative and where you decided to try the different method/technique/idea. What it was that you chose to do differently and why.

- *<u>Purpose</u>: to explore some of the personal and contextual factors that affect a person's desire to try new ways.*

Q5: Do you think that project conditions stifle creativity in engineering?

- *<u>Purpose</u>: to explore the ways in which personal and group creativity and innovation is enhanced or inhibited at the group level.*

Q6: How does COMPANY X create a work environment that makes it easier for people and groups to do things in creative or innovative ways?

- *<u>Purpose</u>: to explore the ways that COMPANY X fosters an environment that is conducive to creativity and innovation.*

APPENDIX B: Data collection matrix: Study information sources

Study title: Creativity in consulting engineering: How civil engineers talk about design

The following table summarizes the sourcing, collection and management of field information likely to assist in answering the study's research questions: (1) What is the meaning of creativity and innovation for participants? (2) How do engineers describe the way they do their engineering design? (Q1 and Q2 will help to describe what is creative about engineering?) (3) How does the project environment influence engineering design? (Does it stifle engineering creativity?) (4) How does the company's organizational climate influence engineering design (and creativity)?

Source, Access & Conditions	Research Question(s) (Priority)	Collection	Management & Limitations
Semi-Structured Interviews Group 1: Project Group Multidisciplinary project team selected by the company study leader based on mutual interests (multidisciplinary, diversity, varied in experience, <=8 staff). Access by consent & ethical guidelines (see Interview Consent Form)	What is the meaning of creativity and innovation for participants? How do engineers describe the way they do their engineering design? How does the project environment influence engineering design? How does the organization support creativity and engineering? Interview guide questions (for exact Qs see Appendix A) How do engineers describe the way they do their engineering design? How does university education prepare civil engineers for project design work? How do engineers describe a design situation where in their opinion, they	Face-to-face semi-structured interviews conducted by the investigator. Broad experience & feeling questions aimed at encouraging discussion in work context; prompts /guiding questions were available for each of the 6 guide questions. The researcher has a 15-yr working experience of conversing with and interviewing engineers regarding their research support needs. A consent form and 'Information package' to be signed by each participant. At least 2-3 weeks notice of time, consent, nature of study & interview questions will be given to each participant. Note: Natural conversation emerged in-line	Signed consent forms to be collected prior to interview. Interview to be of 60 minutes duration. Interviews audio-taped (details given in consent form). Planning & perceptual notes made prior to and each interview. Transcripts will be made available to participants soon after interview, for correction authentication. Ready analysis, interpretation.& reporting

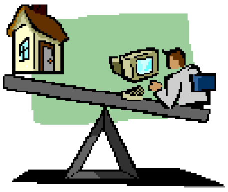
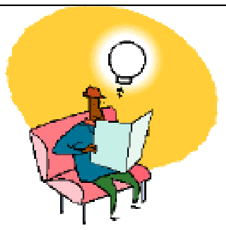
Source, Access & Conditions	Research Question(s) (Priority)	Collection	Management & Limitations
	were being innovative? How do engineers describe their experience of designing within a project-team environment? In what ways do engineers perceive that the Company is assisting or hindering their ability/opportunity to design in new ways? For more specifically worded interview questions, see the Study Package.	with the interests & expertise of interviewees. The guide Qs assumed greater and lesser importance depending on the person's interest, expertise, character, etc. Some Qs became completely redundant. Prompts raised the value of interviews.	
Semi-Structured Interviews Group 2: Innovation Champions (ICs) Multidisciplinary project team selected by the company study leader based on mutual interests (multidisciplinary, diversity, varied in experience, <=8 staff). Access by consent & ethical guidelines (see Interview Consent Form)	How does the organization support creativity and engineering? What is the meaning of creativity and innovation for participants? How does the project environment influence engineering design? How do engineers describe the way they do their engineering design? Interview guide questions (for exact Qs see Appendix A) In what ways do engineers perceive that the Company is assisting or hindering their ability/opportunity to design in new ways? How do engineers describe their experience of designing within a	Face-to-face semi-structured interviews conducted by the investigator. Broad experience & feeling questions aimed at encouraging discussion in work context; prompts /guiding questions were available for each of the 6 guide questions. The researcher has a 15-yr working experience of conversing with and interviewing engineers regarding their research support needs. A consent form and 'Information package' to be signed by each participant. At least 2-3 weeks notice of time, consent, nature of study & interview questions will be given to each participant.	Signed consent forms to be collected prior to interview. Interview to be of 60 minutes duration. Interviews audio-taped (details given in consent form). Planning & perceptual notes made prior to and each interview. Transcripts will be made available to participants soon after interview, for correction authentication. Ready analysis, interpretation.& reporting

Source, Access & Conditions	Research Question(s) (Priority)	Collection	Management & Limitations
	project-team environment? How do ICs describe their involvement in the innovation program? How do engineers describe a design situation where in their opinion, they were being innovative? For more specifically worded interview questions, see the Study Package.	Note: Natural conversation emerged in-line with the interests & expertise of interviewees. The guide Qs assumed greater and lesser importance depending on the person's interest, expertise, character, etc. Some Qs became completely redundant. Prompts raised the value of interviews.	
Participant Observation Innovation Fair; Innovation Champion's (ICs) Meetings; Project Team Meetings; Company visits, researcher presentation (sharing of results) By invitation/permission from company study leader.	How does the organization support creativity and engineering? What is the meaning of creativity and innovation for participants? How does the project environment influence engineering design? How do engineers describe the way they do their engineering design?	Conversations, direct involvement (e.g. giving presentations; asking & answering questions at meetings). Reflection & annotation of notes same day of observation 'event'. Unobtrusive observation; field work-sheet for prompts and notes. Later used to annotate and code themes.	Produce summary of final observational notes, distributed to participants, have returned with corrections/feedback, cross ref & file in locked cabinet. Ready for content & other analysis.

Source, Access & Conditions	Research Question(s) (Priority)	Collection	Management & Limitations
Corporate Document Analysis Corporate Intranet & Information systems Strategic plans, procedures, information systems, evaluation systems (e.g. HR performance) By invitation/permission from the company study leader	How does the organization support creativity and engineering? What is the meaning of creativity and innovation for participants? How does the project environment influence engineering design? How do engineers describe the way they do their engineering design?	Unobtrusive, authorized access, reading and note-taking and same day annotation of print-outs. Reflection about significance regarding research interests; corroboration with other sources. Used principally to develop a good understanding of the field setting, to sharpen the focus on matters of relevance to the Company and to assist in planning in-depth interviews	Research documentation is largely annotated print-outs from the Company Intranet. Ready for content & other analysis.

APPENDIX C: A description of the engineering design practice

The following description compiled from study conversation, is not consistent with how engineering design is described by the general engineering community. It is however similar to descriptions of other palpably creative practices discussed in creativity research and in a small but increasingly cited segment of the engineering education literature (Ferguson, 1992; Gelernter, 1998; Schon, 1991, 1983).

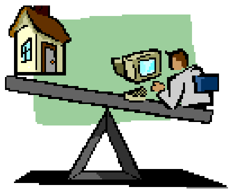
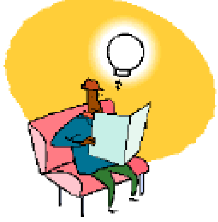
A description of the engineering design practice

(As reflected in conversations with engineers from the study organization)

- A mental or **visual conception** of the design in one's mind [mind's eye]
- A process or system with **sequential and heuristic** aspects
- A practice where new approaches need **time for reflection** and incubation
- A **science**-based practice where analysis is used to **test design** integrity
- A practice where scientific **analysis** and testing is not exact but often **iterative**
- An **artistic practice** involving: visual design conception, creative problem solving, iterative testing and aesthetics
- A practice where substantive **domain-specific knowledge** is a prerequisite for creativity
- A practice where **knowledge sharing** and collaboration can lead to small and large breakthroughs in design through the **cross-fertilisation** of knowledge, talent and ideas
- A practice in which computer **technology can enable** but not replace design or creativity
- A practice where **aesthetics** is an important but **under-resourced** consideration
- A practice which can manifest **small and large scale creativity** and innovation
- A practice in which the prevailing construction **industry culture** negatively **impacts** on their ability and motivation to 'invest' time and energy in creativity ('Big' or 'Small')
- A practice where creativity (in the current industry culture) is more likely to be manifested on a **small scale** through the smart use of technology or daily work practices.

APPENDIX D: A description of the construction industry

The following is a description of the construction industry compiled from recent construction research. The image is not conducive to the type of innovation (technical, breakthrough, creativity) associated with long term gains for industry and society; rather, it is overly focused on short term cost and efficiency gains (McLeish, 2004).

A description of the construction industry

The relationship between industry culture and innovation and creativity

- **Slow to change**: Conservative and disaggregated, therefore slow to change at the grass roots level. This is reinforced by client expectations for bespoke designs (Bernstein & Lemer, 1996; UK Government, 2004)
- **Adversarial**: Traditionally hierarchical not holistic, reinforcing adversarial relationships among the professions and practitioners in the industry, e.g. architecture and construction. This is not conducive to change (UK Government, 2004)
- **High cost products** with long lives – a disincentive to invest any more than is necessary (UK Government, 2004)
- **Procurement**: Government procurement policies currently discourage collaboration and encourage cost innovation. In Queensland, there is a 75-95% weighting on cost criteria when awarding contracts. Non-cost criteria such as aesthetics, innovation, and sustainability, are undervalued). (Queensland Government, 2004)
- **Government incentives:** A lack of incentives for clients to invest in innovation and improved design. Availability of financial capital and tax incentives is severely limited. (ACIF, 2002; UK Government, 2004)

- **Client-focused:** Consultants must deliver to client expectations who seek the lowest cost option. This is not always conducive to innovative design techniques (Keegan & Turner, 2002).
- **Knowledge and awareness:** The benefits of innovative solutions are not in the general industry awareness. This is a key barrier to self motivation and innovation (UK Government, 2004).
- **Minimum consultation**: Design documentation is provided by the principal (designer) – with little consultation between the designer and builder. This often results in oversights in design and construction because relevant issues are not known and discussed earlier enough in the design stage. Consequently many projects go over budget (ACIF, 2002; McLeish, 2004; Queensland Government, 1994, p. 5; UK Department of Trade and Industry, 2002)
- **Price-focused award of contracts**: At least 95% of the weighting criteria is price as distinct from non-cost criteria such as innovation, aesthetics and sustainability. Even larger projects only require a 75% weighting on cost criteria (Queensland Government, 1994, p. 12)
- **Guaranteed lump sum payment**: Contract payments is negotiated and usually delivered irrespective of performance which tends to discourage creativity and innovation because there is little incentive to improve (ACIF, 2002; McLeish, 2004)
- **Cost pressures**: Pressures to minimize cost, alongside short delivery cycles can lead to an over-reliance on tried-and-tested methods, the adoption of short-cuts and risk-avoidance. There is also no ‘slack’ for creativity in this cost-driven scenario. These conditions can lead to oversights in design resulting in cost blow-outs when design and construction faults need correction (Bernstein & Lemer, 1996, p. 93; McLeash, 2004)
- **Sustainability overlooked:** Creative approaches leading to design innovations such as sustainable and environmental (or ‘green building’) buildings are often side-stepped because the needs of the building’s users (e.g. tenants and residents) are insufficiently considered in the design and procurement methods. Lower power bills are not a sufficient incentive for the property developers and investors because energy is inexpensive (Perinotto, 2004, p. 63).
- **Risk and rules**: Voluminous standards, specifications, explicit rules and risk mitigation systems and procedures that emphasize risk avoidance thereby inhibiting investment in innovation (Keegan & Turner, 2002; UK Government, 2004).
- **Attitude to innovation**: Innovation is viewed as risky, costly, dangerous and often wasteful (ACIF, 2002; CEDA, 2004).

- **Innovation management**: The emphasis is on project management rather than design innovation. Tight controls and excessive monitoring and evaluation of innovation projects ensure that minimize risk is taken. This tends to stifle creativity and innovation ((Keegan & Turner, 2002)
- **Slack for creativity**: Though contemporary research says that slack time and resources are critical for innovation, the emphasis on efficiency, lowest cost and quick delivery suggests a contrary view (Amabile, 1999; Keegan & Turner, 2002)
- **Innovation research**: The cross-over between innovation and project management research is poor. The innovation literature is also very normative – outcomes oriented
- **Organizational structure**: The organic, democratic, less mechanistic and less hierarchical organizational forms often associated with innovation (information flows, communication) are not overly common in the industry (Keegan & Turner, 2002)
- **Project management**: Project control systems are tight and rigid (emphasizing efficiency) whereas innovation requires a loosening of control (Keegan & Turner, 2002)
- **Project alliance facilitation**: The high cost of formally facilitating large project alliances make them unaffordable for the majority of small to medium sized projects.